Dietary Intake, and Child Feeding Practices in the context of Climate Change among Indigenous and rural Communities in Uganda

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Declaration of Authorship and Intellectual Property

The candidate confirms that the work submitted is his/her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

Climate change is and is projected to impact negatively on health, food security and nutrition, and its effects are likely to be greater among vulnerable – including Indigenous – communities. However, literature assessing the relationship between dietary intake and child feeding, and climatic factors among Indigenous populations is scarce.

The thesis's aim is to characterize the diet of Indigenous Batwa and neighbouring non-Indigenous Bakiga communities living in southwestern Uganda, and to explore the likely impact of weather and seasonality on nutrients in foods (Chapter 2), on child feeding practices (Chapter 6), and on dietary intake (Chapter 7). This dissertation uses participatory community-based approaches, and mixed methods research to explore commonly consumed foods, included in a locally-relevant food composition database (Chapter 3 & 4), adult and child nutrition. Multiple fieldwork methods are included, such as in-depth interviews, focus group discussions, shop and market assessment, dietary surveys, and also the analysis of secondary data (Chapter 5) and a systematic review.

At global level, climate change impacts on food nutritional content, particularly in marine species. Socio-cultural context and environmental factors, including seasonality, influence Batwa and Bakiga's diet. Nutrient and caloric intake of both communities are inadequate over wet and dry months, especially for women and children. They mostly consume cereal and vegetable-based dishes, poor in vitamin A, zinc, iodine, and fats. Although breastfeeding prevalence is high, food insecurity linked to extreme climatic events, poverty, low health education, and alcoholism limit optimal child and maternal nutrition.

This project contributes to filling the research gap on climatic and non-climatic factors influencing diets among Indigenous communities. Also, it offers insights towards the implementation of nutritional programs for vulnerable food-insecure populations by considering the likely effect of climatic changes. Interventions that are adapted to the unique environmental and cultural context of Indigenous populations can better address individuals' nutritional needs and reduce malnutrition.

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Preface

I am a child, I am a child, although my needs may be different from yours, it does not make me any different from you.

I am a child, I am a child, I may not walk or run fast like you, but I feel and hurt, just the same.

I may not be able to hug you easily, but I love and have emotional needs just like you. I may look a little different, but I can do, and achieve what you can.

We all know being a child has its ups and downs, but for children like me, these are twice as much. So many times, I am labelled helpless, wasting your time as I try to navigate my way, through the door or trying to explain my thoughts to you. Yet, all I need, is for you to be patient with me.

For a second, I want you to be me, It's after school, like all other children. You are looking forward to going home, Outside, the rain is pouring, everybody is rushing not to get wet and so are you. As you are wheeling yourself, through the mud and puddles of water, your wheelchair gets stuck and you fall off your chair.

Struggling to get up. Tears start rolling down, there is no one to help, because everybody is rushing and running, imagine!

I am telling you this, not because I am looking for sympathy. I want to draw your attention, to the many challenges, that children like me still face.

If, and only if, you can make a world, where children like me can move with ease. A world, where children like me, are given a fair chance, to live to their full potential.

Then, only then, can we say there is hope For Every Child!

I Am a Child.

Cleric Tembwe

Chapter 1 – Introduction, Thesis Objectives, Theoretical & Methodological approaches

1.1 Overview

This chapter presents an introduction to the field of climate change, health and nutrition, and it sets out research aim and objectives of my doctoral work. It also outlines the theoretical and methodological approaches underpinning the analysis of the six core chapters (Chapter 2 to 7), and for which I used multiple fieldwork techniques with qualitative and quantitative components, a community-based approach, and analysis of secondary data.

At the center of this research, there is a focus on generating data about weather, seasonality, and food consumption among Indigenous and vulnerable adults and children, including during the breastfeeding and complementary feeding period. A vulnerability framework helped to situate this work within the broad context of health and climate change adaptation. Indeed, understanding the climatic and non-climatic factors affecting the dietary patterns of the Batwa and Bakiga can enable communities to better adapt to climatic changes.

1.2 Background

1.2.1 Climate change, health and nutrition

Human health and environments are interconnected. Climate change is considered to be one of the biggest threats to human health this century (1).

The effects of climatic changes on human health can be direct or indirect. For example, a change in morbidity and mortality rate in association with extreme climatic events is a direct effect, while the transformation of the natural and human systems that affect health, due to climatic factors, is an indirect effect (2-4). Changes in climate can influence natural ecosystems by altering the distribution of vector-borne and foodborne diseases for example, but also by disrupting human systems and causing nutrition issues, mental illness, violence and conflict (5). Projections show that 250,000 excess deaths due to malnutrition, malaria, and heat waves are likely to occur between 2030 and 2050 due to climate change (6). However, the health effects of climatic change will not be evenly distributed. The most affected are likely to be the poorest and the most disadvantaged communities in the world, with significant risks for widening existing health inequalities (7).

Climate change is a threat for food security and nutrition, particularly in Sub-Saharan Africa and South Asia (8). Undernutrition, and obesity affect around 2 billion of people in the world (9), and constitute a syndemic together with climatic changes as they interact, and affect each other(10). Even before Covid-19, the third Sustainable Developmental Goal 'End Hunger' was unlikely to be achieved by 2030. The socio-economic effects of Covid-19 on nutrition have compromised this goal further, exacerbating rising climate stressors on global food security (11). The impacts of climate change are likely to be acute on global agriculture, with a decrease in food production and disruption of water quality, quantity, and sanitation (12, 13). According to forecasting models, greenhouse gas emissions reduce the nutritional content of crops, especially in terms of proteins, and increase the frequency of extreme climatic events, leading to higher food insecurity and undernutrition in low-income settings (14, 15). The effects of climatic changes can also be seen in increased food prices, lower salaries, and disruptions in transport, which limit food accessibility, availability and dietary diversity (16). For this reason, there could be a potential increase of 20% in hunger and malnutrition by 2050 without concerted action on climate mitigation and adaption. This would put at risk millions of children and women, largely in the 33 countries classified as 'extremely vulnerable to climate change' (17).

1.2.2 Climate & nutrition trends in Uganda

Uganda is one of the countries widely acknowledged to be deeply affected by climate change. It is a land-locked country in East Africa with a population of over 47 million people (2022) and a yearly growth rate of 3.3% (18). The climate in Uganda is humid equatorial, with two rainy seasons over the year. Projections show that temperatures are likely to increase by 1.5°C by 2030, and up to 3.3 °C by 2060 with greater a frequency and magnitude of heavy rainfall events (19). Recently, Uganda has been hard hit by extreme weather events linked to climate change, including floods and droughts. The effect of climate change can be seen in changing seasonal and weather patterns, decreasing water levels, and increasing frequency of extreme weather events (20). As Uganda’s economy depends on natural resources and agriculture, food security and nutrition are highly vulnerable to the impact of climatic changes (21).

The SDG ‘Ending hunger’ has not been achieved in Uganda to-date, and climate change is expected to compromise and challenge progress on this goal. According to the 2016 Uganda Demographic and Health Survey (22), 29% of Ugandan children under 5 years were stunted, 4% wasted and 11% underweight, while 24% of women and 9% of men were overweight or obese. Also, more than half of the children (53%), 32% of women, and 16% of men suffered from anemia. These percentages indicate that the proportion of children with anemia and stunting declined in 2016– compared to the previous 5 years (2011)– while the number of obese and overweight adults increased. Also, anemia in women, which increased from 2011 to 2016, is still a major concern in the country, and remains a common cause of maternal death and neonatal morbidity (22).

1.2.3 Climate & nutrition trends in Kanungu District, south-western Uganda

Kanungu District is located in southwestern Uganda, near the Rwanda border and bordering the Democratic Republic of Congo. Similar to the rest of Uganda, Kanungu District is projected under climate change to have a wetter rainy season, with flooding occurring more frequently, and a hotter dry season with more frequent and intense droughts (23). Extremes events are already being observed in the district, though have not been formally attributed to climate change. For example, in 2019 a large flood event destroyed cultivated lands, with widespread and acute consequences for local food availability. Indeed, seasonality, frequency and intensity of precipitation are recognized as important determinants of food security in the area (24).

Kanungu District is inhabited by the Indigenous Batwa minority population and the non-Indigenous Bakiga majority population. Both groups experience high levels of food insecurity and undernutrition, and are considered highly vulnerable to environmental and climate variability (25). However, the cultural history, socio-economic status, and accessibility to health services between the two populations are very different, with implications for the adaptive capacity of the Batwa and the Bakiga (20). According to a study published in 2018, for example, 45% of Batwa adults and

20% of Batwa children suffered from moderate acute malnutrition, and 7% of Batwa children presented severe acute malnutrition, compared to 4% at national level (26, 27).

1.2.4 Land dispossession, environmental change & Indigenous nutrition

Indigenous peoples manage 22% of ecosystems and lands in the world (28). Their traditional knowledge systems, including historically close relationships with the land and food biodiversity, are often tightly connected with Indigenous cultures, lifestyles and identity (29). However, many Indigenous communities such as the Batwa in Kanungu District, have been displaced and evicted from their traditional lands (20). The effects of land dispossession, socio-economic marginalization and stigmatization, combined with environmental changes, have forced many Indigenous populations to transition and transform dietary habits. Indeed, pollution and degradation of lands, urbanization, invasive plant species and other environmental impacts have been reported as key factors driving globally-reported reductions in diet quality, exacerbated by colonialism and globalization (30, 31). In the case of the Batwa, their restricted and negligible legal access to their historic forest lands considerably – and contentiously – limits their ability to consume culturally and nutritionally important wild and traditional foods (25). As reported in the literature, this traumatic situation has been linked to extreme poverty, alcohol dependence, domestic abuse, and mental illnesses, widening health disparities, and consistent with similar trends in a range of Indigenous populations world-wide (32).

1.2.5 What is needed to strengthen Indigenous food systems?

Indigenous communities are among the most left-behind in meeting hunger, inequality and poverty Sustainable Development Goals, and specific needs to strengthen Indigenous food systems have been investigated and published, for example by UNFAO in 2021 (33). Indeed, Indigenous nutritional needs are often recognized as uniquely different from their non-Indigenous neighbours, frequently reported as intimately linked to Indigenous culture and spirituality, and less associated with value chains (34).

Generally, malnutrition, particularly deficiency of vitamin A, zinc and iodine, and stunting are more acute among Indigenous communities than in any other populations in high and low-income countries (35). Strategies for supporting nutrition among

Indigenous peoples have highlighted the need to ensure that food systems are sustainable, promoting biodiverse food and focus on foods rich in nutrients (36). Policies can enable this, and could contribute to satisfying five essential rights: ‘right of the child, right to food, to health, to cultural rights, and to a healthy environment’ (9). To strengthen food systems, research and education are also needed to assess the accessibility and nutritional content of traditional Indigenous foods (37). Growing research argues that doing so is critical for progress towards more sustainable food systems and life habits, adaptable to different ecosystems and to climatic changes, while promoting Indigenous knowledge, culture and identity (38).

1.2.6 Lack of data on Indigenous Peoples’ health and nutrition

High quality and accurate data are essential to monitoring health and nutritional outcomes, and informing policy on appropriate intervention programmes; however, information regarding the health of Indigenous peoples is limited (39, 40). This is partially a consequence of a persistent lack of Indigenous recognition and underrepresentation by governments, but also due to inconsistencies and inaccuracy in data collection and analysis (41). In addition, researchers highlight the importance of strengthening partnerships with Indigenous Peoples to improve data collection, and the interpretation of the findings (42, 43). For this reason, working closely with communities is key to improving health and nutrition among Indigenous populations in Uganda.

1.3 Research rationale

Research on the effects of climatic change on food security has been widely published (1, 44-47), however evidence linking climate change or climatic variables to nutritional outcomes is limited. Also, information is scarce at regional and community levels, yet is critical to respond to the likely health and nutritional impacts of climatic changes (48). As a consequence, adaptation strategies to climate change are more difficult to implement, and may be unsuitable to vulnerable contexts, such as for Indigenous Peoples, given that data are available at national level only (49).

Researchers have consistently reported that Indigenous populations suffer more from health disparities compared to non-Indigenous populations living in the same area (50). Extreme weather events particularly affect Indigenous communities (20), and the impact of climatic changes is likely to be acute not only for food security and nutrition, but also on individuals' health, and wellbeing (51). Other health determinants and compound events, such as Covid-19, make Indigenous population even more vulnerable to the impacts of climate on nutritional status (52). However, evidence about the interaction between diet and climate change is very limited for marginalised communities.

In Uganda, the Batwa are an Indigenous population who experience higher level of health and social inequalities than the neighbouring non-Batwa (53). They were used to be called Pygmies because of their short stature, which was associated with a particular genetic train. Among these communities, the effect of climate change on food security and agriculture has been explored (25, 54), but literature investigating diets and child feeding practices is negligible among Batwa, and Indigenous peoples more generally (55). Although there are several non-governmental organisations' working on health and nutrition in Kanungu, assessment of dietary intake and nutritional deficiencies is limited (56). Additionally, there are no publications on temporal variation of diets in the context of climate change, limiting evidence to support the monthly or seasonal nutritional needs of individuals, and adapt diets to environmental and climatic stressors.

To fill this gap, we first need baseline data on the current dietary intake and child feeding practices as well as information on the climatic and non-climatic factors which influence food consumption. Climate change is not the only driver of the diet and nutritional status of Indigenous Peoples (57, 58). Researchers highlight the importance of non-climatic drivers, including the socio-cultural and environmental factors, which enable individuals to better adapt and respond to extreme climatic stressors (59, 60).

In this thesis, I assess the temporal variation (over six months) of dietary intake among Indigenous Batwa and Bakiga communities, and characterize climatic and non-climatic factors influencing food consumption, and child feeding practices in south-western Uganda. This doctoral project aims to inform policy makers, and Ugandan governmental and non-governmental organizations towards the development and implementation of strategies which reduce malnutrition, by considering child and maternal nutritional needs, the likely impact of climate change, and related and compound social, and cultural factors influencing diets.

1.4 Research Aim & Objectives

The aim of this thesis is to characterize the food and nutrient intake of Indigenous Batwa and neighbouring Bakiga communities, and to explore the likely impact of weather and seasonality on diet, and on child feeding practices. To achieve the research aim of this thesis, I formulated six objectives (which are also synthesized in Tab 1):

1. To systematically review evidence on the effects of climate change on food nutritional content (micronutrients and macronutrients) globally. The aim is to define the state of current knowledge on how climatic factors may affect food composition through the analysis of existing evidence in the scientific literature.

2. To develop an appropriate methodology for collecting information on frequently-consumed foods, meals, and portion sizes among Indigenous and food insecure populations. This objective is designed to develop methods that provide locally-relevant baseline information to inform the creation of food composition databases for Indigenous communities, using the case-study of the Batwa of Uganda.

3. To create an online food composition table for assessing the diet of Batwa and Bakiga adults and children. This objective has the scope of preparing a tool to calculate caloric and nutrient intake, which is adapted to the local Batwa context.

4. To assess complementary feeding in Uganda using the latest available Ugandan Demographic and Health Surveillance (DHS) data. This objective aims to identify key predictors of minimum dietary diversity and minimum meal frequency to address specific nutritional needs of Ugandan children under two years.

5. To investigate breastfeeding and complementary feeding practices and explore socio-cultural and environmental factors which influence child feeding among Batwa and Bakiga communities. The aim is to explore maternal and child nutrition practices, and investigate possible strategies to adapt to climatic stressors. This objective is key for the design of nutritional interventions for children under two years.

6. To investigate the dietary intake of Batwa and Bakiga adults and children under two years over a six-month period. This objective is designed to explore the nutrition patterns of both communities, by assessing nutritional and caloric intake and adequacy, and considering temporal variation and seasonality, taking into consideration other compound events such as Covid-19.

Table 1. 1 Objectives of the thesis with correspondent methodological approaches, scope and chapter/output

Objective	*Methodology*	*Scope*	*Chapter & output*
1. To systematically review evidence on the effects of climate change on food nutritional content.	Systematic mapping review with confidence assessment of published papers	Global-Systematic review	Chapter 2: Published manuscript Scarpa, G., Berrang-Ford, L., Zavaleta-Cortijo, C., Marshall, L., Harper, S.L., Cade,E.J., 2020. The effect of climatic factors on nutrients in foods: evidence from a systematic map. Environ. Res. Lett. 15, 113002. https://doi.org/10.1088/1748-9326/abafd4
2. To develop an appropriate methodology for collecting information on frequently-consumed foods, meals, and portion sizes among Indigenous and food insecure populations.	Mixed methods research with community-based approach (multiple fieldwork techniques used, such as surveys, interviews, focus groups)	Local (community level)-Analysis of primary data	Chapter 3: Published manuscript Scarpa, G., Berrang-Ford, L., Twesigomwe, S., Kakwangire, P., Peters, R., Zavaleta-Cortijo, C., Patterson, K., Namanya, D.B., Lwasa, S., Nowembabazi, E., Kesande, C., Harris-Fry, H., Cade, J.E., 2021. A Community-Based Approach to Integrating Socio, Cultural and Environmental Contexts in the Development of a Food Database for Indigenous and Rural Populations: The Case of the Batwa and Bakiga in South-Western Uganda. Nutrients 13. https://doi.org/10.3390/nu13103503
3. To create an online food composition table to add to myfood24 database for assessing the diet of Batwa and Bakiga adults and children.	Construction of a food composition database (quantitative analysis)	Local (community level)-Analysis of primary data	Chapter 4: Published manuscript Scarpa, G., Berrang-Ford, L., Bawajeeh, A.O., Twesigomwe, S., Kakwangire, P., Peters, R., Beer, S., Williams, G., Zavaleta-Cortijo, C., Namanya, D.B., Lwasa, S., Nowembabazi, E., Kesande, C., Rippin, H., Cade, J.E., 2021. Developing an online food composition database for an Indigenous population in south-western Uganda. Public Health Nutr. 24, 2455–2464. https://doi.org/10.1017/S1368980021001397
4. To assess complementary feeding in Uganda using the latest available Demographic and Health Surveillance (DHS) data.	Quantitative methods, logistic regression models	National-Analysis of secondary data	Chapter 5: Manuscript under *Nutrients* review Scarpa, G., Berrang-Ford, Galazoula, M., Kakwangire, P., Namanya, D.B., Tushemerirwe, F., Ahumuza, L., Cade, J.E Identifying predictors for Minimum Dietary Diversity and Minimum Meal Frequency in children aged 6-23 months in Uganda.

5. To investigate breastfeeding and complementary feeding practices, and explore socio-cultural and environmental factors which influence child feeding among Batwa and Bakiga communities.	Mixed methods research with participatory community-based approach (interviews & surveys, focus groups discussion)	Local (community level)- Analysis of primary data	Chapter 6: Published manuscript Scarpa, G., Berrang-Ford, L., Twesigomwe, S., Kakwangire, P., Galazoula, M., Zavaleta-Cortijo, C., Patterson, K., Namanya, D.B., Lwasa, S., Nowembabazi, E., Kesande, C., IHACC Research Team, Cade, J.E., 2022. Socio-economic and environmental factors affecting breastfeeding and complementary feeding practices among Batwa and Bakiga communities in southwestern Uganda. PLOS Glob. Public Health 2, e0000144. https://doi.org/10.1371/journal.pgph.0000144
6. To investigate the dietary intake of Batwa and non-Batwa adults and children under two years over a six month period.	Mixed methods research with participatory community-based approach (multiple fieldwork techniques used, such as surveys, interviews, anthropometric measurement)	Local (community level)- Analysis of primary data	Chapter 7: Manuscript under *Environmental Research: Health* review Scarpa, G., Berrang-Ford, L., Twesigomwe, S., Kakwangire, P., Galazoula, M., Zavaleta-Cortijo, C., Patterson, K., Namanya, D.B., Lwasa, S., Ninshaba, E., Kiconco, M., IHACC Research Team, Cade, J.E. Exploring dietary adequacy and temporal variability among Indigenous and rural communities in Kanungu District, Uganda.

1.5 Theoretical approach

This research is situated within the transdisciplinary fields of health and nutrition, and human geography.

In the past, different theoretical constructions have been used to explain health and disease processes, for example human ecology and disease theory. However, these theories focused mostly on individual and biological factors, as well as human behaviour, including the socio-cultural contexts that influence how people are exposed to hazards (61). With the development of human/health geography as a discipline, exploring the social and cultural aspects of health became necessary to understand and conceptualize wellbeing, going beyond disease distributions (62). Human geographers, in fact, highlight the importance of the environment's effect on health (63). Environment in this context is defined as the social and physical places and spaces where people live (64, 65).

Different theoretical frameworks investigating health and environments are used within health geography field (64, 65), with an interest in analysing health disparities within and among different communities (66). For example, obesity and heart diseases vary depending on socio-economic status (SES), with a higher proportion of sick people belonging to the lowest SES group (67). According to the literature (68), stress is associated with many illnesses including heart diseases, making people in the lowest SES not only more susceptible, but also less able to cope during stressful situations.

In 1974, Lalonde argued that there are twelve social determinants factors, which influence health disparities, including gender, physical environments, coping practices, child growth and development, health services, and culture (69). Through consideration of social determinants, researchers can investigate *how* and *to what extent* both physical and social environments may influence health (70). Population health determinants have been characterized as either compositional or contextual, reflecting the importance of multi-level drivers of gradients in health (71). Compositional factors reflect the characteristics of individuals, including age, sex, and other demographic information. These combine and interact with contextual factors – for example the socio-cultural and environmental conditions within which individuals live and are exposed to – to characterize populations' health (72, 73).

Studying social determinants of health among Indigenous populations is particularly important to provide in-depth information on the socio-cultural aspects of health, including perceptions, traditional medicine and remedies, in contrast with the western idea of biomedicine (74). Indeed, the idea of health among Indigenous communities refers to the mental, physical and emotional wellbeing, and not to individual health status only (75, 76). Also, through sociocultural approaches, the importance of exploring land and land possession, and environmental changes for Indigenous peoples has been shown (77, 78).

More recently environmental and climatic changes became part of the work of health geographers (79). Climate change has been considered a modifier of health, with many of the mechanisms linking climate to health acting indirectly through processes of food/crop production, food security, and nutrition (80, 81). In this context, the social determinants of health disparities determine *how* climatic conditions influence health (5). To analyse the effects of climatic changes on human health, food security and nutrition, a vulnerability framework has been widely applied in health geography (82).

1.5.1 Vulnerability framework

The vulnerability framework is the theoretical approach used for this work. It was developed to explore the multifactorial drivers of communities' vulnerability to climatic changes (83-85). The United Nations Framework Convention on Climate Change, and Intergovernmental Panel on Climate Change (IPCC) use this framework, which is commonly adapted for Indigenous populations (86). IPCC highlighted the importance of evaluating vulnerability in the context of climate change to inform policy and action (87). The socio-political and economic drivers of vulnerability among populations are important levers for responding to, and building resilience in the face of, climate change, and are critical in underpinning the adaptive capacity of Indigenous Peoples to cope and adapt to climatic stressors (85).

The vulnerability framework describes the extent to which a system is susceptible to climatic changes' effects. Vulnerability is a function of: i) *exposure* to the climatic event or hazard (e.g. flooding, drought, changes to food system), which has an impact on the system; ii) *sensitivity* reflects the extent to which a population is affected by an exposure or climate hazard, and can include demographic, cultural and social factors, and, iii) *adaptive capacity*, which is the ability to respond, and to adapt to climatic impacts (88). While two communities may experience an identical climatic exposure (e.g. a flood), a community with higher sensitivity (e.g. subsistence farming and already food insecure) and/or lower adaptive capacity (e.g. weak social support networks for food sharing) will be more vulnerable in terms of climate risk and impacts (84).

There have been two main conceptualizations of vulnerability: biophysical and contextual vulnerability (89). Biophysical vulnerability takes into consideration the geographical context of a community, in which livelihoods and distribution of resources can make people more susceptible to an exposure (climate hazard) (90). Contextual vulnerability considers the interaction between climatic and non-climatic (socio-economic and political) factors, defining to which extent climatic changes exacerbate existing health inequalities, making communities more vulnerable (60, 89).

This thesis focuses on the evaluation of current vulnerability, and specifically I characterize the ways in which nutrition among young children and mothers interacts with climatic and non-climatic factors in the past and present, with implications for future diet and nutritional pathways.

1.5.2 Conceptual framework

The presented conceptual framework of this thesis aligns with the vulnerability framework (Fig. 1):

- *Exposures* are the climate extremes, variability and changes which affect the area of Kanungu District in south-western Uganda, where the Batwa and Bakiga communities live. The climatic factors have a direct impact on food production, and a negative effect on food security and nutrition.
- *Sensitivity & Adaptive Capacity* refer to non-climatic factors: socio-political and environmental contexts of the communities of interest, including socio-economic and health disparities, and removal from ancestral lands. Given the vulnerable context of Batwa and Bakiga, successful strategies have to include interventions to reduce poverty together with behaviour change interventions to prevent malnutrition.
- *Resulting Vulnerability* reflects predisposition to undernutrition, and other health related issues affecting the individual nutritional status of Batwa and Bakiga young

children and adults. The resulting vulnerability manifests in effects on human health of the interaction between exposure, sensitivity and adaptive capacity.

Some differences exist between the Batwa and Bakiga communities. Non-climatic factors, including poverty, lack of formal education, and health inequalities are considered to affect the Batwa more severely than neighbouring Bakiga populations (91-94). To assess any differences and similarities, a non-Indigenous community sample (the neighbouring Bakiga) has been enrolled in the study to compare diets, child feeding practices, and climate change adaptation strategies, relevant for nutrition security.

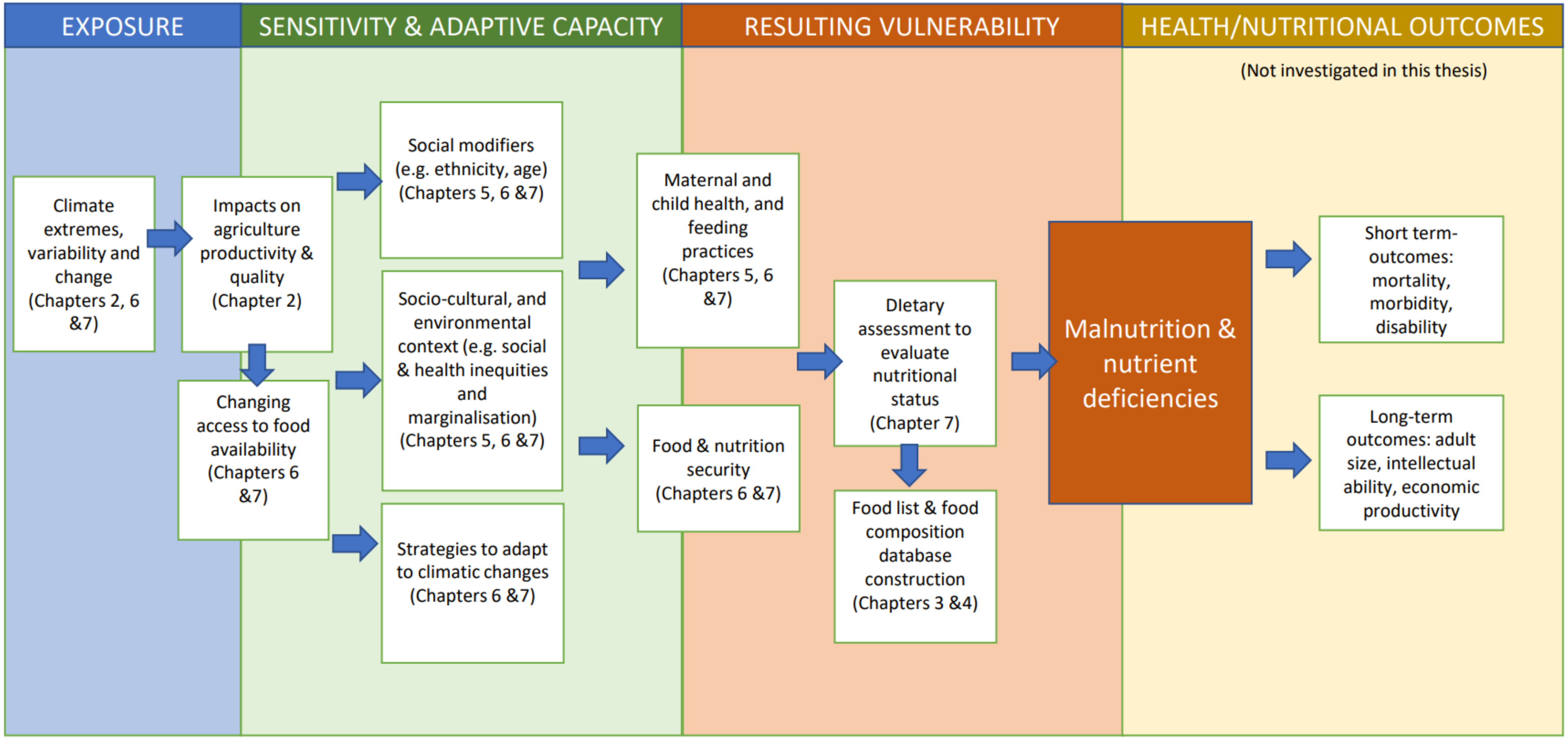

Figure 1.1: Conceptual framework for this thesis

1.6 Methodological approach

1.6.1 Participatory community-based research

The vulnerability framework is generally applied using a participatory community-based research approach. Through this approach, participants can actively participate in the research process, consider and identify problems, and co-produce knowledge with researchers, by continuously reflecting and generating useful data for the community (95). Studies conducted among Indigenous communities in south-western Uganda found that mothers wanted to be actively involved in the research process from the design to the dissemination of the results, enhancing 'bottom-up' research. .

Although research is never completely decolonized, recognizing the implications of colonization and history of research, and highlighting the experiences and local knowledge of Indigenous Peoples are first steps towards the decolonization (97, 98). Community-based research gives the opportunity to the participants to share knowledge rather than having their knowledge taken away (99). Collaboration in the different steps of the study, from the conceptualization to the results dissemination, helps in tackling community's priorities and needs (100).

The different steps of my work were developed in collaboration with community members and local researchers, with the aim of transforming research into action (101). The idea of focusing on maternal and child nutrition was discussed informally before this study started, and the main topics were chosen by the community, who were keen to find solutions to end hunger among children and learn more about nutrition. The research team comprised Batwa, Bakiga, and Ugandan local researchers, including nurses, midwives and nutritionists, who were in charge of the fieldwork, data collection, and translation. They were all involved from the beginning of the study, including ethics clearance, up to the writing of the manuscripts, and dissemination of results within the communities. This facilitated the conceptualization and design of the work, and the discussion of the results with the community members, including the plan to disseminate the findings at the hospital, district and national level. For Chapter 3, 4 and 7, the level of participation of the community was higher in the results and dissemination of findings' stages, while in Chapter 6 the mothers played a significant role in the data collection phase as well as in the results and dissemination of findings. During the dissemination of findings, the community decided how and which results to communicate at the district/local level (local government, hospital, NGOs).

Also, for each step of this research, community, community leaders and relevant stakeholders were involved, and we discussed together the study design to make sure that the methods, data collection's tools and ethical considerations were appropriate for the research participants. Relevant stakeholders were also included as co-authors of the manuscripts published in the journal. Unfortunately, no Batwa and Bakiga were included as co-authors given high levels of illiteracy, but they were always acknowledged in the acknowledgement section.

Debriefings with the local research team were continuously conducted, especially during the data collection and analysis of results, given that I was located remotely throughout all of the fieldwork due to Covid-19 restrictions. These sessions helped in better contextualizing the findings, and improved the rigor and validity of the research (102).

According to local custom and in consultation with local research partners, a gift was given to the participants joining the focus groups and interviews (food to take at home and bars of soap). For the households involved in the multiple dietary surveys (last phase of this work), we decided together with the community chairpersons and members to give a gift of appreciation (e. g. solar panel, mattresses, cushions, etc) for the time spent with the research team.

1.6.2 Mixed methods research

The advantage of a mixed methods design is to explore a research problem from different angles, using both qualitative and quantitative findings (103). In this project, I used concurrent data collection, with the analysis and interpretation of quantitative and qualitative results conducted at the same time. This allowed me to triangulate, complement and confirm results that emerged by improving data validity and authenticity (104, 105). Additionally, studies using mixed methods can provide more accurate, and complete information to implement policies (106). For the qualitative analysis, I used the thematic analysis, which consisted of the description and interpretation of data, both inductive and deductive, highlighting the context, and with the integration of manifest and latent contents. Manifest content, in fact, comes through a deductive approach; latent content results from an inductive analysis.

Multiple qualitative and quantitative methods were used in this work, including:

1. **Dietary surveys (Chapter 3):** The local team collected information on the most commonly consumed foods, snacks and meals among adults and

children, by interviewing women and men on the food they consumed in the previous 24 hours, but not specifying the portion sizes. This method informed the creation of the food composition database for the Batwa and Bakiga.

2. **Shops & markets assessment (Chapter 3):** The local researcher visited local shops and markets, and reported the type of foods for sale. This method was especially useful to triangulate the data collected in the dietary surveys and focus groups, and helped to add some branded foods to the specially-developed food database, which were not collected with the other methods.
3. **Focus group discussions (Chapters 3 & 5)**: From previous research, focus groups were considered the preferred methods by the participants for the possibility to share experiences, and learn from each other, as highlighted in literature by Hunt & Young (107). The participants were treated as "co-researchers and knowing subjects with the same rights as the professional researchers" (108). In the focus groups, we explored commonly consumed foods and dishes, climatic and environmental changes, and investigated child feeding practices. During the debriefings, the local team reported that women felt comfortable sharing ideas within the group as they interacted with well-known local researchers who had worked regularly with the communities in the past. The focus groups were conducted in the local language, Rukiga, and later translated by the local researcher (moderator of the focus groups).
4. **Secondary data analysis (Chapter 6):** We decided to assess child feeding practices using the Ugandan Demographic and Health Surveillance data to characterize the status and determinants of child nutrition in the country, given the scarcity of data at local and national levels. This helped to add national-level quantitative context to the qualitative data collected in south-western Uganda, placing the Batwa within the wider comparative context of Uganda. However, the Batwa were not involved in the DHS survey. We believe that this work could inform policy makers, and guide interventions also in the area of Kanungu District, where many Bakiga are in need of nutrition support.
5. **24-hour recall (Chapter 7)**: The quantitative 24-hour recall has been chosen as method for this study for the accuracy of the results obtainable on caloric and nutritional intake among different populations in low-income countries. Multiple dietary surveys were conducted across the six-month period, which allowed me to evaluate diet trends and variation over seasons. Obtaining

precise measurements and portion sizes was important to assess the dietary quality; and to inform governments for new policies (109).

6. **Individual interviews (Chapter 5 & 7):** We conducted interviews with Batwa and Bakiga participants to investigate the accessibility and availability of foods over seasons and monthly, and their perceived effects of weather and environmental change on diets. Individuals shared difficulties and worries for not being able to feed their families with food of quality, given the high food insecurity in certain periods of the year. For the focus groups and interviews, the local team was trained to reduce power imbalances, and build a relationship of trust, making the participants feeling comfortable in sharing sensitive topics and challenging researchers (107).
7. **Questionnaires (Chapter 5 & 7):** Questionnaires with semi-structured and some open-ended questions were administered to the Batwa and Bakiga participants through short interviews. The questions investigated: i) breastfeeding practices, maternal and infant health; ii) individual socio-demographic information, including questions on food security, water and sanitation, and general health status; iii) information on food availability, accessibility and consumption during the Covid-19 outbreak. The questionnaires were essential to contextualize and add more quantitative details to the results of the dietary surveys, and child feeding practices. The Covid-19 section was added to the study, given the negative impact that the pandemic played on Indigenous food systems, and nutrition (110).
8. **Anthropometric measurements (Chapter 7):** Height, weight and middle-upper arm circumference were measured for all participants as a proxy of nutritional status. We calculated body mass index (BMI) for adults, and stunting, wasting and underweight for children. This information allowed me to assess the relationship between caloric and nutrient intake, and nutrition status of each individual.

1.7 Thesis structure and contributions

This is a manuscript-style thesis with eight chapters, including six manuscripts. The first chapter introduces the entire thesis, explaining the research rationale and objectives, the role of Covid-19 in my work, and my own positionality as a researcher. Additionally, in this first section, I navigate existing scientific evidence which underpins the research questions, methods and interpretation of the research findings.

The six chapters following the introduction are the core of this thesis, and include the analysis of primary and secondary data, a systematic review, and the use of multiple research methods. AParticipatory community-based approach, and mixed methods research guide my work. Chapter two presents a systematic mapping review on the effects of climatic factors on nutrients in foods. This contributes to the interaction between literature on climate (change) and nutritional content, which is an understudied field. An assessment of the study designs and rigor in the research of the articles included in the review is included in this work. Chapter three explores multiple methods to collect critical information on foods and ingredients consumed among vulnerable communities, using the Batwa and Bakiga communities as a case study. This work contributes to integrate socio, cultural and environmental elements during the creation of food lists, which are key to inform locally-relevant food databases. Chapter four describes the development of an online food composition database for the Indigenous Batwa and Bakiga populations. In light of the limited evidence of commonly consumed foods among Indigenous and food insecure communities in south-western Uganda, this study contributes to fill this gap, and enables dietary assessment to be possible in rural Ugandan contexts. Chapter five uses quantitative methods and statistical modelling to identify key predictors of complementary feeding in Uganda, using national and secondary data from the 2016 Ugandan DHS (the latest). This research contributes to better understanding the factors associated with inadequate diet among Ugandan young children with the aim of informing policies, nutrition and nutrition-sensitive programs. Chapter six analyses child feeding practices, including breastfeeding and complementary feeding, among the Indigenous Batwa and Bakiga communities, using participatory, mixed methods and qualitative approaches. This work contributes to describing factors which play a role in child feeding by giving a voice to Indigenous mothers and women involved in childcare, who are often underrepresented in research, and at governmental level. Chapter seven explores the interaction between temporal variation (monthly), seasonality and dietary intake of Indigenous and non-Indigenous adults and children in south-western Uganda. It also reports individuals’ perception on yearly consumption of food and during extreme climatic events. Compound events, such as

Covid-19, and other social factors are considered when investigating diet. This study contributes to understanding the likely impact of climatic changes on caloric and nutrient intake among Indigenous and food-insecure peoples.

The last chapter, eight, concludes the thesis with a discussion of key findings, contributions and gaps for future research.

1.8 The role of Covid-19 in my research

Covid-19 has disrupted my work, but has also given me new opportunities and perspectives. My original research plan involved extensive fieldwork in south-western Uganda within the Batwa and Bakiga communities, and the co-production of a protocol for a nutritional intervention, sensitive to the community needs. Unfortunately, I went to Uganda only once for a period of ten days for an initial scoping and introduction visit in 2019, during which I did not collect data to use for my thesis. This was initially due to an outbreak of Ebola (August 2018-June 2020) in the Democratic Republic of Congo, at the border with Kanungu District, where the communities I worked with live, and which was followed by the Covid-19 pandemic (2020-2022). However, I did not want to change the planned work, and I decided to adapt it to the current situation. The local research staff in Uganda, who are familiar with the communities and the context, played a new and greater leadership role in the research, being in charge of all fieldwork on the ground, and being supervised by myself remotely. With extensive online and on-site training delivered by me and a local nutritionist, the previous ‘research assistants’ who worked in the field became ‘local researchers’. We built a strong relationship of trust and esteem, and each of us brought to this research expertise and enthusiasm, making the work collaborative, and of high quality. Covid-19 transformed the way this work was conceptualized, but also the way I looked at research. I understood that technology can be helpful when conducting anthropological and sociological work. Although I am aware of the limitations of not being in the field, I learnt how to investigate the life of the Batwa and Bakiga through my research team’s eyes. In some ways, I probably learnt more in this way than being there physically. In fact, I questioned every single word, discussed with the members of the team anything that was unclear to me, discussed again to analyse in-depth the situations, and better understand communities’ point of view with local researchers, who were born there, and lived in the same context. We made this research possible in a rural place where wifi is not always available, and communication by phone or email could be very difficult; however, I was able to work with the team remotely, in spite of these challenges.

The outbreak of Covid-19, also, became part of my research, and it is one of the compound factors I explored in my last manuscript/chapter (Chapter 7).

1.9 My place in this research

Each chapter of this thesis reflects a transformative journey for me, learning to be a researcher. From the first to the last manuscript, there is an ‘older’ version of me with more academic and personal experience. ‘Who I am’ informed this thesis. My background, my studies, the people I met during my thesis journey informed this work. Through the western scientific lens, I framed this project, decided the methodologies to use, and interpreted the findings, which is a limitation = important to consider. As a white female researcher, I asked myself if it was fair to do research among Indigenous communities in Africa, and explore problems that I have never experienced in my life. Although I would have never known what a Batwa woman or child feel, I thought I could raise their voice, represent their perspectives, and understand their experiences in order to inform governments, and humanitarian organizations working in the area. In the participatory community-based approach I found the best place for me and my research. It gave me the opportunity to work with Indigenous peoples by actively engaging in the research process, and understand lived experiences through their narratives (111).

My background in pediatric nursing, anthropology and global health gave to me a solid basis to conduct this research. My experience in Sub-Saharan countries helped me to understand better the Ugandan context, despite being aware that each community, each household, and individual is unique. Indigenous communities are unique. Working with and for them was fascinating, and something I wanted to do since I have been working in the global health sector. Their culture, their lifestyle is very different from any other populations in the world. However, the challenges they face are enormous.

Health disparities, poverty, malnutrition, gastro-intestinal diseases, malaria are just some of the causes of morbidity and premature deaths. As a health worker, I wanted to make my contribution to improve Indigenous health status. Dying because of lack of food or due to other preventable and treatable diseases is very common among Indigenous peoples, and unacceptable.

During my thesis, I had also the opportunity to train in mixed methods research. I think that this is key to investigate challenges in vulnerable contexts, where multiple factors are interlinked. In fact, through a mixed methodology and participatory approaches, issues could be explored more in depth, and from different angles in respecting the community’s culture and, traditional knowledge.

I hope that by collecting health and nutrition-related data, and publishing findings in scientific journals, governmental and non-governmental organizations will have sufficient information to deliver locally-relevant nutritional programs. I believe that this could contribute to decrease undernutrition cases among Batwa and Bakiga children and adults.

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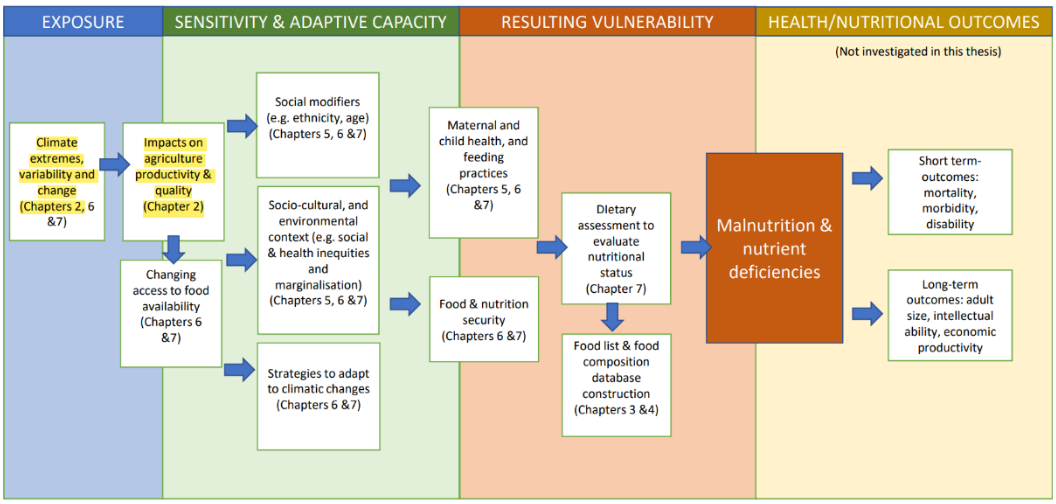
Chapter 2 - The effect of climatic factors on nutrients in foods: evidence from a systematic map

This chapter provides evidence on the effects of climatic factors, and especially seasonality and weather variability, on nutrient content in foods through a systematic mapping review.. Through the Assessment of Confidence GRADE-CERQual (‘Confidence in the Evidence from Reviews of Qualitative research’), I assessed the extent to which a review finding is a reasonable representation of the phenomenon of interest. Chapter 2 discusses the *exposure or hazard* (climatic factors and changes) component of the vulnerability framework. It investigates any difference in nutritional content over the year, and attempts to calculate these differences as a proxy for how climate change might influence food nutritional quality. The findings highlight the importance of considering environmental and climatic changes when constructing food composition databases given the potential impact on food quality, and, as a consequence, when assessing dietary intake. Also, no publications on climate change and nutrient content in foods were found in the African context. Nutritional information under changing climate on staple foods and cereals, largely consumed by rural and food-insecure communities, was not available in the literature



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The Effect of Climatic Factors on Nutrients in Foods: Evidence from a Systematic Map.

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2.1 Abstract

Background. Climate change is projected to negatively affect human health and nutrition. There is a growing literature on the effects of climatic changes on food availability, quantity, and agricultural production, but impacts on the nutritional content of foods has not been widely studied. The aim of this paper is to systematically characterise empirical literature exploring the effects of climatic drivers on macronutrients and micronutrients in foods causing malnutrition globally.

Methods. 69 peer-reviewed empirical articles (excluding experimental and modelling studies) analysing the effect of climatic drivers on nutrients in foods were retrieved from Web of Science™, Scopus® and PubMed® databases (2013-2019). Publication frequency and trends, and existing evidence of the extent of nutrient change associated with variation in climate-related conditions were assessed.

Results. There is relatively limited literature on associations between climate and nutrients in foods. Where it exists, only crude proxies of climate (e.g. wet/dry season) are used, with limited interrogation of the potential causal mechanisms linking climate to nutrient content. 98% of the articles showed a change in nutrient content in relation to a seasonal or meteorological variable. Most analysed the association of nutrient changes between seasons over 1-2 years, rarely over longer periods of time. Preliminary descriptive estimates point to variation in nutrient content by meteorological variability, particularly in ocean and freshwater food sources.

Discussion. Robust assessment of potential climate impacts on nutrient content of foods would benefit from more precise estimation of specific causal pathways and variables that mediate climate impacts on food, going beyond seasonal or crude proxies. There is need for clear articulation of how climate change might impact nutrient content given mechanisms linking meteorological and seasonal variation with

nutrients. This research highlights emerging evidence that climate change may have impacts beyond agricultural productivity by affecting food nutrient content, an understudied but potentially important pathway for climate impact on global food and nutrition security.

2.2 Background

Malnutrition — associated with deficiencies or imbalances in caloric or nutrient intake — is a major cause of ill health and burden of illness worldwide (1, 2). Nearly half of deaths among children under 5 are attributable to undernutrition caused by inadequate dietary intake and disease, typically stemming from a combination of food insecurity, inappropriate maternal and child feeding practices, and/or poor health services (1). Climate change will affect the variability of the weather and environmental conditions that underpin global agriculture (3). Agriculture and crop production are, thus, expected to be among the major pathways of impact for climate on health, with growing projections of decreases in the productivity of major global crops (4-6).

The effects of climate change on agriculture are projected to negatively impact global nutrition, and this is likely to increase in the future (7-11). Effects will be particularly severe in sub-Saharan Africa and South Asian countries where the burden of malnutrition is already high and health systems are in many cases strained or weak (12, 13). Malnutrition is a risk factor for neonatal and child mortality, as well as for maternal reproductive and other health adverse outcomes (14-18). Further, poverty exacerbates food insecurity and undernutrition, and without adaptation strategies malnutrition is expected to increase (4, 19).

There is a growing literature reviewing the evidence of climate change, or proxies of climate change such as seasonality or meteorological/weather variability, on food production and nutritional status. The predominant focus of this literature has been on assessing current/past associations of climate or weather variability with food quantity or crop productivity, or projecting future trends in nutritional status based on estimates of crop productivity. There has been relatively limited consideration, however, of potential climate impacts on malnutrition through mechanisms of *changing nutrient content of foods*. Macronutrients and micronutrients are part of a healthy diet, and they ensure appropriate development and wellbeing and prevent diseases. Children aged between 6 months and 5 years in particular suffer from micronutrient deficiencies (2).

Vitamin A, iodine, and iron are the most common deficiencies and a concern for public health (20). Iron deficiencies in pregnant women increase the risk of maternal and child mortality, and low birth weight. Iodine deficiency affects the neurological development of children, while vitamin A deficiency raises the probability of blindness and mortality due to infectious diseases during childhood (2). One systematic review (21) analysed the impacts of climate change on undernutrition, but did not focus on mechanisms of impact via food micronutrients or macronutrients. A 2018 study by Scheelbeek *et al.* (22) systematically investigated the effect of environmental change on vegetable and legume yields, in particular exploring projections in the potential future nutritional quality of vegetable and legume yields under environmental change.

Generally, climate change affects the molecular function, the developmental process, the morphology and the physiological responses of plants (23). Elevated CO_2 promotes higher yields, but alters the equilibrium of the plant carbon metabolism and mineral composition as well as nutrient-use efficiency (24). Furthermore, the effect on plants mostly depends on genotype and interactions of each nutrient with climatic factors (25). For example, drought and high temperatures induce oxidative damage in legume plants according to the review of Soares (25), and this is more likely to have an effect on the macronutrients.

Despite this emerging interest, we identified no systematic reviews of studies focusing on the impact of climate and climate change on nutrients in foods. This review responds to a research gap on the impact of climate, climate change, and its proxies on nutrient content of foods. The particular and unique focus of this review is on systematically synthesising empirical evidence on the impact of weather, climate, and climate change on *nutritional content* of foods. This focus adds new value to existing evidence, and compliments a predominant focus in existing literature on climate impacts via crop productivity.

2.3 Methods

2.3.1 Conceptualising climate impacts on food nutrient content

Though interested primarily in climate and climate change, we consider proxies of climate change as eligible exposures in this review. Climate is not synonymous with weather/meteorological variability. ‘Climate’ refers to long-term changes in the atmosphere, with climate variability observed over long temporal scales (years, decades, centuries). ‘Weather’ or meteorological variability, in contrast, represents daily observable conditions such as temperature, precipitation and wind, which vary and can be observed throughout the day and at finer timescales (26). Climate change will impact malnutrition by affecting patterns in weather, including trends in precipitation and temperature, as well as the frequency and magnitude of extreme weather events. It is difficult to study climate associations with human health given that data for both climate and health would be required for long time periods (ideally >10 years) (27). It is thus common for research to explore the associations between weather and health outcomes at more feasible temporal scales (daily, weekly, monthly, or yearly over <5 years) as a proxy for potential climate change impacts. This includes variables such as season, short-term trends and variation in precipitation or temperature, and meteorological events such as heatwaves, droughts, and floods (28) as proxies for climatic change. Notably, associations between weather and meteorological variability and health outcomes are not necessarily representative of how outcomes will change under a changing climate. Recognising the predominant use of proxies of climate change, however, eligible articles included variables related to weather and meteorological variability.

Indeed, climate change influences seasonal variability, in terms of averages and variation in precipitation and temperature, as well as the frequency of extreme events (Fig. 2.1), and those may impact on human health. For example, there is an association between higher temperatures and increased heat stress during pregnancy (29), while droughts and floods have the potential to enhance food insecurity, reduce child growth, and increase the burden of diseases (30, 31).

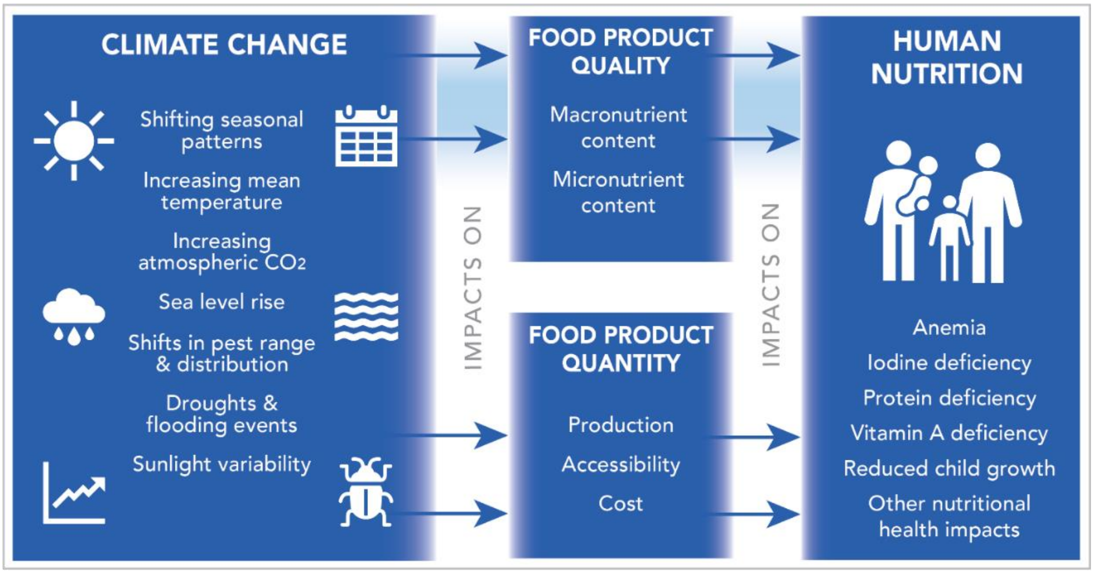

Figure 2. 1 Conceptual Map Climate Change- Nutrition: adapted from FAO (32) & NZFSSRC (33).

This review focuses on the top pathway, specifically the impacts of climate change on human nutrition via food product quality (nutrient content). We do not consider pathways via food product quantity, which has been extensively explored elsewhere.

While the impact of climatic stressors on food security has been explored (7-11), less attention in the literature has focused on how climate change could affect nutritional content of foods as existing nutritional analyses rarely consider changes over time. Some modelling and experimental studies conducted in laboratories have identified correlations between climate change or meteorological variation and a decrease in food quality in terms of diversity, nutrient density, and safety (34-37) (Table 2.1).

Carbon dioxide (CO_2), for example, may have a negative effect on the nutritional content of several crops such as wheat, potatoes, rice, and peas (38). For example, concentrations of iron and zinc in wheat and rice are more likely to be reduced due to increased greenhouse gas emissions (23). Higher CO_2 associated with climate change is hypothesised to lead to micronutrient deficiencies (23, 39-41).

Table 2. 1 Climate variables used to assess the impact of climate on nutritional content of foods.

Climate variables	Definition	**Impact on foods**
Change in CO_2	Carbon dioxide concentrations in the atmosphere	Changes in CO_2 have been associated with decreased availability and production of foods (26). Fanzo et al. (53) postulate that climate change and increasing levels of carbon dioxide could significantly reduce the availability of critical nutrients in food products, including protein, iron and zinc.
General seasonal variability	Inter-seasonal variability (variability among one season and the next one). It includes any intra-annual seasonal categorization, including for example 4 seasons (winter, spring, summer, autumn), 2 seasons (dry, wet), or monsoonal seasons	Shifting seasonal means and increased seasonal variability will impact food production, pests and diseases in crops and livestock (53). This has the potential to include impacts on the nutrient quality of foods due to accelerated development under warmer conditions (53)
Precipitation variability	The quantity and variability over time of precipitation (e.g. rain, snow); extremes are associated with flooding or droughts	Precipitation change and increased variability can decrease land productivity and soil quality (13). Particularly, poor soil quality restricts crop productivity and nutritional quality, particularly micronutrients (6).
Sunlight variability	Quantity and temporal variability of sunshine	The sunlight will impact agriculture, especially by decreasing crop yields, livestock productivity and fisheries (4). An experimental study (2018) showed that the nutritional quality (especially micronutrients) of different type of beans were reduced with the impact of additional solar radiation.
Sea level rise	Rise of sea levels along coasts, associated with thermal expansion of ocean waters and glacial melting	Through sea level rise, there will be an increase of groundwater salinization affecting the quantity and quality of water with consequences on crops and plants quality (11). Further, it will pose new transportation challenges for foods (61). If the food supply chain is interrupted, this can have consequences on the nutritional value of foods during processing (61).
Temperature variability	Change in average or variability of temperature overtime	Food insecurity is projected to increase with global warming (26). Higher temperatures and decreased water availability impact negatively on food quality and safety, and increase food spoilage and waste (13).

2.3.2 Review Approach

A systematic mapping review approach was employed as per the ROSES Reporting Standards for Systematic Evidence Synthesis (42) to assess the association of any climatic/meteorological factors with macronutrients and micronutrients in edible products. We included articles from 1st January 2013, based on the publication date of the keystone IPCC report on climate change (26) to 30th June 2019.

The geographical scope of the review is global, with no restriction by geographical area (population). To be eligible for inclusion, articles were required to include at least one paragraph describing a climate-related variable within analyses, including measures of weather, meteorological variability (temperature or precipitation), season, climate, or climate change (exposure). Articles were also required to explicitly describe and include measures of food nutrient content (outcome), specifically micronutrients or macronutrients that are causes of nutritional deficiencies globally according to WHO (1). The review comprises all types and categories of food. We included empirical papers in order to focus on place-based data in real world contexts; experimental and modelling studies were thus excluded.

2.3.3 Searches

Keyword searches were conducted in Scopus®, Web of Science™, and PubMed®. A search string was created for PubMed® and then adapted for the other databases on consultation with team members and a research librarian. The PubMed® MeSH database was consulted to generate indexing terms for “climate change” and “season” and the terms were adapted from Bryson and Scheelbeek (22, 43). Search terms for nutrients were adapted from WHO and FAO (2, 44, 45). After adapting the search string, Scopus® and Web of Science™ were searched in June 2019 (Tab.2.2). Additionally, reference checking was performed on articles included for the review. A similar search methodology was used in other systematic map and reviews (21, 43, 46). The search was updated until November 2019, but no new articles were found relevant for the review. The reference management software EndNote® was used to extract and collect the search results. No restrictions on language were applied; however, all search terms were in English, restricting the review to articles indexed in English (i.e. title and abstract translated if full text was non-English).

Table 2. 2: Results from each database of the final search string on studies exploring impact of climate on nutritional content of foods included in the review.

Database	Search String
Web of Science	**TITLE:** (climat* OR greenhouse OR temperature OR "extreme weather" OR heatwave* OR heat-wave* OR "heat wave" OR "extreme cold" OR flood* OR "storm surge" OR landslide* OR windstorm* OR cyclone* OR humidit* OR drought* OR "quality W/1 water" OR "availability W/1 water" OR biodivers* OR "health of the planet" OR UV OR season* OR rain* OR precipitation* OR drought) *AND* **TITLE:**(micronutrient* OR macronutrient* OR nutrient* OR nutrition* OR nutritious OR vitamin* OR mineral OR iron OR zinc OR calcium OR beta-carotene OR "beta carotene" OR betacarotene OR folate* OR "folic acid*" OR "folic-acid*" OR folicacid* OR "amino acid*" OR "amino-acid*" OR aminoacid* OR iodine OR phosphorus OR phosphorous OR magnesium OR fat OR fats OR protein OR proteins OR carbohydrate OR carbohydrates) *AND* **TOPIC:** (*nutri* OR food*) Refined by: **DOCUMENT TYPES:** (ARTICLE)
Scopus	TITLE (climat* OR greenhouse OR temperature OR "extreme weather" OR heatwave* OR heat-wave* OR "heat wave" OR "extreme cold" OR flood* OR "storm surge" OR landslide* OR windstorm* OR cyclone* OR humidit* OR droug ht* OR "quality W/1 water" OR "availability W/1 water" OR biodivers* OR "health of the planet" OR uv OR season* OR rain* OR precipitation* OR drought) AND TITLE (micronutrient* OR macronutrient* OR nutrient* OR nutrition* OR nutritious OR vitamin* OR mineral OR iron OR zinc OR calcium OR beta-carotene OR "beta carotene" OR betacarotene OR folate* OR "folic acid*" OR "folic-acid*" OR folicacid* OR "amino acid*" OR "amino-acid*" OR aminoacid* OR iodine OR phosphorus OR phosphorous OR mag nesium OR fat OR fats OR protein OR proteins OR carbohydrate OR carbo hydrates) AND TITLE-ABS-KEY (*nutri* OR food*) AND (LIMIT-TO (DOCTYPE , "ar"))
PubMed	((climat* OR greenhouse OR temperature OR "extreme weather" OR heatwave* OR heat-wave* OR "heat wave" OR "extreme cold" OR flood* OR "storm surge" OR landslide* OR windstorm* OR cyclone* OR humidit* OR drought* OR "quality W/1 water" OR "availability W/1 water" OR biodivers* OR "health of the planet" OR UV OR season* OR rain* OR precipitation* OR drought)) AND (micronutrient* OR macronutrient* OR nutrient* OR nutrition* OR nutritious OR vitamin* OR mineral OR iron OR zinc OR calcium OR beta-carotene OR "beta carotene" OR betacarotene OR folate* OR "folic acid*" OR "folic-acid*" OR folicacid* OR "amino acid*" OR "amino-acid*" OR aminoacid* OR iodine OR phosphorus OR phosphorous OR magnesium OR fat OR fats OR protein OR proteins OR carbohydrate OR carbohydrates)

2.3.4 Article Screening

Articles were screened using predefined selection criteria (Tab. 2.3), screening first by title and abstract, and then by full text. To ensure quality of screening and conduct consistency checking, a second reviewer screened a sample (10%) of articles.

Table 2. 3: Inclusion and Exclusion Criteria on studies exploring impact of climate on nutritional content of foods included in the review.

INCLUSION CRITERIA	EXCLUSION CRITERIA
(1) Empirical papers of studies conducted in real world settings.	(1) Experimental studies in laboratory or greenhouse, model-based studies.
(2) Analyses include a climate variable or a proxy variable of climatic variability (e.g. extreme event, season) - at least one paragraph.	(2) Contain less than a paragraph describing the climate variable or proxy, or no relevant variable analysed.
(3) Analysed the association of a climate variable (or proxy) with a variable measuring nutrient content (food quality).	3) Describes associations with availability/quantity of food rather than quality (nutrient content).

2.3.5 Data Extraction and Analysis

Results were exported to Excel® for coding and analysis. Descriptive information was extracted, including title, name of journal, author(s), year of publication, country of origin, type of food studied, food category, type of micronutrient(s) and/or macronutrient(s), climate variable or proxy studied, scale of temporal comparison, theorised mechanism for climate impact, and main findings in terms of climate-nutrient associations. The foods found in the articles were grouped into 10 main categories following FAO/WHO Food Standards (47): cereals, vegetables, fruits, legumes, dairy, meat, fish, eggs, bee products, and tea leaves. Macronutrients and micronutrients analysed by the studies included carbohydrates, proteins, lipids, iron, vitamin A, zinc, iodine and vitamin D. These specific nutrients were chosen for analysis as they are the most common drivers of nutrient deficiency causing malnutrition globally (45).

Climate factors were analysed into 6 key groups based on an *a priori* review of the literature: change in CO_2, general seasonal variability, precipitation variability, sunlight variability, sea level rise, and temperature variability (Tab. 2.3). The analytic focus of articles as months, seasons, years, and decades was categorized to reflect the temporal resolution of comparisons of change in climate (proxies) and nutrient content over time.

Graphs and descriptive statistics were used to display the number of publications by: year over time, geographical area, climatic variable, methodological approach, and food category. Meta-analysis was not feasible given high heterogeneity in the variables and methods used to measure climate variability and nutrients. Counts of the number of publications were used for all combinations of food type-climate variable and nutrient type-climate variable to generate ‘heat maps’ indicating the frequency of publications across different food type, nutrient, and climate variable categories. Where possible, estimates of change in nutrients for contrasting climatic/meteorological conditions were extracted by calculating the difference between the extreme values, and converting the difference found in percentages. The percentage difference was calculated in nutrient content for fish, dairy, and vegetable categories. Quantitative data were extracted for three food categories only, as there were an insufficient number of studies or relevant data for extraction in other food categories. For this sub-set analysis, we used twenty articles, including fish (n=14), dairy (n=3) and vegetables (n=3). These estimates were categorised by food category and nutrient type and results were summarised in tables as indicative estimates and ranges of nutrient variability by environmental-climatic-weather conditions.

2.3.6 Assessment of Confidence of Key Findings

As this review reflects a systematic map (42), our objective was to summarize the scope and breadth of research on the topic. We thus did not conduct formal critical appraisal of articles included in the review. However, the articles were appraised to extract information to facilitate assessment of confidence in evidence of our key review findings, focusing on adequacy and coherence of findings. In doing so, we adapt the Grade CERQual (48) approach to assessing confidence in evidence. As per Grade CERQual, adequacy is “*an overall determination of the degree of richness and quantity of data supporting a review finding,”* while coherence is “*an assessment of how clear and compelling or supportive the fit is between the data from the primary studies and a review finding that synthesizes that data.”*

Results

The databases search retrieved 3,524 articles (excluding duplicates) of which 67 were included after title and abstract screening; 14 additional articles were identified through reference checking. Following full text screening, 69 articles met the inclusion criteria, and proceeded to data extraction and analysis (Fig. 2.2).

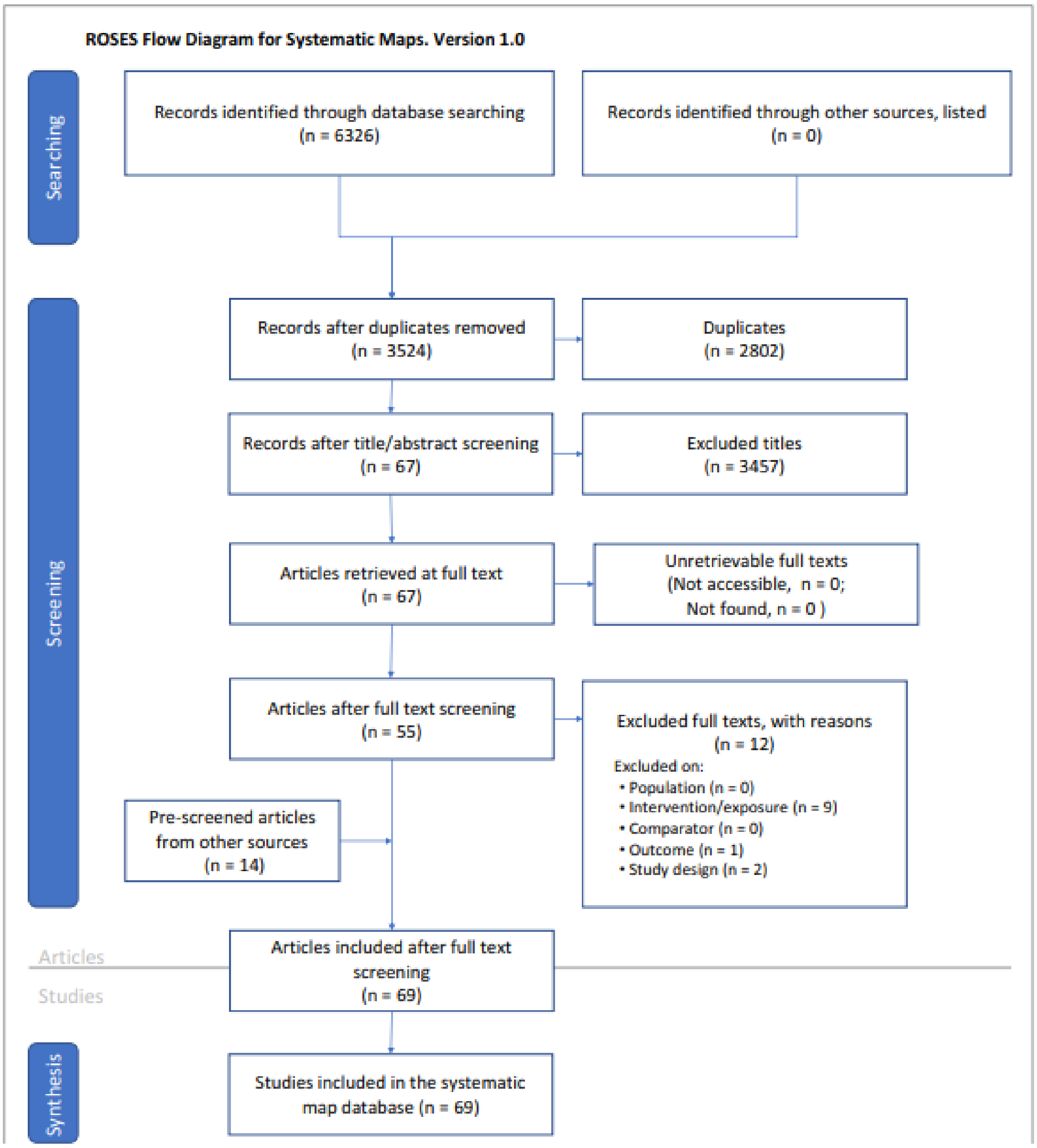

Figure 2. 2 ROSES Diagram Flow for Systematic Map on studies exploring impact of climate on nutritional content of foods.

Reproduced from https://www.roses-reporting.com/flow-diagram. CC BY 4.0.

Of 69 studies included in the systematic map data analysis, over the period of publication approximately 10 papers were published per year (Fig. 2.3). All included articles (n= 69) are empirical and field-based, and employed quantitative methods to analyse the association of climate variability on nutrient content.

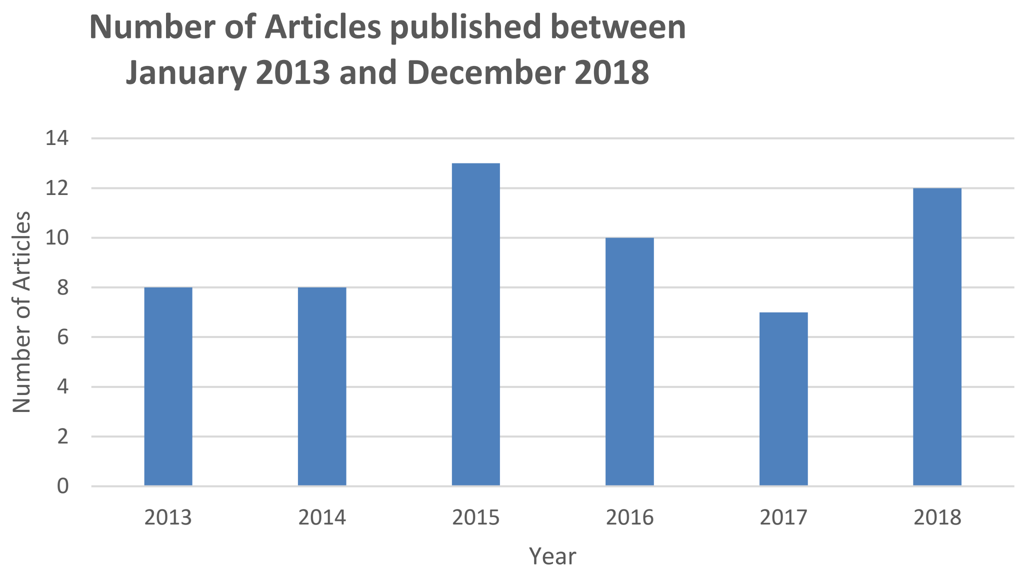

Figure 2. 3: Number of articles published in the last 6 years on studies exploring impact of climate on nutritional content of foods included in the review.

2.3.7 Geography of Included Studies

Studies in the systematic map spanned a range of geographic areas (Fig. 2.4). The most studied areas were South Asia, the Middle East, Europe, and the Americas. The three countries with the most articles were India (n = 12), Turkey (n = 9), and the USA (n= 5), which together accounted for ~40% of all included studies (Fig. 2.4).

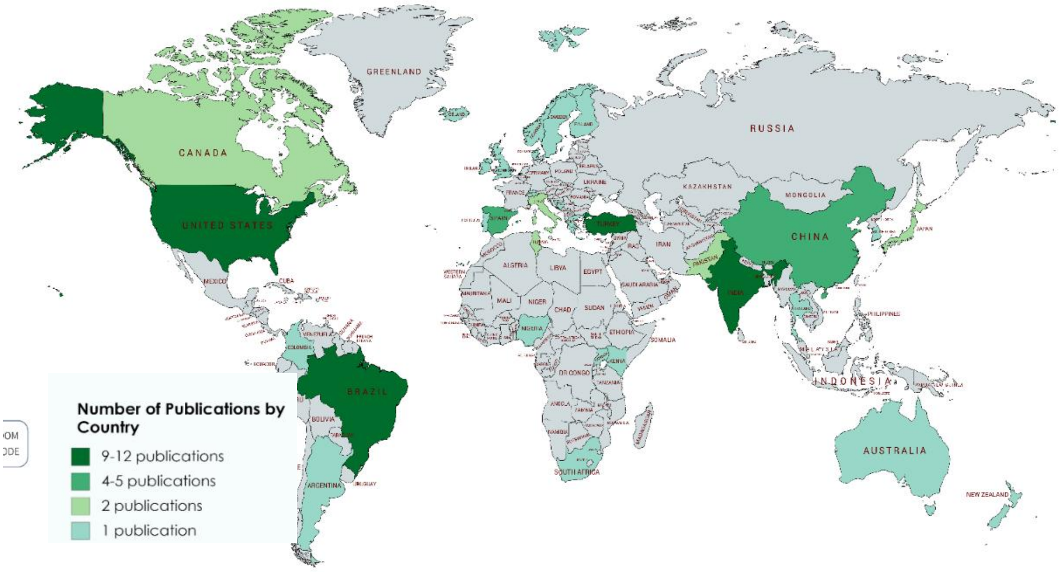

Figure 2. 4: Countries reporting on studies exploring impact of climate on nutritional content of foods included in the review.

2.3.8 Climatic Variables and Methodological Approach

From the six climate variables investigated, seasonal variability was the most frequently used exposure variable (n=62). Seasonal variability included a range of categorisations, including two (rainy and dry), three (pre-monsoon, monsoon, and post-monsoon), and four (winter, spring, summer and autumn) seasons. Articles investigating data on temperature variables accounted for 11 of 69 articles, including articles on global warming, heat stress, and marine heatwaves. Furthermore, 6 of 69 articles analysed precipitation variability, including floods, droughts, and rainfall intensity. Only one article referred to sunlight variability (Fig. 2.5). No articles considered variability in CO_2 or sea levels.

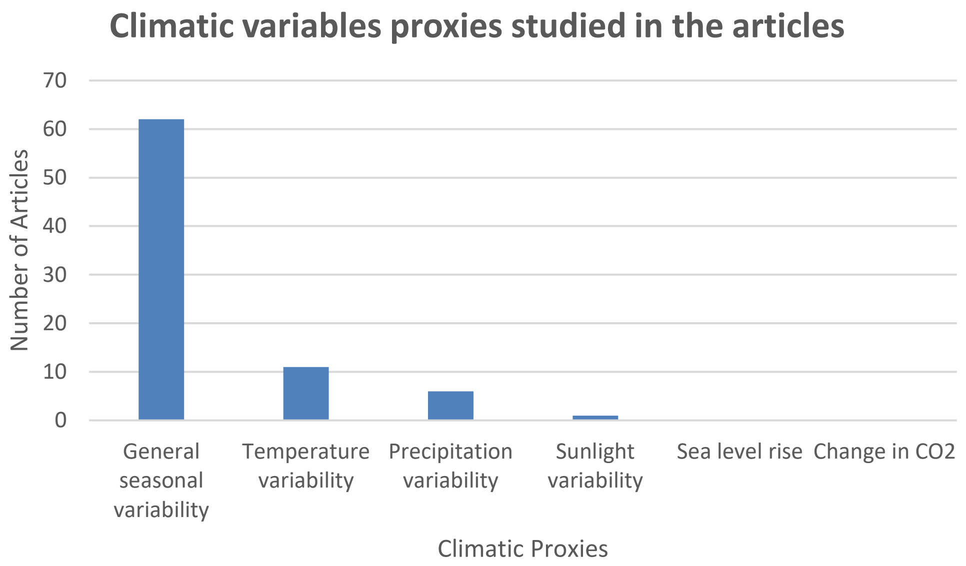

Figure 2. 5: Climatic variables studied in the articles (n=69) exploring impact of climate on nutritional content of foods included in the review.

Analyses were conducted at a range of temporal scales (Fig. 2.6). Comparison between seasons was the most frequent (45 of 69 articles), followed by comparison between years, studying over a period of ≤5 years only (21 of 69 articles), and comparison between months (3 of 69 articles). Conversely, no articles analysed changing nutrients for longer than 5 years.

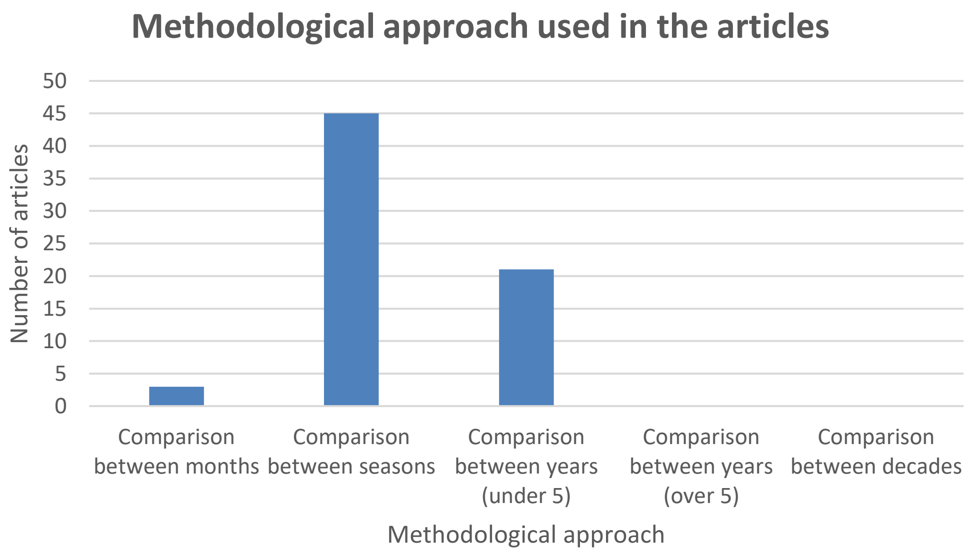

Figure 2. 6: Methodological approach on studies exploring impact of climate on nutritional content of foods included in the review.

2.3.9 Food Products and Nutrients Studied

The articles explored different food products (Tab. 2.4). No variety of legume or cereal was investigated, despite comprising a key component of global diets and daily intake of carbohydrates and proteins. In the vegetables category, the majority of the research referred to seaweeds (n=7), mostly consumed in Asia. Results on vegetable articles (n= 10) are restricted to India, China, and Japan, with no comparable evidence from other countries. Few articles on eggs (n= 1) and meat (n=3) were published. There were no studies investigating chicken eggs or chicken meat. Generally, animal products were under-investigated, except for fish products (n=26). Many different types of fish were studied worldwide, including shellfish and saltwater fish. Data on dairy products included milk and a few types of cheese (n=11). Studies explored bee products and other plant based products (e.g. artemisia) not only for their quality as foods, but also for their use as medicines.

Table 2. 4: Food categories and types studied in the articles exploring impact of climate on nutritional content of foods included in the review.

Food Category	Food type
Legume	Lentil, Bean, Lupin, Soybean
Cereal	Maize grain, Cassava
Vegetable	Caper, Seaweeds, Pepper, Squash, Broccoli, Olive, Artemisia species, Lettuce, Potato, Spinach, Tomato
Fruit	Pomegranate, Guava, Grapefruit, Peach, Apple, Bilberry, Kiwi, Orange, Aonla, Ber, Banana, Matooke
Egg	Goose eggs
Fish	Shrimp, Crayfish, Prawn, Scallop, Octopus, Squid, Cuttlefish and Different types of salt water fish
Meat	Beef, Pig, Mutton
Dairy	Bovine milk, Goat milk, Different types of cheese
Bee Products	Bee pollen, Propolis (bee resin)
Tea	Different types of tea leaves, yerba mate

2.4.4 Intersection of Climatic Factors and Food/Nutrients examined

There are limited data available on the change in percentages of nutritional content in foods in relation to different climatic variables (Tab. 2.5 and 2.6). The effect of general seasonal variability on food products was the most commonly studied, followed by the links between dairy, vegetables, and fruits with season. The number of articles published on the relationship between legumes and climatic variables is low. Frequently explored nutrients were lipids and proteins, while micronutrients were less studied (iron, zinc, vitamin A, vitamin D and iodine) (Tab. 2.6). Although proteins were the most studied, predominantly the literature explored the relationship between proteins and seasonal variability. This related to comparison of rainy and dry, summer and winter or pre- and post-monsoon depending on the location. Temperature, precipitation and sunlight variability were overall less studied in relation to nutrients.

We expected a greater volume of evidence on cereal products as there are many models for crops in the literature (7, 49-51). Despite this, we did not retrieve empirical studies on nutrients in wheat or rice, and generally the number of papers studying the effect of climate proxies on nutrients in other cereals was very limited, as shown in the heat maps (Tab. 2.5).

Seven of 10 studies on vegetables referred to edible seaweeds, but these results are unlikely to be generalizable to other vegetables. The category of fish was the most studied, however there is no available evidence on the effect of sea level rise on macronutrients and micronutrients in fish. Conversely, there is research on the impact of environmental changes on aquaculture and quantity of marine flora and fauna (52).

Table 2. 5: Heat Map- Number of articles available for climatic pathway per food category published between 2013 and 2019.

FOOD CATEGORIES

CLIMATIC VARIABLES	Cereals	Vegetables	Fruits	Legumes	Dairy	Meat	Fish	Eggs	Bee products	Tea
General Seasonal variability	0	10	9	2	11	3	24	0	2	2
Temperature variability	1	0	1	1	0	0	1	1	0	0
Precipitation variability	2	0	1	1	0	0	2	0	0	0
Sunlight variability	0	0	0	1	0	0	0	0	0	0
Sea level rise	0	0	0	0	0	0	0	0	0	0
Change in CO_2	0	0	0	0	0	0	0	0	0	0

The intensity of the blue colour varies depending on the number of articles in literature (dark blue: > 20 publications, medium blue: 5-19 publications, light blue: <5 publications, white: no publications).

Table 2. 6: Heat Map- Number of articles available for climatic pathway per nutrient category published between 2013 and 2019.

		MACRONUTRIENTS & MICRONUTRIENTS							
		Carbo-hydrate	Proteins	Lipids	Iron	Zinc	Vitamin A	Vitamin D	Iodine
CLIMATIC VARIABLES	General Seasonality	11	20	33	12	11	6	3	3
	Temperature variability	0	2	2	0	0	1	0	0
	Precipitation variability	0	3	0	1	0	2	0	0
	Sunlight variability	0	1	0	0	0	0	0	0
	Sea level rise	0	0	0	0	0	0	0	0
	Carbon dioxide change	0	0	0	0	0	0	0	0

The intensity of the blue colour varies depending on the number of articles in literature (dark blue: > 20 publications, medium blue: 5-19 publications, light blue: <5 publications, white: no publications).

All reviewed papers reported an association between climate-related variables (season, precipitation, temperature, or sunlight variability) and changes in food nutritional content. However, the magnitude and the direction of the change varied according to the food category or nutrients analysed, the climatic variables considered, and also in relation to the animal or plant species studied, the nature of the food product (e.g. organic or not organic), and the geographical area where the research was conducted. In the case of fish, macronutrients varied more between seasons than micronutrients, and this was particularly pronounced for proteins and lipids. While some reported changes were low between seasons (e.g. variation in carbohydrates in prawns and crabs in India; variation in iron and zinc in *Liza aurata* fish in Tunisia), other estimates indicated potentially large percentage changes in nutrient content. Percentage change in lipid content, for example, included estimates of 6% (change in lipid content in sardinella in India over pre-monsoon, monsoon and post-monsoon period with an increase during monsoon season), 9% (change in lipid content of *Colossoma macropomum*, *Leporinus friderici*, *Prochilodus nigricans*, *Brachyplatystoma filamentosum*, and *Brachyplatystoma flavicans* between flood and drought periods in Brazil with an increase during drought season), and 16% (change in lipid content of *Capoeta antalyensis* between summer and winter with an increase during summer), as shown in Tab. 2.7. In 6 of 9 studies, lipid content was higher in summer.

There were more limited data available for dairy products, and papers that were retained for this review exclusively focused on seasonal variation. Estimates varied from a 0.6% change in the protein level of bovine milk with a decrease from spring to autumn in Australia, to a 3% change in vitamin A in goat milk with an increase from winter to summer in Spain. In the studies, protein content was greater in spring, while lipids, zinc, and vitamin A were higher in winter/autumn (Tab. 2.7).

Data on changing nutrient content in vegetables was restricted to estimates in seaweeds. There was evidence of potentially high variation in carbohydrates (5-21%) and proteins (2-11%), with lower estimates of change in the case of lipids (<5%), zinc and iron (<1%). No other climatic data were used other than seasonal variability (Tab. 6). Both studies in India present higher carbohydrate and protein content in summer, whereas lipids and iron were greater during the rainy season (Tab. 2.7). No information on the effect of sunlight variability, carbon dioxide change or sea level rise on nutritional content in fish, dairy and vegetables was available.

2.4.5 Assessment of Confidence

A key finding in this review is a substantial research gap regarding the precision and richness of climate-related variables and causal theory within this literature. Data describing climatic factors were generally less detailed, and sometimes poorly described (n=2). Nutritional data were, in contrast, richer and more detailed.

Table 2. 7: Examples of nutrient variability (% change) under different climatic factors for fish, dairy & vegetable categories.

Grey cell: no data available or cannot be estimated from existing data.

FISH (shellfish included)	**Carbo-hydrate**	**Proteins**	**Lipids**	**Iron**	**Zinc**	**Vitamin A**
General seasonal variability	1%[1]	2-16%[2]	0.3-16%[3]	2%[4]	1%[5]	
Temperature variability		5%[6]	6%[7]			3%[8]
Precipitation variability			9%[9]			
DAIRY (milk)	**Carbo-hydrate**	**Proteins**	**Lipids**	**Iron**	**Zinc**	**Vitamin A**
General seasonal variability		0.6%[10]	1%[11]		1%[12]	3%[13]
Temperature variability						
Precipitation variability						

VEGETABLES	**Carbo-hydrate**	**Proteins**	**Lipids**	**Iron**	**Zinc**	**Vitamin A**
General seasonal variability	5-21%[14]	2-11%[15]	0.1-4%[16]	0.1%[17]	0.1-0.6%[18]	
Temperature variability						
Precipitation variability						

[1] 1 article (India): prawns and crabs - 1% change between rainy season and winter (higher in rainy season).
[2] 8 articles (Turkey, India, South Korea): 2-16% change [1.7% crayfish (higher in summer)-Turkey, 9% Silver bellies (higher in monsoon period)- India, 16% (higher in monsoon season) ribbon fish- India, 15% Capoeta antalyensis- (higher in winter) Turkey, 5% prawn and crab (higher during rainy season)-India, 2% cockles (higher in autumn)- South Korea, 5% sardinella (higher pre-monsoon season)- India, 3% capoeta angorae (higher in winter)- Turkey] between summer/monsoon period and winter.
[3] 9 articles (Turkey, India, South Korea, Iceland):0.3 -16% change [0.3% shrimp and prawn (higher in summer)- Turkey, 0.6% crayfish (higher in summer)- Turkey, 16% Capoeta antalyensis (higher in summer)- Turkey, 16% prawn and crab (higher in rainy season)- India, 1.4% cockles (higher in spring)- South Korea, 6% sardinella (higher during monsoon season)- India, 5% capoeta angorae (higher in summer)- Turkey, 9% sarda (higher in summer)- Turkey, 6% scomber (higher in summer)- Iceland] between summer/monsoon period and winter.
[4] 1 article (Tunisia): liza aurata fish - 2% change between winter and spring [the highest content varies between females (spring) and males (winter)]
[5] 1 article (Tunisia): liza aurata fish - 1% change between winter and summer (higher in summer)
[6] 1 article (India): sardinella - 5% change with pre-monsoon temperature (higher during pre-monsoon temperature)
[7] 1 article (India): sardinella - 6% change over pre-monsoon, monsoon and post-monsoon temperature (higher during monsoon period).
[8] 1 article (India): sardinella - 3% decrease over years (higher post-monsoon)
[9] 1 article (Brazil): C. macropomum, L. friderici, P. nigricans, B. filamentosum and B. flavicans - 9% change with floods and droughts (higher content depends on the species, generally flood period).
[10] 1 article (Australia): bovine milk - 0.6% change between summer and autumn (higher in spring).
[11] 1 article (Spain): goat milk - 1% change between autumn and spring (higher in autumn).
[12] 1 article (Australia): bovine milk - 1% change between spring and autumn (higher in autumn).
[13] 1 article (Spain): goat milk - 3% change between winter and summer (higher in winter).

[14] 3 articles (India, Thailand): 5-21% change [5% seaweeds (higher in summer) - India, 21% seaweeds (higher in summer) –India, 5% seaweeds (higher in dry season) - Thailand] between summer or spring and winter.
[15] 3 articles (India, Thailand): 2-11% change [11% seaweeds (higher in summer) -2 articles (higher in summer) - India, 2% seaweeds (higher in rainy season) – Thailand] between spring/summer and winter.
[16] 3 articles (India, Thailand): 0.1-4% change [1% seaweeds (higher during rainy season) -India, 0.1% seaweeds (higher during rainy season) - India, 4% seaweeds (higher in dry season) – Thailand] between spring and winter.
[17] 2 articles (India): 0.1% change (both articles, seaweeds-higher during rainy season) between dry and rainy season.
[18] 2 articles (India): 0.1-0.6% change (both articles, seaweeds-higher in winter) between spring and winter.

2.5 Discussion

This systematic map synthesized the available published evidence from empirical studies on the impact of climatic variability on nutritional content in foods. The evidence base remains limited and fragmented, though does highlight some important trends. Firstly, this review highlights emerging evidence that climatic (and meteorological and seasonal) variables are associated with changes in the nutrient levels of edible foods. The importance of nutrient level as an indicator of climate change impact is growing in recognition, as reflected in Scheelbeek's (22) assessment of the quality of vegetables and legumes under different climatic scenarios. The majority of studies use categorical measures of seasonality; we thus cannot infer causal mechanisms regarding what aspects of seasonal extremes drive nutrient content beyond crude hypotheses of precipitation and temperature variability.

Many articles included in this systematic map present data on general seasonal variability only (45 of 69 studies), often over a limited period, and without detailed information on climate-related variables (e.g. change in CO_2). This precludes empirical analysis of the impact of longer-term changes in climate on food nutrient content. If the quality of food were to change over time due to climate variability, the consequences are expected to include an increase of stunting and micronutrient deficiencies (53). However, it is difficult to understand the role of climatic factors in shifting the nutritional composition of foods and the consequences on human health (54). Indeed, the literature describing the mechanisms of climate impact on nutrients lacks information, as the empirical evidence is limited.

A key finding in this review is a substantial research gap regarding the precision and richness of climate-related variables and causal theory within this literature on nutritional composition. Indeed, the lack of detail in the description of environmental elements (e.g. description of the season with information on weather conditions or temperature) has prevented further investigation of the effects of climatic factors on nutritional content in foods. This is particularly acute in the case of a total absence of empirical (non-experimental) evidence reporting on the long-term nutritional impact of climatic variability .In addition, despite extensive literature on CO_2 change impacts on nutrients, there were negligible empirical data, with the literature dominated by experimental studies and models (40, 55). Indeed, heatwaves and rise of global temperatures are identified as major causes of changes in food systems and human diet (56, 57). Although environmental models show that extreme climatic events will affect the nutritional content of crops such as wheat, maize, and rice (23, 55, 58), there remains limited empirical validation and evidence to characterize and document these changes on-the-ground. Studies assessing the impact of season variability on nutrients are mostly focused on plants often grown under environmental condition in the laboratory, and the analysis is usually conducted over 1-3 year (58).

Additionally, there are limitations related to the design, methods and reporting of included papers. Many of the studies were primarily designed to report the quantity of macronutrients and micronutrients in food; the main objective was often not to explore environmental change, thus climatic variables were usually not well described or theorized. Furthermore, it is not possible to generalise the results on the variation of nutritional content across the food categories due to variation of the type of food, geographical location, and climatic factors considered.

Similarly, national food databases contain negligible data on variation in nutrients by season or climate. Food composition tables are resources containing nutritional information of foods for a specific country. They are not often updated, especially in settings with limited resources. Furthermore, the environmental conditions used to grow plants and crops are unknown. In the UK, for example, food compositional tables include differential nutritional data for summer and winter for milk, but no other foods (59). However, literature shows that seasons have changed in the past decades (60), and more information on weather parameters such as precipitation, sunlight, and temperature change are essential to study differences over time. Given evidence of temporal and seasonal variability in nutrient content, inclusion of environmental data in food databases may improve accuracy and precision when assessing nutritional intake. Consideration of differential nutrient content by season within food databases is rare. Integrating climatic conditions and recognising temporal variability in nutrient content within food databases could support prioritisation of efforts in fighting micronutrient and macronutrient deficiencies, and respond to the mandate of addressing and integrating multiple Sustainable Development Goals.

Our review has some strengths and limitations. We conducted a systematic search of published literature in three main databases without language restriction. We included empirical studies in real world settings from all continents over the past 7 years to achieve a global understanding of the observed climatic-related effects on nutrients. We presented the totality of the available data, and where possible we calculated the variation of nutrient change due to climatic events from baseline nutritional content in foods. However, due to the variety of measurement methods and outcome results, only percentages of variations of nutritional content in foods were analysed. Some nutrients in the analysed food products (fish, milk and vegetables) have shown potential non-minor variations between different climate-related conditions. For example, proteins and lipids in fish had a variation up to 16% over different seasons, while carbohydrates in vegetables varied from 5% to 21%. A larger number of studies would be necessary to extract robust meta-analysis and synthesis of results beyond the mapping of existing evidence presented here.

We were surprised at the limited amount of literature on the effect of climatic factors on nutrients in foods. We believe that interdisciplinary work involving environmental scientists and nutritionists is just beginning. Historically, these collaborations have not occurred, environmental scientists have explored the impact of climatic factors on agriculture and food production rather than quality of food, and nutritionists have worked more on health-related topics rather than agriculture. Although collecting data during emergencies (e.g. during a drought or flood) would be particularly challenging, however, empirical research is needed to assess the climate change impact on the ground. The decision of exploring literature on the effect of climate change on nutrients in foods on the ground only was a limitation as modelling studies were excluded. However, this is the first study investigating what happens in the reality, and not in a laboratory or through projections, facilitating comparison between on-the-ground observations and modelled predictions.

The ability to adapt and respond to environmental changes will be important for population health and in economic terms. The impacts of climate change are likely to be greater in areas with existing poor food security, and ensuring access to safe and nutritious food, optimal child feeding practices, and health services will be challenging (61). Indeed, IFPRI (62) forecasts 4.8 million more individuals will be malnourished worldwide due to climate change impacts on food security. Improved precision and clarity on how climate change and its impacts on environmental variability will affect the nutrient content of foods is critical to preparing for, and adapting to, climate change. To date, this literature remains sparse.

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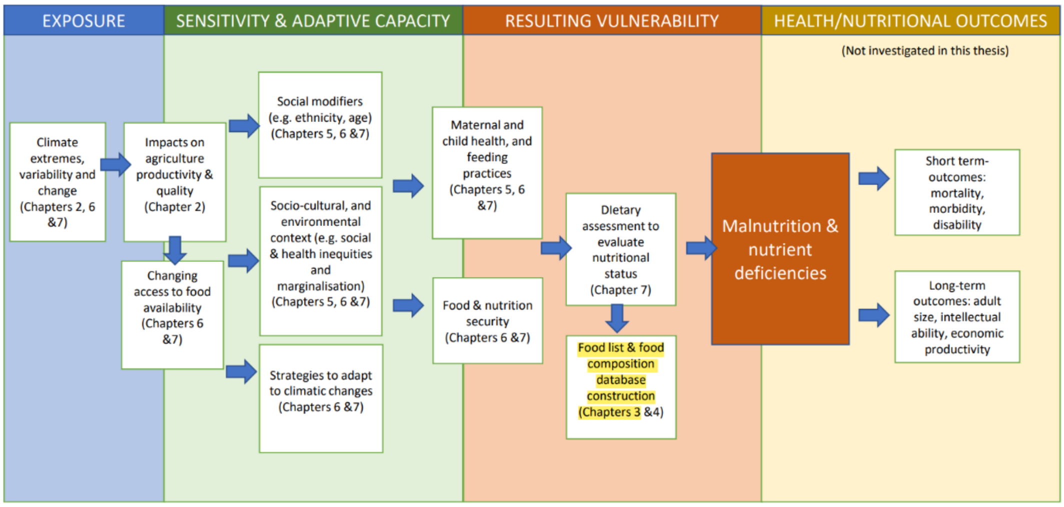
Chapter 3 - A Community-Based Approach to Integrating Socio, Cultural and Environmental Contexts in the Development of a Food Database for Indigenous and Rural Populations: The Case of the Batwa and Bakiga in South-Western Uganda.

Chapter 3 is a methodological manuscript, which describes the methods used to construct the food list of vulnerable populations, with the case study of the Indigenous Batwa and Bakiga communities in south-western Uganda. It emphasizes the importance of including exploration of the socio-cultural, and environmental contexts, and the understanding of the impact of climatic variability on food consumption, while collecting information on food, dishes, and portion sizes. Indeed, without investigating these components, critical details to construct food databases would be missed. This is the first phase of the food composition database development, which required extensive fieldwork and mixed methods approaches.



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For this manuscript, G.S. prepared the first draft of the manuscript, coordinated the data collection (remotely), and the methodological design, and conducted the data analysis. L.B.-F. and J.E.C. (doctoral candidate's supervisors) provided input on the data analysis, and supervised the work. S.T. coordinated the fieldwork and collected the data with P.K., E.N. and C.K. R.P., C.Z.-C., K.P., D.B.N., S.L. and H.H.-F. reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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A community-based approach to integrating socio, cultural and environmental contexts in the development of a food database for Indigenous and rural populations: the case of the Batwa and Bakiga in south-western Uganda.

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3.1 Abstract

Comprehensive food lists and databases are a critical input for programs aiming to alleviate undernutrition. However, standard methods for developing them may produce databases that are irrelevant for marginalised groups where nutritional needs are highest. Our study provides a method for identifying critical contextual information required to build relevant food lists for Indigenous populations. For our study, we used mixed-methods study design with a community-based approach. Between July and October 2019, we interviewed 74 participants among Batwa and Bakiga communities in south-western Uganda. We conducted focus groups discussions (FGDs), individual dietary surveys and markets and shops assessment. Locally validated information on foods consumed among Indigenous populations can provide results that differ from foods listed in the national food composition tables; in fact, the construction of food lists is influenced by multiple factors such as food culture and meaning of food, environmental changes, dietary transition, and social context. Without using a community-based approach to understanding socio-environmental contexts, , we would have missed 33 commonly consumed recipes and foods, and we would not have known the the variety of ingredients and their varying

quantitiesin each recipe, and traditional foraged foods. The food culture, food systems and nutrition of Indigenous and vulnerable communities are unique, and need to be considered when developing food lists.

3.2 Introduction

"Zero hunger", the second of the Sustainable Development Goals, aims to ensure nutritious, diverse and healthy food for everyone (1). To meet this goal, the United Nations Work Programme for the Nutrition Decade (2016-2025) was developed to promote healthy dietary practices. This includes focus on the implementation of country-specific commitments for action (2) to improve nutrition. Key prerequisites for nations aiming to implement actions to support nutrition are assessment of dietary patterns and nutrient gaps, and the identification of locally available foods that could fill these gaps. To do this, locally relevant food composition tables are required, yet are often unavailable in low income regions and for vulnerable, marginalized, and Indigenous populations (3).

Existing tools for assessing nutritional intake in populations need to be responsive to different cultural and environmental contexts, especially in the case of Indigenous and rural populations. For example, climate change has a negative impact on food quantity and access, and decreases dietary diversity and quality of foods (4); also cultural beliefs and social circumstances can affect nutrition and feeding practices (5). Food items and portion sizes included in locally relevant food composition tables necessarily vary according to the context and population. Detailed information on food lists, such as types, ingredients and recipes using local foods is required for calculating caloric and nutritional intake (6) and for linking foods to nutrient information available from food composition tables.

Standard methods to estimate food portions(7) and generic food composition tables, are unlikely to be appropriate for Indigenous populations due to their unique cultural and dietary contexts (8). Food acquisition and preparation are highly influenced by the cultural and environmental context and local traditions, which will influence the development of valid food composition tables (9). However, the comprehensiveness of national food lists, and accuracy of nutritional composition of mixed dishes is rarely described in the literature, implying limited interrogation of foods which may be missing (10) or different names given to local foods (11).

Here we present a mixed-methods study using a community-based approach for sourcing food and recipe data which considered socio-cultural-environmental factors to construct a food database for the Indigenous Batwa and neighbouring rural Bakiga communities of Kanungu District, south-western Uganda. Prior to our work, the only available food database was designed for central and eastern Uganda (12), and it does not include local foods consumed by Batwa and Bakiga individuals.

Inclusion of adjacent Indigenous and non-Indigenous communities allowed us to explore the extent to which cultural constructs of food systems might influence the development of food lists and nutritional assessment methods at the local level. We therefore formulated the following objectives: 1) to identify the range of foods and dishes consumed by households (with nutrient composition details in the manuscript of Scarpa et al. (13); 2) to investigate production, cooking, processing and store methods of consumed foods; 3) to document the factors affecting the food list construction, including food culture, social, environmental, and climatic changes on food consumption, and use of locally-relevant tools to measure portion sizes.

3.3 Materials and Methods

3.3.1 Study region and Population

The Batwa, who identified themselves as an Indigenous group, and the rural Bakiga people reside in Kanungu District, south-western Uganda. Before 1991, the Batwa primarily lived in the forest and mainly practiced hunting and gathering to meet their nutrition needs. In 1991, they were displaced when the Ugandan Government established Bwindi Impenetrable Forest National Park in the forest where they were residing. Their transition to agriculture has occurred only in the past 20 years (14). Most of the Batwa in Kanungu District now live in 10 communities on land held in trust by an NGO, the Batwa Development Programme (15). The Bakiga population, with a longstanding history of agricultural production, represents the majority of the Kanungu District population and resides in the same area as the Batwa. The Bakiga depend on agriculture and livestock, and employ a proportion of Batwa women, and in lesser numbers men. Farming is now the primary source of income and nutrition for Batwa (16, 17), but they are also involved in non- food livelihoods such as tourist performances, brickmaking, charcoal sales, and handicrafts. For both groups, the major crops comprise cassava, beans, millet, bananas, sweet potatoes, and Irish potatoes (18).

Both populations are highly vulnerable to the health impacts of climate change and suffer from social and health inequalies (17, 19-21). Recent survey data indicate that the risks of contracting infections and being malnourished are higher among Batwa compared to the neighbouring Bakiga (15).

3.3.2 Study design

We used a two-stage process to develop the food database of south-western Uganda for the Batwa and Bakiga communities (Table 3.1). The first stage, including the generation of food list and recipes, explores the factors affecting food list construction , such as the meaning of food in the local cultural context, social and environmental changes, and the tools to measure portion sizes. In addition, we described how food was cooked, processed and stored. The second stage involves development of an automated online food database (22) for south-western Uganda, and results are reported in Scarpa *et al.* (13).

To create the food list, we used a mixed-method research design with field-based data collection, including focus group discussions, individual dietary surveys and market and shop visits. We use mixed methods to triangulate the data, collecting both quantitative and qualitative data on food and nutrition together with social and environmental contexts(23-26). The collection of data was concurrent, and the results from all components were integrated during the interpretation phase (27).

Table 3. 1. Methods used for local, field-based sourcing of food and recipe data.

Steps	Methodology	Purpose
1.1 Generate list of foods and collect recipes	Shop and market assessment	• To characterise foods and brands (if available) sold in the shops and markets.
	Focus group discussions	• To document the foods and recipes consumed by the communities
	Individual dietary survey	• To confirm the foods consumed and ensure saturation of data for the food list
1.2 Document cooking, processing and storage methods	Focus group discussion	• To characterise cooking and storing methods, and document condiments used for local recipes/forest foods (composite dishes)
	Individual dietary survey	• To identify missing cooking and storing methods of foods and recipes & foods given to children
1.3 Document factors influencing the food list construction	Focus group discussions	• To list foods available in the dry and wet season (seasonal calendar) & consumed during the weekends and holidays/special occasions • To investigate food culture, the meaning of food, and socio-economic and environmental factors
	Individual dietary survey	• To explore tools to measure portion sizes

3.3.3 Settlement, participant, and market sampling

We used a matched sample of Batwa and Bakiga communities, selecting 4 Batwa communities and the 4 adjacent Bakiga communities (the name of their settlements is the same or similar to the Batwa ones, and the only difference is the adding of the word ‘cell’ to the settlement name). To maximise geographical and culinary variation, we purposively selected pairs of communities according to four strata: close to markets and shops (Bikuto and Bikuto cell), far from markets and shops (Kitariro and Kitariro cell), mid-way between the other two (Kebiremu and Kebiremu cell), and forest-adjacent (Mpungu and Kikome cell). In each of these 8 communities, we conducted one focus group (8 focus groups; n=58 participants in total) and later interviewed the same participants individually. To select the participants, the local researcher met with the community leaders and acquired a list of residing community members. In our sample, we included mothers with children under 5 years, and other women and men of different ages.

The research team also collected data from the four weekly markets in the district, and the top ten most visited shops out of approximately twenty. Although market assessment was conducted by a team member residing in, and familiar with, Kanungu district, five informal conversations conducted with locals helped to confirm the shops where Batwa and Bakiga buy foods most frequently.

3.3.4 Data collection

The data were collected between July and October 2019 by a local non-Indigenous male researcher from Kanungu District, and female Mutwa and Mukiga (singular for Batwa and Bakiga, respectively) researchers. This facilitated the communication with Batwa and Bakiga chairpersons and male and female participants. Permission for the research was sought from the village chairpersons. Informed written consent was obtained from each individual prior to data collection, with the possibility of withdrawing the consent at any point of the study. Survey tools were pre-tested to ensure they were appropriate and understandable. The dietary surveys and FGDs were conducted in the local language, Rukiga, audio-recorded, transcribed verbatim and later translated into English by the local researcher.

3.3.4.1 Market and shop visits

In the four markets and 10 food shops, the research team recorded all foods available using paper forms during a single visit to each market and shop. Of these foods, the type, price, brand, and weight, if indicated, were collected (tool used in Supplementary Material Chapter 3).

3.3.4.2 Focus group discussions

We conducted eight FGDs (tool used in Supplementary Material Chapter 3) with Batwa and Bakiga community members. Through the FGDs, participants had the possibility to discuss and reach consensus about the preparation, processing and storing methods used for foods and dishes, highlighting the potential variability of recipes among the different households. The recipes were collected through focus group discussions and semi-structured interviews. Each recipe was collected from at least 2-3 different participants in order to compare ingredients, cooking methods and portion sizes/quantity. The final recipe recorded in myfood24 included an average of the ingredients' quantity and type, and cooking methods collected in the different interviews/FGDs.

We then investigated factors influencing the generation of the food list with the collaboration of local nutrition experts, which included the exploration of food culture, social and environmental changes affecting food consumption. Additionally, we documented the availability of food in different seasons throughout the seasonal calendar. The FGD guide included open-ended questions only, and the quality of the qualitative study was appraised using the CASP checklist (28). Power dynamics between research team and respondents were critically examined, and training to the local researchers was given to minimise bias (28), although the local team had experience in conducting FGDs with the Batwa and Bakiga communities. The data saturation (the point in the study where no new information is provided) was reached after interviewing the eight groups. The average length of the discussions was 55 mins.

3.3.4.3 Individual dietary survey

We conducted single-pass 24-hour dietary recall surveys to identify number and types of foods consumed (not amount), using individual interviews with the same individuals participating in the FGDs (tool used in Supplementary Material Chapter 3). We recorded the number of meals, snacks, and we documented the different tools used to measure portion sizes including volumetric measurements; also, we collected types of foods and composite dishes consumed on the previous day, including ingredients and quantities. The data collected at this stage helped to confirm foods and recipes collected through FGDs and markets and shops assessment. Dietary information for children under 5 was collected through interviews with their mothers. The dietary survey included open- and closed-ended questions, and the data were audio-recorded and reported on papers. The average dietary survey length was 18 mins.

3.3.5 Data analysis

Findings of the FGDs were analysed with NVivo Software, and the data presented through quotes and figures. We generated word clouds to provide graphic representations of most commonly consumed food. Any identifiable data was removed to ensure confidentiality.

Thematic analysis, including latent and manifest content, was used to analyse qualitative responses. Latent content analysis is used to extract themes and meanings that are similar in multiple individuals, and this allows for comparison of data. Manifest content analysis is used to count the frequency of topics repeated by multiple individuals (29). Topics where participants contradicted or discussed different experiences were also reported.

Quantitative data from the individual dietary surveys was analysed using descriptive statistics in Excel®. Graphs and tables were generated in Excel® and NVivo 12®.

3.4 Results

3.4.1 Study participants

The research involved 74 participants, including 58 adults and 16 children (Table 3.2). The participating mothers gave information on their children's diet during the individual dietary surveys. All participants invited agreed to participate in the FGDs and individual dietary surveys, except two individuals that decided to be interviewed in the individual dietary survey only.

Table 3. 2: Number of participants in the focus group discussions and individual dietary surveys.

	Focus group discussions	**Individual dietary surveys***
Batwa participants	27 Batwa individuals interviewed: • Community 1: 6 individuals • Community 2: 8 individuals • Community 3: 5 individuals • Community 4: 8 individuals	• Women: 14 • Men: 12 • Mothers' reports for children (under 5): 9 • Declined to participate: 1
Bakiga participants	31 Bakiga individuals interviewed: • Community 1: 7 individuals • Community 2: 8 individuals • Community 3: 8 individuals • Community 4: 8 individuals	• Women: 18 • Men: 12 • Mothers' reports for children (under 5): 7 • Declined to participate: 1

**Individual dietary surveys were conducted with mothers and children from the same household, but men were from different households.*

3.4.2 Diets of the Batwa and Bakiga communities

From the focus group discussions, dietary surveys, and market and shop visits, we collected 116 food items and 32 local recipes. When we confirmed the foods collected during the FGDs through the individual dietary surveys, no new items were matched as data saturation was already reached.

Although women were more likely to cook food for the family and list the ingredients of local dishes when interviewed, men also gave information on alcoholic beverages and other packaged foods consumed outside the house.

Results from the individual dietary survey showed that cereals were the category of foods most consumed on a daily basis (40% of the number of foods reported by Batwa and Bakiga), followed by legumes (32% of the number of foods reported by Batwa; 23% of the number of foods reported by Bakiga) and fruits and vegetables (25% of the number of foods reported consumed by Batwa and 32% of the number of foods reported by Bakiga) (Figure 3.1).

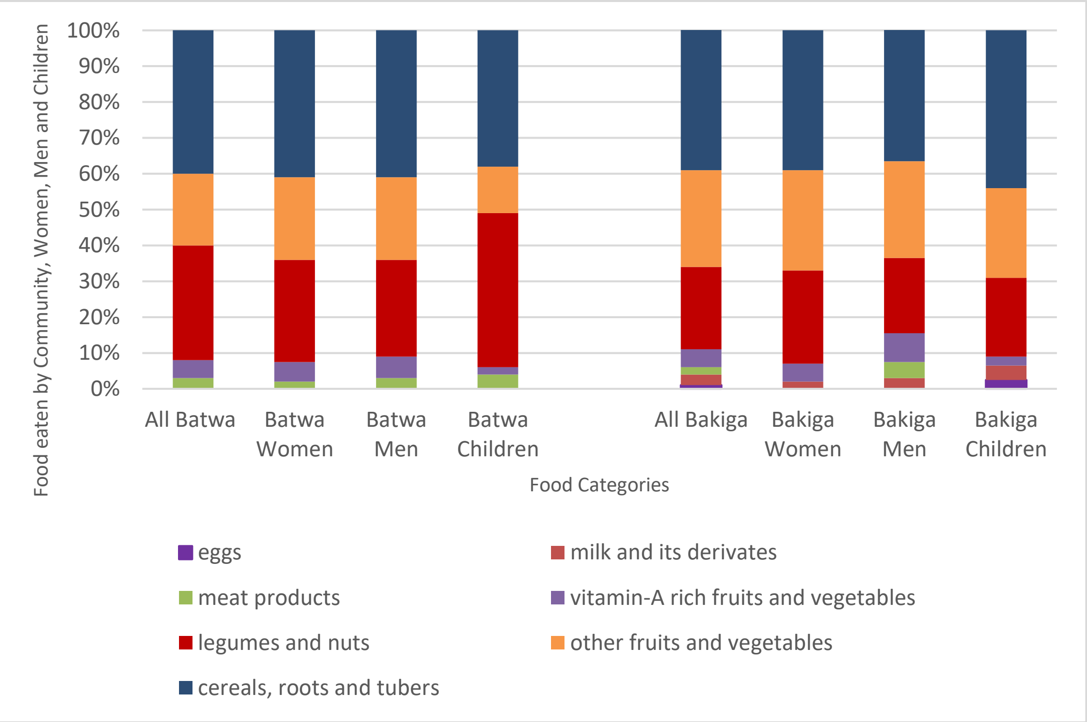

Figure 3. 1: Percentages of frequency of different food groups eaten by the Batwa and Bakiga participants (women, men and children) in the previous 24 hours (data collected through the individual dietary survey).

Beans were the foods most reported to the interviewers in the individual dietary survey (Figure 3.2). No Batwa in our sample reported consuming dairy products or eggs the day of recording. Animal proteins were rarely consumed in both populations with lower absolute amount of meat products eaten by the Batwa interviewees. Vegetable proteins (mostly beans) were mostly consumed by Batwa children (43% of the number of foods reported). There was minimal difference in the consumption of fruits and vegetables among adult participants (with higher absolute amounts of fruit and vegetable items consumed by women), with lower amounts consumed by Batwa children (15% of the number of foods reported) (Figure 3.1).

Both Batwa and Bakiga women and men during the FGDs and dietary surveys reported a similar number of food items consumed (Figure 3.1), although Bakiga participants identified slightly higher variety of foods compared to Batwa during the FGDs and dietary surveys (Figure 3.2). Foods consumed by Bakiga but rarely by the Batwa included more expensive items such as dairy products (e.g. milk and yogurt), insects (e.g. grasshoppers, which are highly seasonal) and fruits (e.g. oranges).

Some animal-source foods such as meat (goat, pork, chicken) and fish (tilapia, silver fish) were only consumed on special occasions due to their high cost. For example, religious celebrations were the most common days of meat consumption, or when Batwa, and rarely Bakiga, received food aid from governmental and non-governmental organisations (NGOs). In the case of Bakiga, the government only gives food to the community when elephants from the forest destroy their crops and gardens.

Alcohol was consumed by both Batwa and Bakiga communities' members, and according to the women participants "men are used to drink a lot to fill the stomach especially when they are hungry", and "they buy alcohol instead of buying food for the family". However, they added that also some women in the communities drink alcohol. 'Waragi', locally prepared from matoke and sugar cane, is the most produced and consumed alcoholic beverage in south-western Uganda.

Batwa

Bakiga

Figure 3. 2: Word frequency analysis to explore the most eaten foods among Batwa and Bakiga participants.

The bigger the word size, the more times the food item was mentioned during the individual dietary surveys (Scale: 1-50 words). tBeans were the foods most commonly eaten in both communities together with matoke (type of banana). Posho and cassava were more consumed among the Batwa, while greens and porridge among the Bakiga.

3.4.3 Production, cooking, processing and storage methods

The food products consumed by the Batwa and Bakiga populations were typically sourced through subsistence agriculture in small plots/own gardens. Those foods comprised: cereals and tubers such as millet, maize, yams, potatoes, cassava, sorghum; legumes and nuts such as beans, groundnuts, peas; vegetables and fruits such as dodo (leafy greens), matoke, cabbage, tomatoes, onions, avocado, mango, jackfruit, eggplants, watermelon, and carrots; sweets and beverages such as sugarcane and tea. Conversely, animals such as duck, rabbits, and chickens were likely to be bred and then sold in markets to earn enough money to buy foods for the family.

The most common and cheapest cooking method was reported to be boiling. Frying was reserved for meat and fish, and for tomato sauces, when onions and cooking oil were available. To store food, usually drying was the preferred processing method. Sometimes salt was used to preserve meat or fish, and for seasoning. However, most food (especially fruits and vegetables) was not storable for a long period due to lack of refrigerators. Indeed, foods were kept on shelves at home with other non-edible products. A participant argued that this was another factor affecting the food security in the community: "*it is why we do not have enough food*" (Batwa FGD). The other Batwa participants in the FGD agreed with this.

3.4.4 Factors affecting the generation of the food list (Table 3):

Table 3. 3: Main qualitative findings of our study with associated quotes collected during the Batwa and Bakiga FGDs and individual dietary surveys.

Factors affecting the food list construction	***More details from quotes****
Importance of food culture and meaning of food when collecting food lists.	• "*We call 'sauce' the foods that accompany cereals, for example beans*" (Batwa FGD, male participant) • "*Forest foods (including medicinal plants) are part of (our) culture and (our) sense of community*" (Batwa FGD, female participant)

Food type and consumption change overtime, and they are influenced by climatic, environmental and demographic changes.	• *"People cannot harvest as before during the dry season, and food is decreasing in the forest too"* (Batwa FGD, male participant) • *"Life is changed, and it does not rain when it is supposed to, thus we no longer have enough food [...]"* (Batwa, male participant) • *"Children eat only sweet potatoes, cassava and beans, and (children) do not grow like before"* (Batwa FGD, female participant) • *"If rain is there, everything grows, but too much rain can destroy plants [...]".* (Batwa FGD, male participant) • *"Also, if there is too much sunshine, plants will not grow"* (Bakiga FGD, female participant)
Dietary transitions due to displacement and market influence	• *"We eat less, sometimes once a day"* (Batwa FGD, male participant) • *"We use a new food, maize flour"* (Bakiga FGD, male participant) • *"We have to measure what to eat. In the past, if we had to cook beans, we cooked lots of beans, but now just little beans to protect us from hunger"* (Batwa FGD, female participant) • *"We have substituted (our) food because we do not have enough local foods. In the past we used to eat greens and beans without water soup"* (Batwa FGD, female participant)
Production, cooking, processing and storage methods limit the consumption of certain types of foods during the dry and wet season.	• *"We usually grow foods in our gardens, and we usually sell animals to get enough money to buy food for our family"* (Batwa FGD, female participant) • *"We boil most of our foods, and we use onions and Kimbo (cooking oil) only when we have money"* (Batwa FGD,female participant) • *"Most of our food is not storable: we don't have refrigerators and (this) is why we do not have enough food"* (Batwa FGD, male participant)
Frequency of meals and foods type consumed is linked to social context	• *"I am a teacher at school; thus, I eat two meals (breakfast and lunch) when I work, but over the weekend is different"* (Bakiga Individual Interview, male participant) • *"We usually eat meat during Christmas, but not always. Only if we have money"* (Batwa FGD, female participant)
Tools to measure portion sizes vary among individuals and are influenced by social and cultural context.	• *"The family usually eats from the same plate"* (Batwa FGD, female participant) • *"One kilo of beans now is shared by 8 people and before by 3"* (Batwa FGD, male participant) • *"We use plastic cups for porridge"* (Bakiga FGD, female participant) • *"Women eat more (1/4 more) than men, and children eat less, but if a child is over 10, he can eat more than a man"* (Bakiga FGD, male participant)

	• *"Child eats more because he eats often […]. If there is little food, it is for the child that cries if he is not fed"* (Bakiga FGD, female participant)

* *Authors' interpretations or clarifications within quotes are indicated using square brackets and non-italic font.*

3.4.4.1 Meaning of food among Batwa and Bakiga communities

The term 'food' for the Batwa and Bakiga communities was conceptualised as including a wide range of consumed products. During the FGDs, women described in depth foods and recipes, and men talked more about beverages. It included cereals, legumes, meat, vegetables (especially leafy vegetables) and fruits, but also herbal drinks and medicinal plants that were frequently consumed by both Indigenous Batwa and Bakiga. Medicinal plants included infusions prepared with local herbs, especially herbs from the forest. Some nutrient-rich vegetables, fruits, cereals, and fish were also considered to have curative properties. For example: kirungi and kazire were factory-bottled herbal drinks believed to treat malaria; jackfruits were consumed to heal stomach pain; roasted yams for diarrheal diseases; greens (green leafy vegetables) to 'generate blood'; watermelon to cure headaches; honey, milk, avocado and eggplant to heal ulcers; and mudfish to cure worms and malnutrition. Conceptualisations of food also included what were referred to as 'forest foods' that were rarely consumed but were still perceived to be part of the culture and sense of community (both Batwa and Bakiga FGDs). These included wild foods such as wild meat, wild yams, honey, or mushrooms found in the Bwindi Impenetrable Park, the forest adjacent to Kanungu District, that the communities are not legally allowed to access.

The term 'sauce' was frequently used to indicate any protein-source food that was eaten in conjunction with cereal foods, thus households might refer to a meal of a cereal carbohydrate (e.g. posho) with 'sauce' (e.g. beans). Also, the word 'greens' was used to categorize various types of green leafy vegetables, including eggplant leaves, pumpkin leaves, cabbage, okra, Irish potato leaves, guava leaves, amaranth, bean leaves and others.

3.4.4.2 Seasonal, climatic, and environmental changes

Participants explained when the main staple crops, and other vegetables and fruits were usually harvested during the year, although with climatic changes respondents believed the timings could vary. The seasonal calendar was confirmed through markets and shops assessment (Table 3.4).

The wet seasons were identified as the best season in terms of availability of fruits and vegetables, however one Bakiga settlement argued that the *"dry season* (harvesting season) *is better because we have food* (only crops) *saved from the rainy season"* Cassava was reported as 'a resilient crop' available during both dry and wet seasons (Bakiga FGD).

The participants noted changing reliability of seasons: "there are no real seasons nowadays" […] "if rain is there, everything grows, but too much rain can destroy plants […]". "Also, if there is too much sunshine, plants will not grow" (Batwa FGD). Batwa and Bakiga interviewees noted that "understanding when to grow crops is very hard, as the weather changes quickly" (Bakiga FGD). According to both Batwa and Bakiga communities, climatic and environmental changes were important factors affecting food availability and quality. Participants discussed that the quality of the soil was decreasing due to over-cultivation and population growth: "people cannot harvest as before during the dry season, and food is decreasing in the forest too" (Batwa FGD). Foods from the forest were perceived to be very nutritious, especially honey, wild meat and greens. "Life is changed, and it does not rain when it is supposed to, thus we no longer have enough food, and we have to go to Bakiga settlements to obtain it. For this reason, we do not have energy and we are sicker, also we have stomach problems" (Batwa FGD). Some participants perceived that the growth of children was compromised due to overconsumption of sweet potatoes, cassava, and beans, without meat or other foods to balance their diet.

Some participants mentioned that past extreme weather events had a negative impact on foods and diet, contributed to food insecurity and lack of food availability. Also, they added that due to extreme climatic events crops get destroyed, and foods are not eaten 'in the right season', following the time of growth and harvesting of the seasonal calendar. For example, some Bakiga community members recalled: *"[In] 1980, when the county was hit by drought and many died of hunger"* and *"[In] 1999, when rain and storms destroyed gardens, and the government had to help"* (Bakiga FGD). Other participants recalled more recent events: *"[In] 2004 and 2017 when there was famine in Kanungu, crops dried up, malnutrition was high, and many children became sick"* (Bakiga FGD).

Table 3. 4: Seasonal calendar with the most eaten crops, fruits and vegetables according to the Batwa and Bakiga participants.

Type of food (common names)	*Wet season (mid January-end of February)*	*Dry season (end of February-mid May)*	*Wet season (mid May- mid August)*	*Dry season (15^{th} mid August-15^{th} mid January*
Cassava	⚡	☀	⚡	☀
Maize	⚡		⚡	
Millet	⚡		⚡	
Beans	⚡		⚡	
Sweet potatoes	⚡	☀	⚡	☀
Irish potatoes	⚡		⚡	
Cabbage	⚡		⚡	
Mango		☀		☀
Jackfruit	⚡	☀	⚡	☀
Pineapple	⚡	☀	⚡	☀
Green leafy vegetables	⚡ ⚡		⚡	
Groundnuts			⚡	
Yams	⚡	☀	⚡	☀
Eggplants	⚡	☀	⚡	☀
Watermelon	⚡	☀	⚡	☀

Lightening (wet season) and sun (dry season) icons indicate when the food items are harvested and eaten.

3.4.4.3 Dietary transitions: forest displacement and market influence

The displacement of the Batwa from their ancestral home in Bwindi Impenetrable Forest was noted as one of the major causes of diet transitions. To adapt to social and environmental changes, Batwa reported that they "*eat less, sometimes once a day*", and "*use a new food, maize flour*", that was not produced and consumed in the forest. The use of herbal medicine has also evolved: "*we have changed type of foods, portion size and we get sick more easily*" and "*we go to the hospital when we get sick rather than using herbs from the forest*" (Batwa FGD). In addition, food was considered less nutritious: "*food does not satisfy (us) as it is not nutritious anymore, does not have enough nutrients*" (Bakiga FGD). One Bakiga participant highlighted the high level of food insecurity among the community households: "*we have to measure what to eat. In the past, if we had to cook beans, we cooked lots of beans, but now just little beans to protect us from hunger. One kilo of beans now is shared by 8 people and before by 3*" (Bakiga FGD).

The Batwa and Bakiga communities substituted their traditional foods with packaged food purchased from shops and markets: "Nowadays we grow tea and coffee to earn money to buy food, posho and beans […]. We have substituted (our) food because we do not have enough local foods. In the past we used to eat greens and beans without water soup" (Bakiga FGD). Packaged foods bought by both communities comprised bread, posho (produced with millet or maize flour), sweets, soda, honey, rice, cooking oil, pancake, maize, water, sugar, and cassava.

3.4.4.4 The social context influences the number of meals consumed

The number of meals consumed by Batwa and Bakiga individuals are represented in Figure 3.3. Four interviewees reported that those who work in public spaces, such as schools or international companies, often received breakfast and/or lunch in the workplace. In some cases (n= 7, including 6 Batwa and 1 Bakiga participant), the interviewees ate the same types of foods for breakfast and dinner or lunch and dinner. Breakfast was the most frequently skipped meal of the day; around half of Batwa and Bakiga men and women did not eat breakfast regularly.

Dinner was the meal most consumed by both Batwa and Bakiga participants, although 2/18 Bakiga women did not have dinner the day before due to lack of food. Lunch was consumed by all Batwa and Bakiga children and most other participants. Children typically ate at least 3 meals per day (8/9 Batwa and 6/7 Bakiga children). Some mothers said that they kept food from the day before to ensure their children had 3 meals per day.

Generally, participants explained that number and type of foods in meals vary depending on the day of the week, market availability, work starting time, household food insecurity status, and religious events (including fasting): *"I am a teacher at school; thus, I eat two meals (breakfast and lunch) when I work, but over the weekend is different"* (Bakiga Individual Interview, male participant).

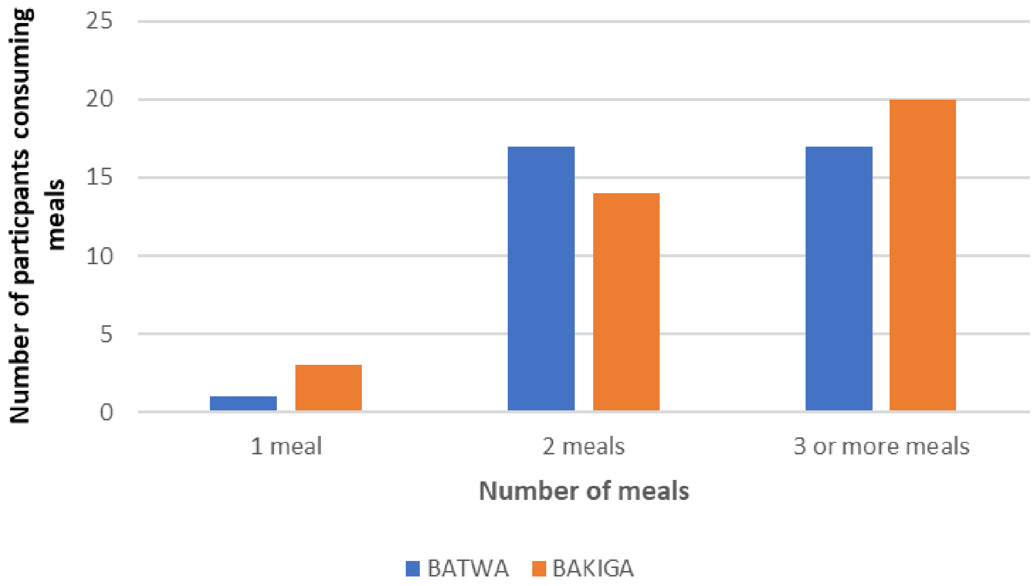

Figure 3. 3: Number of meals among Batwa and Bakiga participants.

3.4.4.5 Tools to measure portion sizes

During the FGDs, the participants reported the most common tools to measure portion sizes: 'plastic cups' (500 ml) were used for liquids, 'kilos' for cereals and any unpackaged foods available in the market, 'tea spoons' (5 g) for oils and 'soup spoon' (20 g) for margarine. However, they also added that the family often share meals from the same pan (Bakiga FGD) or plate (Batwa FGD), especially mothers and children, but this is not typical for 'special occasions' when each component of the family eats his own food in separate plates. Leftover food is usually eaten by children at the end of the meal, except some 'richer' families who may throw it away (Batwa and Bakiga FGDs).

The focus group participants affirmed that portion sizes changed over the year. The communities reported eating larger portions of foods in the past compared to the current intake. The quantity of food consumed by gender varied between Batwa and Bakiga communities. In the Batwa settlements, men ate more than women and children, according to the participants: "*if a man eats a kilogram of food, a woman eats half, and a child ¼*". "*This is because men work hard and need more food than women*" (Batwa FGD). In the Bakiga settlements there were different, more egalitarian norms, and women or children were equally likely to eat more than men. In Bakiga settlements, men tended to believe that women eat more: "*women eat more (1/4 more) than men, and children eat less, but if a child is over 10, he can eat more* *than a man*" (Bakiga FGD), while women reported that children eat more "*child eats more because he eats often […]. If there is little food, it is for the child that cries if he is not fed*" (Bakiga FGD).

3.5 Discussion

By using multiple fieldwork approaches, we demonstrated a method for collecting comprehensive data on food, recipes, cooking and storing methods, and factors influencing the development of the food list to construct a locally relevant and contextually specific food database. Our research focused on the Indigenous Batwa and Bakiga communities in southwestern Uganda where this locally contextualised information is lacking, but also provides a general approach that could be adapted method for other contexts.

In our food list and food database, we included medicinal plants, herbal drinks and traditional foods from the forest, such as grasshoppers and fermented beverages, which were not available in the existing Ugandan database, (12). The consumption of medicinal plants is common among Indigenous communities (30-32) and is part of their culture (33). Without conducting this fieldwork, we would have missed 27 local recipes, and 6 commonly consumed foods that we included in the online food database.

Although research on methods for documenting data on food, recipes and portion sizes is growing (7, 34-36), methods to specifically identify Indigenous dishes and foods remain scarce. Our study highlights the need to include qualitative and community-based methods to get more detailed information on commonly consumed Indigenous foods. The lack of Indigenous food databases does not occur only in Uganda, but worldwide; often they are missed in national food composition tables, limiting the assessment of caloric and nutritional intakes in these communities (8).

Furthermore, given the trend towards electronic data capture of dietary intakes, it is increasingly important for nutritionists to obtain a comprehensive food list before the dietary assessment begins. The food list is an important input for programming the questionnaires, and incomplete food lists may mean interviewers have to enter missing food items manually or may lead to incorrect entry of similar but different foods.

3.5.1 Key elements to be considered when collecting food lists

We identified key insights that had important implications for the collection of food lists and development of the food database in this region.

First, we found that the exploration of nutritional patterns and traditional cooking methods to collect robust local data is difficult without field-based methods informed by anthropological consideration of local knowledge regarding food cultures and peoples' eating habits (37). Our findings highlighted the importance of working in collaboration with the community and local researchers to clarify the terminology used to describe foods and recipes (22, 38, 39). For example, lack of clarity of the term 'greens' used to indicate different green leafy vegetables (as explained by participants and local nutritionists) would have affected the nutritional and caloric intake as it could refer to any unspecified greens available in the food composition table with a different nutritional composition (12). Also, this highlights the need to use specific probe questions during the dietary intake assessment stage, to ensure that the required level of details is captured.

Second, we found that understanding not only food culture, but also the meaning of food has implications for mapping the nutritional content of foods, during the food lists collection and the analysis of the results (37). For example, without understanding the term 'sauce' used to indicate the component of a dish rich in vegetable or animal proteins, foods might have been misclassified. A lack of clarity could have resulted in using the nutritional values for any prepared sauce (e.g. tomato sauce) instead of the more precise values for the specific food consumed (e.g. beans as sauce) (12, 40) (Table 3.5):

Table 3. 5: Nutritional values of tomato and bean sauces.

100 ml of each item:	***Kilocalories*** (12, 40)	***Proteins*** (12, 40)	***Lipids*** (12, 40)	***Carbohydrates*** (12, 40)
Tomato sauce	68 kcal	2.0 g	5.0 g	6.0 g
Beans sauce	81 kcal	5.7 g	0.2 g	14.6 g

Also, we illustrated the importance of interviewing both male and female participants to include the maximum number of food items and recipes in the food list. As we have shown, men talked more about beverages and women more about foods. Also, some gender-related issues about the quantity of food usually eaten by men and women in the household raised: male individuals stated that men usually eat less than women, while female participants argued the opposite.

Third, we demonstrate the importance of calculating the nutritional content of recipes at regular intervals to take account of households' adaptations. Our results indicate that the ingredients of the recipes and cooking methods varied depending on seasonality which influenced the availability of food, and for economic reasons. For example, we found that the recipe for 'boiled beans' traditionally was prepared with a minimal quantity of water. However, in highly vulnerable Bakiga and Batwa households there was substantial variation in the bean:water ratio. If the ingredients are not well described, an individuals' caloric intake would be overestimated (30 kcal / 100g vs 10 kcal / 100g for preparations with less or more water respectively) (12, 40).

Fourth, we were able to collect data on culture, society and environment together with the food and dishes consumed in highly food insecure Indigenous and non-Indigenous populations. Only a few studies in literature explored and compared the type of food produced or bought and consumed in Indigenous and non-Indigenous populations, and evidence is especially lacking for sub-Saharan Africa regions (41-43). The Batwa and Bakiga participants reported that they changed diets as they could not hunt or find the same type of food available in the forest thirty years ago. In some cases, the participants turned to purchasing food from markets, substituting traditional dishes with packaged foods with lower micronutrient content. Similar dietary transitions have been documented in many Indigenous communities globally (9, 44). Therefore, Indigenous food lists and databases should be frequently updated as the foods consumed change, and more industrialised and processed foods are eaten. Marketing and advertising promotes purchase of highly processed foods such as factory-bottled herbal drinks, that are energy dense products (45) but often low in fibre, vitamin and mineral content (46). Such highly processed foods are becoming more popular among rural and Indigenous communities in Uganda, and food lists should reflect this aspect.

Lastly, the Ugandan communities affirmed that the quantity and quality of foods changed over time. Climate change is a particular concern for many Indigenous communities as it affects traditional food systems at regional and global level (47). Climatic changes can contribute to the extinction of wild animals and plant species, and resulting diets, as shown in the research conducted among Canadian Indigenous communities (30). These changes need to be captured when interviewing the community as foods and recipes can change depending on the availability of foods in a specific time.

Also, while the effects of environmental changes on crop yields are widely studied (48-50), research assessing the impact on nutritional composition of foods remains limited (51). Modelling studies have shown the potential for a decrease in food quality due to climate change, and differences in food content between seasons (9, 52-54). Our study participants perceived that seasons are different now, and more extreme climatic events are occurring. Consequently, food lists and databases should include the nutritional content of foods over different seasons and in different geographical locations.

3.5.2 Limitations of our approach

Some study limitations should be noted. We explored the foods consumed and the cooking and storing methods among the communities together with the local meaning of food, availability of foods and seasonal changes, and tools to measure portion sizes. Although we reached data saturation, possible variations in food preparation methods, and new processed or commercial food products could be missed (37); continued collaboration with the community and local nutritionists is needed to identify new foods and composite dishes that are introduced over time. We could not find the nutritional information of 7 commonly eaten traditional plants in any of the other West African databases (the food composition table for central and eastern Uganda, the Tanzania food composition tables(55) and the Kenya food composition tables (56)). This limitation can be further addressed by conducting laboratory analyses of Indigenous foods.

Our work included a seasonal calendar and detailed dietary recalls, but we limited our fieldwork to the harvesting season, therefore more variation may be found in other months of the year. Additionally, finding the most appropriate tools to measure portion sizes among Batwa and Bakiga was difficult because families often ate from the same plate; estimation of leftover foods was also complex, although not very common as food was usually given to the children at the end of a meal. Further work is needed to develop accurate and ‘easy-to-use’ tools to measure food portions, such as the use of video-cameras (57) to quantify eaten foods in remote areas.

3.6 Conclusions

Despite some limitations, the data resulting from the study were essential to develop the food list for south-western Uganda. We used a community-based method for collecting rich information required to develop an Indigenous food list by taking into account the social, environmental and cultural factors influencing the food lists construction. Our study design -- including FGDs, individual dietary surveys and shop and market visits-- enabled development of a comprehensive assessment of Batwa and Bakiga food consumption and diet. These methods can be used in other Indigenous communities, although some tailoring to the social, environmental and cultural context would be required. Detailed and culturally-relevant food lists will improve the calculation of individual food and nutrient intake, which will enable policy makers, international and governmental organizations to adapt nutritional interventions to the specific community needs (58). This will aid work aiming to improve Indigenous peoples' nutritional status, and achieve the sustainable development goal of "Zero Hunger" (1).

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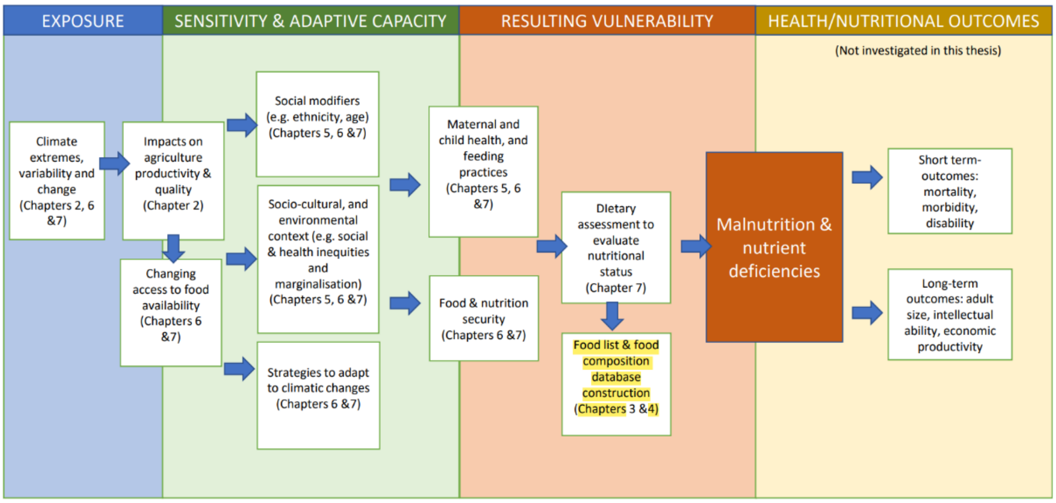
Chapter 4 - Developing an online food composition database for an Indigenous population in south-western Uganda.

Chapter 4 is the second methodological manuscript, which describes the development of myfood24 food database for the Batwa and Bakiga communities in south-western Uganda, including 148 commonly-consumed and traditional dishes.

Local food databases are generally scarce, and especially lacking in low- income countries, limiting the nutritional assessment. The data used for the database come from the food list collected in Chapter 3. Myfood24 provides information on calories and nutrient intake to the participants as soon as the 24-hour recall is performed, and the data are inserted into the system. Myfood24 takes account of the portion size as eaten (eg. if bones or inedible parts present), and takes account of cooking changes. All data on caloric and nutrient intake, including information on the type of food consumed and the quantity, can be downloaded into an Excel file which can be exported to undertake more advance statistical analysis.

Although we need biomarkers to validate the accuracy of our food database, and further research is needed in this direction, the newly developed myfood24 tool gave plausible results during the pilot phase. The local researchers observed first some dishes consumed by the community's members, and then asked them to describe and quantify the ingredients. However, we did not note how long foods were cooked, and we didn't take account of nutrient losses due to excessive cooking times. The information given corresponded to those recorded by the local researchers. Also, the food database was checked by experts with nutritional expertise. Each food, in fact, went through a rigorous quality-checking process by nutritionists in Uganda and the UK, increased the accuracy of the database.

Most of the dishes consumed by the two communities are cereal or vegetable based, low in fats and calories, and likely preventing children and women from achieving daily nutrient requirements.



Chapter 4 was prepared as a manuscript and formatted according to the submission guidelines of the journal Public Health Nutrition. This is the reference of the published manuscript:

Scarpa, G., Berrang-Ford, L., Bawajeeh, A.O., Twesigomwe, S., Kakwangire, P., Peters, R., Beer, S., Williams, G., Zavaleta-Cortijo, C., Namanya, D.B., Lwasa, S., Nowembabazi, E., Kesande, C., Rippin, H., Cade, J.E., 2021. Developing an online food composition database for an Indigenous population in south-western Uganda. Public Health Nutr. 24, 2455–2464. https://doi.org/10.1017/S1368980021001397

For this manuscript, G.S. prepared the first draft of the manuscript, coordinated the data collection (remotely), and the methodological design, and conducted the data analysis. L.B.-F. and J.E.C. (doctoral candidate's supervisors) provided input on the data analysis, and supervised the work. S.T. coordinated the fieldwork and collected the data with P.K., E.N. and C.K. H.R., C.Z.-C., A.O.B., R.P., S.B., D.B.N., S.L. and G.W. reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Ethics approvals were obtained from the University of Leeds Research Ethics Board (AREA 18-156), the Ugandan National Council for Science and Technology (SS5164), and the Makerere University Research Ethics Committee (MAKS REC 07.19.313/PR1). For participants under 18y, consent was obtained from the parents

Developing an online food composition database for an Indigenous population in south-western Uganda.

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4.1 Abstract

Objective: To develop an online food composition database of locally consumed foods among an Indigenous population in south-western Uganda.

Design: Using a community-based approach and collaboration with local nutritionists, we collected a list of foods for inclusion in the database through focus group discussions, an individual dietary survey and markets and shops assessment. The food database was then created using seven steps: identification of foods for inclusion in the database; initial data cleaning and removal of duplicate items; linkage of foods to existing generic food composition tables; mapping and calculation of the nutrient content of recipes and foods; allocating portion sizes and accompanying foods; quality checks with local and international nutritionists; translation into relevant local languages.

Setting: Kanungu District, south-western Uganda.

Participants: 74 participants, 36 Indigenous Batwa and 38 Bakiga, were randomly selected and interviewed to inform the development of a food list prior the construction of the food database.

Results: We developed an online food database for south-western Uganda including 148 commonly consumed foods complete with values for 120 micronutrients and macronutrients. This was for use with the online dietary assessment tool myfood24. Of the locally reported foods included, 56% (n=82 items) of the items were already available in the myfood24 database, while 25% (n= 37 items) were found in existing Ugandan and Tanzanian food databases, 18% (n= 27 items) came from generated recipes, and 1% (n=2 items) from food packaging labels.

Conclusion: Locally relevant food databases are sparse for African Indigenous communities. Here we created a tool that can be used for assessing food intake and for tracking under-nutrition among the communities living in Kanungu District. This will help to develop locally relevant food and nutrition policies.

4.2 Background

Food composition database information with relevant local foods is required to assess nutritional intake. Indeed, evidence-based nutrition policies needed to improve population nutrition-related health may be lacking without the analysis of individual caloric and nutrient intake (1). However, few countries hold accurate and up-to-date food composition tables. Many low and middle-income regions lack these data and use other countries' food composition tables as a proxy (2).

To investigate population food intakes, methods include 24-hour recall studies, food diaries and food frequency questionnaires (FFQs), though all methods are prone to substantial measurement error (3). The 24-hour recall is the most common nutritional assessment method in low and middle-income countries (3). It is frequently used to obtain caloric and nutritional intake measurements and assess dietary quality in individuals and populations across a range of cultural contexts (4-5). Nowadays, electronic, automated systems have been validated, and used to reduce costs and time of data collection (6-12).

All methods to collect food intake data must be underpinned by food composition databases appropriate for the study population. However, those are often inadequate, especially in highly-food insecure contexts where the type and quantity of ingredients in a recipe can change depending on food availability (In submission). Engaging with the community and local nutritionists can be the key to getting more accurate food data, and to understanding the evolution of populations' dietary patterns overtime.

Such information can also enrich the level of details that we need to develop relevant food composition tables in low-income and food-insecure settings (In submission).

Food composition databases representing food consumed by Indigenous communities are scarce. We contribute to this knowledge gap by constructing an online database of locally consumed foods with complete nutrient information for two vulnerable populations in south-western Uganda, the Batwa and Bakiga. Like other low-income countries, no food composition tables are available for south-western Uganda. The only existing food database was designed for central and eastern Uganda (13) and does not include all common recipes and local foods eaten by the Batwa and Bakiga communities (Scarpa et al., 2020, In submission).

We created a framework to collect unique and relevant food and recipes data for a specific population by engaging with the local community, and we formulated the following steps to develop the food composition database: 1. To identify foods for inclusion in the database; 2. To clean initial data and remove duplicate items; 3. To link foods to existing food composition tables; 4. To map and calculate nutrient content of recipes and foods; 5. To allocate portion sizes and accompanying foods; 6. To perform quality checks with local and international nutritionists; 7. To translate food items into relevant local languages.

4.3 Methods

4.3.1 Study region and Population

The Batwa community, self-identified as Indigenous, lives in south-western Uganda, and represents a minority group in Kanungu District (14). The Bakiga community reside in the same area and constitute the majority population in the district (15, 16). The Batwa were originally hunter-gathers until their displacement in 1991 from the forest, now known as Bwindi Impenetrable National Park (17). They became a sedentary population frequently employed by the Bakiga in agriculture. However, many Batwa still rely on humanitarian aid to survive (18). Conversely, the Bakiga are traditionally farmers whose income comes primarily from food crops (16). Both populations are highly vulnerable to food insecurity, malnutrition (especially stunting), acute gastrointestinal diseases (including vomiting, diarrhoea and associated symptoms) and malaria (19).

4.3.2 Study Design

The food database construction for south-western Uganda follows the framework in Fig.4.1. The framework aimed at constructing food composition tables for low-income areas. It is composed of two stages: the first stage comprised fieldwork and a mixed methodology to collect a list of foods consumed, along with recipes and portion sizes (Scarpa et al., 2020, In submission). To develop the online south-western Ugandan database, we used six steps for food composition database creation previously used by other researchers (6, 20). The data on foods and recipes were collected by the local research team, and the food database was created by the PI in collaboration with local nutritionists and myfood24 team in UK.

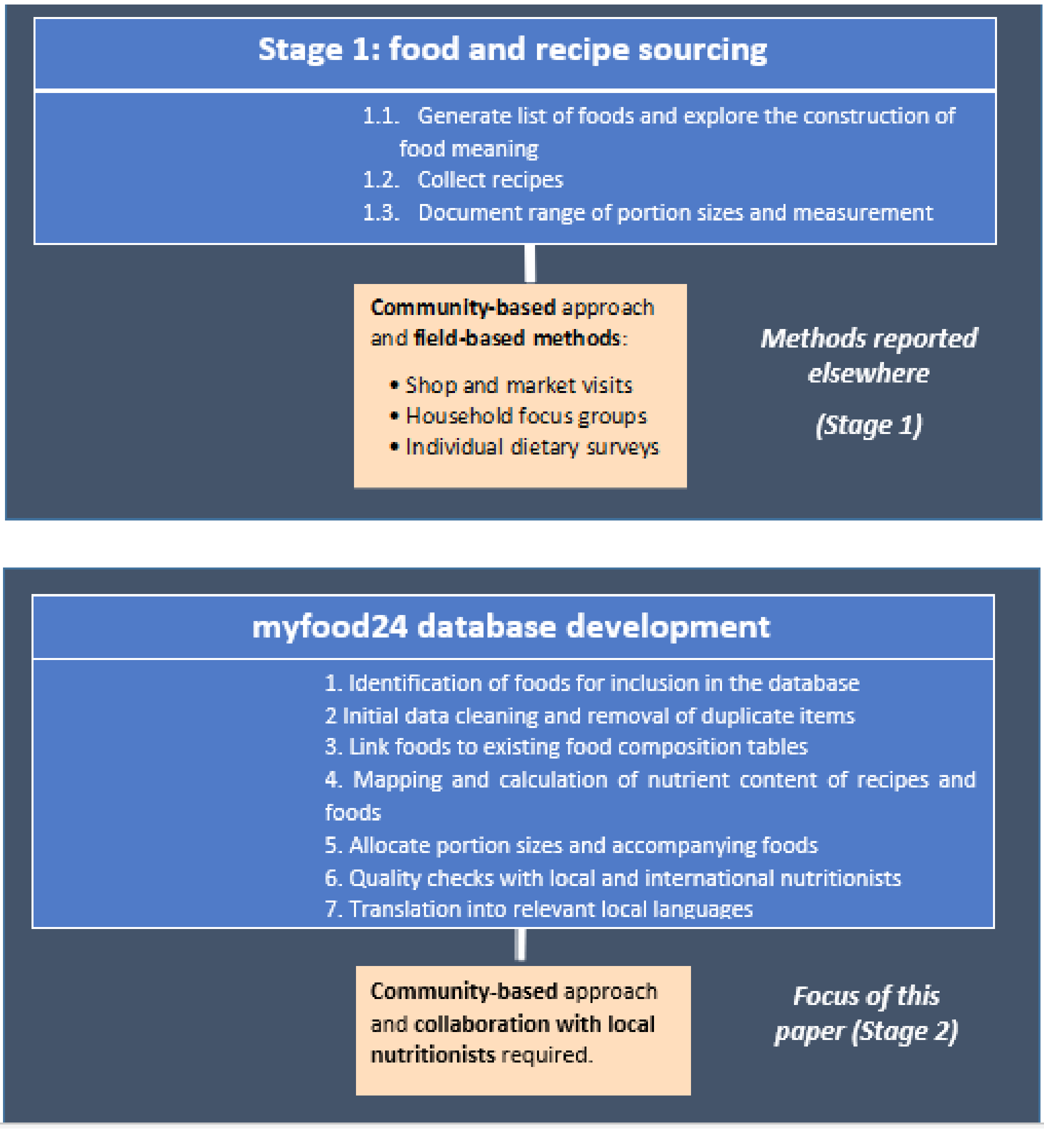

Figure 4. 1: Framework used to characterise the south-western Ugandan food database. This paper documents the methods and results from Stage 2.

4.3.2.1 Stage 1

Detailed methods and results from Stage 1 are presented elsewhere (Scarpa et al., 2020, In submission), with this paper focusing primarily on Stage 2. In the first stage, food and recipe data were collected through market and shop assessment (n=4 markets and 10 shops visited in total), focus group discussions (n=8 in total) and individual dietary survey (n= 76) from July to October 2019 (Supplementary material Chapter 4). A male local researcher supported by a Batwa and a Bakiga female researcher conducted the fieldwork. The data were collected in the local Rukiga language, and then translated in English by the local researcher (Scarpa et al., 2020, In submission). For the individual dietary survey and focus groups (74 participants in total, 36 Batwa and 38 Bakiga), four settlements among Batwa and four adjacent (geographically matched) Bakiga settlements were sampled, ensuring a representative sample of people of different age and sex. To explore the range of foods in different geographical areas, data were collected in four different Batwa and Bakiga communities: close to the markets and shops, far from the markets and shops, mid-way between the two zones and close to the forest. Individuals participating in the study were randomly selected from village lists (Scarpa et al., 2020, In submission) (3).

4.3.2.2 Stage 2

Stage 2 was comprised seven steps summarised in Fig. 4.1.

2.1 Identification of foods for inclusion in the database

We identified the most common foods and dishes consumed among the Batwa and Bakiga communities and we removed non-edible items (e.g. cigarettes). Additionally, a food photo album briefing was created with the pictures of local foods taken by a local nutritionist. It consisted of a description of the most frequently eaten foods and local recipes, and associated images of tools used to measure portion sizes. This supported the development of the food database by giving background information to non-local nutritionists on traditional foods consumed by the Batwa and Bakiga.

2.2 Initial data cleaning and removal of duplicate items

We cleaned the data and removed duplicates. We included all different cooking methods and ingredients for each food and dish eaten in south-western Uganda. Unit conversions were computed to match myfood24 database values; for example, some micronutrients were converted from grams to milligrams. Additionally, some missing values such as kilojoules were calculated using mathematical formulae (e.g. we used the value of the kilocalories and we divided it by 4.184).

2.3 Linking foods to existing food composition tables

Four existing food composition tables (13, 21-23) from Uganda, Kenya, Tanzania and the UK were identified as relevant for the creation of the local food table.

The Ugandan database was created in 2012, and it includes 728 foods and recipes. No foods were chemically analysed for nutrients in the Ugandan table, except for orange sweet potato (13). Most of the food items were sourced from the USDA (24) food composition table. The Tanzanian and the Kenyan food composition tables (21) and myfood24 database were consulted if a dish or item was not available in the Ugandan food database. The Tanzanian food composition database was developed in 2008 and comprises over 400 foods and recipes, while the Kenyan food composition table was created in 2018 and contains 509 foods (22). The myfood24 database includes UK, German, Danish, and Australian foods and recipes, both branded and generic products. The data on nutritional content in the British food table comes from the UK Composition of Foods Integrated Database (COFID) (23) for generic products and back of pack nutrition labels for branded items which are mapped to similar generic products in COFID to allocate nutrient values for the remaining nutrients.

We used back-of-pack labels of packaged foods identified in Uganda to collect nutritional content information when this was not available in existing food composition tables. The estimated portion sizes were derived from focus group discussions which we held in the first stage of this study.

2.4 Mapping and calculation of nutrient content of foods and recipes

Recipes were collected during the Stage 1 of the study. In the case of beans-based dishes, two versions of the same recipe, one with fresh and the other with dried beans, were used, as both were cooked and eaten by the communities in similar amounts.

When possible, we matched the south-western Ugandan foods with the items already available in the myfood24 database (Tab. 4.1). This database is more complete in terms of nutritional content analysed than the other food composition tables. It contains 120 nutrients available for each food item (6). The decision to keep a food item already available in myfood24 was made by three independent researchers, including at least one Ugandan nutritionist.

Table 4. 1: Example of matched foods for creating the online south-western Ugandan my food24 database.

Ingredients and local dishes in Rukiga language with English translation in brackets	Closest matched foods
Emboga zadodo (dodo)	100% boiled amaranth leaves
Akatogo kebitookye nebihimba byomiire (matoke with dried beans)	70% banana (matoke), 1% salt, 29% dried beans (average of 3 different type of beans: blackeye beans, haricot beans and red kidney beans)
Esano yoburo egoyire/oburo (millet bread)	100% boiled millet flour
Emboga zadodo nebihimba byomir (dodo with dried beans)	31% amaranth leaves, 1% salt, 68% dried beans (average of 3 different type of beans: blackeye beans, haricot beans and red kidney beans)

Cooked ingredients were used for nutrient information for the majority of the recipes. Nutritional and caloric content was available from existing African food databases. Therefore, we did not add water nor calculate the cooking factor as those elements were already included in the cooked food items. Only in the case of two dishes, firstly we converted the raw ingredients of the recipes to percentages, to facilitate allocation of nutrients to each composite food per 100g (6). Secondly, we applied cooking factors to calculate the quantity of cooked items (18). Lastly, we calculated water evaporation or absorption as required (1).

To determine the ingredients' quantity in the dishes, we used an average of each ingredient described by the participants for every recipe; then, we created nutrient values for each recipe using the percentage of each ingredient in the recipe.

2.5 Allocate portion sizes and accompanying foods

Each food and dish was associated with portion size measures (Scarpa et al., 2020, In submission). Local researchers weighed the quantity of food contained in each household utensil to estimate the portion sizes. For example, posho contained in a ladle weighted 100 g, therefore when the participant said he used 2 ladles of posho to prepare the dish, we translated to 200 g.

Additionally, we added a list of 'accompanying foods' which automatically appears on myfood24 when a food item that is commonly consumed with another one, is selected. For example, milk and sugar were identified as 'accompanying ingredients' for 'porridge'.

2.6 Quality checks with local and international nutritionists

A team composed of two nutritionists in Uganda and two nutritional researchers in the UK conducted quality checks after the first stage of fieldwork. Subsequently, two independent researchers and the myfood24 team checked the calculation of the recipes and the mapping of foods to ensure nutrient values were sensible.

2.7 Translation into relevant local languages

Translation of food names was performed by a local nutritionist and checked by a second Rukiga speaker. Synonyms of foods were added to facilitate searching in the database.

4.3.3 Data analysis

The data were analysed using Excel® for calculating the recipe ingredients and for basic descriptive statistics. MS Access® was used to create a database for inclusion into myfood24. This included all foods and nutrients, along with standard portion size information, prompts for foods commonly consumed with dishes, and mispellings or different names to indicate foods if necessary.

4.4 Results

4.4.1 South-western Ugandan foods and dishes available in myfood24 database

The southwestern Ugandan food database contains 148 of the most consumed foods among the Batwa and Bakiga communities living in Kanungu District, with complete information on 120 micronutrients and macronutrients. The foods were collected through the focus group discussions (collected information on 139 foods), individual dietary surveys (collected information on 69 foods) and shops and markets assessment (collected information on 95 foods). Some foods identified by the communities through one method (e.g. focus group discussions) were repeated in another method (e.g. market and shop assessments or individual dietary survey). We identified 303 food items by using the three methods, representing 148 unique items after duplicate removal.

As shown in Fig. 4.2, the sources for developing the south-western Ugandan food composition database were multiple. Fifty-six percent (82 items) of the foods were already available in the myfood24 database from the generic UK COFID tables, while the other 43% (64 items) were added from African food composition tables (26%) and generated recipes (18%). Only 1% (2 items) of the nutrients in foods included in the composition database were extracted from back-of-pack labels.

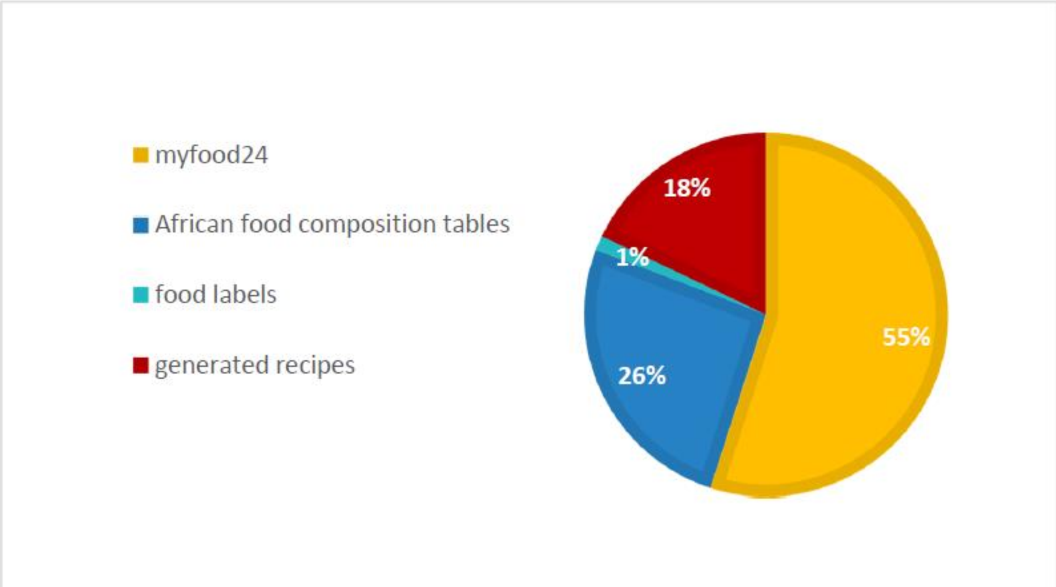

Figure 4. 2: Sources used to develop the southwestern Uganda myfood24 database (n=148 items).

The south-western Ugandan myfood24 database included 43% (64 of 148) of fruit and vegetable items and dishes, 26% (38 of 148) of cereals items and cereal based dishes (including dishes with higher percentages of cereals than vegetables), 14% (20 of 148) of meat and fish dishes, and 5% (7 of 148) of eggs and dairy. Only 3.5% (5 of 148) of products were sugary or sweet-based and 3% (5 of 148) were included in oils, fats and condiments (Tab. 4.2). Some cooking oils and fats were branded, while the majority of the other food items did not have any brand. Soft drinks (4%, that is 6 of 148) and alcoholic beverages (1.5%, that is 2 of 148) corresponded to 4.5% of the foods included in the database.

The composite foods (including recipes already available in other food composition tables and new generated recipes) were mostly bean- and vegetable-based (9 of 32) or bean- and cereal-based (10 of 32) (Tab. 4.2). Thirty-one of 32 composite foods did not contain any animal protein. We inserted in our composition database five recipes (5 of 32) that were already available in the Ugandan food composition table. A selection of nutrients calculated for the 27 generated recipes is reported in Tab.4.3 and shown as per 100g of the cooked dish (the complete information can be found in Supplementary material Chapter 4). The food products used for cooking were fresh or dried, and no recipes for preparing soups were mentioned. A high proportion of foods that needed to be cooked before consumption were boiled, except for some items such as fish and meat which were either boiled or fried. Sauces and condiments were prepared at home, while biscuits and sweets were packaged and bought from the markets and shops.

Many identified generic fruit and vegetable items were already available in the myfood24 database (45 of 58 items). The new vegetables items added to the online database contained various types of wild leafy vegetable and fruit (13 new items). Local fish and meat, commonly consumed in south-western Uganda, were also added to the database (e.g. goat meat). Their nutritional content was derived from the Ugandan and UK food composition tables.

Table 4. 2: Sources of the food list and the food database (myfood24 database, African food composition tables, back-of-pack labels products and generated recipes).

		FOOD LIST SOURCES[1]			FOOD DATABASE SOURCES			
Food Category	**Total (n= 148 foods)**	**Focus Groups**	**Individual dietary assessment**	**Market and Shops assessment**	**Food already in myfood24 (n=82)**	**African food composi-tion tables (n=37)**	**Back of pack labels products (BOP) (n=2)**	**Generated recipes (n=27)**
Fruits and vegetables	53	50	31	48	40	13	0	0
Meat and poultry	11	9	0	5	8	3	0	0
Dairy and eggs	7	7	2	6	7	0	0	0
Cereals and tubers	18	17	7	10	11	7	0	0
Drinks	6	6	3	6	4	0	2	0
Honey and other sugars	4	4	1	3	2	2	0	0
Fish	9	8	1	6	3	6	0	0

[1] The total of foods collected through focus group discussions, individual dietary surveys and shop and market assessments is not equal to 147, but it is higher. However, some foods and recipes were repeated by using different methods.

Oils and fats	3	3	2	3	3	0	0	0
Sauces and condiment	2	2	2	2	2	0	0	0
Alcohol	2	2	2	0	1	1	0	0
Cakes, biscuits, chocolates and other snacks	1	1	0	1	1	0	0	0
Dishes with vegetables and cereals or tubers	15	15	10	0	0	0	0	15
Dishes with fish and vegetable	1	1	0	0	0	0	0	1
Dishes cereal-based	5	5	1	5	0	5	0	0
Dishes vegetable - based	11	9	7	0	0	0	0	11

Table 4. 3: Description of south-western Ugandan generated recipes (for 100 g of each cooked dish).

Local dishes	***Nutrients (for 100 g of each cooked dish)***									
	Energy (Kcal)	***CHO[2] (g)***	***Fat (g)***	***Prot[3] (g)***	***Ca[4] (mg)***	***Fe[5] (mg)***	***Vit[6] C (mg)***	***Zn[7] (mg)***	***Vit[8] A (mcg)***	***Folate (µg)***
Boiled matoke with boiled fresh beans[9] (70% matoke, 29% beans and 1% salt)	82	19.3	0.3	2.4	11.0	0.8	4.6	0.3	1.4	25.7

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[2] Carbohydrates
[3] Proteins
[4] Calcium
[5] Iron
[6] Vitamin C
[7] Zinc
[8] Vitamin A
[9] Fresh beans: fresh kidney beans.

Boiled matoke with boiled dried beans[10] (70% matoke, 29% beans and 1% salt)	89	20.3	0.4	3.0	14.8	0.9	4.8	0.5	1.7	32.1
Boiled dried beans with boiled yellow sweet potatoes (70% yellow sweet potatoes, 29% beans and 1% salt)	110	24	0.2	3.7	38.6	1.2	1.7	0.6	124.1	33.4
Boiled dried beans with boiled orange sweet potatoes (70% orange sweet potatoes, 29% beans and 1% salt)	110	24	0.2	3.7	40.0	1.2	1.8	0.6	306.1	33.4
Boiled fresh beans with boiled yellow sweet potatoes (70% yellow sweet potatoes, 29% beans and 1% salt)	103	23	0.1	3.1	34.8	1.1	1.9	0.5	123.9	27.1
Boiled fresh beans with boiled orange sweet potatoes (70% orange sweet potatoes, 29% beans and 1% salt)	103	23	0.1	3.1	36.2	1.1	2.0	0.5	305.9	27.1
Boiled dried beans with boiled yam (70% yam, 29% beans and 1% salt)	124	28.4	0.4	3.5	20.4	1.0	2.9	0.6	0.3	28.6
Boiled fresh beans with boiled yam (70% yam, 29% beans and 1% salt)	117	27.3	0.3	2.8	16.7	0.9	3.0	0.5	0.0	22.1

[10] Dried beans: mix of dried blackeye beans, dried haricot beans and dried red kidney beans.

Local dishes	*Nutrients (for 100 g of each dish)*									
	Energy (Kcal)	*CHO (g)*	*Fat (g)*	*Prot (g)*	*Ca (mg)*	*Fe (mg)*	*Vit C (mg)*	*Zn (mg)*	*Vit A (mcg)*	*Folate (mcg)*
Boiled pumpkin and boiled dried beans (70% pumpkin, 29% beans and 1% salt)	44	8.7	0.2	2.8	22.5	1.1	3.4	0.4	175.3	30.7
Boiled green leaves[11] with boiled fresh beans (79% beans, 20% green leaves and 1% salt)	69	12.3	0.2	5.0	50.6	1.8	3.3	0.6	28.8	57.8
Boiled green leaves with boiled dried beans (79% beans, 20% green leaves and 1% salt)	87	5.5	0.5	6.7	60.9	2.1	3.3	0.8	29.6	75.2
Boiled fresh beans with boiled dodo (68% amaranth leaves, 31% beans and 1% salt)	60	10	0.2	4.8	87.3	2.1	10.2	0.6	76.0	58.0
Boiled dodo and groundnuts (68% groundnuts, 31% amaranth leaves and 1% salt)	221	14.6	15.0	10.1	105.7	1.4	9.8	1.4	75.9	66.8
Boiled peas with boiled matoke	82	17.9	0.7	3.4	8.4	0.6	9.1	0.4	13.6	15.6

[11] Green leaves: different green leaves including amaranth leaves, eggplants leaves and cabbage leaves.

(70% matoke, 29% peas and 1% salt)										
Boiled peas and orange sweet potatoes (70% orange sweet potatoes, 29% peas and 1% salt)	103	21.6	0.5	3.4	33.6	1.0	6.4	0.6	318.1	16.9
Boiled peas and yellow sweet potatoes (70% yellow sweet potatoes, 29% peas and 1% salt)	103	21.6	0.5	3.4	32.2	1.0	6.3	0.6	136.1	16.9
Fried fish[12] with groundnuts sauce (38% fish, 13% onion, 32% groundnuts paste, 16% tomatoes and 1% salt)	356	8.2	19.2	41.3	35.9	1.7	2.5	1.5	5.3	59.4
Boiled fresh beans with groundnuts sauce (34% fresh beans, 14% onion, 34% groundnuts paste, 17% tomatoes and 1% salt)	236	13.6	17.3	10.7	29.1	1.4	2.9	1.3	5.7	49.9
Boiled fresh beans with dried corn (33% fresh beans, 66% maize grain and 1% salt)	151	30.1	1.7	5.1	12.0	1.5	0.3	1.0	0.0	26.4

12 Fish: tilapia

Local dishes	Nutrients (for 100 g of each dish)									
	Energy (Kcal)	***CHO (g)***	***Fat (g)***	***Prot (g)***	***Ca (mg)***	***Fe (mg)***	***Vit C (mg)***	***Zn (mg)***	***Vit A (mcg)***	***Folate (mcg)***
Boiled fresh beans and Irish potatoes (70% Irish potatoes, 29% peas and 1% salt)	74	16.1	0.1	2.9	11.7	0.9	4.4	0.4	0.0	31.2
Boiled cassava and peas (70% cassava, 29% peas and 1% salt)	114	26.3	0.6	2.3	17.5	0.8	16.6	0.5	12.2	15.5
Boiled pumpkin and fresh beans (70% pumpkin, 29% beans and 1% salt)	37	7.6	0.1	2.1	18.7	1	3.5	0.3	175.0	24.2
Boiled dried beans and Irish potatoes (70% Irish potatoes, 29% peas and 1% salt)	81	17.2	0.2	3.6	15.5	1.0	4.3	0.5	0.3	37.7
Boiled peas and Irish potatoes (70% Irish potatoes, 29% peas and 1% salt)	73	14.8	0.5	3.2	9.1	0.7	8.8	0.5	12.2	21.1
Boiled dodo with boiled dried beans (68% amaranth leaves, 31% beans and 1% salt)	76	12.4	0.5	6.3	96.2	2.3	9.8	0.9	76.6	72.9
Boiled mushroom and eggplants (66% eggplants, 33% mushrooms and 1% salt)	25	5.5	0.3	1.4	8	0.7	2.7	0.4	0.7	20.5

The identified branded products had incomplete nutrient content information on the back of pack label and therefore had to be matched to similar foods from the myfood24 database which held complete nutritional data. The products, reported in Tab. 4.4, are mostly produced in Uganda or in Africa, and one is an international item.

Table 4. 4: Branded products missing some important nutritional information that required mapping of nutrients.

Branded product	Type of food	Country of production	Matched with:
Waragi	Alcohol	Uganda	100% gin
Blue Band	Cooking fat	International	100% margarine
Coke, Fanta	Drinks	Uganda	Already in myfood24 database
Kimbo	Cooking fat	Africa	100% margarine
Butto	Cooking Oil	Uganda	100% vegetable oil
Kayonza	Tea	Uganda	100% black tea

4.5 Discussion

We created an online food database with the most common foods and dishes consumed by the Batwa and Bakiga communities. Recognising the importance of collecting information on food meanings and social and environmental factors that affect individual food consumption, we used multiple fieldwork techniques and a community-based approach (Scarpa et al., 2020, In submission). We also believe that gaining knowledge on communities' food systems can increase the understanding of local nutrition practices and facilitate the collection and analysis of local food intake data. Designing a locally relevant food composition database may be useful for monitoring the prevalence of under-nutrition and identifying individuals potentially at risk of nutritional deficiencies (e.g. iron) (25). It can also inform nutrition policies and future health intervention towards the third Sustainable Development Goal, 'Zero Hunger' (26).

4.5.1 Challenges in developing the south-western composition database

We used different food composition tables to calculate the nutritional content of foods such as the Ugandan food composition database containing data from USDA (United States Department of Agriculture) and UK food composition tables. As a result, the nutrient content of foods analysed in high-income settings may not fully represent the nutritional values of an Indigenous meal as those vary according to the geographical position, but also food colour, species and season (1, 27-30). Therefore, relying on western food analysis may lead to miscalculation of the real nutritional content (31). Although we are aware of possible limitations, before inserting any food in the myfood24 database, the Ugandan and UK teams evaluated the existing nutritional content. We thus included the most accurate nutritional values for each food according to existing knowledge. Indeed, we compared the macronutrient and micronutrient content in four databases (African and UK myfood24 databases), and if the nutritional values of African food composition tables were similar to those in myfood24 database, we choose to insert myfood24 values as they contained detailed analysis of over 120 nutrients.

Data on food labels were missing as in many low income countries (32-35), therefore we could not extract information on nutrients except for two food items. In addition, we could not include some leafy vegetables consumed by the communities to cure specific diseases, due to lack of information on nutritional content in the scientific literature. We recommend further research to analyse the nutritional value of local plants and traditional herbs to be inserted in the south-western Ugandan food database. Including local foods also underpins a focus on Indigenous justice and the importance of recognising and valuing Indigenous food systems and practices, which in many contexts have been found to have nutritional and environmental benefits for communities (36).

Portion sizes were also challenging to measure as the Batwa and Bakiga often ate from the same plate. The participants in the focus group discussions did not like the potential to illustrate portions of dishes consumed through pictures (37), a medium often used in high-income countries to support food portion size estimation (38, 39). Household measurements were used to quantify food portions not only for the composition database of south-western Uganda, but also for other African and South-Asian countries such as Burkina Faso and Vietnam (39). A more precise method may be needed to assess individual portion sizes. The use of wearable cameras was investigated by *Bulungu et al*. (40) in Eastern Uganda to explore type of foods consumed and nutrition practices, however further research is required to assess the reliability of this method to measure food portions in extremely low-income contexts.

4.5.2 Recipes and foods low in calories and poor in nutrients

As in other lower-income countries, economic constraints caused low consumption of foods rich in proteins and fats in south-western Ugandan populations (41). In previous focus group discussions (Scarpa et al., 2020, In submission), Batwa and Bakiga participants argued that in the past, when they lived in the forest, they used to hunt and often ate wild meat. Evidence suggests that hunting saved from starvation different Indigenous communities, for example the Inuit in the Arctic (42). However, the study participants reported that now their diet is low in animal proteins, and the consumption of vegetable- and beans-based dishes is higher due to the high cost of meat in the markets.

The caloric level of the Batwa and Bakiga dishes is, in fact, generally low, and some micronutrients including iron content may not be adequate to satisfy nutritional requirements, particularly of children and pregnant women. In vegetable protein-based dishes, non-haem iron absorption varies between 5% and 12%. The variation depends on individual iron status and other factors such as food preparation and calcium content (43-45). Phytate and other inositol phosphates, which are present in many edible plants, may also inhibit iron absorption (46-48). Conversely, if the iron intake comes from mixed diets (animal and vegetable-based dishes), the quantity of iron absorbed is between 14% and 18%, and the influence of inhibitors of iron absorption are reduced, with a smaller effect on individual's iron status (43, 44).

Most of the local dishes collected had a total of kilocalories between 25 and 236 per 100 grams. Only the intake of the fish-based dish had more than 350 kilocalories per 100 grams. As an example, we calculated the amount of matoke with fresh beans required by a male child aged 1 year. Indeed, this is one of the most consumed dishes used during the complementary feeding period (Scarpa et al., 2020, In submission). According to FAO guidelines, a 1 year old boy needs 770 kilocalories per day (49). Therefore, if this is all that is available, nearly 1000 grams of matoke with fresh beans are required to satisfy his energy needs based on the recipes obtained locally. This is a large quantity of food for a 1-year old boy, with insufficient nutritional content. Also, the iron intake from vegetable foods (8 mg for 1 kg of matoke with beans) would be much lower than the standard requirement (50-100 mg for 1 year old boy (49)) as well as the vitamin A content (14 mcg for 1 kg of matoke with beans compared to 400 mcg standard FAO requirement (49)). Conversely, if the meals consumed included fish or meat, the amount of food to be eaten would have been lower. For example, 100 g of a fish-based dish already contains half of the calories that a 1-year old infant has to consume daily. The foods used for complementary feeding practices in western countries are much higher in terms of energy density, even for vegetarian diets (50).

Therefore, further research is needed to explore infant and young child nutrition, to provide clear guidance on complementary feeding and weaning practices among the south-western Ugandan Indigenous communities.

4.5.3 The limitation of myfood24 use in south-western Uganda

We believe that the use of myfood24 with a local food database can ease the assessment of the food intake in less time and burden compared to the traditional interview-led approach. However, the level of literacy of Batwa and Bakiga is generally low, and accessibility to mobile phones or other computers is limited (16, 19), therefore self-recording of foods is challenging. Local researchers may play an important role to collect the data on the myfood24 database for the participants that do not have a mobile phone. Further research would be needed to investigate the usability of myfood24 in extremely low-income settings, as this is the first database created for Indigenous populations. Some Indigenous community data collectors may be trained in the future to collect dietary data.

Additionally, as the myfood24 system only functions with internet connection, more work is needed to make it available offline. This would facilitate the data collection in rural settings, avoiding the use of paper-based methods to record the data, and reducing working hours and transcription errors.

4.6 Conclusion

We developed the first online food composition database for an Indigenous population in an extremely low-income context. We used multiple fieldwork techniques, we engaged with the local communities and nutritionists, and we applied a novel framework to collect locally relevant information on foods and recipes. This database can be used in research to assess food intake of individuals' vulnerable to malnutrition in south-western Uganda.

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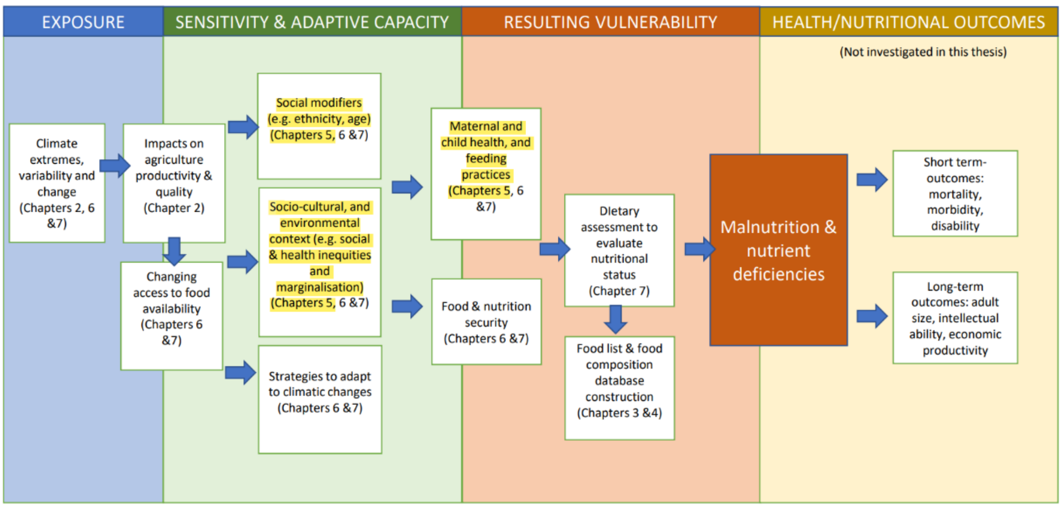
Chapter 5 - Identifying predictors for Minimum Dietary Diversity and Minimum Meal Frequency in children aged 6-23 months in Uganda.

This chapter explores complementary feeding indicators, minimum meal frequency (MMF) and minimum dietary diversity (MDD) in Uganda. Complementary feeding is, in fact, a critical time for children, and corresponds to the age between 6 months and 2 years, when children can easily get malnourished if they do not consume an adequate diet(1). This work gives an overview of the child feeding practices' situation at national level. I used secondary data from the Ugandan DHS to assess the predictors of MMF and MDD. It is important to highlight that there is no information about the Batwa of Kanungu District, however other minorities and vulnerable groups are included in this study. The findings suggest that wealth, health and vaccination status are associated with complementary feeding indicators. Although there are no data about climatic conditions or temporal variation, this chapter investigates social modifiers and *sensitivity* to climate change, which are elements of the vulnerability framework.



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Dietary Diversity and Minimum Meal Frequency in children aged 6-23 months in Uganda.

For this manuscript, G.S. prepared the first draft of the manuscript, and the methodological design, and conducted the data analysis. L.B.-F. and J.E.C. (doctoral candidate's supervisors) provided input on the data analysis, and supervised the work. G.M. provided statistical advice. P.K., D.B.N., F.T. and L.A. reviewed and edited the manuscript. All authors have read and agreed to the submitted version of the manuscript.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the University of Leeds Research Ethics Board (AREA 18-156), the Ugandan National Council for Science and Technology (SS5164), and the Makerere University Research Ethics Committee (MAKS REC 07.19.313/PR1). Additionally, Ethical approval was granted by the DHS program to use the UDHS datasets (Reference letter: 142276). All methods were carried out in accordance with relevant guidelines and regulations.

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Identifying predictors for Minimum Dietary Diversity and Minimum Meal Frequency in children aged 6-23 months in Uganda.

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5.1 Abstract

Adequate complementary foods contribute to good health and growth in young children. However, many countries are still off-track in achieving critical complementary feeding indicators, such as minimum meal frequency (MMF), minimum dietary diversity (MDD) and minimum acceptable diet (MAD). In this study, we used the 2016 Ugandan Demographic Health Survey (UDHS) data to assess child feeding practices in young children aged 6–23 months. We assess and describe complementary feeding indicators (MMF, MDD and MAD) for Uganda, considering geographic variation. We construct multivariable logistic regression models—stratified by age—to evaluate four theorized predictors of MMF and MDD: health status, vaccination status, household wealth and female empowerment. Our findings show an improvement of complementary feeding practice indicators in Uganda compared to the past, although the MAD threshold was reached by only 22% of children. Children who did not achieve 1 or more complementary feeding indicators are primarily based in the northern regions of Uganda. Cereals and roots were the foods most consumed daily by young children (80%), while eggs were rarely eaten. Consistent with our hypotheses, we found that health status, vaccination status and wealth were significantly positively associated with MDD and MMF, while female empowerment was not. Improving nutrition in infant and young children is a priority. Urgent nutritional policies and acceptable interventions are needed to guarantee nutritious and age-appropriate complementary foods to each Ugandan child in the first years of life.

5.2 Introduction

Appropriate feeding practices are required for infants and young children to ensure good health, growth and development (1). While in the first six months of life the World Health Organization (WHO) recommends exclusive breastfeeding, the introduction of complementary foods is recommended from six months onwards for every child (2). Ensuring adequate nutrition is a key pillar to achieving the right of every child to sufficient nutrition, as laid out by the Convention of the Rights of the Child (3). However, appropriate and sufficient complementary feeding remains a particular challenge in Sub-Saharan Africa (4).

Undernutrition is still an underlying cause of child mortality and morbidity for children under 5 years globally (5). In Uganda, rates of stunting and underweight have declined since 2000 according to the last available Uganda Demographic and Health Survey (2016). Stunting has decreased from 45% in 2000 to 29% in 2016 in Uganda, and underweight from 18% in 2000 to 11% in 2016 (6). Despite this, high rates of both types of malnutrition persist in the country, together with wasting (4% in 2016) and overweight (4% in 2016) cases among children under five years (6). To end malnutrition by 2030, the Uganda Nutrition Action Plan 2018-2025 includes in the priority actions the promotion and support of breastfeeding and complementary feeding practices policies and programmes (7).

Recent research has identified potential determinants of adequate complementary feeding, highlighting the role of social and health factors in driving parental choices and ability to support complementary feeding (8, 9). Studies report that the health status of the child is one of the main elements that needs to be considered at the individual level when assessing complementary feeding practices (5). However, family and social contexts, and especially maternal factors, also influence child nutrition (10). Maternal education, female empowerment, number of antenatal visits, and household wealth have also been associated with complementary feeding practices (11). For example, greater female empowerment was found to be associated with reduced wasting in a randomised control trial in Burkina Faso (12). Findings in Sub-Saharan Africa, however, are mixed, with both increases and decreases in complementary feeding indicators associated with female empowerment (13).

Studies assessing the factors that affect complementary feeding practices in Uganda are limited. A study published in 2017, analysing UDHS data collected in 2006 and 2011, assessed child attributes, but did not explore socio-economic or environmental determinants (14). Other research has explored complementary feeding practices in specific districts or areas of Uganda (15, 16) without assessing predictors of child feeding. Some studies that focus on determinants of infant and young child feeding have been conducted in specific Ugandan regions (17-19). To date, we are aware of no research at the national level assessing the combination of socio-economic, child, and family determinants of child complementary feeding in Uganda. Qualitative and mixed-methods research evaluating barriers of child feeding practices is also scarce (20).

In this manuscript, we draw on the Ugandan Demographic Health Surveys (UDHS) to assess data collected in 2016 — the most recently available DHS data for Uganda —on child feeding practices in young children aged 6-23 months. The aim of this study is to identify priority areas that could be targeted by national authorities, health organisations and the Ugandan Ministry of Health to improve nutrition and complementary feeding practices in young children in Uganda. Our objectives were: 1. To describe complementary feeding indicators in Uganda, considering geographic variation; 2. To assess key determinants previously identified in the literature (empowerment score, wealth index, vaccination and health status) of selected complementary feeding indicators (MMF, MDD) in 2016.

5.3 Methods

5.3.1 Data source

The sampling used in the most recent UDHS (2016) comes from the Uganda National Population and Housing Census (NPHC) undertaken in 2014. It followed a two-stage sampling design, including initially 697 clusters (165 urban and 535 rural) from NPHC 2014, and then a sample of 20880 households from April to October 2016. One hundred and twelve districts were included in the sample, grouped into 15 regions (6).

The data used for this study include socio-economic and demographic information from the Household Questionnaire, and on maternal and child health, nutrition and complementary feeding from the Women's Questionnaire (6). The response rate for the household questionnaire was 98% and for the women's questionnaire was 97%. For this work, we created a subset of the existing UDHS dataset including women with children aged 6-23 months only.

The maps were created through the QGIS program, using the Ugandan subnational administrative boundaries data, and shapefiles for the Lake Victoria (21, 22).

5.3.2 Indicators of complementary feeding

The World Health Organisation has identified indicators to assess complementary feeding, including introduction of solid, semi-solid or soft food at 6-8 months, MMF, MDD, and MAD (23). The description of these indicators can be found in Tab. 5.1 which refers to 2010 WHO guidelines (23) used in the 2016 UDHS report.

Table 5. 1: Description of complementary feeding indicators used in this study according to WHO guidelines (2010). .

Indicators	**Indicator definition**	**6-8 months**	**9-23 months**
Introduction of solid, semi-solid or soft food 6-8 months	Percentage of infants 6–8 months of age who consumed solid, semi-solid or soft foods during the previous day.	Same for all age groups	Same for all age groups
Minimum dietary diversity (MDD)	Percentage of children 6–23 months of age who consumed foods and beverages from at least four out of seven defined food groups during the previous day	Same for all age groups	Same for all age groups
Minimum meal frequency (MMF)	Percentage of children 6–23 months of age who consumed solid, semi-solid or soft foods (also including milk feeds for non-breastfed children) at least the minimum number of times during the previous day.	Breastfed children: Number of solid, semi-solid, or soft foods ≥2 Non-breastfed children: Total of solid, semi-solid, or soft foods AND milk feeds ≥ 4	Number of solid, semi-solid, or soft foods ≥3
Minimum acceptable diet (MAD)	Percentage of children 6–23 months of age who consumed a minimum acceptable diet (see columns to right for definitions according to age group and breastfeeding status) during the previous day.	Breastfed children: Number of food categories ≥ 4 AND Number of solid, semi-solid, or soft foods ≥ 2	Number of food categories ≥ 4 AND Number of solid, semi-solid, or soft foods ≥ 3

		Non-breastfed children: Number of food categories≥ 4, AND Number of milk feeds ≥ 2, AND Total number of solid, semi-solid, or soft foods AND milk feeds ≥ 4	

Minimum number of meals recommended for breastfed children is two, and for non-breastfed is four. The 7 food categories used for the MDD indicators are those identified by WHO (24): 1. grains, roots, tubers and plantains; 2. pulses (beans, peas, lentils), nuts and seeds; 3. dairy products (milk, infant formula, yogurt, cheese); 4. flesh foods (meat, fish, poultry, organ meats); 5. eggs; 6. vitamin-A rich fruits and vegetables; and 7. other fruits and vegetables.

5.3.3 Descriptive analysis of complementary feeding indicators

We used descriptive statistics to characterize the prevalence of complementary feeding practices in children aged 6-23 months, stratifying by age. We also mapped geographic variation at the district level for these indicators in Uganda.

We additionally summarized key characteristics of the child, mother, father, and household which are considered proximal factors determining complementary feeding practices (5, 25). Specifically, for the child we report information on health and vaccination status, breastfeeding patterns, and other socio-demographic data, including perceived birth weight and birth interval/order. Maternal characteristics comprised data related to birth, number of antenatal visits, education and information level, female empowerment, and domestic violence. We created a score for female empowerment (Supplementary material Chapter 5) following previous research criteria (26, 27), and we assigned four different levels based on the resulting distribution (Level 1=very low; Level 2=low; Level 3=medium; Level 4=high). Paternal characteristics included age, education level and type of occupation; household information referred to the sex of the household, water and toilet condition, and the wealth index composed by UDHS researchers using a principal components analysis method (28).

Other data, which can be included in the societal level of factors potentially influencing complementary feeding practices, related to the geographical regions and the type of areas where the participants involved in the survey lived (urban or rural).

5.3.4 Multivariable analysis of the determinants of complementary feeding

We used multivariable logistic regression to assess key theorized predictors of complementary feeding. For multivariable analysis, we focus on two outcome variables: MMF and MDD only. Meal frequency and dietary diversity are two of the four main indicators used to assess complementary feeding (CF) practices. Meal frequency is a proxy of individual food security, and it indicates the number of meals received per day; dietary diversity refers to the number of different food groups consumed daily (23). Evidence suggests that both indicators have an impact on child nutritional and health status (29); indeed, adequate quality and quantity of foods are linked to better health and nutrition outcomes (30, 31). We could not evaluate the MAD indicator through a multivariable logistic regression model as the number of Ugandan children reaching the MAD was low (63% between 6 and 11 months, and 0% from 12 to 23 months).

5.3.5 Selection of predictors

To select specific predictor variables, we were guided by a conceptual framework highlighting multi-level determinants of complementary feeding, adapted for Ugandan communities by Scarpa et al. (30) and informed by previous work (5,10,24). We focused our assessment on three mechanisms theorized as drivers of complementary feeding: child health, household wealth, and female empowerment. Research demonstrates that nutritional status could deteriorate rapidly when a child is sick or unhealthy; in fact, if adequate nutritional intake is not reached, the child’s body is not able to build the immune response, therefore infections and stunting are more likely to occur (31,32). A particular aspect of child health which may affect complementary feeding is vaccination. Previous research conducted in Uganda with 2006 and 2011 UDHS data showed that administration of DPT3 and measles vaccines were associated with better complementary feeding outcomes (14). Family or household wealth is widely associated with complementary feeding practices in many studies (33–35). Additionally, according to the literature, wealthier households are likely to have less undernourished children (36,37). Previous research has demonstrated that female (specifically maternal) empowerment has an effect on complementary feeding practices, but this trend is not seen consistently across research conducted in low-income countries (38). However, women are usually responsible for the preparation of food and preservation of local food culture in many contexts (39,40). For this reason, it is not surprising that a higher level of empowerment is associated with better child nutrition outcomes (41–43).

To select predictor variables for inclusion in the model(s), we identified a list of variables that were relevant to our three predictors/mechanisms of interest (child health, family wealth, female empowerment), and available within the UDHS dataset. To account for substantial collinearity between available variable options, we undertook the following process: (1) we tested the univariate association for each candidate predictor variable with our two outcome variables (MMF and MDD); (2) we assessed collinearity and/or correlations between predictor variables to identify clusters of similar and highly collinear predictors; (3) we assessed variance inflation factors (VIFs). We reduced the list of potential predictor variables, excluding predictors with a VIF greater than 5 or factors which were highly (positively or negatively) correlated to avoid collinearity.

5.3.6 Control variables

We additionally controlled for potential confounding variables. We followed the same procedure for control variables as for predictor variables to select final variables for inclusion, and to avoid collinearity. We controlled for the sex of the child, whether or not the child is currently breastfeeding, number of antenatal visits, maternal education and residential location (urban/rural).

Final variables included in the multivariate logistic regression modes are summarized in Tab. 5.2.

Table 5. 2: Dependent and independent variables, control variables and stratification variables used in this study.

Variable	**Definition**	**Description**
Outcome variables		
Minimum dietary diversity	Did the child consume food and beverages from at least four out of seven defined food groups during the previous day? Binary variable: Yes/No	This variable was also stratified by age groups (6-11 months, 12-17 months, 18-23 months) based on international indicators.
Minimum meal frequency	Did the child eat the minimum number of times which is appropriate for his/her age during the previous day (2, 3 or 4 times depending on breastfeeding status)? Binary variable: Yes/No	This variable was also stratified by age groups (6-11 months, 12-17 months, 18-23 months) based on international indicators.
Predictor variables		
Female empowerment	What is the female empowerment score for the mother? Categorical variable: Very low, low, medium, high	This score (0-13 points) was created and previously used as a discrete variable by Jennings et al. (26); however for this study we grouped the score in 4 categories (very low if the score was lower than 4, low if the score was equal to 5-6, medium if the score was equal to 7-9, high if the score was higher than 10).
Family wealth	What is the wealth percentile of the child's family? Categorical variable: lowest, second, middle, fourth, highest	The family wealth is a composite variable found in the UDHS 2016, which is calculated based on: house`s ownership; materials used to build the house; typology of sanitation facilities and water access. It was generated using principal components analysis. The variable divides household wealth into 5 wealth quintiles.
Child health – vaccination status	Has the child completed vaccinations for his/her age? Categorical variable: fully vaccinated, partially vaccinated, not vaccinated	Fully vaccinated children included those who received all vaccinations according to their age group (6-11 months, 12-17 months & 18-23 months). Partially vaccinated children included those who received at least 1 vaccination, but not all vaccinations according to their age group. Not vaccinated children included those who did not receive any vaccinations.
Child health – sick in the past 2 weeks	Was the child sick with fever, cough or diarrhoea in the past 2 weeks? Binary variable: Yes/No	This variable is composite, and derives from 3 different variables available in the UDHS 2016: Did the child have fever in the past 2 weeks? Did the child have a cough in the past 2 weeks? Did the child have diarrhoea in the past 2 weeks? A child was considered sick when one or more of these three variables was positive.
Control variables		
Sex of child	Which is the sex of the child? Binary variable: Female/Male	Female or male child
Current breastfeeding status	Is the child currently breastfeeding? Binary variable: Yes/No	This variable investigates if the child is still being breastfed and not only if he/she was breastfed.
N. Antenatal visits	How many antenatal visits did the mother attend during pregnancy? Categorical variable: No visits, 1-3 visits, >4 visits	Number of antenatal visits attended during pregnancy by the mother.

Maternal education	What is the mother's education level? Categorical variable: No education, primary education, secondary education or higher	Highest level of education that the mother acquired in her life, divided into 3 categories: no education, primary education and secondary education/higher.
Geographic location	Do the family live in a city or rural area? Binary variable: urban/rural location	Place of residence: urban or rural. The answer is not formulated by the respondent, but it is defined based on the place where the cluster or sample is based.

5.3.7 Multivariable model

We constructed multivariable logistic regression models for the two selected complementary feeding indicators (MMF and MDD) separately as dependent variables, using female empowerment, wealth index, health and vaccination status as independent predictor variables. Previous studies using DHS data and initial scoping of our data confirmed that there was a substantial difference in MMF and MDD results across age groups (6-11 months, 12-17 months and 18-23 months) (14); for this reason, we stratified models by age. We included unadjusted (one predictor variable in the model at a time) and fully adjusted (all predictor and control variables included) models. We reported p-values and 95% confidence intervals (C.I.) for our findings. Our hypotheses are summarised in Tab. 5.3.

Table 5. 3: Hypotheses formulated for this study.

Hypothesis number	Hypothesis for the MDD indicator	Hypothesis for the MMF indicator	Evidence justifying the hypothesis
H1	Children who have reported as being sick in the past 2 weeks are more likely to have met the standard for minimum dietary diversity.	Children who have reported as being sick in the past 2 weeks are more likely to have met the standard for minimum meal frequency.	Children, when sick, are more likely to be fed with more and more nutritious food by their mothers [44,45]
H2	Children who have received complete age-appropriate vaccinations are more likely to have	Children from who have received complete age-appropriate vaccinations are more likely to have	Mothers attending vaccination clinics get more information on child feeding [11]

	met the standard for minimum dietary diversity.	met the standard for minimum meal frequency.	
H3	Children are more likely to have met the standard for minimum dietary diversity at increasing levels of household wealth.	Children are more likely to have met the standard for minimum meal frequency diversity at increasing levels of household wealth.	Children living in wealthier households are more likely to eat a diverse and balanced diet [46]
H4	Children are more likely to have met the standard for minimum dietary diversity with increasing levels of female empowerment.	Children are more likely to have met the standard for minimum meal frequency with increasing levels of female empowerment.	Mothers with higher level of female empowerment are more likely to have children with better nutritional outcomes [43,47]

Lastly, we ran sensitivity analyses, using three different methods to calculate the missing values in the dataset: 1. we considered the missing values as zero; 2. we imputed the missing data using the multiple imputation change equation (MICE); 3. we used the complete case-analysis.

We used Python 3.8 to analyse the data, and Excel to generate graphs.

5.4 Results

5.4.1 Sample characteristics

The sample from the 2016 UDHS dataset included 5485 children aged 6-23 months; demographic and socio-economic factors are described in Tab. 5.4 and Supplementary Material Chapter 5. Seventy-four percent of children were breastfed when the survey was conducted. Fewer than half (45%) were the second to fourth child in the family, with the majority (59%) born two or more years after the previous child. While 60% of the children were reported to have received vitamin A and 40% were fully vaccinated, fewer than 10% of children received iron supplementation. More than half of the children sampled (60%) were reported as having been sick in the previous two weeks.

The majority of mothers delivered at health facilities with skilled health professionals (76%) and attended four or more antenatal visits appointments (63%) during pregnancy. More than 60% of mothers had a primary school level of education, 55% used a radio as source of information, and 74% were employed in manual activities. Most mothers scored low to medium for level of empowerment (42%). The majority of fathers attended primary school only (55%) and worked in an agriculture-related field or did other manual jobs (74%).

In nearly all cases (96%) the water source was not in the same dwelling or yard of the household and was reachable within 1 hour of distance (56%). Two-third of the families did not have an improved toilet facility (67%) and 81% of lived in a rural area.

Table 5. 4: Sample characteristics of children aged 6-23 months (UDHS 2016).

	Sample N	**Count (Percentage)**
Child characteristics		
Child sex	5485	
Female		2711(49%)
Male		2774 (51%)
Breastfeeding status	5485	
Still breastfed		4077 (74%)
Not breastfed		1408 (26%)
Age (in months)	5485	
6-11		1989 (36%)
12-17		1820 (33%)
18-23		1676 (31%)
Completed age-appropriate vaccination	5485	2196 (40%)
Child reported as sick in the past 2 weeks	5148	3112 (61%)
Child health: had the following symptom in the past 2 weeks	5148	
Diarrhoea		1766 (34%)
Fever		2118 (41%)
Cough		2442 (47%)
Maternal characteristics		
Antenatal clinic visits	4800	
None		87 (2%)
1-3		1699 (35%)

>=4		3014 (63%)
Highest educational level	5485	
No education		690 (13%)
Primary		3332 (61%)
Secondary or higher		1463 (27%)
Female empowerment - woman involved in decision making on:	5485	
How woman's income is used		2404 (44%)
How man's income is used		2313 (42%)
Large household purchases		2896 (53%)
Visiting family and friends		3229 (59%)
Regarding own health care		3334 (61%)
Female empowerment - other		
Woman salary similar/higher than man salary		562 (10%)
Woman owns a land		2062 (38%)
Woman owns a house		2619 (48%)
Attitude towards domestic violence - Beating justified if a woman does the following:	5485	
Goes out without telling him [male/husband]		2151 (40%)
Neglects the children		2247 (61%)
Argues with him [male/husband]		1650 (30%)
Refuses to have sex with him [male/husband]		1092 (20%)
Burns the food		827 (15%)
Women's empowerment score	5485	
Very low (score 1-3)		1374 (29%)
Low (score 4-6)		2000 (43%)
Medium (score 7-9)		1115 (24%)
High (score 10-13)		218 (5%)
Household characteristics		
Household wealth	5485	
Poorest		1536 (28%)
Poorer		1102 (20%)
Middle		1027 (19%)
Richer		908 (17%)
Richest		912 (17%)
Geographical region	5485	
Capital		257 (5%)
Central Uganda		942 (17%)
West Uganda		1379 (25%)

East Uganda		1558 (28%)
North Uganda		1349 (25%)
Type of residence	4707	
Rural		3809 (81%)
Urban		898 (19%)

Description of complementary feeding foods and distribution of CF indicators by child age groups and by region

A greater proportion of children between 6 and 11 months were found to reach MMF (76%) compared to older children. Conversely, the MAD indicator was met by the youngest age group only (63%). However, the proportion of children meeting the MDD indicator was low among all age groups, ranging from 26% (children 6-11months) to 34% (18-23months) (Fig. 5.1).

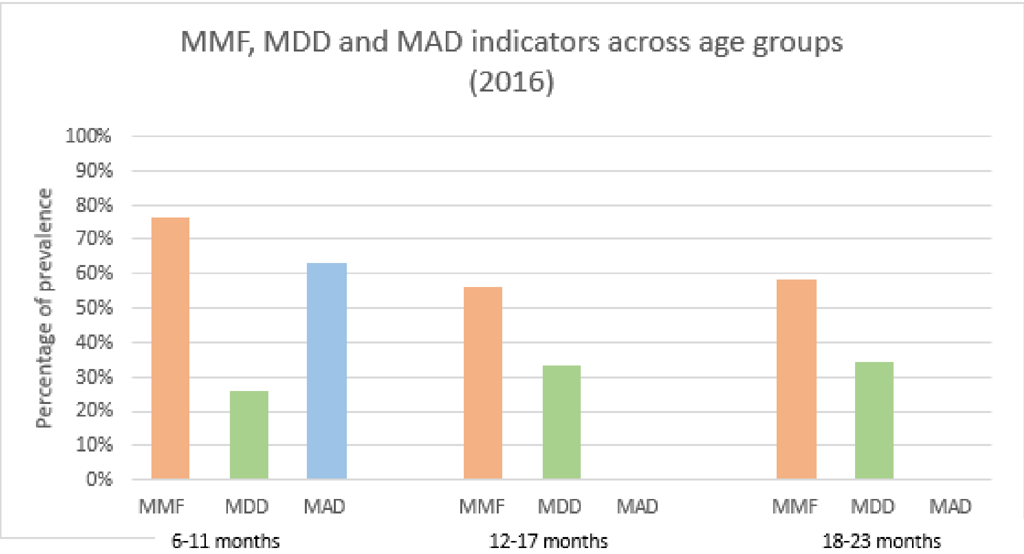
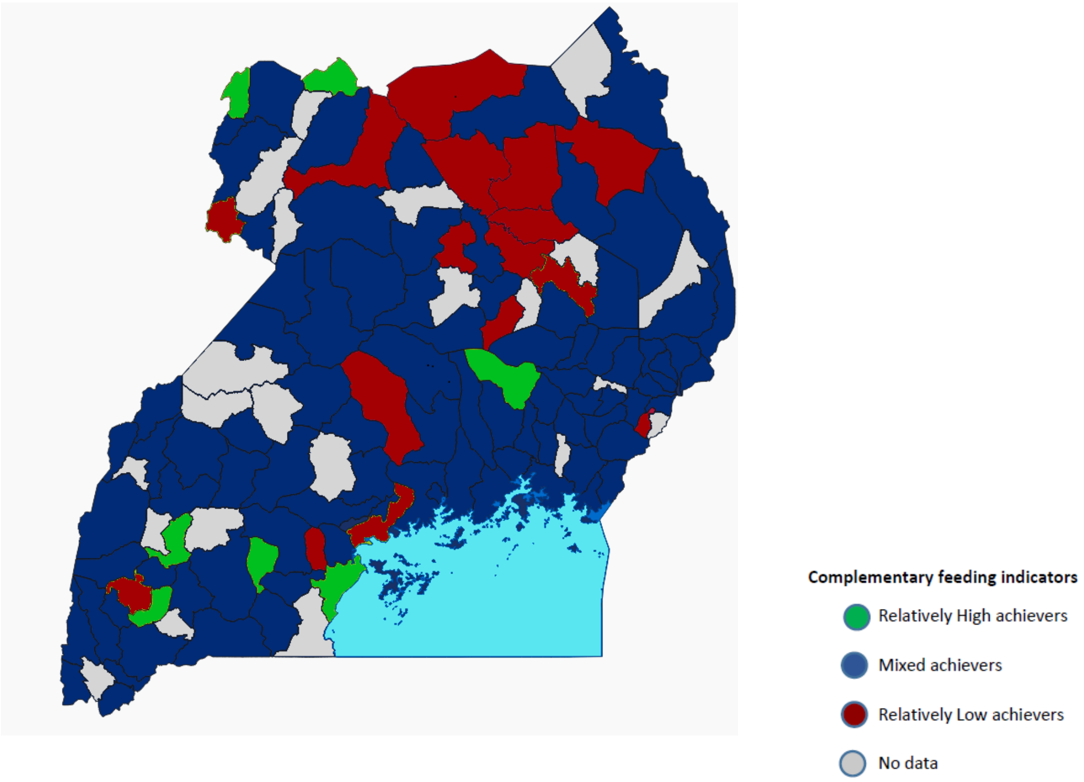


Figure 5. 1: Complementary feeding practices indicators (2016) by child age groups.

Overall, only one-third of children in the sample consumed four or more different food groups (Fig. 5.1). The most consumed food group included cereals and roots, which accounted for 80% of reported foods by the participants. This was followed by fruits and vegetables (55%), and legumes (45%), showing that the diet was largely vegetarian. Although flesh foods, including meat and other animal products, accounted for 30% of eaten foods among the children, meals containing eggs were not frequent (10%). The consumption of sweets was also generally limited (10%), but fats and oil were added to main meals (33%). No substantial differences were found in the consumption of food categories among the three age groups (Supplementary material Chapter 5).

Complementary feeding prevalence varied geographically within Uganda, with areas of high and low prevalence inconsistent across indicators (Fig. 5.2 A & B). A relatively low percentage of children living in the northern districts of Uganda met three or more complementary feeding indicators, although most of them started complementary feeding at 6 months of life. Conversely, in western and central Ugandan districts, we observed the highest percentage of children achieving three or more complementary feeding indicators, but this trend was not found for Kampala district. Sixty to eighty percent of children in many Ugandan districts reached the timely introduction of complementary feeding indicator, while the MDD and MAD indicators were only achieved by 20-40% of children in most of the regions.

A)



B)

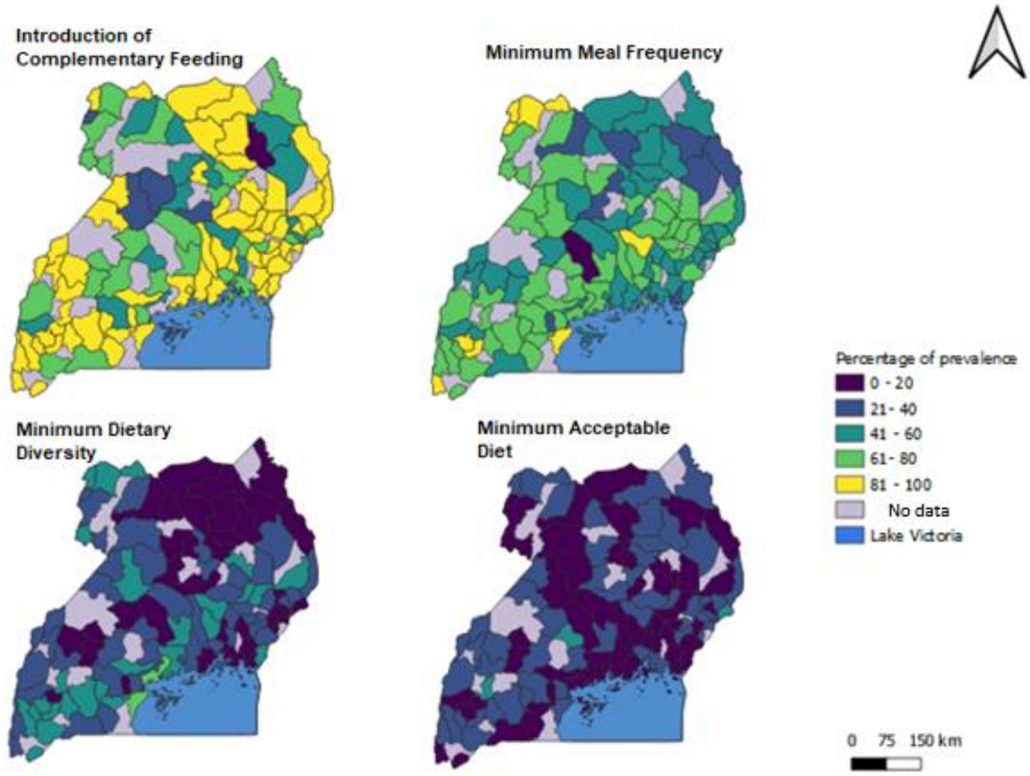


Figure 5.2: A & B: A) Composite map describing the complementary feeding indicators (MMF, MDD & MAD) in Uganda.

A) Group 1, in green, represents those falling into the top quartile of districts (higher %) for 3 or more indicators (relatively high achievers); group 2, in red, represents those falling into the bottom quartile of districts (lowest %) for 3 or more indicators (relatively low achievers); Group 3, in blue, represents all other districts (mixed achievement).

B) Geographical distribution of children meeting each complementary feeding indicator in Uganda indicated with different colours (yellow=81-100%; light green= 61-80%; dark green= 41-60%; blue= 21-40%; purple= 0-20%). Maps created through the QGIS program.

5.4.2 Determinants of MMF and MDD

We assessed evidence of statistically significant association between our 4 hypothesized predictor variables (female empowerment, wealth index, health and vaccination status) and 2 outcome variables (MMF and MDD), testing each of the hypotheses presented in the methods text (Table 5).

Consistent with our hypotheses, a child who was reported as having been sick in the previous 2 weeks was significantly associated (in both unadjusted and fully adjusted models) with a greater odds of meeting the MMF and MMD thresholds except for the youngest age group (6–11 months). At the 95% confidence level in the fully adjusted model, a child reported as sick in the past 2 weeks, in fact, had a 1.46 (CI 1.14–1.90, p =< 0.001) (12–17 months) and 1.28 (CI 1.00–1.61, p = 0.04) (18–23 months) times greater odds of meeting the MDD threshold, and a 1.48 (CI 1.17–1.87, p =< 0.001) (12–17 months) and 1.31 (CI 1.05–1.64, p = 0.02) (18–23 months) greater odds of meeting the MMF threshold than a child who did not report being sick in fully adjusted models.

In line with our hypotheses, the vaccination predictor (being partially and fully vaccinated) was significantly associated with both MMF and MDD indicator across all age groups. However, in the stratified models it was a significant predictor of MMF in the fully adjusted models for the 12–17 months age group, and of MDD only in the 6–11 months age group; vaccination was a significant predictor of MMF in unadjusted models only. At the 95% confidence level in the fully adjusted model, a child who was fully vaccinated had a 1.27 (CI 0.76–2.15, p = 0.36) (6–11 months) and 4.33 (CI 2.42–7.74, p =< 0.001) (12–17 months) times greater odds of meeting the MMF threshold, and a 2.86 (CI 1.43–5.71, p =< 0.001) (6–11 months) and 4.65 (CI 2.15–10.00, p =< 0.001) (12–17 months) greater odds of meeting the MDD threshold than children who were not vaccinated. In the 18–23 months age group, more than three quarter of children were partially or fully vaccinated, and it was not possible to perform multivariable logistic regression.

Despite mixed results, the wealth index was found to be significantly associated across the majority of models and across all age groups for both MMF and MDD; despite reductions in significance between the unadjusted and full adjusted models, significance largely persisted when accounting for other predictors and control variables. Indeed, at the 95% confidence level in the fully adjusted model, household in the highest wealth percentile had a 1.90 (CI 1.23–2.92, *p* =< 0.001) (6–11 months), 2.73 (CI 1.74–4.30, *p* =< 0.001) (12–17 months) and 1.80 (CI 1.20–2.77, *p* = 0.01) (18–23 months) times greater odds of meeting the child MDD threshold than a household in the lowest wealth percentile. This was largely consistent across age groups except for mixed results for households at lower levels of wealth for children 12–17 months. The results also indicate greater confidence in the association of higher levels of wealth with the odds of reaching the MDD threshold, and mixed confidence in the role of moderate increases in wealth. Wealth was significantly associated with MMF in unadjusted models but reached significance for only a third of strata in fully adjusted models. Among children 6–11 months and 12–17 months, only the highest quintile of wealth was significantly associated with greater odds of a child reaching the MMF threshold, though we do observe increasing odds at higher levels of wealth with borderline *p*-values (particularly for 6–11 months). Indeed, at the 95% confidence level in the fully adjusted model, household in the highest wealth percentile had a 1.90 (CI 1.23–2.92, *p* =< 0.001) (6–11 months), 2.73 (CI 1.74–4.30, *p* =< 0.001) (12–17 months) and 1.80 (CI 1.20–2.77, *p* = 0.01) (18–23 months) times greater odds of meeting the child MDD threshold than a household in the lowest wealth percentile

Female empowerment was not statistically associated with either MMF or MDD in the models for all age groups, but it was in some of the models for the 18–23 months children, particularly at lower levels of female empowerment. The association between female empowerment and MDD reached statistical significance for the middle categories only (‘low’ female empowerment and ‘medium’ female empowerment). Indeed, at the 95% confidence level in the fully adjusted model, a mother who had a level of empowerment equal to ‘low’ and ‘medium’ had a 1.48 (CI 1.15–1.92, *p* =< 0.001) and 1.39 (CI 1.04–1.87, *p* = 0.03) times greater odds of meeting the child MMF threshold, and a 1.38 (CI 1.10–1.80, *p* = 0.02) and 1.62 (CI 1.20–2.20, *p* =< 0.001) greater odds of meeting the child MDD threshold than a mother who had a very low level of empowerment. The fact that this predictor is significant only in the adjusted models implies that female empowerment interacted and/or was confounded by other variables which had an effect on MMF and MDD.

The sensitivity analysis showed no significant differences in the results when we considered the missing values as zero, and when we imputed the data. However, when we used the complete case analysis with the sample reduced of over 40% there were differences in the OR of the vaccination predictor, which was lower than in the other models. This was due to a different distribution (number of participants) of the variable (Supplementary material Chapter 5).

Table 5. 5: Unadjusted and fully adjusted models for the MMF and MDD indicators for all age groups and stratified by the three age groups 6-11 months, 12-17 months and 18-23 months (a & b). The results in the table were obtained considering missing values as zero. (a) Unadjusted and fully adjusted models for the MMF indicator for all age groups and stratified by age; (b) Unadjusted and fully models for the MDD indicator for all age groups and stratified by age

A)

	All ages				6-11 months				12-17 months				18-23 months			
MINIMUM MEAL FREQUENCY	**UNADJUSTED**		**ADJUSTED**		**UNADJUSTED**		**ADJUSTED**		**UNADJUSTED**		**ADJUSTED**		**UNADJUSTED**		**ADJUSTED**	
	OR (95% CI)	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**
Vaccination status																
Not vaccinated	1		1		1		1		1		1		1		1	
Partially vaccinated	2.91 (2.30-3.71)	<0.001	2.21 (1.70-2.88)	<0.001	2.20 (1.41-3.42)	<0.001	1.44 (0.84-2.47)	0.18	5.82 (3.36-10.08)	<0.001	3.40 (1.89-6.10)	<0.001	n/a	n/a	3.39 (2.10-5.59)	n/a
Fully vaccinated	4.04 (3.15-5.19)	<0.001	2.70 (2.04-3.57)	<0.001	2.00 (1.33-3.01)	<0.001	1.27 (0.76-2.15)	0.36	7.51 (4.37-12.90)	<0.001	4.33 (2.42-7.74)	<0.001	n/a	n/a	n/a	n/a
Female empowerment																
Very low female empowerment	1		1		1		1		1		1		1		1	
Low female empowerment	1.08 (0.94-1.25)	0.13	1.11 (0.96-1.29)	0.16	0.85 (0.64-1.12)	0.24	0.86 (0.65-1.13)	0.28	1.05 (0.82-1.34)	0.69	1.02 (0.79-1.31)	0.91	1.33 (1.05-1.70)	0.02	1.48 (1.15-1.92)	<0.001
Medium female empowerment	1.03 (0.87-1.21)	0.75	1.08 (0.91-1.29)	0.36	0.87 (0.63-1.20)	0.41	0.91 (0.66-1.27)	0.59	1.02 (0.77-1.34)	0.92	1.01 (0.75-1.36)	0.96	1.20 (0.91-1.58)	0.19	1.39 (1.04-1.87)	0.03
High female empowerment	0.84 (0.63-1.13)	0.25	0.90 (0.66-1.21)	0.48	1.05 (0.58-1.89)	0.88	1.12 (0.61-2.06)	0.71	0.88 (0.54-1.43)	0.59	1.02 (0.60-1.72)	0.95	0.65 (0.39-1.09)	0.10	0.64 (0.37-1.10)	0.10
Wealth index																
First wealth percentile	1		1		1		1		1		1		1		1	
Second wealth percentile	1.34 (1.13-1.59)	<0.001	1.28 (1.07-1.53)	<0.001	1.40 (1.01-1.94)	0.04	1.39 (1.00-1.95)	0.05	1.32 (0.98-1.76)	0.06	1.25 (0.92-1.70)	0.15	1.43 (1.07-1.92)	0.02	1.22 (0.89-1.67)	0.21
Middle wealth percentile	1.30 (1.08-1.55)	0.04	1.24 (1.03-1.50)	0.03	1.49 (1.07-2.08)	0.02	1.44 (1.02-2.03)	0.04	1.10 (0.81-1.49)	0.53	1.06 (0.76-1.46)	0.74	1.38 (1.01-1.89)	0.04	1.20 (0.85-1.67)	0.30
Fourth wealth percentile	1.45 (1.20-1.75)	<0.001	1.43 (1.17-1.76)	<0.001	1.53 (1.07-2.20)	0.02	1.44 (0.98-2.13)	0.06	1.38 (1.00-1.89)	0.05	1.40 (0.99-1.99)	0.06	1.61 (1.16-2.22)	<0.001	1.43 (1.00-2.05)	0.05
Highest wealth percentile	1.43 (1.19-1.72)	<0.001	1.52 (1.18-1.94)	<0.001	1.63 (1.14-2.34)	0.01	1.74 (1.10-2.75)	0.02	1.60 (1.15-2.22)	<0.001	1.88 (1.20-2.93)	0.01	1.27 (0.93-1.73)	0.13	1.07 (0.70-1.63)	0.74
Health status																
Not sick	1		1		1		1		1		1		1		1	
Sick	1.47 (1.30-1.66)	<0.001	1.21 (1.06-1.38)	<0.001	1.09 (0.86-1.39)	0.48	0.95 (0.73-1.24)	0.71	1.85 (1.49-2.30)	<0.001	1.48 (1.17-1.87)	<0.001	1.47 (1.19-1.81)	<0.001	1.31 (1.05-1.64)	0.02

B)

	All ages				6-11 months				12-17 months				18-23 months			
MINIMUM DIETARY DIVERSITY	**UNADJUSTED**		**ADJUSTED**		**UNADJUSTED**		**ADJUSTED**		**UNADJUSTED**		**ADJUSTED**		**UNADJUSTED**		**ADJUSTED**	
	OR (95% CI)	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**
Vaccination status																
Not vaccinated	1		1		1		1		1		1		1		1	
Partially vaccinated	4.28 (2.95-6.19)	<0.001	3.95 (2.69-5.80)	<0.001	2.86 (1.52-5.39)	<0.001	2.72 (1.34-5.49)	0.01	5.67 (2.69-11.93)	<0.001	4.14 (1.90-9.00)	<0.001	n/a	n/a	n/a	n/a
Fully vaccinated	3.82 (2.63-5.56)	<0.001	3.63 (2.45-5.41)	<0.001	3.13 (1.69-5.78)	<0.001	2.86 (1.43-5.71)	<0.001	6.15 (2.94-12.85)	<0.001	4.65 (2.15-10.00)	<0.001	n/a	n/a	n/a	n/a
Female empowerment																
Very low female empowerment	1		1		1		1		1		1		1		1	
Low female empowerment	1.02 (0.87-1.18)	0.83	0.98 (0.84-1.14)	0.80	0.79 (0.61-1.03)	0.08	0.80 (0.61-1.05)	0.10	0.96 (0.75-1.24)	0.75	0.94 (0.73-1.20)	0.69	1.24 (0.96-1.59)	0.11	1.38 (1.10-1.80)	0.02
Medium female empowerment	1.12 (0.94-1.34)	0.21	0.97 (0.82-1.15)	0.76	0.95 (0.70-1.28)	0.73	1.03 (0.75-1.41)	0.85	0.71 (0.52-0.96)	0.02	0.80 (0.58-1.10)	0.18	1.33 (0.99-1.77)	0.05	1.62 (1.20-2.20)	<0.001
High female empowerment	0.92 (0.66-1.29)	0.62	0.73 (0.53-1.02)	0.06	1.21 (0.71-2.04)	0.48	1.50 (0.87-2.58)	0.14	0.64 (0.37-1.11)	0.11	0.85 (0.48-1.50)	0.59	0.44 (0.22-0.86)	0.02	0.52 (0.30-1.04)	0.06
Wealth index																
First wealth percentile	1		1		1		1		1		1		1		1	
Second wealth percentile	1.43 (1.18-1.73)	<0.001	1.34 (1.18-1.53)	<0.001	1.17 (0.83-1.66)	0.36	1.16 (0.81-1.65)	0.42	1.84 (1.33-2.54)	<0.001	1.67 (1.20-2.30)	<0.001	1.29 (0.94-1.78)	0.12	1.21 (0.90-1.69)	0.27
Middle wealth percentile	1.54 (1.27-1.87)	<0.001	1.43 (1.17-1.75)	<0.001	1.41 (1.00-1.98)	0.05	1.34 (0.94-1.91)	0.10	1.47 (1.04-2.08)	0.03	1.32 (0.92-1.90)	0.14	1.77 (1.27-2.47)	<0.001	1.69 (1.20-2.39)	<0.001
Fourth wealth percentile	2.03 (1.66-2.47)	<0.001	1.80 (1.45-2.22)	<0.001	2.04 (1.44-2.89)	<0.001	1.86 (1.28-2.71)	<0.001	2.27 (1.61-3.19)	<0.001	1.93 (1.34-2.80)	<0.001	1.78 (1.27-2.50)	<0.001	1.66 (1.10-2.41)	0.01
Highest wealth percentile	2.51 (2.06-3.04)	<0.001	2.03 (1.58-2.60)	<0.001	2.17 (1.54-3.06)	<0.001	1.90 (1.23-2.92)	<0.001	3.34 (2.36-4.71)	<0.001	2.73 (1.74-4.30)	<0.001	2.20 (1.59-3.05)	<0.001	1.80 (1.20-2.77)	0.01
Health status																
Not sick	1		1		1		1		1		1		1		1	
Sick	1.34 (1.18-1.53)	<0.001	1.22 (1.06-1.41)	0.01	1.13 (0.89-1.44)	0.32	1.06 (0.82-1.37)	0.64	1.62 (1.28-2.06)	<0.001	1.46 (1.14-1.90)	<0.001	1.36 (1.09-1.69)	0.01	1.28 (1.00-1.61)	0.04

5.5 Discussion

Our study investigated the complementary feeding practices among children aged 6-23 months in Uganda using 2016 UDHS data. Specifically, we assessed the main complementary feeding indicators— including MMF, MDD, MAD — and the introduction of complementary feeding together with the food groups consumed by the participants. Also, we analysed the variation in complementary feeding practices across geographical areas, and we tested four predictors (wealth, vaccination, sickness and female empowerment) of complementary feeding to evaluate any association with MMF and MDD indicators.

In general, children who are reported as having been sick in the past 2 weeks, who have received complete age-appropriate vaccinations and who lived in households with higher wealth indices were more likely to have met the standard for MMF and MDD. Female empowerment was not a significant predictor for the selected complementary feeding indicators.

The proportion of children meeting complementary feeding indicators improved compared to the previous UDHS in 2011 (4), especially for the MMF and MDD indicators, but still remained low. A greater proportion of children also started complementary feeding at 6 months of age. Yet infant and young child feeding practices remain suboptimal across Uganda. This implies that many children are still vulnerable to stunting and micronutrient deficiencies, with a risk of increased morbidity and mortality (1, 47). In fact, stunting prevalence remains high, up to 40% (6) in the northern areas of the country. According to our findings, in these same districts the percentage of children meeting the MDD, MMF and MAD was low, although complementary foods were mostly introduced at the advised age of 6 months (Supplementary material Chapter 5).

We also explored the most consumed foods during the complementary feeding period, finding similarities with results from elsewhere in Sub-Saharan Africa and Southern Asia (19,49). The most frequently eaten food groups were cereals and roots, while proteins and foods rich in iron were less frequently consumed. This pattern of consumption was found to be common in many low income settings, and likely to be the cause of protein and iron deficiency in disadvantaged communities (50). In fact, the quality of the proteins consumed is often low, limiting the availability of the protein for use in the body (50). More investment in the development of local agriculture interventions is needed to guarantee nutritional well-being (51). Eggs were rarely eaten by children in the 24 h prior to the survey. Previous studies demonstrated that egg consumption can bolster growth in highly vulnerable periods, and in a 2015 randomized controlled trial consuming eggs reduced stunting by 47% in Ecuador (52–54). Therefore, increasing the consumption of eggs among Ugandan children may be beneficial for their nutritional status. Additionally, eggs and animal protein-based foods may reduce the prevalence of anaemia in Uganda, which is especially high among children 6–23 months old (6).

We found wealth to be a statistically significant predictor of MMF and MDD indicators across all age groups. This may evidence the need of reducing household poverty to address complementary feeding practices as demonstrated by other studies (55,56). Research has shown that children living in deprived households were associated with an increased risk of inadequate dietary diversity (57). An unsuitable diet can lead to a greater risk of undernutrition; household wealth inequality has been found to be strongly associated with childhood stunting in other studies (58,59).

Children's health status was found to be significant for both MMF and MDD indicators in our models. Being sick was associated with the two complementary feeding indicators in the older age groups, but not among the 6–11 months old group in which the prevalence of breastfeeding was higher. This may be due, in the first instance, to the cross-sectional nature of the UDHS dataset. Additionally, parents are more likely to feed a sick child better as reported in other studies conducted in Ethiopia and India (60,61). In fact, findings showed that mothers increased the frequency and quality of foods when the child was ill (44,45). Although appetite may be reduced, diverse food is required for a sick child to recover quicker and maintain an adequate nutrient intake (62).

Having completed the relevant course of vaccinations for each age group was also positively associated with the complementary feeding predictors. Mothers who bring children for vaccinations may access information on various health and nutrition subjects, including complementary foods (11,63). Researchers elsewhere have reported success in integrating nutritional education into vaccinations campaigns (64); however, literature on this remains limited, and feasibility is context dependent.

Female empowerment variables were not statistically significant predictors of our outcome indicators, apart from the adjusted model for the age group 18–23 months. This is consistent with the results of other studies using DHS data (11,13), and may be due to heterogeneity in describing and defining women's empowerment (65,66). In this study, we used a female empowerment score, which has been previously applied in other research studies (25,67). However, female empowerment is a context-specific process (68); although there is evidence that it is associated with child nutritional status (69), ways to measure it and associated findings may not be generalizable (38). In our data, for example, wealthier and urban households reported lower levels of female empowerment than poorer and rural households, suggesting potential interaction and confounding of female empowerment with wealth and geography, and reflecting complex mechanisms and measurement of female empowerment more generally. Empowered mothers are, in fact, more likely to be economically independent, and to invest in foods of higher quality for their children (11,13). However, findings are different in the youngest cohort of children (aged 6-11 months), likely due to the high rate of breastfeeding and lower consumption of solid food, which may limit assessment of the impact of female empowerment on child diet quality.

5.5.1 Study limitations

Some limitations are present in our study. First, we recognize the cross-sectional nature of DHS data, which limited our ability to assess variation over time. Second, there are missing data in some Ugandan districts, and for some ethnicities such as the Batwa Indigenous population, despite well-recognized differences in food systems and food culture by ethnicity (70,71). More research targeting vulnerable groups is needed to tailor future nutrition interventions to the different Ugandan areas. Third, mothers were interviewed only once about foods and liquids consumed by the children the previous day, so that variation by day of week was not available. Fourth, standardised questions are used in the UDHS without additional consideration or validation within diverse socio-cultural contexts, and not directly observing the feeding practices with the possibility for the participants of over or under-reporting. Fifth, we could not validate the empowerment score on the field due to budget restrictions.

5.6 Conclusions

Our work highlights that a Ugandan child’s health, either being sick, or partially/fully vaccinated and living in households with higher wealth index had higher odds of meeting MMF and MDD indicators compared to children who were well; not vaccinated or living in poorer households. This study calls for urgent nutritional policies on child nutrition, and complementary feeding practices targeting disadvantaged children. Integration of poverty eradication interventions along with health and nutrition education is required to make the nutritional programmes successful. These joint strategies, in fact, would support provision of nutritious and age-appropriate complementary foods to each Ugandan child in the first 1000 days of life, and improve child health and nutrition outcomes in the longer term.

List of abbreviations

1. WHO: World Health Organization
2. (U)DHS: (Ugandan) Demographic and Health Surveillance
3. MMF: Minimum meal frequency
4. MDD: Minimum dietary diversity
5. MAD: Minimum acceptable diet
6. DPT: Diphtheria, pertussis and tetanus vaccine
7. CF: Complementary feeding
8. CI: Confidence interval

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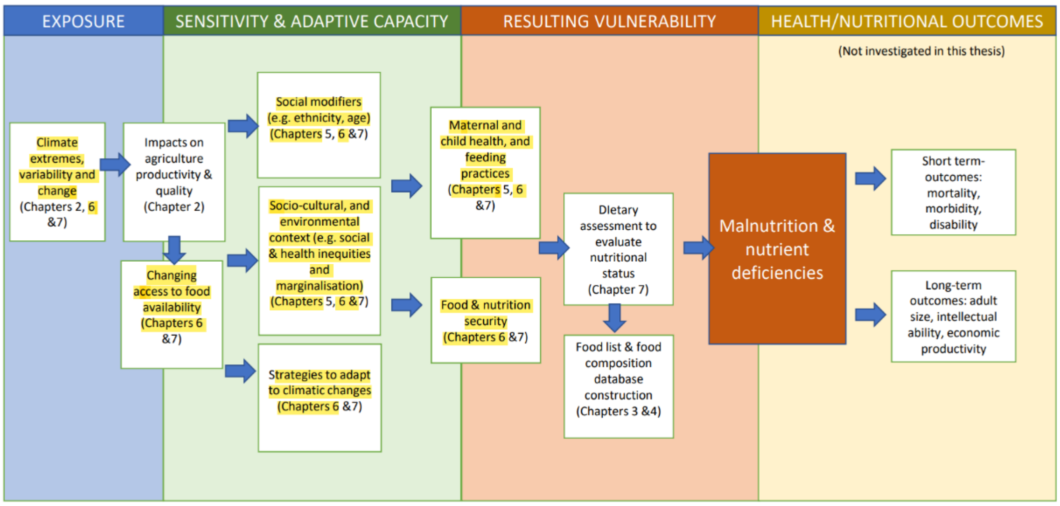
Chapter 6 - Socio-economic and environmental factors affecting breastfeeding and complementary feeding practices among Batwa and Bakiga communities in south-western Uganda.

Chapter 6 provides information on breastfeeding and complementary feeding practices among the Batwa and Bakiga communities, by using mixed-methods and participatory community-based approaches. It explores populations' *sensitivity* and *adaptive capacity* to climate change, which are key elements of the vulnerability framework. Inadequate child feeding practices, and infectious diseases are known to be the main causes of stunting, the commonest form of malnutrition among Indigenous Peoples (1). These findings contribute to understand the factors that mostly affect child food consumption in south-western Uganda. Those include climatic and non-climatic factors, such as poverty and marginalization, lack of support, lack of information on child nutrition, and extreme climatic events.



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Socio-economic and environmental factors affecting breastfeeding and complementary feeding practices among Batwa and Bakiga communities in south-western Uganda.

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6.1 Abstract

Improving breastfeeding and complementary feeding practices is needed to support good health, enhance child growth, and reduce child mortality. Limited evidence is available on child feeding among Indigenous communities and in the context of environmental changes. We investigate past and present breastfeeding and complementary feeding practices within Indigenous Batwa and neighbouring Bakiga populations in south-western Uganda. Specifically, we describe the demographic and socio-economic characteristics of breastfeeding mothers and their children, and individual experiences of breastfeeding and complementary feeding practices. We investigate the factors that have an impact on breastfeeding and complementary feeding at community and societal levels, and we analysed how environments, including weather variability, affect breastfeeding and complementary feeding practices.

We applied a mixed-method design to the study, and we used a community-based research approach. We conducted 94 individual interviews (n=47 Batwa mothers/caregivers & n=47 Bakiga mothers/caregivers) and 12 focus group discussions (n=6 among Batwa & n=6 among Bakiga communities) from July to October 2019. Ninety-nine per cent of mothers reported that their youngest child was

currently breastfed. All mothers noted that the child experienced at least one episode of illness that had an impact on breastfeeding. From the focus groups, we identified four key factors affecting breastfeeding and nutrition practices: marginalisation and poverty; environmental change; lack of information; and poor support.

Our findings contribute to the field of global public health and nutrition among Indigenous communities, with a focus on women and children. We present recommendations to improve child feeding practices among the Batwa and Bakiga in south-western Uganda. Specifically, we highlight the need to engage with local and national authorities to improve breastfeeding and complementary feeding practices, and work on food security, distribution of lands, and the food environment. Also, we recommend addressing the drivers and consequences of alcoholism, and strengthening family planning programs.

6.2 Introduction

In 2019, 21% of children under 5 years globally were stunted and 2% wasted (1). Undernutrition in infants exacerbates the risk of mortality, morbidity, and chronic diseases, and causes delays in neuro-psychomotor development (2, 3). Poor children living in vulnerable settings are 20 times more at risk of undernutrition than others (1), and especially among Indigenous communities (2, 4). This is caused by economic disparities, socio-cultural discrimination, and colonial legacies that translate into health inequalities (5) .

Research demonstrates that improvements in infant and young child feeding (IYCF), and traditional feeding practices are critical to supporting good health, enhancing child growth, and reducing child mortality (6). Breastmilk is the only nutritional source recommended by the WHO for newborns and infants up to 6 months (7). According to WHO statistics, however, only 1 out of every 3 children worldwide is exclusively breastfeed for their first six months of life, and only 2 of 5 are immediately breastfed in the first hour after birth (8). In addition, the WHO and UNICEF recommend starting complementary feeding along with breastfeeding after the first 6 months of life to avoid stunting in childhood (9, 10). Breastmilk alone is insufficient to ensure adequate child growth after 6 months of age (2). Low quality and quantity of foods, and late introduction of solid foods are found to be causes of undernutrition (11).

Maternal diets influence infant diets. Tiedje et al. (12) proposed an ecological approach to understand the influences of maternal nutrition on breastfeeding and infant feeding practices by analysing contextual factors such as family, community and healthcare system. Later, others extended the focus of this model to also include societal contexts and changing environments (13). Indeed, child feeding has been observed in Indigenous populations (14) to be driven by social and environmental contexts, which were identified as critical in understanding breastfeeding and infant feeding practices. For example, Sellen documented changes in individual choices and food behaviour among Indigenous families due to changes in socio-environmental conditions, such as culture, work activities, natural environment, and traditional food supplies (15). In some cases, mothers substituted traditional infant foods with packaged food during the complementary feeding period (16).

While there are well-established indicators to measure changes in child nutrition linked to health (breastfeeding duration, starting age of complementary feeding, minimal dietary diversity, minimum meal frequency, minimum acceptable diet), few studies have assessed IYCF among Indigenous groups or in the context of environmental change (14, 17). The aim of this study was to investigate past and present breastfeeding and complementary feeding practices within the Indigenous Batwa and Bakiga populations. The main objectives were: 1. To describe the demographic and socio-economic attributes of breastfeeding mothers and their children, and individual experiences of breastfeeding and complementary feeding practices at the individual level; 2. To investigate the factors that have an impact on breastfeeding and complementary feeding at community and societal level; 3. To analyse if and how environments, including weather variability, affect breastfeeding and complementary feeding practices.

6.3 Material and Methods

6.3.1 Study population

The Batwa and Bakiga communities live in the District of Kanungu in south-western Uganda, located on the border with the Democratic Republic of Congo. The Bakiga are historically an agrarian society, who depend on agriculture and livestock, and represent the majority of the population (18). Both populations suffer from high burden of illness, and especially the Batwa have high incidence of malaria, malnutrition and gastrointestinal diseases (19-21), while the Bakiga have higher levels of HIV (22). From previous studies, there is evidence that malnutrition is very high among Batwa communities, especially among children under five: 8% of male children classified as wasted (18), for example, compared to 4% nationally (23). The proportion of male undernourished cases among Batwa is higher than among females, with boys at greater odds of being severely malnourished. In every Batwa age-sex grouping, 15% or more individuals are malnourished (20). Also, according to *Patterson et al.* (24), more than 90% of Batwa households are rated as "very highly food insecure". In 2017, Batwa mothers reported being malnourished and having malnourished children due to a scarcity of food (25).

6.3.2 Conceptual framework

We adapted the conceptual framework of Hector et al. (13) (Figure 6.1). Our framework is composed of four levels: individual, group, societal and environmental. The individual level analyses the characteristics of the mother, the child, and the dyad (mother-child pairing), including knowledge on breastfeeding, mother-child interactions, and health status. The group level describes factors that influence breastfeeding practices in their proximal social setting, for example accessibility to health facilities, and mothers' work and community environments. The societal level considers contextual elements that have an impact on breastfeeding choices such as the role of women and men in society, and cultural norms (13). Finally, we included an environmental level to the framework to further analyse the impact of environmental contexts and events (weather, land suitability for food production, and extreme events such as flooding or drought) on breastfeeding and complementary feeding practices.

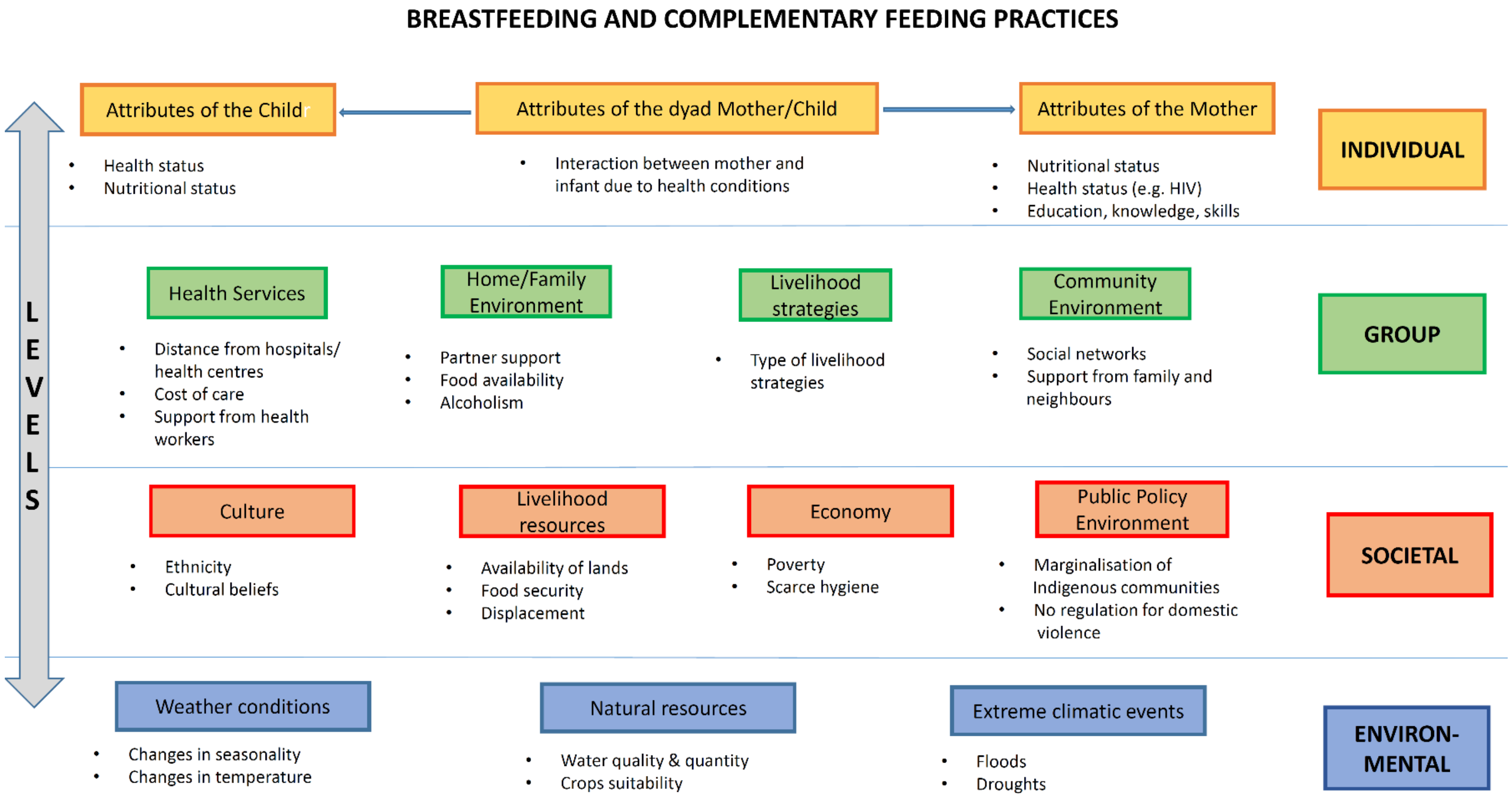

Figure 6. 1: Conceptual framework used to analyse breastfeeding and complementary feeding among the Batwa and Bakiga communities.

The group level refers to the level of household and community; the societal level refers to the level of region, ethnicities and country. There is interaction across all levels; for example, the environmental level interacts with the societal and group levels.

Marginalisation of Indigenous Batwa communities is present at all levels of society. The Batwa represent 1% of the Ugandan population, and were displaced in 1991 by the Ugandan Government from their ancestral forest lands to create the Bwindi Impenetrable National Park (26). Traditionally hunters-gathers, since 1991 the Batwa have begun transitioning to cultivating crops (24). They work mostly as farmers, hired by the Bakiga; some are craft makers or brick makers or work in tourism (18). However, the absence of a traditional culture of farming and low socio-economic status exacerbate food insecurity (27) which have an impact on individual nutrition, and can affect negatively child health (28). Although many Batwa and Bakiga families are poor, Batwa per capita income is substantially lower than the national average (0.36 US dollars/day compared to 0.99 US dollars/day) (24). Inequities are also found in education. Less than 12% of Batwa living in Kanungu District are able to write and read, and to access education (24); the school drop-out rate is especially high following marriage at a young age (29).

Persistent poverty underpins poorer access to healthcare services among Batwa, despite similar health facilities for both populations (20). For example, compared to the rest of Uganda where 57% of mothers gave birth with health professionals, only 40% of Batwa births occurred in health facilities in 2017 (22). . Also, in cases of child malnutrition, Batwa mothers tend to stay at home rather than go to the hospital for treatment (20). One of the main reasons for scarce hospital attendance is the cost of health insurance premiums (30), which are not affordable for many Batwa families, as well as persistent social and ethnic discrimination (18). Also, Batwa more frequently report not having soap or access to health facilities compared to non-Indigenous neighbours, with negative consequences on maternal and child health (31). Poverty and discrimination are linked to poor mental health, alcoholism and domestic violence. This link is documented in previous studies, although the research on mental health among the Batwa and Bakiga communities remains limited (24). Previous research indicates that internal displacement, as occurred among the Batwa population, can have a negative effect on health, wellbeing and socioeconomic status (32). Batwa and Bakiga report high levels of alcoholism, particularly among men and during periods of food insecurity. High consumption of alcohol is an emerging problem among these communities, and the local hospital has addressed this by offering alcohol rehabilitation services (33). Alcoholism has been linked to domestic violence (24, 34). Reported implications of alcoholism among Batwa include compromised food security for adults and children, mental health concerns, and poorer health outcomes (24).

Poverty and marginalisation are projected to be exacerbated by the impacts of climate change with consequences on nutrition and health, especially for young children (35, 36). The District of Kanungu is affected by extreme climatic events, such as the floods that occurred in 2019. Climate change projections anticipate an increase in annual mean temperature and change in seasonal variation (37, 38). The dry season is usually between December and February, and between June and August, however rainfalls are now longer (from September to December, and then from March to June) and less predictable, with fewer sunny days (39). These changes are impacting key local crops (groundnuts, beans and cassava) that are an important nutritional source for the Batwa and Bakiga communities (39).

6.3.3 Study design

We undertook a mixed-method study to explore breastfeeding and complementary feeding practices among mothers with children under two years in Kanungu district.

The research was guided by a community-based participatory research approach which engage researchers and community participants as equal partners during the research process; the objective is to educate or promote social change (40, 41). This approach has been used among marginalised groups, especially Indigenous communities, as it helps to reinforce the respect and collaboration between stakeholders and researchers (42).

Batwa and non-Batwa participants assessed the barriers to breastfeeding and complementary feeding practices, evaluated and shared their level of knowledge on maternal and infant nutrition, and critically explored solutions to improve mother and child health.

6.3.4 Settlement and Individual Sampling

Twelve communities, six Batwa and six geographically matched adjacent Bakiga settlements, were included in the study (Figure 6.2).

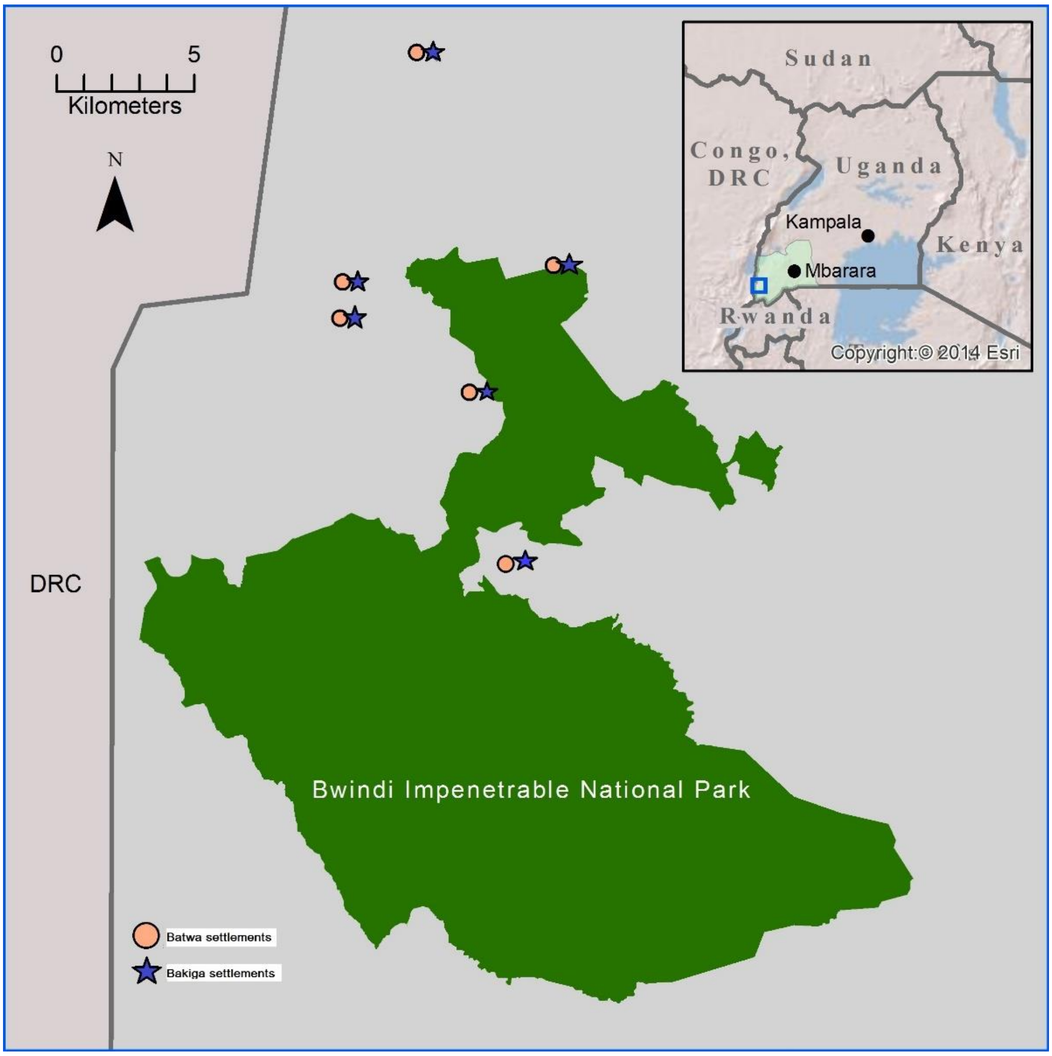

Figure 6. 2: In the map we represented the ten Batwa settlements that participated in the research; there is a correspondent Bakiga settlement for each Batwa settlement.

In our study, we involved 6 Batwa and 6 Bakiga settlements: Bikuuto (Batwa) & Bikuuto cell (Bakiga), Kihembe (Batwa) & Kengoma cell (Bakiga), Kitariro (Batwa) & Kitariro cell (Bakiga), Mpungu (Batwa) & Kikome cell (Bakiga), Kebiremu (Batwa) &Kebiremu cell (Bakiga) and Byumba (Batwa) & Byumba cell (Bakiga). Map adapted from Patterson, 2017 (24). Coordinates of settlements described in Supplementary material Chapter 6.

The selection of communities sought a sample representing variation in terms of geographic location and market access. Mothers with children aged under two years were sampled from 12 settlements (6 Batwa and 6 Bakiga): 1) two settlements located very close to the market and shops (Bikuuto/Bikuto cell and Kihembe/Kengoma cell),

2) two settlements close to the forest and located very far from the market and shops (Kitariro/Kitariro cell and Mpungu/Kikome cell area), and two settlements situated mid-way (Kebiremu/Kebiremu cell and Byumba/Byumba cell). The selection of samples in the different areas allowed for exploration of geographically linked variation in practices and availability of food for infants' complementary feeding between Batwa and Bakiga communities and between settlements with different proximity to market centres.

Twelve focus groups were conducted, one in each of the communities (n=6 Batwa and n=6 Bakiga), with 7-11 mothers per group. First, the research assistant met the local leader of each community, sought the permission to conduct the study and asked for a list with the names of mothers with children under 2 years living in Kanungu District. We invited all eligible Batwa mothers to participate, as the number of mothers was limited (47 individuals). In the case of the Bakiga, we conducted a random sample of eligible mothers, as the number of women with children under 2 years was greater. A number was consecutively assigned to each eligible individual starting at one. A table of random numbers was used to sample the 47 individuals who were invited to participate (43).

6.3.5 Data collection

Three Ugandan researchers collected the data from July to October 2019. The research team was composed of a Ugandan male researcher living in Kanungu district, and a Mutwa (Batwa singular) and a Mukiga (Bakiga singular) female researcher. Focus group discussions (FGDs) and the individual interviews were conducted and audio-recorded in the local language, Rukiga, transcribed and then the information was translated into English by the local researcher (ST). Before sampling individuals, the research team contacted the chairperson of each community to introduce the study and seek his/her approval. Written consent was obtained before all interviews.

We created an interview guide with open questions for the FGD (Supplementary material Chapter 6). The questions followed the themes from the Optimal IYCF guidelines, specifically the complementary feeding section (9, 10); IYCF programmes aim to prioritize and improve breastfeeding and complementary feeding practices to reduce malnutrition worldwide (9). FGDs helped to explore the complexity of lived experiences that were not capturable with standard questionnaires, and encouraged women to share knowledge and perceptions on IYCF. Each group discussion lasted on average 62 minutes.

The individual interview questionnaire included primarily closed questions, with some requiring brief explanation (Supplementary material Chapter 6). Some were adapted from the Standardized Monitoring and Assessment of Relief and Transition Methodology (44) to evaluate some factors linked to the nutritional status such as hygiene, food and water accessibility level. Interviews lasted on average 12 minutes.

6.3.6 Data analysis

To respect the multi-perspectivity and the multivocality of the data (45-47), we coded, analysed and organised the qualitative data using NVivo 12® software. Contextualized thematic analysis (latent and manifest) was used to analyse the data (48). The analysis process involved data familiarization, generating initial codes, defining, reviewing, and naming themes. In this manuscript, we reported the findings of the themes that were discussed by the participants during the FGDs as key factors of successful or unsuccessful breastfeeding and complementary feeding practices. Additionally, we descriptively analysed demographic data on Batwa and Bakiga women and children using Stata® version 15.

6.3.7 Ethical considerations

Ethics approvals were obtained from the University of Leeds Research Ethics Board (AREA 18-156), the Ugandan National Council for Science and Technology (SS5164), and the Makerere University Research Ethics Committee (MAKS REC 07.19.313/PR1). For the minors included in the study, we obtained consent from their parents or guardians, and minors signed the assent form.

6.4 Results

6.4.1 Characteristics of mothers/child caregivers and children

Ninety-four women (47 Batwa and 47 Bakiga) took part in the individual interviews and focus group discussions (FGDs). A description of the 94 mothers/child caregivers and 95 child participating in the individual interviews included data on attributes and interaction between mothers and children and can be found in Table 6.1. The response rate in both FGDs and individual interviews was 100%. In the case of four Batwa children, the participating primary carer was a grandmother rather than mother (e.g. the mother had died or left the settlement). The number of Bakiga children included in the study was 48 as there was one set of twins.

From the data collected through the individual interviews, there were some differences in demographic and health characteristics between Batwa and Bakiga, primarily related to wealth/assets, sanitation/hygiene, and place of birth. The majority of Batwa did not have regular access to soap (32 of 47 participants, 68%); although most of the participants reported washing their hands with water only before and after breastfeeding, after visiting the toilet and eating, none reported hand washing before cooking or preparing food for the children and family. Eighty-three percent (n=39) of Bakiga mothers reported owning at least one animal compared to 40% (n=19) of Batwa mothers. During the interviews, most Batwa mothers (91%, n=43) reported receiving food aid from NGOs or government, while only a few Bakiga mothers (11%, n=5) living close to the forest reported receiving compensation in the form of food (when elephants destroyed their gardens).

Children of Batwa mothers in this study were generally younger (n=20 or 43% of children aged 0-6 months) compared to children of Bakiga mothers (n=18 or 38%). Births among Batwa mothers occurred more frequently at home (40%, n=19) compared to Bakiga mothers (15%, n=7). Reporting of child loss during pregnancy and after birth was higher among Batwa (43%, n=20) compared to Bakiga (17%, n=8) mothers.

Mothers reported that nearly 99% of children were currently breastfed, and were able to breastfeed at their place of work or livelihood activity, typically their family farm. Mothers of all children older than 7 days reported that their child had experienced one or more episodes of illness in the first 6 months of life that had had a negative impact on breastfeeding.

Table 6. 1: Description of the women and children participating in the study.

Sample: **94 women with 95 infants**	**Batwa women (N=47)**	**Bakiga women (N=47)**
	Counts (percentage)[1]	*Counts (percentage)*
Age of female primary caregivers		
15-19	5 (11)	4 (9)
20-24	10 (21)	13 (28)
25-29	7 (15)	17 (36)
30-34	14 (30)	5 (11)
>=35	11 (23)	8 (17)
Community of residence		
Kebiremu/Kebiremu cell	8 (17)	7 (15)
Kitarir/Kitariro cell	7 (15)	7 (15)
Mpungu/ Kikome cell	6 (13)	7 (15)
Bikuuto/Bikuuto cell	10 (21)	7 (15)
Byumba/Byumba cell	7 (15)	8 (17)
Kihembe/Kengoma cell	9 (19)	11 (23)
Number of children under 5 years in the household		
One child	9 (19)	11 (23)
Two children	8 (17)	9 (19)
Three children	8 (17)	9 (19)
Four Children	8 (17)	8 (17)
More than four children	14 (30)	10 (21)
Mothers who lost at least 1 child during pregnancy or after birth	20 (43)	8 (17)
Birth interval (referred to last child)		
< 24 months	2 (4)	3 (6)
>=24 months	45 (96)	44 (94)
No illnesses/complications during child birth[2]	41 (87)	40 (85)
Received food from Government/NGOs	43 (91)	5 (11)
Own land (small size)	44 (94)	47(100)
Own animals[3]	19 (40)	39 (83)
Pit latrine access	47 (100)	47 (100)
Access to soap		
Yes	2 (4)	30 (64)
Sometimes	32 (68)	16 (34)
No	13 (28)	1 (2)

Protected water facilities	39 (83)	47 (100)
Age at first pregnancy	*Mean/(SE)* 18.9 (0.4)	*Mean/(SE)* 19.5 (0.4)
Child age	**Batwa children (N=47)**	**Bakiga children (N=48)**
0-6 months	20 (43)	9 (19)
7-12 months	13 (28)	12 (25)
13-18 months	8 (17)	9 (19)
19-23 months	6 (13)	18 (38)
No illnesses/complications at birth[4]	45 (96)	44 (92)
Currently breastfed	46 (98)	48 (100)
Child looked after by the mother/caregivers only	40 (85)	38 (79)
Place of birth		
Home	19 (40)	7 (15)
Health Centre	4 (9)	17 (35)
Hospital	24 (51)	24 (50)
Reported child illnesses/symptoms in the first six months of life by caregivers		
Cough	31 (66)	32 (67)
Diarrhoea	38 (81)	35 (73)
Flu	23 (49)	20 (42)
Fever	7 (15)	8 (17)
Malaria	40 (85)	20 (42)
Pneumonia	15 (32)	11 (23)
Vomiting	8 (17)	4 (8)
Skin diseases	4 (9)	8 (17)
Other	8 (17)	5 (10)

[1]The percentages were calculated over 47 participants for both Batwa women and children and Bakiga women, and over 48 for Bakiga children.

[2]Illness/complications refer here to post-partum haemorrhage, retained placenta and death. Death occurred in 1 case among the Batwa participants.

[3]Animals include chickens, rabbits, goats, pigs and cows.

[4]Illnesses/complications refer here to respiratory problems needed resuscitation management at birth.

6.4.2 Main findings from the focus group discussions

We identified the key factors constraining child feeding through the focus group discussions which are summarised in Table 6.2. The elements are interlinked and positioned across the four levels of the framework (Figure 6.1): marginalisation and poverty at group/societal level, crossing the environmental and individual level; environmental changes at environmental level, crossing the societal level; lack of breastfeeding and complementary feeding-related information at individual level, crossing the group/societal level; and poor support at group level, crossing the societal level.

Table 6. 2: Summary of the key factors affecting breastfeeding and complementary feeding according to the participants in the FGD.

For each key factor we identified the correspondent level(s) explained in the framework (Figure 1).

Key factors	***Level(s)***	***Description***
Marginalisation and Poverty	Group & Societal	Due to marginalisation and high poverty levels, Batwa and Bakiga participants cannot afford to buy enough and high-quality foods. This had a negative impact on child nutrition and growth.
Environmental changes	Environmental	Extreme climatic events, especially droughts and floods, negatively impacted food security, especially accessibility and availability of foods with consequences on child and maternal nutrition.
Lack of breastfeeding and complementary feeding information	Individual	Lack of information received from health workers on complementary feeding practices and cultural beliefs were found to be limiting factors to achieve good nutrition in children according to the Batwa and Bakiga mothers.
Poor support	Group	Support is fundamental during breastfeeding and complementary feeding practices. However, this was limited for the Batwa and Bakiga women, who were used to live in contexts of domestic violence and alcoholism.

6.4.2.1 Marginalisation and poverty

The Batwa and Bakiga participants identified poverty as the dominant driver limiting the success of breastfeeding and complementary feeding practices. They repeated during the discussion that "*we don't have enough money, we are poor, thus we cannot feed our children*" (Batwa FGD), and drew a link between lack of money and resources, and poor nutrition outcomes:

> *"If you are poor, and you don't eat enough, you become sick. If mother and baby cannot eat properly, they both become sick and malnourished […] The mother cannot produce enough (milk), she is very weak, has dizziness, is dry, so she cannot produce milk and the baby cries"* (Batwa FGD).

Batwa mothers added that the Bakiga are also impoverished: *"not only the Batwa do not have food, but also the Bakiga, so the Batwa cannot really work for them for food"* (Batwa FGD). Batwa and Bakiga participants talked about their eviction from the forest, their traditional land, where previously they looked for food, now forbidden by the Government; they linked their historic displacement — and persistent restriction of forest access —to their current poverty and food insecurity:

> *"Most of the women do not have enough milk when the baby is older than 1 year, because they do not have millet porridge and other helpful foods such as cassava leaves. You can have enough breastmilk if you eat porridge, meat and fish […]. But we don't have access to this food now because we cannot go to the forest, and we don't have money to buy it"* (Batwa FGD).
>
> Also, *"In the past children started on wild meat, yams, mushrooms, greens from the forest as we were allowed to enter. Now we don't have access, so we use what we can afford"* (Bakiga FGD).

During the discussion, mothers also gave advice on specific foods that pregnant and lactating women should eat to increase milk production: millet porridge, greens, beans, Amaranthus leaves, and cassava leaves (Batwa FGD), and some Bakiga participants added also the consumption of meat and fish.

Women explained that children have a greater risk of malnutrition due to maternal poor diet, and infants are more likely to get sick with vomiting and diarrhoea due to 'low-quality' food, poor in proteins. They agreed that the quality of nutrition depends on money availability: *"only if we have money, we can buy eggs, which are very nutritious for the baby"* (Bakiga FGD). The most common foods for complementary feeding listed by mothers, and given from 4-5 months of age are matoke (green bananas), sweet or Irish potatoes, cassava, groundnuts, soup from meat (if available), and beans.

A Mutwa woman highlighted how their situation has changed compared to the past in terms of food availability: infants now are fed with what is available at home, and they don't always have 'sauce' (beans, groundnuts or greens) to accompany cereals. According to the participants, poor quality food causes sickness in both mothers and children:

> *"If the woman is sick, this means that even the child won't eat as the mother cannot go to work, and without working there is no food for that day".*

Participants added that appropriate complementary feeding practices get more complicated to follow in case of twins or multiple children under 5 years of age as it is difficult to provide sufficient foods to satisfy their nutritional needs. Also, they argued that is harder to produce enough milk for two or more children at the same time, therefore weaning usually starts before 4 months (Bakiga FGD).

Participants suggested that improving food availability and land accessibility through collaboration with the Government and district would have a positive effect on dietary diversity, *"to have a balanced diet*", and increase the quantity of food consumed by household (Batwa and Bakiga FGD).

The participants explained that food insecurity is also a consequence of limited availability of land, and overpopulation; therefore, food production is decreasing with negative effects on child nutrition:

> *"The land is not fertile, there is no sorghum or honey available that we gave before to babies […] We need more land, our pieces of land are small and the population is growing.*" (Batwa FGD).

> *"We don't have enough land to grow nutritious food for the children, and the little we have, we have to share among families and none get satisfied from the food"* (Bakiga FGD).

For this reason, the women addressed the need of more land to distribute among the community, and they sought to assess and redress barriers related to insecure land tenure and poor land quality to increase food production and availability (Batwa and Bakiga FGD).

6.4.2.2 Poor support

Batwa and Bakiga participants reported that they lack support from partners, the community, and health workers during the breastfeeding and complementary feeding period.

The women in the study identified the role of partners and older children as important in supporting successful breastfeeding and complementary feeding. They suggested that older children usually help mothers to collect food for the family and look after the younger siblings when the mother works or is out of the home (Batwa and Bakiga FGDs). According to participants, partners (generally a husband) provide support by purchasing food for the family, assisting during feeding the child when ready for complementary foods, but partners' support varies from household to household (Batwa and Bakiga FGDs). They also added that if the father does not buy food for the family, there may be a delay in the start of complementary feeding even in the case of poor breastmilk supply, leading to a deterioration in child nutrition (Bakiga FGD). For this reason, women requested more economic and social support from men, including help from the local district authorities to reduce alcohol consumption (Bakiga FGD).

In fact, participants indicated that domestic violence (verbal and/or physical) is exacerbated by high rates of alcoholism in the communities, in particular among men but also, in lower percentage, among women; they suggested to ask for the help of the district and Government to as this is also disruptive to child feeding:

> *"Alcohol is a big problem […]. Some men spend money on alcohol and do not provide food for the family. Sometimes there are also women that drink, and this can also cause miscarriages if they fight when they are pregnant […] Also, women cannot produce enough milk for the baby if they are stressed"* (Omutwa participant).

The participants articulated their perspectives on the causes of alcoholism and domestic violence, suggesting that alcoholism and domestic violence are driven by extreme poverty, inequalities and general and persistent food insecurity (Figure 6.3):

> *"[..] men drink also if they are very hungry, they have to fill their stomach to feel satisfied, but when they drink alcohol, they can beat their wife"* (Bakiga FGD).

Women mentioned that other support is usually offered by the community, and especially by relatives, friends, parents and neighbours. They usually provide food or help a mother to look after the baby and share information and knowledge on breastfeeding and weaning practices:

> *"Usually parents or grandparents tell their daughter how to raise the child, which food to eat and to give to the child for complementary feeding, especially if this is the first child"* (Mutwa participant).

Participants also reported other conditions where mothers lack support for breastfeeding. Many mentioned that they are able to breastfeed while working, but they also argued that in some workplaces breastfeeding is not allowed, and they reported the case of sex workers:

> *"Some educated mothers may not breastfeed the child because they cannot bring him/her at work; (in this case) the infant is left at home with the baby sitter who usually offers cows milk and porridge rather than breastmilk"* (Batwa FGD).

Additionally, Batwa women explained how breastfeeding was difficult among sex workers:

> *"Usually (sex workers) are young and they are not ready to have a child. When they have a child, they do not have support, and they won't breastfeed the baby because this changes the body shape, and they need to keep beautiful for their work"* (Batwa FGD).

The women also noted that they lack strong support from health professionals to support mothers to breastfeed longer:

> *"Batwa usually get pregnant fast, and for this reason they stop breastfeeding at 1 year. Some stop at 9 months or 6 months if they get pregnant, and we need more support from the hospital to end this"* (Batwa FGD).

Bakiga women highlighted the need to strengthen family planning services to help women not only to breastfeed longer, but also to decide when conceiving. According to the participants, young women and teenagers are in fact more likely to have their next child within 23 months due to lack of information and lower use of contraception. Specifically, they suggested to involve governmental institutions to address this need.

Additionally, Batwa and Bakiga participants argued that support is also needed to improve hospital and health centre accessibility as mothers face challenges in accessing medical services when they need assistance:

> *"The problem is that the hospital is too far from here [..], there are mothers that lose their child because they need to walk too much or they do not reach [the hospital] in time. Also, once we reach it, we don't have food to eat in the days we stay there. There is no free service for us when we are hospitalised. And who [takes care of] the children that we left at home?"* (Batwa FGD).

Figure 6. 3: Word frequency analysis with the most recurrent terms used by the participants to articulate the key drivers at the nexus of alcoholism, domestic violence, and child nutrition (breastfeeding and complementary feeding).

The bigger the word, the more often it was mentioned during the FGDs (Scale: 1-50).

6.4.2.3 Lack of information on breastfeeding and complementary feeding

Both Batwa and Bakiga participants indicated that they had a good understanding of breastfeeding practices, and noted that it is healthy for their child and should be started as soon as possible after birth (Table 6.4). However, mothers felt that information on complementary feeding was insufficient. For this reason, they asked for more advice during antenatal visits and immunisations as in these circumstances the health professionals talk about breastfeeding in particular (Batwa FGD). Information on child feeding is provided to mothers by the hospital or NGOs (Table 6.3); the main topics covered in these sessions includes breastfeeding practices, complementary foods and malnutrition, importance of giving birth at the hospital and vaccinating children, family planning, and HIV testing before delivery. The participants reported that some information on child nutrition was also available through radio programmes that could be easily accessed by Batwa and Bakiga families. Some mothers reported receiving information from peers, local religious leaders, and at school (Batwa and Bakiga FGDs).

Knowledge on breastfeeding and HIV was limited, and participants mentioned that breastfeeding should be stopped at six months if the mother is HIV positive. Also, they reported that if the child has teeth, it is better to start food sooner to avoid any bites on the breast that could facilitate the spread of HIV from mother to child. They also added that this is a suggestion given by health professionals (Batwa and Bakiga FGD).

Table 6. 3: Subjects covered by the hospital and NGOs related to breastfeeding and complementary feeding.

Courses mentioned by the Batwa and Bakiga participants	**Course organiser**
i) the principles of breastfeeding practices from positioning the baby to the breast to hygiene measures to apply	Hospital
ii) some information on the introduction of complementary feeding, and solid foods	Hospital
iii) the importance of delivering at the hospital with qualified health workers, taking supplementation during pregnancy and breastfeeding, and vaccinate the child at appropriate age	Hospital
iv) the causes of malnutrition, and how to avoid it	Hospital/NGOs

v) the importance of using family planning measures to control births and breastfeeding longer	Hospital/NGOs
vi) the need of testing the mothers for HIV before delivery (factor highlighted in the Bakiga FGD only) to know how long to breastfeed	Hospital
vii) the importance of microfinance courses to teach how to save or earn money by selling animals, and use it for transport to the hospital at the time of delivery or to cover any expenses when the mother or the child need to be hospitalised (e.g. in case of malnutrition)	NGOs

6.4.2.4 Cultural beliefs

Mothers discussed how cultural beliefs and local knowledge influence choices during breastfeeding and the complementary feeding period. Specifically, they discussed the role of traditional birth attendants (TBAs), and the practice of 'chewing' food for the child to make the first solid food softer.

Mothers reported confidence in the expertise of TBAs, including their knowledge on breastfeeding and complementary feeding, and willingness to be supported by them for antenatal and postnatal care together with the health care workers:

> *"We like TBAs because they are cheaper than the hospital, they help us during delivery and they give us advice on breastfeeding and solid foods. Also, they do not shout at us if we don't bring clothes for the baby as happens in the hospital [...]. Also, there is no transport cost, and they cure (malnutrition) much faster with local plants. Indeed, when you go to the hospital you stay at least 1 week [...]."* (Batwa FGD).

Some Batwa participants mentioned also that TBAs offer traditional herbs to help with milk production, especially when mothers cannot buy millet porridge or do not have enough food to eat; therefore, mothers approach TBAs to ask for help with breastfeeding. A Mutwa mother also added that according to traditional practice, mothers are expected to stay at home in the first four days after birth to produce more milk: "*If you do not stay at home, you won't produce milk*".

Mothers discussed other practices used in the past to help children eat first solid foods, such as 'chewing': *"This is not in practice anymore to avoid the diseases that came here [...]. Those changes (type of food and chewing practice) had an impact on child growth, children now grow better"* (Batwa FGD). However, many Batwa and Bakiga women did not support this position, arguing that children were healthier in the past when mothers used to chew wild foods from the forest before feeding the chewed food to the infant.

6.4.2.5 Environment changes and environmental change

Weather variability, shifting seasonality, and environmental factors were discussed by the mothers as playing a role in the success or failure of breastfeeding and complementary feeding practices. Participants perceived that due to climate change, the seasons '*are not the same as before'* and production of food has decreased, with consequences on maternal and child health status and nutrition:

> *"[It is a] hard to time to grow crops as unexpected heavy rainfalls or droughts can come, and cause famine. This has an impact on children's growth"* (Bakiga FGD).
>
> *"There has been a change in the weather: food is available in harvesting seasons, but less than before. Sometimes it rains a lot, and crops are destroyed […]. We don't have enough food and our bodies become weak"* (Batwa FGD).
>
> *"Land is overcultivated and food is scarce now, without a good rainy season there is not enough food for children"* (Bakiga FGD).

Also, participants perceived that a rise in temperatures has spread new diseases, such as malaria that before was uncommon, and due to this, children eat less, and get malnourished easily:

> *"It is hotter than before and new diseases [such as] malaria are affecting mothers and children. […] Children get sick, and often undernourished"* (Bakiga FGD)

Further, women stated that 'December, January' and 'May and June' are the harvesting months, the preferred time to introduce solid food, but '*these seasons may not be always good'* anymore; therefore, the introduction of complementary feeding may be started later than 6 months, and weaning may be postponed:

> *"We can wait until [the child is] 1 year and a half or 2 years [old], but we need to wait for good times, target the best season when crops are grown, otherwise children become sick and malnourished very easily"* (Bakiga FGD).

Mothers also reported that the type of food consumed during the complementary feeding period is 'not energetic' as wild meat is not consumed or consumed rarely. Participants argued that some families depend on only one type of food for the whole week because of food unavailability (Bakiga FGD), and they mostly eat once or twice a day only. A Mukiga mother discussed the consequences of extreme weather events on child nutrition and growth, adding that environmental changes contributed to food insecurity and reduced breastmilk production:

> *"If you do not have food due to too much sunshine that causes droughts, you cannot feed the child well. If there are droughts and dust, this can lead to sicknesses, and limits the mother to breastfeed the child well. When there is not food, you cannot express enough breastmilk, so the child is not satisfied"* (Batwa FGD).

6.5 Discussion

This study explored the key factors affecting breastfeeding and complementary feeding among the Batwa and Bakiga communities in south-western Uganda. Other studies in Uganda have only quantitatively investigated factors affecting complementary feeding by using Uganda Demographic Health Survey (UDHS) data focussing on child health, vaccination status and maternal education (49, 50), and data on Indigenous communities are scarce. Our mixed-methods design allowed us to explore the socio-cultural and environmental barriers to child feeding practices among the Indigenous Batwa population for which there are no data in the UDHS. Also, we compared the information with the neighbouring Bakiga who shared a similar experience in terms of breastfeeding and complementary feeding practices.

Additionally, in collaboration with the community we synthesized recommendations to improve breastfeeding and complementary feeding practices among Batwa and Bakiga communities (Table 6.4). These included suggestions to enhance the food environment, such as food availability and accessibility, health services, and community and medical support as summarised in Table 6.4. The community, also, recognized barriers and opportunities across levels and themes identified in our framework (Figure 6.1).

Table 6. 4: Summary of recommendations to improve child and maternal nutrition.

Recommendations	Expected outcome	Themes
1. Improve food availability and accessibility	Expected positive effect on dietary diversity and quantity of food consumed by mothers and children.	Livelihood resources & Natural resources
2. Targeted provision of 'good foods' to lactating and pregnant mothers, including millet porridge, greens, beans, dodo, cassava leaves, meat and fish	Expected increased milk production in lactating mothers with benefits for child nutrition.	Home/Family environment & Livelihood strategies
3. Assess and redress barriers related to insecure land tenure and poor land quality in communities	Expected increased food production.	Livelihood resources
4. Promote increased economic and social support from men/partners during breastfeeding and complementary feeding period	Expected decreased level of stress in mothers, increased household food availability, and increased milk production and the possibility to breastfeed longer.	Health services, Family environment, Community environment & Economy
5. Support and treatment to address the drivers and consequences of alcoholism in Batwa and Bakiga families	Expected decreased level of stress in mothers, increased household food availability, and increased milk production and the possibility to breastfeed longer.	Family environment, Community environment & Public policy environment
6. Targeted training and rural outreach to support complementary feeding practices, potentially in conjunction with immunisation/antenatal medical services and trained traditional birth attendants	Expected improvement in complementary feeding practices with better child nutrition outcome.	Health services, Family environment, Community environment
7. Strengthening family planning services	Expected more awareness when making the decision of conceiving, taking into account the importance of breastfeeding longer before giving birth to another baby.	Health services
8. Promote sustainable agriculture, including taking into account smallholder practices and local knowledge.	Expected better adaptation to extreme climatic events to improve food production and availability, which could benefit mothers and children.	Livelihood strategies

The Batwa and Bakiga are aware of the consequences that unavailability of food can have on maternal and child health. A study conducted in 2019 showed that the diet of Batwa and Bakiga communities is low in proteins and fats, and the caloric content of the most commonly consumed foods is low or very low, with negative implications for child nutrition (28). For these reasons, women highlighted the need for the District and Government to improve access to, and security and ownership of, more land to cultivate, and distribution of food to pregnant and lactating mothers and children.

The issue of lack of land, land ownership and access, and loss of Indigenous food is linked to the eviction in 1991 from the ancestral forest; this phenomenon is also common in many other Indigenous communities globally (24, 51, 52). Assessing barriers to land access, insecure land tenure and being supported by the Government are priorities to increase food production and improve children' nutritional status.

Lack of representation and socio-economic marginalisation of Indigenous communities persists in the region; the Batwa lack representation at political levels, have limited voice in political decisions, perceive disenfranchisement from local leaders, and need to compete with non-Batwa to be elected to leadership positions (29). Batwa and Bakiga women are especially marginalised and are victims of domestic violence. Marginalisation is linked to poverty (53-55); the Indigenous Batwa communities are among the poorest communities in the world (18). Studies have shown how wealth index and education level influences nutritional status (56, 57); indeed, both Batwa and Bakiga populations have extremely low education levels and income, and suffer from underweight and stunting, especially in children under 5 years (20).

Similarly, studies have demonstrated that increasing female empowerment can be beneficial to improve nutritional and caloric intake, especially dietary diversity, in infants and children (58, 59). Batwa and Bakiga participants reported that domestic violence is common among the communities, suggesting that empowerment levels remain low, and support from — and for — the community is required. Alcoholism, linked to domestic violence, is a factor affecting breastfeeding at individual, group and societal level within our framework, and has been reported in other low income settings (53, 60). Alcohol is closely linked to poverty and food insecurity, with alcohol use perceived as partially driven by the desire to quell hunger pains. Women noted that being stressed by a non-supportive and alcohol-consuming partner coupled with food insecurity were some of the main factors associated with inadequate production of milk. For this reason, social and economic support from partners, and engagement from the district and Government to address the consequences of alcoholism in the community were identified as key needs. Indeed, research has shown that support from partners and family had, in fact, a positive effect on breastfeeding as mothers reported to be more confident and motivated (61). Also, laws and regulations to support victims of abuse are needed at local level; the aim is to ensure an environment where women can safely nourish their children.

Additionally, women reported the importance of professional support at the hospital similarly to other research conducted in Kenya (62). From the health care providers, mothers expected to get more information on feeding practices, especially complementary foods, and support to access family planning services to breastfeed longer . Previous research has shown that getting information and support at the health facility is not easy during antenatal visits due to the number of patients and amount of work of nurses and midwives (62). Benefits from creation of breastfeeding and complementary feeding support groups led by community workers, volunteers or outreach nurses and midwives have been demonstrated in literature, and may be appropriate in this region and context (63).
However, participants also highlighted the important role of TBAs to provide essential newborn care in the communities, including advice on breastfeeding and complementary foods. The role of TBAs has long been discussed, although their potential contribution in helping mothers during the delivery and afterwards has been recognized in research (64). In Uganda, there was a transition from the promotion of skilled birth attendants to the ban of their involvement during deliveries in according to the recommendation of WHO and the Safe Motherhood initiative (65). However, TBAs continue to look after around 50% of pregnant mothers, especially in remote areas (66). Studies in some low-income countries have suggested that trained TBAs can help remote communities in accessing health services, and giving support to families by promoting effective neonatal care (67, 68). Therefore, there is the need for health workers to collaborate with TBAs in order to encourage culturally accepted care for the rural and Indigenous communities in the hospitals and health centres in south-western Uganda.

Our study also found that environmental variability and change can play a role in food insecurity by affecting breastfeeding and complementary feeding practices. For example, according to the participants, seasonality was taken into account when introducing the first solid foods; in fact, complementary feeding was found to be delayed or anticipated depending on the season, and availability of food in the household. The time of introduction of solid foods impacts child nutrition and nutritional status, especially if the food insecurity persists for long periods (69). Studies conducted in the same area show linkage between environmental factors and maternal and neonatal health. For example, *Bryson et al.* (25) described the link between pregnancy outcomes and climate change in Kanungu District among Indigenous and non-Indigenous populations, highlighting the impact of environmental factors on food security and maternal diet. Also, *MacVicar et al.* (22) found a causal pathway between weather, seasonal variability and birth weight among the same communities. These findings suggest that changing climate may have an impact on breastfeeding and complementary feeding practices through pathways of environmental variability and food security in the region.

Research has demonstrated that promoting sustainable agriculture is key to maintain and/or increase food security in a changing climate (70). Sustainable agriculture has been identified as an important climate response with the potential for double benefits: potential reduction in emissions and adaptation to the implications of climate change for food security (71). Common principles of sustainable farming include intercropping, high plant diversity and seed recycling (72). Efficient adaptation strategies to climate change stressors on agricultural productivity will be important in underpinning nutritional outcomes for Batwa and Bakiga mothers and children during the breastfeeding and complementary feeding period. However, transitioning to climate-smart or sustainable agriculture in many cases requires a strong knowledge base, financial resources, and adequate policies; for populations in extreme poverty such as the Batwa – where baseline development remains severely inadequate − transitions to sustainable pathways are unlikely to be feasible without substantial and targetted support (73).

6.5.1 Strengths and limitations

This study followed *Hector et al.* ‘s breastfeeding model (13), which is used to plan health interventions, and was adapted to investigate not only breastfeeding, as in the original framework, but also complementary feeding practices. The use of a mixed methods design and a community-based approach enriched the quantitative data with qualitative narratives, describing in detail key factors affecting child nutrition; also, group discussions offered the opportunity to share experiences and compare situations of lactating mothers living in the community. In spite of a relatively low number of FGDs (n=12) conducted among the communities, we reached data saturation.

Although in the FGDs may be difficult for all participants to raise their voice due to a few dominant personalities in the group and power imbalances (74), the local research team had worked for many years with the communities and knew how to engage with the participants, mitigating this issue by making sure that everyone had the possibility to talk. Despite the expertise of the local team, there is a possibility that the researchers' positionality may have influenced the results (75).To counteract this, the researchers ensured that interviews were conducted in a safe and confidential environment. Participants discussed sensitive topics such as domestic violence and alcoholism or mental health related-issues without any specific question on this matter because they were eager to highlight the problem, share their experience, and think of possible solutions.

Another strength of this study is the addition of the environmental level to the framework which allowed us to explore the relationship between weather and extreme climatic events with child feeding practices. Interesting recommendations have been suggested by the participants, and they may be useful for interventions in rural Uganda and other low-income regions where food insecurity and malnutrition are exacerbated by climatic changes (76-79).

The findings of this research, coming from a minority group, contribute to the research field of global public health and nutrition among Indigenous communities with a focus on women and children, and they will aid in tailoring nutrition interventions to specific local community's needs. Future research exploring breastfeeding and complementary feeding practices in the area may involve fathers, TBAs and health workers to investigate different perspectives, and to create more awareness on child nutrition and feeding practices among men. Indeed, the focus on IYCF, and in particular on the first 1000 days of life, is needed to prevent malnutrition and ensure that the children grow healthy and fully develop their capacities into adulthood (7).

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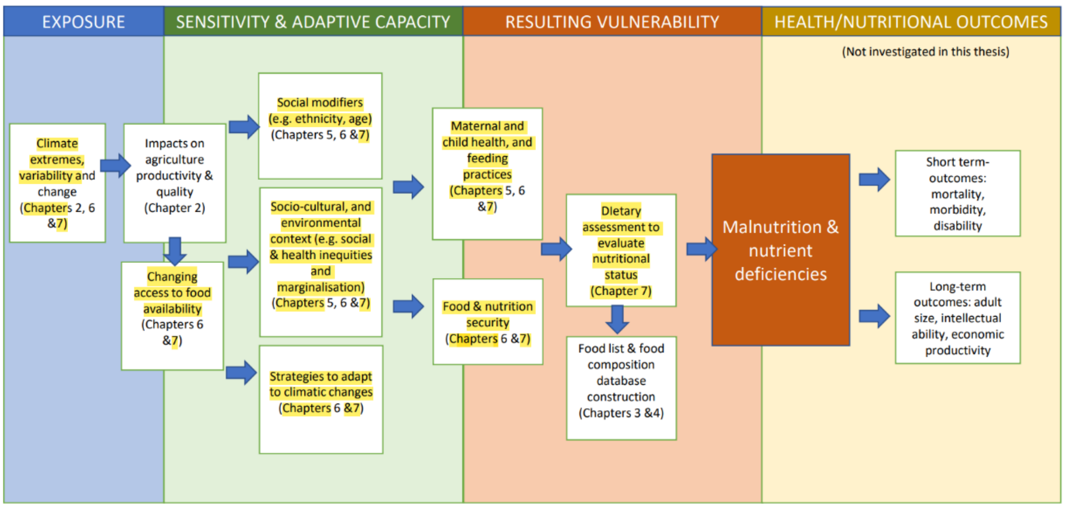
Chapter 7 - Exploring dietary adequacy and temporal variability among Indigenous and rural communities in Kanungu District, Uganda

This final empirical chapter of my thesis contributes to the assessment of the dietary intake of the Batwa and Bakiga communities over a six-month period. Multiple fieldwork techniques producing quantitative and qualitative data have been applied. Although due to budget and time constraints a nutritional evaluation over the whole year was not possible, this work provides information on the temporal variation of food consumption of young children and adults over different seasons. Also, I described compound events, which are other factors influencing individual dietary intake. Compound events are, in facts, occurring together with climate change, such as the outbreak of Covid-19 (1). Here, the resulting vulnerability and nutritional outcomes are described as a result of the interaction between the *exposure* (weather variability and seasonality), *sensitivity* and *adaptive capacity* (explored in Chapter 5 & 6).

The findings suggest that the Batwa and Bakiga diet is mostly inadequate, in spite of some differences across the months. In order to reduce the vulnerability of these populations to climatic changes, and improve nutritional outcomes, strategies targeting the elements included in the *sensitivity* (e.g. poverty, health inequalities) and *adaptive capacity* (e.g. sharing of meals) are recommended.



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For this manuscript, G.S. prepared the first draft of the manuscript, coordinated the data collection (remotely), and the methodological design, and conducted the data analysis. L.B.-F. and J.E.C. (doctoral candidate's supervisors) provided input on the data analysis, and supervised the work. S.T. coordinated the fieldwork and collected the data with P.K., E.N. and M.K. M.G. provided statistical advice. C.Z.-C., K.P., D.B.N., and S.L. reviewed and edited the manuscript. All authors have read and agreed to the submitted version of the manuscript.

Ethics approvals were obtained from the University of Leeds Research Ethics Board (AREA 18-156), the Ugandan National Council for Science and Technology (SS5164), and the Makerere University Research Ethics Committee (MAKS REC 07.19.313/PR1). For participants under 18y, consent was obtained from the parents

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Exploring dietary adequacy and temporal variability among Indigenous and rural communities in Kanungu District, Uganda.

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7.1 Abstract

Dietary adequacy is hard to achieve for many people living in low-income countries, who suffer from nutritional deficiencies. Climate change, which alters weather conditions, has combined with other cascading and compound events to disrupt Indigenous communities' food systems, limiting the consumption of adequate diets. The aim of this work was to conduct a proof-of-concept study exploring dietary adequacy, and to investigate evidence for temporal variation in the dietary intake of Indigenous and non-Indigenous communities in Kanungu District, Uganda in the context of the Covid-19 outbreak.

We randomly selected 60 participants (20 mothers, 20 fathers and 20 children aged between 6 and 23 months) from two Indigenous Batwa and two Bakiga settlements. A mixed-methods study with concurrent qualitative and quantitative data collection was conducted. Monthly dietary intake data were collected from each participant from February to July 2021 through 24-hour recall surveys using a specially developed Ugandan food composition database included in the online tool myfood24. At the same time, we also collected: i) demographic and contextual data related to Covid-19; ii) data on weather and seasonality; iii) data on the perception of dietary intake over the year, and during the Covid-19 period; iv) baseline anthropometric measurements.

The majority of the participants did not achieve nutrient adequacy over the six month period, and household dietary diversity scores were generally low. Pregnant and lactating women consumed a diet which was severely inadequate in terms of nutrient consumption. Caloric and nutrient intake varied over the six-month period, with the highest food consumption in June and lowest in April. Temporal variation was more evident among

Batwa participants. Vitamin A intake varied more over months than other nutrients in adults' and children's diets, and none met iodine requirements. Participants characterised the diverse mechanisms by which season and weather variability determined the type and amount of food consumed each month. Dietary intake showed indications of temporal variation that differed between nutrients. Also, they reported that the Covid-19 pandemic influenced their diet. During lockdown, 58% of adults reported changing dietary habits by consuming less ─ and less nutritious ─ foods.

The findings of this work highlight that the majority of the Batwa and Bakiga participants did not meet the dietary requirements for their age and gender. Also, our research indicates that weather patterns and seasonality may cause variations in smallholder food production with consequences on households' dietary intake. Emerging evidence suggests that nutrients and caloric intake vary monthly and under different weather conditions. Accurate and time-varying nutrition evaluations would help in identifying seasonal and monthly dietary needs, supporting preventive interventions protecting children and their parents from any form of malnutrition. Consideration of time-varying nutritional intake will become increasingly important as climate change affects the seasonality and availability of smallholder subsistence crops.

7.2 Introduction

Accessing adequate food is a human right, yet not achieved by many in the world (1). Ending hunger by 2030 -- the third Sustainable Developmental Goal -- has been compromised by several major drivers, such as the Covid-19 outbreak, which have disrupted food systems (2). A diet is said to be adequate when it satisfies the needs of a person in terms of quantity and quality of food, contributing to maintaining good health (3). Over 2 billion people worldwide consume an inadequate diet, and suffer from micronutrient deficiencies (4). Vitamin A, zinc, iodine and iron deficiencies are the most common, affecting primarily young children and pregnant women in sub-Saharan Africa and south Asia (5). Due to vitamin A deficiency, around 2.8 million children under five are at risk of blindness, while 33% of the worldwide population is iron deficient (6).

Several factors lead to inadequate dietary intake, including climate change. Climate change affects traditional food system security regionally and globally, with implications for individual nutrition and health status (7, 8). The effects of climate change on human health are often not direct, but rather manifest via impacts on the environmental factors that drive health and its determinants, including altered weather conditions and extreme weather events (e.g. floods, droughts, heatwaves, storms)(9). Understanding how food and nutrition vary with changing environmental conditions and seasonality is critical to preparing for the impacts of climate change on health. Growing research indicates that climate change will have substantial impacts not only on food production (10), but also on food and pest species distributions and abundance, global food chains, and livelihood security (11). Yet nutritional studies rarely investigate temporal variation in nutrient intake, or the role of seasonality and changing weather conditions. Where weather effects are considered, research has documented dietary intake during a specific timeframe only, for example after the monsoon season (12). Temporally-sensitive evidence is needed to design and adapt interventions in specific times of the year to better address communities' varying nutritional needs over time.

Indigenous populations are particularly vulnerable to all forms of malnutrition, from undernutrition to obesity, and this is due to many factors, including poverty and persistent health inequalities (13). Colonisation, for example, has played a role in contributing to dietary shifts. In fact, colonisers brought their own food customs, leading to a change of food types and livestock among many Indigenous communities, and promoting globalised food systems associated with multinational corporations (14). This limited in some places the consumption of nutrient dense foods, rich in proteins and micronutrients, and promoted lower-quality food intake. (15). Additionally, climate change has played a role in disrupting Indigenous food systems in conjunction with other health determinants and compound events, such as Covid-19 (16). The Covid-19 outbreak has contributed to increasing vulnerability of already vulnerable communities, accentuating discrimination, social exclusion and health disparities, particularly in women and girls (17, 18). Extreme flooding and heat, for example, combined with Covid-19 and longstanding health inequalities to compromise the food system, increase malnutrition cases, and compromise local diets of Indigenous Shawi in the Peruvian Amazon (19, 20) and the Inuit in the Canadian Artic (21). However, data on Indigenous populations' health are especially scarce in the domain of nutritional intake and maternal and child undernutrition, which require public health attention and urgent action (19).

This article presents a proof-of-concept study to investigate dietary adequacy and assess evidence for temporal variation in the dietary intake of neighbouring Indigenous and non-Indigenous communities in Uganda, taking into account the context of the Covid-19 outbreak as a compounding event. The main objectives were: 1. To describe the dietary intake and adequacy of Indigenous and non-Indigenous adult and child populations over a period of 6 months; 2. To explore the temporal variation in caloric and nutrient intake in the Indigenous and non-Indigenous adult and child populations over a period of 6 months; 3. To investigate participants' perceptions of food availability over 6 months, including the role of Covid-19 as a compound driver interacting with existing temporal variation in food security.

7.3 Methods

7.3.1 Study setting & population

The study was conducted in Kanungu District, south-western Uganda, where the Bakiga and Indigenous Batwa reside.

Although the Batwa communities were evicted from the forest in 1991 to establish the Bwindi Impenetrable Forest and the Mgahinga Gorilla National Parks (22), they are still strongly connected to their traditional lands. The forest represents an essential source of food, traditional medicines and knowledge, which is shared with the young generations (23). However, continued barriers to accessing the forest make the connection between Batwa and their land more difficult (24). As Batwa are adapting to a more sedentary lifestyle, they now engage primarily as labourers in the agriculture sector on Bakiga farms, and in tourism. The Bakiga represent more than 95% of the population in Kanungu District (approximately 75000 people) (25). A traditionally agrarian people, the Bakiga also work as brick-makers, handcrafters and in the tourism sector (26, 27). Both populations have limited access to markets and health services due the remoteness of the land where they live (23, 27). Although high among both populations, the Batwa experience greater food insecurity, malnutrition, health disparities, marginalization, and discrimination compared to the neighbouring Bakiga (28).

Climate change affects the area of Kanungu district, in south-western Uganda, especially with flooding events alternating with long periods of drought (29). Changing climate exacerbates the effects of poverty and Indigenous stigmatisation on food security among the two communities in south-western Uganda (21). The Batwa are likely to be more vulnerable due to their socioeconomic position, lack of agricultural knowledge and infertile land (30). In this region, malaria is seasonal with peaks in January and February (31), and gastrointestinal illnesses are more prevalent in the dry season (32). Also, the link between seasonality, precipitation and food security is well documented in the region, with families being more food insecure in the dry season (30). Conversely, the pattern of nutritional status, and nutrient and food intake over the year is uncertain (33). In March 2020, Covid-19 and measures to prevent disease transmission began affecting Batwa and Bakiga. To avoid the spread of coronavirus, they adhered to some measures, such as maintaining physical distancing and staying at home, and limiting access to markets and work due to a prolonged lockdown. This had a direct impact on food and nutrition security, exacerbated by the current effects of extreme weather events, and changing seasonal patterns (21).

7.3.2 Study design

This research was designed as a proof-of-concept study to test the feasibility of assessing the adequacy and temporal variability of dietary intake in remote and vulnerable communities at multiple periods over time.

A mixed method design was used to understand dietary patterns, and how they may change over a period of six months. We also considered the role of Covid-19 as a compound stressor on the Bakiga and Batwa populations' health. Qualitative and quantitative data were collected during the same period and interpreted concurrently to contextualise and triangulate results (34). Through a community-based approach, in which the researchers advocate for community engagement in the decision-making process by prioritising local knowledge, the participants shared and discussed their experiences, and challenges during the Covid-19 pandemic.

7.3.3 Settlements and households sampling

Four communities, two Batwa and two geographically adjacent Bakiga communities, were sampled for the study (Fig. 7.1). The communities were: Kebiremu (Batwa) and Kebiremu cell (Bakiga), and Kihembe (Batwa) and Kengoma cell (Bakiga).

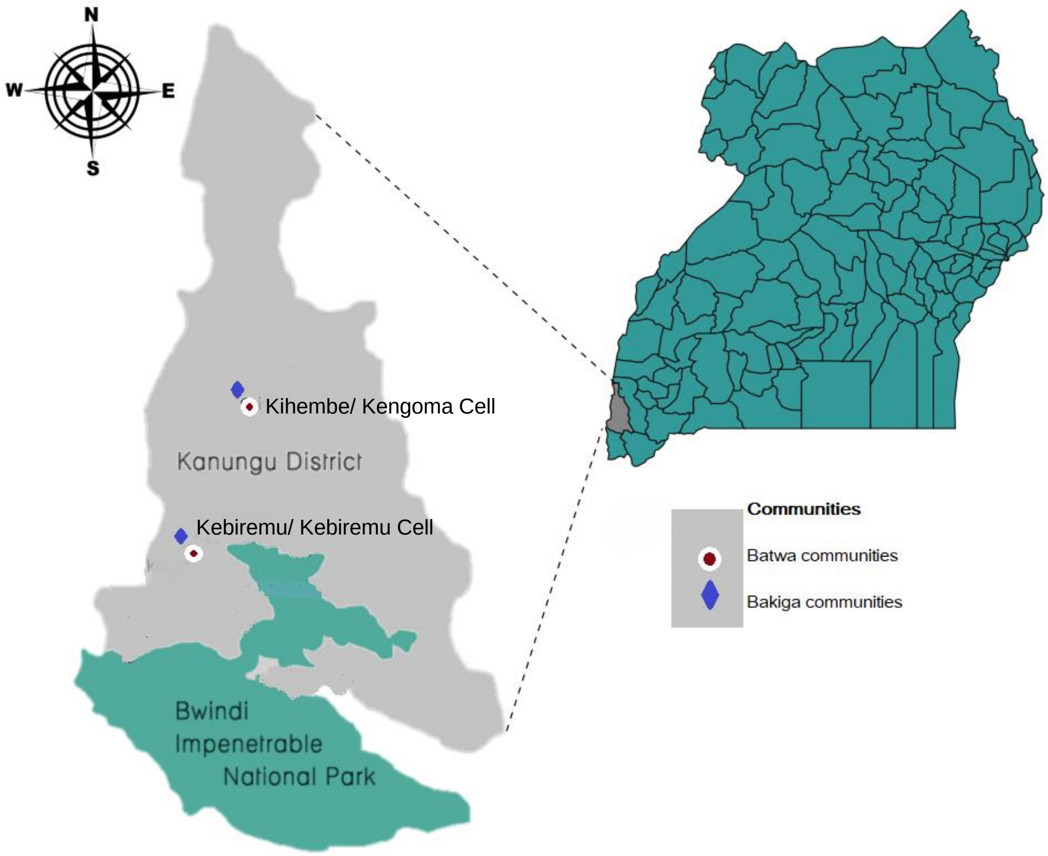

Figure 7. 1: Illustration indicating the four settlements where the study was conducted. The grey area represents Kanungu District where both Batwa and Bakiga communities live.

We selected these communities to evaluate dietary patterns in areas which present differences in local weather patterns and temperature (cooler temperature in Kihembe/Kengoma compared to Kebiremu), and access to markets and shops (easier and closer access to markets from Kebiremu compared to Kihembe/Kengoma). In each community, we randomly sampled five households using the lottery method (35), comprising a mother, a father and a child aged 6-23 months, with a total of 20 households and 60 participants (40 adults and 20 children) included in the study. The inclusion of adults and children allowed us to investigate dietary patterns across ages and genders.

7.3.3.1 Data collection

The fieldwork was conducted between February and July 2021 by the local research team in Rukiga (local language), and comprised of two Ugandan male and two Ugandan female researchers living in Kanungu District and with previous experience working in the Batwa and Bakiga communities. Extensive training on the data collection tools, research methods, anthropometric evaluation and ethical dilemmas concerning research and research participants was conducted online and on-site prior to the start of the study (January 2021). We discussed the ethical implications of studying food insecurity in impoverished communities and followed international ethics guidelines throughout the study (36). The exploration of food and nutrition security is considered to be vital for the Batwa and Bakiga communities, and their wellbeing, and for this reason a proof-of-concept study was conducted. The sample size was set by feasibility, and we used standard sampling techniques. The study was designed by imposing the absolute minimum of additional risk to the participants, and following the highest standards for obtaining informed consent, and ensuring confidentiality. Theoretical and practical sessions were delivered over one week of training, which were coordinated on the ground by ST (Sabastian Twesigomwe), and supported remotely by GS (Giulia Scarpa).

The data collection comprised: i) 24-hour recall surveys, ii) anthropometric measurements, iii) socio-demographic and Covid-19 information, iv) weather and season information, and v) qualitative interviews.

7.3.3.2 24-hour recall survey

A 24-hour recall survey investigating the type and quantity of food consumed the previous day was collected once per month over 6 months (from February to July 2021) for each participant (n=60 for 6 month—total of 360 surveys) (Supplementary material Chapter 7). The mothers answered dietary questions for their young children. The leader of the local research team conducted a sampling procedure with the local chairperson, and mobilized households each month. The mothers answered dietary questions for their young children. The leader of the local research team conducted a sampling procedure with the local chairperson, and mobilized households each month. The first time the survey was undertaken, the local researcher explained the type of information needed for the study to the adult participants. Plates, cups, spoons and ladles, which were commonly used by the two communities, were provided before the 24-hour recall for each household to facilitate and standardize the measurement of portion sizes across the participants. To measure the portion sizes, first we collected information on the most common tools used to quantify edible food. For example, participants reported that 'plastic cups' (500 mL) were used to measure the quantity of milk or water. Afterwards, two local researchers weighted the quantity of each food contained in the correspondent household tool, for example, a ladle contained 100 g of cooked rice. These measurements were used as a reference to calculate the dietary intake throughout the 24-hour recall method.

The 24-hour recall survey was recorded upon participant consent, and notes were taken by the research team during the interview. The information was later entered into an online nutritional assessment programme, myfood24. myfood24 included a community-specific food composition database, which was previously developed to include the most commonly consumed foods and dishes eaten by the Batwa and Bakiga (36). It was not possible to record the data on the online database during the fieldwork given the remoteness of the area and related wi-fi constraints. More than 20% of the dietary data were assessed for quality-control by a local nutritionist to make sure they were appropriately collected and reported.

7.3.3.3 Anthropometric measurements

Weight, height, presence of bilateral pitting edema and middle upper arm circumference (MUAC) were performed using the procedures recommended by WHO (38). The measurements (n=60) were collected at the beginning of the study to have baseline anthropometric information. The local nutritionist was in charge of the MUAC, weight and height data collection together with a member of the local research team. We decided to collect both MUAC and WHZ measurements to classify wasting, including severe wasting, in order to avoid missing wasting cases among the Batwa and Bakiga communities. In fact, the majority of children with severe wasting have either severely low WHZ or severely low MUAC (39, 40). However, the degree of overlap between these two measurements is approximately of 40%, and differs by country (41). The data were reported on paper copies. Two trained researchers with background in nutrition collected the anthropometric measurements separately. After collecting the data, an expert nutritionist on the field compared their measurements to ensure that the differences between their measurements was within the maximum allowed differences (7mm for length and 50g for weight). A third measurement was taken if any measurements exceeded the maximum allowed differences. Standardisation sessions were part of the training. During training, the researchers were familiarised with the measuring equipment and techniques. We assessed accuracy and precision by calculating any difference between the measurements of the nutritional expert (considered 'gold standard') and the other researchers while measuring anthropometry of a group of children. During the training, the measurements taken by the expert and the other researchers did not show any systematic bias or overestimation/underestimation of the measures taken.

For this study, we calculated the body mass index (BMI) for adults and classified individuals into categories of underweight (BMI<18.5), normal weight (BMI 18.5-24.9), overweight (25-29.9) and obese (BMI>30) (42). For children under 2 years, we calculated weight for height (WHZ), weight for age (WAZ) and height for age (HAZ) Z score to check for wasting, underweight and stunting respectively, using the WHO 2006 growth standard as the reference population (43). Participants who presented bilateral oedema or severe malnutrition were referred to the Bwindi Hospital in Kanungu District.

7.3.3.4 Socio-demographic & Covid-19 information

During the first set of community visits, we collected current socio-demographic information for the participants. For the adults, we included sex, age, education level, occupation, food access and production (including crops and animals), access to water and sanitation, mosquito net usage, health status, smoking and alcohol use, pregnancy status, access to health facilities, household level's information about family size, number of children, and other proxy data for wealth status. For the children, we included data on child sex, place of birth, pre- and post-natal visits, breastfeeding status, general breastfeeding habits and issues, and introduction of complementary feeding.

Additionally, we collected data on household food security during the Covid-19 period using structured and semi-structured questions. We investigated individuals' perception of change in diet and in food accessibility, availability, and consumption from March 2020. Other questions explored the role of humanitarian organisations providing foods to the Indigenous communities during the pandemic. The data were recorded on paper copies by the research team.

7.3.3.5 Weather and season information

The leader of the local research team (ST) collected information from internet broadcasting radio on daily weather conditions, extreme climatic events, and temperature (on the day of the fieldwork) over 6 months, and reported on paper copies using monthly calendars for the four selected settlements. Additionally, information on traditional seasons and changes in seasonality in the year 2021, monthly agricultural practices and availability of the main crops in the gardens, markets and shops were collected during the interviews.

7.3.3.6 Qualitative interviews

Qualitative interviews (n=40 adults) were conducted at the beginning of the fieldwork with the same participants who were part of the 24-hour recall. Open questions explored: i) Food availability and access over months and in different seasons, ii) perception of diet and food nutrition quality change over months, and iii) perception of changes in nutritional status among the Batwa and Bakiga communities over the year.

Despite a small sample size, we reached data saturation during qualitative interviews. The interviews lasted on average 24 minutes. The team leader of the local research team (ST) reviewed all qualitative interviews for quality-control. The interviews were audio-recorded and translated from Rukiga to English language by a proficient speaker (ST) on the research team.

7.3.3.7 Data analysis

The socio-demographic data and the information related to Covid-19 responses were statistically analyzed using Python 3.8.

For the nutrient and caloric intake assessment, we selected specific macro and micronutrients which are essential for children's growth and for lactating and pregnant women (40), including protein, iron, zinc, iodine, folate, vitamins A and C. Due to missing data in the food composition database, we could not include information on other B vitamins. We drew time-series graphs and used boxplots to explore these nutrient and caloric changes over months and seasons. Mean values for the month with the highest and lower nutrient intake were reported for each macro/micronutrient and calories. We then calculated percentages of nutrient variation over months, with confidence intervals to assess the difference of nutrients and calories in the best and worst months for Batwa and Bakiga women, men, and children.

We also calculated Household Dietary Diversity Scores (HDDS) by summing the number of food groups eaten by each household every month. The total possible number of food groups is 12, and includes: (i) cereals; (ii) roots and tubers; (iii) vegetables; (iv) fruits; (v) meat, poultry and offal; (vi) eggs; (vii) fish and seafood;

(viii) pulses, legumes and nuts; (ix) milk and milk products; (x) oils and fats; (xi) sugar and honey; and (xii) miscellaneous foods, including condiments, coffee, salt and spices (45). Finally, we evaluated individual nutrient and caloric adequacy by comparing the values to the EAR recommended nutrient intake references (intake as % EAR) for protein, vitamin A, B12 and C, iodine, zinc, iron, calcium and folate (46). Mean status was defined as adequate (≥100 % of EAR), inadequate (≥50 to <100 % of EAR) or severely inadequate (<50 % of EAR).

Finally, we conducted a contextualized thematic analysis (42) using NVivo 12 with the qualitative information collected through interviews. We used the framework of Ford et al. (48) to structure the questions and the analysis. We explored Batwa and Bakiga's lived experiences and perceptions on the impact of weather and climatic extremes, and Covid-19 on food security and nutrition. To do that, we investigated the interaction between 'slow' stressors, such as environmental change, socio-economic factors, and knowledge, and 'fast' stressors, such as extreme climatic events, changes to livelihood, food prices, and market access. The analysis involved multiple steps, from data familiarization to the development of codes, codebook and themes, and revision of the themes (49). It was performed by a single author, however 10% of the analysis was checked by a second researcher. The qualitative data were integrated with the quantitative results, and were used to identify key narratives about dietary patterns over the year and during Covid-19, and also to gather information about weather, seasonality, and monthly agricultural practices in Kanungu district.

7.3.4 Ethical considerations

Ethics approvals were obtained from the University of Leeds Research Ethics Board (AREA 18-156), the Ugandan National Council for Science and Technology (SS5164), and the Makerere University Research Ethics Committee (MAKS REC 07.19.313/PR1). For participants under 18y, consent was obtained from the parents.

7.4 Results

7.4.1 Sample characteristics

The sample for the study included 60 participants; however, seven 24-hour recalls out of 360 were missing as participants moved from the community due to work or other family circumstances.

Nearly 80% of the adults, including women and men, had a BMI classified as normal weight, between 18.5 and 24.9kg/m^2. Five (13%) adults were underweighted (BMI 16-18.5), all of whom were Batwa, and four (10%) were overweight (BMI 25-28), all of whom were Batwa as well. More than half of the children (n=12, 60%) presented a form of malnutrition (underweight, wasting or stunting), particularly among the Batwa, who were also more affected by stunting (n=6, 60%) compared to the Bakiga (n=2, 20%). Two children were classified as wasted, one (5%) of them identified through MUAC and bilateral pitting oedema checks, and the other one (5%) with the WHZ calculation. The majority of the children (n=16, 80%) were regularly breastfed (more times during the day), and 65% (n=13) of mothers reported that they started complementary feeding at 6 months of age.

Most of the adults were employed, working as subsistence farmers(n=26, 65%). Most of the food consumed by the participants was produced in their gardens (n=28, 70%), and half reported owning at least one animal (e.g. chicken, pig, cow, or guinea pig) (n=20, 50%).

Most families lived in impoverished conditions with limited access to basic public services: the source of drinking water was generally unprotected (n=6, 30%), toilet facilities were uncovered pit latrines (n=18, 90%) and shared (n=11, 55%), electricity was not available (n=17, 85%). Only 7 families out of 20 (35%) treated the water before using it. Fifty percent (n=10) of the households had more than 3 children and 5 or more family members (Tab. 7.1).

Table 7. 1: Main characteristics of the participants.

Variable	***Sample N***	***Count (Percentage)/Mean***
Adults (Women and Men)	40	
Age		
18-25		7 (18)
26-35		21 (52)

36-45		12 (30)
Nutritional status (same with MUAC and BMI calculation)		
Underweight		5 (13)
Normal weight		31 (77)
Overweight		4 (10)
BMI means		
Women		21.8
Men		20.6
MUAC means		
Women		251.8
Men		250.2
Education Level		
No formal education		7 (18)
Primary education		26 (65)
Secondary or higher		7 (17)
Working status		
Employed		27 (67)
Unemployed		13 (33)
Type of work		
Agriculture		26 (65)
Digging work		6 (15)
Non-agriculture related job		7 (18)
Involvement in one of the following activities each month:		
Drinking alcohol		25 (63)
Smoking		12 (30)
Physical activity		10 (25)
None		14 (35)
Own animals		
Yes		21 (52)
No		19 (48)
Main Source of food		
Own garden		28 (70)
Labour		15 (38)
Markets		4 (10)
Shops		5 (12)
Currently pregnant (women only)	20	
Yes		4 (20)
No		16 (80)
Children	20	
Sex		
Female		11 (55)
Male		9 (45)
Nutritional status (a child can have more than one category below)		
Underweight		4 (20)
Wasting		3 (15)

Normal weight		10 (50)
Stunting		8 (40)
Means of nutritional status		
MUAC		145.3
WAZ		-0.7
WHZ		0.1
HAZ		-1.5
Height means		
Women		150.1
Men		158.8
Regularly breastfed		
Yes		16 (80)
No		4 (20)
Breastfeeding times		
No breastfeeding		4 (20)
Less than 6 times per day		3 (15)
More than 6 times per day		13 (65)
Introduction of complementary feeding		
At 6 months		13 (65)
Before than 6 months		7 (35)
Households	20	
Number of people in the household		
Five or less		10 (50)
More than five		10 (50)
Source of drinking water		
Unprotected		6 (30)
Protected		14 (70)
Number of children:		
1		5 (25)
2-3		5 (25)
More than 3		10 (50)

7.4.2 Dietary intake and adequacy

Caloric intake was adequate for Batwa and Bakiga children, but inadequate for all Batwa and Bakiga adults, and especially low for lactating mothers . Children's calories were derived primarily from carbohydrates (77%), with 10.5% coming from proteins, and 13.5% coming from fats, with no differences among the two communities. Seventy-six percent of adults' calories came from carbohydrates, 10% from proteins and 13% from fats, and this was consistent among both communities.

Most of the nutrient requirements of lactating women were classified as 'inadequate' (nutrient value ≥50 to <100 % of EAR) or 'severely inadequate' (nutrient value <50 % of EAR), especially for Batwa women. All children, women and men had vitamin A, iodine and calcium intakes that were inadequate or severely inadequate, and Batwa lactating women had also a very low iron intake (Fig. 7.2 and Supplementary material Chapter 7). Only both Batwa and Bakiga children aged 12-23 months had an adequate intake of iron.

Generally, more Bakiga women met the caloric and nutrient requirements compared to Batwa women (Supplementary material Chapter 7). Caloric intake, vitamin A, zinc and calcium were not met by the majority of breastfeeding and pregnant women across months. None met the iodine requirement, and only one woman met the folate requirement. Overall, Bakiga men were more likely to meet the nutrient and caloric requirements than the Batwa men over the six month-period. Although iron intake was met each month by less than 50% of men, generally they achieved iron requirements more frequently than women and children. A similar pattern can be seen for zinc intake, which was adequate for more male participants than for women and children. Only a few men achieved vitamin A and iodine requirements. Protein intake was most frequently met by children: every month at least 50% of children met the requirements.: every month at least 50% of children met the requirements. Vitamin A was overall inadequate among most of the children (adequacy percentage per month from 5 to 15%). No one met the iodine requirement in the six-month period.

Table 7. 2: Overall caloric and nutrient adequacy of main nutrients for the Batwa (a) and Bakiga (b) participants.

Mean status defined adequate (≥100 % of EAR) highlighted in green, inadequate (≥50 to <100 % of EAR) in yellow, and severely inadequate (<50 % of EAR) in red. In our sample, all Bakiga women were lactating.

a) *Batwa participants*

	Children 6-11 months N=5		***Children 11-23 months N= 5***		***Lactating women N=6***		***Non-lactating women N=4***		***Men N=10***	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Calories	109.9	64.9	98.2	62.4	45.7	21.5	91.6	29.9	64.9	25.3
Protein	136.3	81.8	213.7	162.4	63.8	36.2	127.8	52.7	92.3	45
Iron**	89.2	86	88.6	81.4	36.2	20	84	32	76	33.3
Vitamin A	7.6	8	52.3	83	19.6	24	48.8	56.5	52.6	60.8
Zinc***	71.1	44.7	97.4	60.5	57.5	23.8	120	36.4	84.9	41.1
Iodine	23.3	13.3	15.7	11.4	13	12	9.3	8.6	22.1	40
Calcium	54.5	57	48.7	35.6	19.5	13.6	51.8	27.2	49.5	41.9
Folate	292.5	177.5	256	110	86.2	39.5	117.6	46	139.3	44.6
Vitamin C	220	153	290	275	134.5	101.8	352	240	332	280
Vitamin B12	33.3	66.7	175	425	22.9	57.1	112	200	112	240

b) Bakiga participants

	Children 6-11 months N=5		***Children 11-23 months N= 5***		***Lactating women N=6***		***Men N=10***	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Calories	121.2	92.4	99.8	70.2	55.7	29.3	66.4	28.3
Protein	163.6	118.2	230.8	145.3	85.1	44.7	90.1	42.8
Iron*	67.7	48.4	99.5	98.3	51.3	33.9	86.6	60
Vitamin A	39.2	68.4	49	60	33.3	54.3	60	78.2
Zinc**	76.3	44.7	107.9	60.5	76.3	37.5	85	41
Iodine	13.3	11.7	31.4	28.6	12	13	22.9	49.3
Calcium	36	27.5	88.4	53.8	31.4	23.5	71.6	66.5
Folate	292.5	175	274	138	111.4	58.1	158	72.6
Vitamin C	206.7	220	140	110	100	74.5	292	284
Vitamin B12	100	300	125	0.6	51.4	142.8	80	2.5

7.4.3 Caloric and nutrient intake trends over seasons and under different weather patterns

Caloric and nutrient intake showed temporal variation over the six months, which spanned wet and dry seasons corresponding to the planting and harvesting periods. Also, crop availability varied through the same period (Fig. 7.3).

Table 7. 3: Description of months, weather, temperature, observed seasonality, seasonal expectation and seasonal availability of main crops (typically available in markets/shops and home gardens) according to the Batwa and Bakiga participants.

YEAR 2021	February	March	April	May	June	July
Actual observed season	Dry season with some rain	Rainy season	Rainy season	Dry season with some rain	Dry season with some rain	Dry season
Observed temperature (the day of fieldwork)	26-29 °C	24-26 °C	26-28 °C	25-28 °C	25-27 °C	26-28°C
Observed weather (for the month when fieldwork was conducted)	26 sunny days 2 rainy days	18 sunny days 13 rainy days	11 sunny days 19 rainy days	17 sunny days 14 rainy days	18 sunny days 12 rainy days	28 sunny days 3 rainy days
Typical agricultural season	End of harvesting season	Planting season	Planting season	Beginning harvesting season	Harvesting season	End of harvesting season
Seasonal expectation	This month had the typical pattern of weather and temperature expected by the communities.	This month was expected to be much rainier than it was.	This month had the typical pattern of weather and temperature expected by the communities.	This month was expected to be much sunnier than it was.	This month had the typical pattern of weather and temperature expected by the communities.	This month had the typical pattern of weather and temperature expected by the communities.
Availability of: Beans	✓		✓	✓	✓	✓
Cassava	✓	✓	✓	✓	✓	✓
Sweet potatoes	✓	✓	✓	✓	✓	✓
Groundnuts	✓				✓	
Maize	✓	✓	✓	✓	✓	✓
Millet	✓				✓	✓
Matoke	✓	✓	✓	✓	✓	✓

Temporal variation can be seen in caloric intake in both Batwa and Bakiga diets, however in adult Batwa participants the fluctuation was modestly more accentuated. For the adult Batwa community, a drop in calories was seen in the month of April (rainy season, end of planting season), and the highest calorie intake in June (harvesting season). The diet of adult Bakiga varied less seasonally than for the Batwa, with slightly higher caloric consumption in May (beginning of harvesting season). Children's caloric intake had a different pattern, showing less variation in the first four months, but with a peak in the month of June in both Batwa and Bakiga children. Nutrient intake varied over the months of the study period in the diets of Batwa and Bakiga adults and children (Supplementary material Chapter 7) . Each nutrient had its own pattern with peaks and drops in different months. For example, the consumption of calcium in adults was higher in June and lower in May, while folate intake had a peak in May and dropped in June. Nutritional intake of calcium, for example, varied more than 50% in the six-month period for women, men and children in both communities, with overall higher difference among women and children. Vitamin A was the nutrient which varied more across months in adults' and children's diets, although for children the variation was slightly higher, up to 97% (C.I. 96 to 99) among Batwa children, and 94% (C.I. 92 to 96) among Bakiga children. These confidence intervals did not overlap despite the small sample size, pointing to a significant difference in variation of vitamin A over seasons between Batwa and Bakiga children, with variation greater among Batwa children. The differences in carbohydrate intake for all participants was lower compared to the other nutrients over the six-month period: around 60-65% for Batwa and Bakiga adults, except for Bakiga children for whom the variation was higher (82%, 95% CI 73 to 90). Iron intake varied a minimum of 62% among Batwa men to maximum 84% among Bakiga women across the six months.

7.4.4 Household Dietary Diversity scores

The mean HDDS ranged between 4.4 to 5.5 (out of 12) over the six months, with no statistical difference between Batwa and Bakiga's households. The HDDS was, in fact, stable through the period of the study with no significant variation over months and seasons. The participants consumed in average 4 to 5 food groups per day, which is considered a moderate diverse diet. Fruits and vegetables (constituting between 30% and 43% of their diet), and cereals and tubers (constituting between 28% and 38% of their diet) were the most consumed food groups, and dairy and eggs (constituting between 0% and 1% of their diet) the least eaten by the participants over the six months. Additionally, all animal proteins coming from meat, poultry and fish (constituting between 0.5% and 3% of their diet) were rarely consumed by the communities (Supplementary material Chapter 7).

7.4.5 Perceived and experienced effects of Covid-19 and climatic changes on diets

During the interviews, participants discussed the interacting factors affecting their dietary intake in the first six months of 2021.

1. Environmental change and seasonal shifts

Participants characterised weather, food availability, and consumption for the six months of fieldwork and compared this to a ‘typical’ seasonal calendar,. They reported that two of the six months during the study period differed from typical expectations in terms of weather and food security: March was expected to be rainier and May sunnier, and this delayed the planting season, decreasing in some cases crop production. In fact, February was typically the time to prepare the field for the agricultural season, and March and April the time to plant. These two months corresponded also to a ‘critical time’ in terms of food availability and accessibility (Tab 7.3).

Women and men also commented on the quality of food over the months. They reported that in the dry season the type of food consumed was less nutritious, more expensive and less affordable, while in the rainy season the quality was higher:

In dry months, when there is a lot of sunshine, there are no greens (which are a mix of vegetables, such as amaranth, also called ‘dodo’), which are very nutritious. During the rainy season, greens are available— there are greens in the bush. We do *not plant them, but we find and collect them in the bush directly. (Batwa man, Interview)*

Cassava and *dipuri* (poor quality matoke, plantain species) were the only two ‘fresh’ foods available during food insecure and dry periods according to the Batwa and Bakiga participants. Indeed, cassava ‘could easily grow under any weather condition’ and without the need to purchase seeds as ‘planting the stem was sufficient’ to grow this crop. However, participants agreed that both foods were not ‘nutritious’:

Health workers say that dipuri and cassava are not nutritious, and give suggestions for a balanced diet but they (health workers) do not have food for doing so. Children are sick because of lack of food and they go to the hospital. The majority of the Batwa are thin because of poor food. […] Bakiga pay me 5000 [Ugandan shillings, 1.33 US dollars] a day, but we need 16000 [Ugandan shellings] for one kilo of meat. This means I have to work more than 3 days for that. Also 1 kilo of meat is not enough to feed my family (6 people). (Batwa man, Interview)

Participants added that during the planting season food was usually dried, for example dried beans and maize, and kept in stores. Conversely, in the harvesting season corresponding to May and June, ‘the best’ period for food quantity and quality according to the participants, people consumed fresh foods (e.g. fresh beans, fresh maize). People felt generally healthy in this season, full of energy to work, and satisfied with the food that is on average consumed over two meals. Some participants explained, however, that food was not enough for their families:

During the rainy season there are more foods, but this does not mean that is enough for all the Batwa, but it is certainly more available. (Batwa woman, Interview)

1. Extreme climatic events

No extreme weather events occurred in the four settlements over the six-month period. However, participants did report previous experiences with extreme events: when floods or droughts occurred, the food security level was drastically reduced, and the price of foods increased for both Batwa and Bakiga communities:

Food is expensive when droughts or floods occur. […] I usually eat different types of food and I think that the food I consume is nutritious, but not when there is an extreme climatic event as everyone is in crisis of food. (Bakiga woman, Interview)

However, some participants who reported no variation in their diet over months explained that there were circumstances in which a change occurred, for example in case of an extreme weather event:

I rarely change my diet, but this happens with long drought or floods. Sometimes I need to go to markets as crops do not grow under some climatic changes. Lots of wind destroys banana plantations […]. If coffee trees fall down, we do not have any income. (Bakiga woman, Interview).

2. Socio-economic factors

Others, however, explained that their diet did not change because of the 'permanent poverty condition', explaining that usually they cannot afford diverse food as they don't have enough money, or thanks to economic stability and availability of lands, which ensured enough food for the family:

No change in my diet—most of the time I have food at home as I have coffee plantations that give me enough money to eat well (Bakiga man, Interview)

Additionally, seventy-five percent of the adult participants reported changing their diet since March 2020 (Tab X). Most of them reported having consumed food in lower quantities and less frequently due to lack of money, but also due to access restrictions for markets and shops, and lack of availability of work. However, two participants reported to have eaten more than usual to protect themselves from Covid-19, and given that their social life was reduced drastically:

I eat more since Covid started because we have more time to stay at home due to the lockdown (Bakiga man, Interview).

During the adult interviews, 17 of 20 Batwa and 12 of 20 Bakiga participants reported that their diet usually changed over the year, due to 'climate change' and 'famine', but also depending on the economic situation of the family, market access and availability of work:

Diet changes depending on what I get when I work for the Bakiga […]. I work for different families, and everyone gives me different foods. Some months we eat only once a day, a jackfruit for example. Sometimes no meals for the whole day, only a snack. […] Children cry as they are hungry (Batwa woman, Interview).

3. Culture and knowledge

Adults perceived that some foods had higher nutritional properties, while others were consumed only to 'not die' from hunger. Generally, beans, groundnuts, meat and matoke were thought to be 'good' foods. However, participants had different opinions about the 'most nutritious' type of food. Some of them called 'good food' food that was fried and rich in fat:

When I eat beans fried with cooking oil or meat with matoke, I get satisfied. In fact, when I eat any food that is fried with oil, I know that I am eating very well. (Batwa man, Interview)

Others explained that greens and protein-rich foods made people healthy. Also, they commonly felt that 'good taste' meant 'having many nutrients':

Foods less nutritious are cassava and dipuri because they do not taste very good. I do not like them, but I eat them because I have no options (Batwa man, Interview)

4. Food and market availability and accessibility

Also, more than half of the participants (58%) reported that some foods previously consumed were not available during the Covid-19 period (Appendix 5). The consumption of certain types of foods such as fish, meat, matoke, rice, posho, and Irish potatoes decreased due to high costs at the market. Nearly 68% of the participants had limited or no access to markets and nearly 88% no access to shops due to the pandemic restrictions. In 2020, however, all Batwa participants received help at least once from humanitarian organizations, which provided food, but this did not happen among the Bakiga community.

A participant also mentioned that during the lockdown the cases of malnutrition increased due to lack of food:

In February [2021] people became thinner because there was no food due to Covid-19, which made our situation worse (Bakiga man, Interview).

5. Malnutrition as consequence of the interaction between climatic changes, Covid-19 and other interacting factors

Participants reported that the number of malnutrition cases in the communities varied over the year with a peak during the planting season when food was scarce, and individuals were more likely to get sick:

People are thinner whenever entering in a new season […], and especially during the planting season. Also, because malaria comes with the rainy season, people get sick and end up malnourished. Flu also makes people thinner. When food is not there, people get malnourished. (Batwa man, Interview)

Malnutrition was perceived to be exacerbated by extreme climatic events, which affected Batwa more than the Bakiga, and in particular hit breastfeeding mothers as they reported that due to inadequate food, they did not have the strength to breastfeed. The occurrence of flooding and droughts posed additional vulnerability to already vulnerable individuals:

With extreme events, Batwa suffer more. There is no food also for Bakiga, but Batwa suffer more because there is no labour for Batwa when there is no work for Bakiga. However, Bakiga can sell something like animals, or they could have saved money before the droughts or floods destroy everything (Bakiga woman, Interview)

However, participants also reported that other compound events contributed to food and nutrition insecurity and increased the number of malnutrition cases, including alcohol abuse, family conflict, and scarcity of lands that according to them were consequences of poverty.

7.5 Discussion

Through this proof-of concept study, we assessed the caloric and nutrient intake of 20 Batwa and Bakiga households in south-western Uganda. In spite of the small sample size, we found that calories and nutrient intake varied over the six-month period with a peak in the month of June and a drop in the month of April. The novelty of this work lies in the longitudinal nature of the study, and in the simultaneous collection and interpretation of qualitative and quantitative information on diet, environment and climatic factors in the context of Covid-19. The qualitative component of the study contributed insight on communities' perceptions of diet change over the year, and in the context of climate change and pandemics. Indeed, food-insecure households can be heavily hit by shocks and food deficits as a consequence of climate change (50).

This study contributes to providing useful data to identify nutritional needs of individuals vulnerable to malnutrition and infectious diseases in south-western Uganda.

The findings indicated that weather patterns and seasonality -- and associated variation in smallholder food production -- influence households' dietary intake. For example, the peak of caloric intake occurred in June given the higher food production during the harvesting season. This has been reported elsewhere in Kenya (51), and linked with low dietary diversity and seasonal weather extremes events in other Sub-Saharan countries (52). During the dry season, participants reported that food prices in the market fluctuated, and that they experienced difficulties affording commonly consumed foods, a challenge also reported in other low-income and food-insecure countries (53).

For the majority of the participants, nutritional intake was inadequate overall compared to reference intakes. This trend has been found in many studies in low-income countries, which assessed dietary adequacy of mothers and children (54-59). According to UNICEF data, children aged 6 to 11 months did not have a diverse diet in Sub-Saharan Africa (60). Younger children (up to 12 months), who belonged mostly to the Bakiga community, had a nutrient intake lower than the Batwa. The diet of both Batwa and Bakiga participants was mainly composed of cereals, and was poor in animal proteins, which is common in Africa (61). As reported in the interviews, families in non-harvesting seasons consumed a very limited number and type of foods, and this was reflected in the household dietary diversity low scoring. Although some participants stated that health workers promoted the consumption of diverse food, this was challenging for families to achieve, especially during the dry season.

The inadequacy of dietary intake is a major factor leading to stunting, wasting, undernutrition and nutrient deficiencies, which are especially high among Batwa young children according to our research and previous studies (33). Deficiencies linked to dietary intake are preventable by providing individuals with sufficient and diverse foods. There are some essential nutrients which are particularly scarce in the Batwa and Bakiga diet. First, consumption of iron, which has many vital functions, such as transporting of oxygen to body tissues, (62) was inadequate. Second, none of the study participants consumed sufficient iodine, which is involved in the thyroid hormone synthesis (62). The consequences of extreme iodine deficiency are irreversible, causing brain damage especially in infants (63). The literature highlights that Ugandan Districts bordering the Democratic Republic of Congo grapple with iodine deficiency (64). Finally, the intake of vitamin A, which is an essential nutrient for growth and development, but also for the immune function, vision and reproduction (65), was also low. Vitamin A deficiency is common in populations consuming vitamin A from provitamin carotenoid sources (e.g. leafy green vegetables), such as in Uganda (65), and with a diet very poor in fat (66).

The participants described the cascading effects of climate change on weather and seasonal variability, and food availability, explaining that Covid-19 exacerbated food insecurity and malnutrition among both communities. Given economic instability in 2021, participants reported shifting their diet towards cheaper sources of calories, especially cereals and other foods poor in proteins and fats. This occurred in many countries during the lockdown as food prices increased (67). There is evidence that during the pandemic a household's ability to meet dietary requirements decreased, while food insecurity increased together with the consumption of poor-quality diets, leading to increased risk of malnutrition (68). Studies conducted in Uganda, Kenya and Nigeria, in line with our work, showed a deterioration of individual food security status in 2020-2021 (69-71). As the Batwa and Bakiga participants reported, people consumed less food and more alcohol during the pandemic, , hitting already food insecure communities hardest. This is likely to increase the rate of malnutrition in the post-Covid-19 era (72). However, the effects of Covid-19 on the communities in south-western-Uganda are difficult to estimate due to a lack of longitudinal studies and pre-pandemic dietary information, which make it difficult to distinguish the consequences on diet due to seasonal variation and weather-driven variability vs. the pandemic and associated restrictions (73).

7.5.1 Limitations of the study

This study has some limitations. First, the sample size was adequate for a proof-of-concept to assess the feasibility of undertaking longitudinal dietary assessment in a remote and vulnerable population, but not to generalize the findings among the entire Batwa and Bakiga communities. Also, the study was conducted over six months only. This limited the assessment of diet over time across a larger population, and generalisation of the findings. However, the results are representative of the diet during a specific time, the Covid-19 outbreak, and provide critical information on how local populations responded to protect their food security, and nutrition in this specific period.

Second, the 24-hour recall surveys were conducted only once a month, limiting the possibility to model possible scenarios of dietary intake in the future or to explore day-to-day variation. A year-long longitudinal study with multiple 24-hour recall surveys per month, and a higher number of households involved would allow estimation of more accurate usual dietary intakes among the Batwa and Bakiga (through the probability of adequacy calculation applying BLUPs of usual nutrient intakes where appropriate). The 24-hour recall approach has some limitations itself as a method given that it is subject to recall bias (74), and under and over-reporting (75). Also, although we developed a food composition database for the population previously (37) and the information was collected by trained and knowledgeable local researchers, the estimation of portion sizes for the participants was difficult given that usually people eat from a common plate. New methods for the data collection may be proposed in the future to overcome this issue (76).

Third, anthropometric measurements were performed only at the beginning of the study due to budget constraints, and the technical error of measurement was not applied, therefore we were not able to assess the effect of seasonality and weather patterns on participants' nutritional status. This would have enriched our work to assess the link between diet and nutritional status, especially by assessing the children's growth curve. Also, this could have started the discussion about the relation between nutrient/caloric intake and the short stature typical of the Batwa population.

Fourth, there was no information about dietary intake during extreme climatic events. Although Kanungu District was recently hit by a devastating flood (2019), at the time when the data were collected no extreme events occurred. These data would have helped in assessing nutritional requirements in times of very low nutrients intake, when people are most in need.

Fifth, we could not evaluate any difference in dietary intake before and after the pandemic, given that no data on caloric and nutrient intake was available in the literature for these two communities. However, our study is the first one assessing dietary intake among these two food-insecure populations.

Recommendations and further research

1. To adapt to climatic changes and weather variability in Kanungu District, Batwa women highlighted the need for more land to cultivate different crops which could help when food is very expensive and largely unavailable (29, 77). In line with this, adequate facilities to store crops from the garden or sell food in excess could reduce the economic gap (78). Also, the promotion of Indigenous and wild foods still available in Bwindi National Park could aid in reducing food-related costs at this time of year.
2. Evidence has demonstrated that wild foods may be more resilient to climate change than other crops, and be a protective factor for highly food insecure families (79). Additionally, researchers have reported the importance of consuming wild fruits and vegetables to improve maternal and child nutritional outcomes (80). However, eviction and continued exclusion from the forest has almost completely eliminated access to wild foods according to the Batwa (77). Further research is needed to investigate if wild foods follow a seasonal pattern to identify key food items over the year. Additionally, avoiding the exploitation of endangered animals species for food would be critical when implementing nutrition interventions.
3. To improve the dietary diversity and adequacy, together with nutrition and health messages, adaptive agricultural strategies which consider local climate trends and seasonal patterns, such as the use of plants resistant to droughts, could mitigate the risks of agriculture production losses, and ensure crops' growth to provide enough food to the communities every month (81).
4. To reduce micronutrient deficiencies, some recommendations need to be taken into account: i) communication campaigns targeting young children and women of childbearing age have been successful in other low income countries to prevent anemia (82), and may be helpful for the Batwa and Bakiga communities. Indeed, during the complementary feeding period, the need for iron is particularly high to support infant growth, and difficult to meet in food insecure populations (3).; ii) Raising awareness on the importance of consuming food rich in iodine (for example fish), and promoting iodised salt campaigns would help in reducing iodine deficiency's cases among the Ugandan communities (83). Also, the use of iodine-containing supplements

may decrease the risk of iodine deficiencies for pregnant and breastfeeding women (84); iii) Vitamin A supplementation is critical for the growth of Ugandan children, and improving coverage would help in reducing vitamin A deficiency (65).

5. Knowledge of the nutrient composition of Indigenous and wild foods, but also common locally-consumed dishes, could help in guiding nutritional interventions to reduce deficiencies and improve nutritional status (37). For example, poultry interventions, which are well documented in the literature, and are associated with an increase of chicken and egg production and consumption, could prevent vitamin A deficiency (85), but need to be implemented with broader poverty eradication projects, education and interventions which address other compounding social risks, such as excess of alcohol consumption. Indeed, culturally-sensitive and feasible nutritional programs are needed to maintain the integrity of Indigenous and local food systems, but also to contribute to economic development (50).

Despite some limitations, the findings of this study highlight emerging evidence that nutrients and caloric intake may vary each month among rural and Indigenous communities, although there is need for longer longitudinal studies calculating daily variation in dietary intake, and involving a higher number of participants. Ensuring monthly adequate dietary intake, and addressing individuals' nutritional needs in case of food crisis would prevent children and adults from malnutrition and ensure healthy growth (86).

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Chapter 8 - Discussion and Conclusions

8.1 Overview

This thesis aimed to characterize the food and nutrient intake of Indigenous Batwa and neighbouring non-Indigenous Bakiga communities, and to explore the likely impact of weather and seasonality on diet, and on child feeding practices. In this last chapter, I discuss key findings at the global, national and local levels by defining how each objective informs the thesis' aim. Also, I highlight the contributions of the thesis for policy and methodological innovation, and summarize study limitations and needs for future research.

The main objectives of this thesis were:

1. To review the available evidence on the effects of climate change on nutrients in foods at global level (Chapter 2);
2. To develop a locally-relevant methodology for collecting data on commonly consumed foods and dishes, and portion sizes among Indigenous and food insecure populations (Chapter 3);
3. To create an online food composition database to evaluate Batwa and Bakiga's food consumption (Chapter 4);
4. To identify predictors of complementary feeding in Uganda by analysing Ugandan Demographic and Health Surveillance (DHS) data (Chapter 5);
5. To explore child feeding practices among Batwa and Bakiga communities (Chapter 6);
6. To calculate the dietary intake of Batwa and Bakiga adults and children over a six-month period (Chapter 7).

8.2 Key findings & knowledge contributions

8.2.1 Overall contribution

This thesis contributes to the transdisciplinary field of nutrition and environment/human geography, brings together nutritionists and environmental researchers, and guides health interventions in the context of a changing climate. This applies the consideration and analysis of seasonality and weather variability when assessing diet, which may change how nutrition programs are delivered.

Food production, security and consumption are all interlinked, and highly susceptible to environmental and climate impacts (1). Similarly, dietary intake and nutritional deficiencies follow yearly and seasonal patterns, particularly in rural places as outlined in this thesis. Population-level nutritional trends can also change in emergency situations, such as in the event of a flood or drought (2). For this reason, both nutrition and environment as disciplines cannot be studied separately, but a mutual understanding and cooperation is needed to adapt diets and prevent individuals from all forms of malnutrition. Nutritionists are well-positioned to support the fields of human and planetary health by collaborating with experts from different disciplines, and with other nutrition experts in different domains (3). For example, nutritionists specializing in humanitarian contexts, and those engaged in preventing undernutrition in long-term projects should work together, and share information to eliminate boundaries, which can impede the identification and implementation of public health interventions related to healthy and sustainable diets in the context of climate change (4, 5).

To be useful and successful, the research has *to engage* the communities as partners throughout the research process. In this dissertation, working closely with the Batwa and Bakiga communities, listening to, and valuing, individual voices allowed me to better understand the nutritional and climatic situation, and particularly the needs of children and mothers, who are under-represented and often forgotten. The importance of collaborating with the research participants is a key message that my work brings, which is not only a methodological contribution, but it is the essence of my thesis, what I wanted to achieve as a researcher and professional working *for people* in health and human science. I used a 'person/patient-centered' approach (6), with the communities 'coming first', to make a difference for the beneficiaries in how research, and consequently nutrition interventions, are delivered, in order to achieve the second Sustainable Development Goal, *Ending Hunger* (7).

Each chapter of this thesis brings specific contributions to the field of nutrition and environment, which I presented according to the vulnerability framework.

8.2.2 Exposure - Impact of climate change on nutrients in foods

One of the key results of this thesis is the identification of potential variation in nutrient content of food, particularly in marine animal sources, as an effect of climatic variability and seasonality (Chapter 2). The changes in foods' nutritional content can affect individual diets, which would increase or decrease depending on climatic stressors. To our knowledge, this is the first systematic review assessing the impact of climatic changes on the quality of food at the global level. Models and projections are available in the literature, evaluating possible scenarios of nutrient content in crops in the short and long term (8, 9), but empirical studies remain scarce.

In order to study and understand the impact of climate change on nutrients, collaboration between nutritionists and experts in environment is required. Chapter 2 shows that the effect of climatic changes may influence not only the quantity, but also the quality of food. Among the climatic factors, seasonality has been found to influence the content of food. This suggests the updating of national and local food composition databases by including information on food nutritional intake under different climatic events, and seasons (more details in Chapter 2). This would be particularly relevant for vulnerable settings, where frequent climatic extreme events occur (10, 11).

8.2.3 Sensitivity & Adaptive capacity - Climatic & non-climatic factors affecting child feeding, and diets

Globally, literature exploring the impact of climate change on breastfeeding and complementary foods is limited, particularly in the Global South. A few studies assessed the benefits of breastfeeding for planetary health (12, 13) but did not explore both climatic and non-climatic factors shaping the vulnerability of child feeding to climate change, which we investigated in Chapter 6 among the Batwa and Bakiga communities. According to the literature, Indigenous young children have a risk of death which is double than of non-Indigenous young children (14). Appropriate child feeding practices contribute to healthy growth and development (15). However, there are other factors explored in Chapter 5 and 6, for example hygiene and sanitation, access to health services, socio-economic status, which can and affect child nutrition, and health status. Additionally, this thesis provides evidence that the physical and social environment may play a role in the high prevalence of malnutrition by limiting the quantity and quality of food available among vulnerable and Indigenous Peoples as suggested in previous studies (16-18). Results from Chapter 5 show that most of Ugandan young children's nutrition is already vulnerable due to existing socio-economic and health conditions, which create sensitivity and reduced adaptive capacity to extreme climatic events.

As described in previous research (16) and in my work (Chapter 3 & 6), poor environmental conditions and extreme climatic events affected child feeding, contributing to chronic malnutrition. Climate change does not occur in isolation, however, but it is experienced in conjunction with, other health determinants, and in some cases as compound events, such as Covid-19 (19). The Covid-19 pandemic in particular revealed and reinforced vulnerabilities across sectors, systems and societies, with severe impact on food security and child nutrition and health, especially among the most vulnerable communities as described in Chapter 7. The pandemic affected all Sustainable Development Goals (SDGs), particularly SDG 1 'no poverty' and SDG 3 'health and wellbeing' (7). However, data on the effect of climate change and Covid-19 on food systems among Indigenous and vulnerable communities are still scarce. The information provided in my work (Chapter 7) could help in monitoring child nutrition, considering not only climate change but also other determinants of health, and compounds events for the planning of adaptation strategies in the south-western regions of Uganda.

8.2.4 Vulnerability - Data on nutrition and climatic factors among unrepresented populations

This thesis provides insight into dietary intake and the nutrition of Indigenous and unrepresented communities in Uganda, and describes the needs and local perspectives of communities to effectively adapt to climatic stressors in an equitable way (20, 21). Undernutrition has multiple negative effects on health, especially on child development and growth (22). For Indigenous communities, nutritional status and health outcomes are worse than for non-Indigenous peoples (23). However, the literature on dietary intake for Indigenous populations has not been extensively explored (24). In the case of Uganda, data on Batwa Indigenous communities are not available in any Demographic and Health Survey database, which collect dietary and other health related information at national level. The Batwa do not exist in the national surveys, limiting the ability to understand needs and inform interventions accordingly.

Chapter 7 of this thesis contributes to providing an assessment of caloric and nutrient intake in the context of climate change uncertainty in Uganda. Although there are models and projections available to assess the impact of climatic changes on food production and availability, likely effects on nutrition intake at local level remain poorly understood, especially among the most vulnerable populations (25). Through the findings of chapter seven, we now know that nutritional intake of Ugandan Indigenous and vulnerable individuals is mostly inadequate, given that most of nutrient requirements are not met (nutrients’ value ≥50 to <100 % or <50% of RNI requirements). Consumption of vitamin A and iodine is particularly lower compared to the national average.

8.2.5 Nutrition outcomes - Stunting in Indigenous populations

My thesis results suggest that stunting and the typical short stature in Batwa children and adults cannot be solely attributed to genetic inheritance (26), but a complex phenomenon, in which nutrient intake plays an important role. Stunting is associated with higher morbidity and mortality, including vulnerability to infectious diseases, and cognitive deficits, which result in – and may arise from intergenerational persistence of – low socio-economic status and poverty (27). According to the literature, stunting is a consequence of environmental factors and exposure to pathogens, but also inadequate consumption of food (28, 29), as described in this thesis (Chapter 6 & 7). Poverty and inequalities are likely to be the major causes of stunting worldwide (30), including among the Batwa and Bakiga communities. As discussed in this work (Chapter 6), food insecurity, inadequate complementary feeding, but also other factors such as fragile domestic context, and inaccessibility to health services are found in literature to influence maternal and child health and nutrition (31). Particularly among the Batwa and Bakiga, food insecurity is linked to lower quantity and quality of food consumed, and change of diet, given the economic difficulties. This directly affects the individual, and family nutritional intake and status, as reported in other studies (32).

8.3 Policy contributions

8.3.1 Health and climate adaptation priorities at global and local level

This thesis contributes to the climate change adaptation plans and strategies at international (Chapter 2), national (Chapter 5) and local level (Chapters 3, 6 and 7) by describing nutritional outcomes, and socio-economic inequalities of Indigenous and non-Indigenous populations in south-western Uganda. Sub-Saharan Africa is, in fact, one of the most unequal places in the world (33). Without considering and collecting information on Indigenous populations, marginalized communities, such as the Batwa, may incur the risk of being excluded from adaptation planning and targeting. Although previously research (34), and my work have shown the high level of food insecurity and malnutrition among the Batwa, and other food insecure population inhabiting the same area, local food systems and climate change policies are still unavailable. Even though malnutrition at the national level in Uganda has declined (35), the food insecurity and stunting rate among Ugandan Indigenous Peoples remains high as described in Chapters 3, 6 and 7. Also, climate change has worsened the (under)nutrition situation among the Ugandan communities (Chapter 3, 6 and 7), and globally (36).

My work provides evidence to justify targeted policy development, support, and engagement of the Batwa and Bakiga in both food security and climate adaptation strategies, and in development strategies more generally (Chapter 3, 6 and 7). It also provides a justice argument justifying the need for stratifying health data to reflect highly vulnerable populations such as the Batwa community.

8.3.2 Improving nutrition through local food systems

This thesis describes existing coping approaches that could help policy makers to improve the nutritional situation of rural and vulnerable communities in Uganda. Coping mechanisms are, in fact, critical to guide locally-relevant adaptations measures (37). For example, the Batwa and Bakiga populations highlighted the importance of using traditional and Indigenous foods, which could reflect climate-resilient strategies handed down from generation to generation. Some livelihood approaches are also described in Chapter 4 and 7, for example sharing food within the family or neighbours during droughts or other extreme climatic events, when food is very scarce.

Often there is substantial disconnection between policies, interventions, and local food practices and needs (24) as shown in my thesis. During the doctoral project, communities highlighted the importance of traditional foods for their diet, which is an essential element to take into consideration for locally-relevant and locally-sensitive nutritional programs. The Batwa communities should be allowed to access the forest to collect wild foods rather than being completely barred from it. Indigenous foods, in fact, have been found to be healthy, and sustainable for the planet (38, 39). There are several nutritional, environmental, and socio-economic benefits in using local products as found in Chapter 3. For example, Indigenous foods have higher nutrition density if compared to other foods, as well as can be resistant to some extreme events, as shown in my work and in other studies (40, 41). Additionally, Batwa and Bakiga communities reported the importance of Indigenous foods for livelihoods and income generation, as people can sell it in the market. These economic benefits were found also in other research projects (42).

8.3.3 Strategies to promote breastfeeding and complementary feeding practices

Breastfeeding prevalence was high among the communities in Uganda, and this helped to avoid exposure to unsafe water or other contaminated food at a young age (Chapter 6). Breastfeeding, in fact, helps in boosting the child's immune system, and improving health outcomes in very insecure places (43). However, the complementary feeding period is much more challenging and 'risky', given that most of the vulnerable families are food-insecure with a low hygiene level (Chapter 5 and 6). Contamination of food can occur when the sanitation situation is precarious, affecting child nutritional status (16). With an increase in temperatures, proliferation of plant pests is common, and the Batwa and Bakiga participants reported it during my research. For example, aflatoxins affect crops, such as groundnuts and maize (44), which are widely consumed in south-western Uganda. These pathogens can harm human health, and particularly child growth (45-47). Temperature increases will also result in the proliferation of pests and pathogens (Chapter 2) in ways that may harm both crop production and human health (48). Policy makers should consider food safety

(Chapter 6), and prevention of the pathogens' spread that can limit healthy child development, together with total sanitation programmes and appropriate food drying and preservation technologies, by reflecting those in the policies.

In Chapter 6 of my thesis, I highlighted the importance of strengthening safe and healthy introduction of solid and semi-solid foods in young children after 6 months of age, by making sure that before that age only breastmilk (and when not possible, formula milk) is given. Also, health and nutrition education in the hospitals and at the community level should be implemented together with local traditional birth attendants to enable them to offer appropriate breastfeeding and IYCF support (Chapter 6). To guarantee a good diet intake to children, and adults, the Batwa and Bakiga participants requested to increase food accessibility and promoting sustainable agriculture, by taking into consideration local practices and knowledge (Chapter 3 and 7). All these strategies cannot be put in place, however, without the planning of poverty eradication, climate-smart agriculture, distribution of lands to displaced people, and general education programs to promote child growth.

8.4 Methodological contributions

8.4.1 Remote fieldwork and data collection

Indigenous and vulnerable populations are usually difficult to reach given the remoteness of the places where they live (49). Covid-19, and previously the Ebola outbreak in Democratic Republic of Congo on the border with south-western Uganda, made this situation worse. While in other places data collection through digital platforms (e.g. Zoom or Teams) is feasible, this is not possible in rural places without a stable internet connection or possibility to collect the data offline, and access to IT equipment, such as among the Batwa and Bakiga communities. Also, no literature explaining how to collect data remotely among Indigenous population was available at the time of my fieldwork (June 2019-June 2021). Recently, literature investigating how to adapt qualitative and mixed-methods research to the pandemic situation is growing at global level, but still lacking locally (50-52). However, there are now available considerations about the difficulties in accessing remote populations (53). In the case of this thesis, the fundamental methods underpinning this work did not change, but their operationalization did. I added one extra section to this thesis, which was the consideration of the impact of Covid-19 on Batwa and Bakiga nutrition, and Chapter 5, a desk-based component. However, what substantially changed was *who* led the work on the ground, and *how* the fieldwork was conducted. New roles and new capacity building resulted, contributing to a greater leadership role for Ugandan research members. As I was unable to travel to Uganda, the entire data collection, and planning of results dissemination at community level was coordinated by my Ugandan colleagues, with me working remotely. This contributed to strengthening the collaboration with the researchers in the field, and increased the level of partnership, which was reflected in participants commitment and high quality of data collected (54). Avoiding simultaneous translation from the local language (Rukiga) into English during the interviews and focus groups, which was the praxis before Covid-19 in Kanungu District, also prevented interruptions in the discourse flow of the participants. This was especially important when participants shared sensitive arguments and personal experiences.

8.4.2 An anthropological and environmental lens to investigate nutrition

Previous research highlighted the need to include social and environmental sciences' perspectives in nutrition to overcome the limitations of focusing only on biological mechanisms (55). Undernutrition and obesity, for example, not only have genetic causes, but arise from a complex interaction between many factors, including genes, socio-economic contexts, and food security (56, 57). Mechanisms gain complexity considering that both under- and over-nutrition can exist in the same area, as in Uganda (58) and the same household (59). Indeed, the nutritional transition is a phenomenon typical of many low-income countries due to a rapid urbanization and food system changes (60). Understanding intermediary factors of this phenomenon and creating a robust scientific evidence base is important in underpinning, developing and justifying nutrition policy (61).

In my thesis, intermediary factors of poor dietary intake and nutrition are identified, and investigated in detail using a participatory approach. The novelty of this work lies in the use of a mixed methodology, and the use of a socio-cultural, and environmental lens to assess food consumption, child feeding, and vulnerability to climate change (Chapter 6). Chapters 3, 4 and 7 also play a part in the discussion on the importance of local foods for sustainable diets among rural and vulnerable communities using mixed methods. Particularly innovative is the use of anthropology and human geography methods to create food composition databases (Chapter 3 & 4). Using qualitative and mixed methods in the nutrition field is relatively novel, and important to raise Indigenous voices to guide policies. In Chapter 6, through qualitative methods, I explored the factors contributing to poor child feeding outcomes, which were difficult to explain using quantitative information only. Particularly, qualitative data documented the strategies and needs of the Batwa and Bakiga to adapt to climatic changes across the chapters. Combined with the results of the systematic review, the qualitative findings indicate that consideration of environmental change matters when creating food composition databases, and assessing dietary intake over the year to promote sustainable adaptation measures, considering local capacity and existing strategies.

Additionally, shaping the research within a vulnerability framework, which is consistent with other studies among Indigenous Peoples (62), allows comparison and appraisal of the context of the communities in south-western Uganda with different parts of the world. For example, despite cultural and geographical differences, both the Shawi in the Peruvian Amazon (63), and the Batwa in Uganda eat mostly cassava during the year, and particularly in the time of droughts, given its likely high resilience to extreme climatic events.

8.4.3 Development of food composition databases for Indigenous and vulnerable communities

Chapter 4 describes the creation of an Indigenous food database listing the traditional and most common foods consumed by the Batwa and Bakiga communities. This work contributes to develop locally relevant tools to collect cross-sectional or longitudinal data on dietary intake at different times of year or after a climatic hazard event. Regional and local food composition databases are scarce, especially for low-income settings (64).

The construction of online food diary systems can have the advantage of reducing transcription errors, but also allowing participants to collect their own data without needing a researcher, and receiving immediate nutritional analysis feedback (65, 66). Collecting robust longitudinal data on food consumption can also explain dietary patterns and changes over time (67). However, trained Indigenous data collectors are needed to collect this information within the communities.

During the period when we collected data, the myfood24 database was only available online, and this limited the data collection where the wifi was not available. The food database is now functional offline, allowing data collection in rural areas where nutritional needs are the highest. Most of the dishes consumed by the Batwa and Bakiga are plant or cereal-based, with a low intake of meat, oils (or other fats) and dairy, and this is common in other Indigenous populations worldwide (68). The dietary assessment is particularly beneficial in the case of individuals with nutrition deficiencies, of which there are over 2 billion in the world (69). Among Indigenous communities the prevalence of micronutrient deficiencies may be higher than the average, given that Indigenous Peoples face greater vulnerability and suffer more from the consequences of poverty (39). Nutritional deficiencies are predictors of a range of morbidities and of mortality, particularly among women and young children (70). However, many individuals globally suffer from macronutrient deficiencies to some extent (71). Improving nutrient intake is a cost-effective public health strategy to ameliorate the overall health of individuals globally (31).

8.5 Limitations

Some overall limitations need to be considered across the chapters. Specific limitations are described in each manuscript/chapter of this thesis.

8.5.1 Generalizability

As the majority of the chapters of this thesis refer to specific communities only, findings are not generalizable to other contexts. However, the arguments and discussions are relevant to understanding nutritional patterns, and vulnerability to climatic changes within vulnerable people living in different settings. Given that climate change is a global exposure with differences in impact at national and local level, the information gathered through this thesis can help to guide adaptation measures in Uganda, and in other areas where other Batwa communities live. Also, health and social inequalities are common in many Indigenous and non-Indigenous communities (72, 73) globally. This means that distal drivers of vulnerability of the

Batwa and Bakiga may contribute to understanding health determinants of other vulnerable communities living in low-income areas.

8.5.2 Seasonality as a proxy of climate change

In this dissertation, I mostly used weather variability over months and seasonality as proxies of climate change, without using multi-year climate variability or change; this was due to budget and time constraints. Therefore, the dietary assessment of the Batwa and Bakiga was conducted in the first six months of 2021 only. My data focused on a comparison of both the dry and wet seasons. There are many debates around the use of seasonality as a proxy for climatic change. For example, researchers have argued that it is difficult to quantify increases or decreases in seasonality (74). Pezzulli et al. (75) showed the importance of using *annual cycles* as a proxy, given the non-linearity of climate, and the annual differences between seasons. However, the seasonal changes in precipitation, which have been assessed in this dissertation, and temperature, influence the climate system with an effect on vegetation and animals, and therefore on food availability and nutrition (74, 76, 77).

8.5.3 Sample size

Due to lack of budget, the sample achieved to assess changes in nutritional and caloric intake over months was low (Chapter 7). However, this was a feasibility study, so the number of individuals was adequate, but not enough to generalize the results, and predict the diet trends of the following years. Also, the number of articles included in the systematic mapping review was low (Chapter 2), due to the scarcity of research assessing the nutritional content in foods over time. Although the evidence is fragmented, there is a potential trend showing variation in the nutrients in foods, which will need to be confirmed in the future with the review of other studies, and a meta-analysis.

8.5.4 Use of instruments

In this work, I used quantitative instruments to measure and assess the nutritional status, and diet intake of the Batwa and Bakiga participants (Chapter 6 &7), as well as to evaluate child feeding practices in Uganda, using the UDHS data (Chapter 5). However, the qualitative tools were constructed taking into account the socio-cultural, and environmental context of the communities.

Regarding the nutritional status and intake assessment, we used reference nutrient intake (%EAR), which are globally recognized (78-83). Moreover, as the short stature of the Batwa can also be a consequence of the genetics and environmental impact (84), this measure may not be appropriate for this specific population, and more evidence is needed to confirm this. Additionally, we used the 24-hours recall method to assess the diet intake, which is useful to collect data on types of foods eaten, portion sizes and frequency, food sources, and preparation methods (85). However, many challenges exist in reliably estimating food and intake among vulnerable populations (86). One of them, which I found in my work, was the estimation of food portion sizes. Indeed, although we conducted previous work (Chapter 3) to understand how to measure the quantity of food among the Ugandan communities, and we used household measurements as suggested by the participants, we still faced difficulties in measuring leftovers on the plate, and to calculate the exact quantity of food consumed, given the common habit of a family eating from a common plate. Additionally, we requested participants not eat from shared plates for the duration of the study for the 24-hour recall data. However, when this happened (in a small percentage of cases), we asked to quantify the portion by using household methods. For example, the number of spoons of rice eaten from the common plate.

Lastly, in Chapter 5, I analysed UDHS data, which were collected using standardized questions, and this could be a limit given the high variety of populations involved in the survey. Also, for the analysis of the predictors (e.g. female empowerment and wealth), I used internationally standardized methods, which may not be fully representative of the Ugandan context. However, each instrument was carefully studied, and reviewed with local researchers prior to the use.

8.6 Further research & action

The findings of this work leave space for future research and actions in the local context of the Batwa and Bakiga, but could also be applicable to other Indigenous and vulnerable communities globally.

8.6.1 Promoting local and Indigenous foods

From the findings of this thesis, I highlighted the difficulty for the Batwa and Bakiga of consuming an adequate, and diverse diet due to several climatic, non-climatic factors and compound events in the first six months of 2021. However, for the two communities, and particularly for the Batwa, the key to good nutrition is eating locally biodiverse food (87). Indigenous foods have, in fact, several health and cultural benefits, which should be transmitted across the generations (88). For this reason, Indigenous young people need to be encouraged to develop campaigns, and lead projects for promoting local foods, and Indigenous knowledge, in their communities and at national level. According to the research, wild food is, in fact, rich in nutrients (89). However, the chemical analysis of the nutrition content of a few Batwa and Bakiga wild foods is not available yet, and would need to be carried out to complete the food composition database I developed.

8.6.2 Empowering women to improve child and maternal nutrition in the context of climate change

Further studies should investigate the role of Indigenous and vulnerable women to improve child feeding practices, maternal nutritional status, and also create locally relevant strategies in response to climatic changes. Research in other low-income settings has suggested the importance of educating and empowering mothers to make a difference in children' growth since birth (90-92). In this thesis, I highlighted across the chapters the willingness of mothers to be represented at national level to express needs, and provide a perspective to improve child and maternal health. However, many of the women are not educated or have low education, preventing them from reaching stakeholders at district or national level. Indeed, research reported that individuals with higher education, and wealth could better access information and governmental aid during climatic disasters, preventing from mortality, and other morbidities (93). Non-governmental and governmental organizations should recognize the important role of Indigenous women for appropriate child development, and should invest in interventions empowering women to reduce stunting and other forms of undernutrition in the context of climate change. On the other hand, women, with their extensive traditional knowledge, could participate in the debates with policy makers and Ministry of Health to find strategies to adapt Indigenous nutrition to climate change.

8.6.3 Nutrition transition in Uganda

In this thesis I only mentioned, but did not expand, the discourse around the nutrition transition, which is happening in many low-income countries, including Uganda (60, 94). The Batwa and Bakiga (Chapter 3 and 4) do not eat only traditional foods, but also some highly processed and packaged food, which is often high in energy content, contributing to a shift in their diet. This could promote the double burden of malnutrition to occur in rural areas, where traditionally only local food was consumed (61, 95). Overweight and obesity among adults in Uganda is, in fact, rising, leading to an increase of non-communicable diseases (35). Among the Bakiga, we found cases of overweight, while children were mostly stunted (Chapter 7). This trend is particularly evident in the cities, but now spreading to rural areas, in Sub-Saharan Africa, Latin America and South Asia (96). The double burden of malnutrition also affects other Indigenous Peoples, for example the Shawi in Peru (97, 98). Further research should investigate the mechanisms leading to the nutrition change in the context of changing climate in vulnerable and Indigenous settings. Additionally, studies could explore the feasibility of engaging with community participants to conduct surveillance programs monitoring health, nutrition and indicators of climate vulnerability to find strategies to improve nutrition.

8.6.4 How to achieve healthy and sustainable diets in Uganda?

Another important step following this work is to investigate and promote sustainable and healthy local foods, which could contribute to the health and wellbeing of Batwa and Bakiga communities. One of the biggest issues is that not always foods that are healthy are sustainable and resilient to climate change, and vice versa, sustainable foods can be unhealthy (25). For this reason, studies assessing metrics for sustainable diets are needed, as well as for evaluating the effectiveness of nutritional programs promoting both sustainable and healthy diets among vulnerable communities (99). The key is the cooperation between nutritionists and environmentalists to study the effect of healthy foods on the environment at local level. Indeed, there are global estimates for healthy and sustainable diets (100, 101), which may not be applicable for some communities with different nutritional needs, such as Indigenous Peoples.

8.6.5 Disentangle the mechanisms of short stature among Indigenous communities

In this thesis I highlighted the inadequacy of child feeding practices, and dietary intake among the communities in south-western Uganda, which are likely to have an impact on child growth. However, more research is needed to better understand the likely concurrent role of genetics, environment and nutrition impact. According to the literature, in Indigenous populations with short stature there is a disturbance in the development of the hormone-insulin-like growth factor axis (102). The African Pygmy populations are an example of short stature not related to an idiopathic disease. Children, in fact, show normal anthropometric and endocrine parameters until puberty, and adults present a low level of growth hormone, growth hormone receptor and insulin-like growth factor-I (84). However, more research, particularly in the field of epigenetics, is needed to better understand the likely concurrent role of genetics, environment and nutritional drivers of Indigenous Peoples growth trajectories. Longitudinal studies collecting data on Indigenous children from birth are particularly required to assess the role of child feeding nutrition, and nutritional status overtime. Also, research would be useful to identify the moment in which the growth stops or is non-linear in the children development with longer longitudinal studies, which are not available in the literature yet (103, 104). This work would help to explore how and at which age or stage is critical to intervene with *ad hoc* nutritional interventions, which may help to reduce stunting among Indigenous children and adults.

8.6.6 Innovative methods to measure diets, climatic and non-climatic factors for vulnerable populations

Given the limitation of calculating food portion sizes through the 24-hour recall method, further research is needed to find more appropriate fieldwork methods to assess the dietary intake among vulnerable communities, and collecting information on the other climatic and non-climatic factors. One possible solution, which I proposed as a post-doctoral work, could be the use of 'active videography', in which participants prospectively and concurrently measure their household's diets and food environments. Indeed, Batwa and Bakiga participants expressed the need to be engaged in the research process, and speak to the national leaders of their nutritional needs. This approach could also reduce costs – by streamlining data collection efforts and shifting the responsibility of data collection to participants – and could increase data quality by switching from recall to prospective measurement and collecting individual perspectives of the food environment. However, validation of this method is required.

8.7 Conclusion

My thesis provides information on the dietary intake and likely impact of climatic factors on food consumption, and child feeding practices among unrepresented Indigenous Batwa and Bakiga communities in south-western Uganda. Also, I made contributions towards understanding the likely effect of seasonality and weather variability on nutrients in foods through a systematic mapping review. Methodologically, I experimented with new approaches working remotely to collect the data in the field, by partnering and creating capacity building with local researchers in Uganda. I used multiple mixed-methods, and a participatory community-based approach to collect the data, and to create the food list. Also, I contributed to construct an online food composition database, which was critical to calculate the communities' caloric and nutrient intake over a period of six months, and under different climatic conditions.

Overall, this work contributes to the health and nutrition adaptation to climate change strategies among vulnerable communities. It argues that through the promotion of traditional food systems, the strengthening of local knowledge, planning of poverty eradication interventions, and consideration of the likely impact of climatic changes on food and nutrition security, nutritional outcomes of both children and adults can improve by reducing the prevalence of stunting, and other forms of malnutrition among the community in south-western Uganda.

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Supplementary material - Chapter 2

Information extracted from the articles

Title	Journal	Author	Year	Country	Type of food studie	Food Category	Type of nutrients studie
Nutritional quality evalu	Eurasian J Soil Sci	Akhtar, N et al.	2019	Pakistan	Pomegranate	Fruits	TSS, acidity, vitamin C, reducin
The effects of season	Eur. J. Lipid Sci. Technol.	Ayas, D. et al.	2013	Turkey	Shrimp and prawn	Fish	lipids
Interactions of season, s	Food Science and Techn	Bahadir Koca, S. et al.	2017	Turkey	crayfish	Fish	proteins and lipids
Yerba mate: Nutrient lev	Journal of Food Compos	Bastos, M.C., et al.	2018	Brazil	yerba mate	Tea	N, K, Cu and Na
Seasonal variation and r	Annals of Agri Bio Resea	Baksh, H., et al.	2017	India	guava, aonla and ber	Fruits	not specified (possibly N, K and
Effect of the climatic per	Revista Facultad Naciona	Bustamante-Córdoba, L.	2016	Colombia	milk and cheese	Dairy	ash, calcium, phosphorus, fat,
Seasonal variation of ma	Journal of Plant Nutritio	Cancela, J. J., et al.	2018	Spain	grapevine	Fruits	Phosphorus (P), potassium K),
Seasonal variation in vit	Domestic Animal Endocr	Casas, E., et al.	2015	U.S.	beef	Meat	Vitamin D
Inter-annual and season	Journal of the Marine Bi	Chakraborty, K. and D. Jo	2015	India	Silver bellies, Leiognath	Fish	protein, aminoacids, fat and wa
Inter-annual variability a	International Food Rese	Chakraborty, K., et al.	2014	India	Ribbon fish	Fish	protein, aminoacids, fat and wa
Seasonal variation in the	Indian Journal of Marine	Chitra Som, R. S. and C. K	2013	India	Sardinella	Fish	lipids
Seasonal and regional va	Mljekarstvo	Crnkic, C., et al.	2015	Federation of Bosnia and	bovine milk	Dairy	iodine
Mineral and Citrate Conc	Agriculture-Basel	Dunshea, F. R., et al.	2019	Australia	bovine milk	Dairy	Calcium, Magnesium, Citrate, P
Seasonal and Sexual Var	Aquatic Sciences and En	Emre, N., et al.	2018	Turkey	Capoeta antalyensis	Fish	Lipids, proteins
The interaction of droug	Maydica	Ferreira, G., et al.	2015	U.S.	Maize	Cereals	fibers, starch, proteins
Do we need more droug	Science of the Total Envi	Fischer, S., et al.	2019	Uganda,Kenya	Maize, grain, matooke, c	Cereals	P, K, Ca,Mg, and S, Mn, Fe, Cu, a
Assessing the effect of s	Food Chem	Garrido-Fernandez, A. an	2019	Spain	Pig	Meat	fatty acid
The determination of vit	International Dairy Journ	Gill, B. D., et al.	2016	New Zealand	bovine milk (early lactat	Dairy	vitamin D-3 and 25-hydroxyvita
Seasonal variation in prox	Pakistan Journal of Agric	Gull, T., et al.	2015	Pakistan	Capparis spinosa	Vegetables	proteins, fibers, fats, ash and m
Fatty acid profile and vit	Journal of Food Compos	Gutierrez-Pena, R., et al.	2018	Spain	goat milk	Dairy	fatty acids and vitamin A and E

Supplementary Material - Chapter 3

Template for the food list data collection in shops and markets.

MARKET ☐ SHOP ☐

AREA: Please specify the area of the shop/market visited.

PRODUCT TYPE	**BRAND (if any)**	**COST**	**WEIGHT (if packaged food)**	**Seasonal availability**	**Comments**

Guide topics for the focus group discussions.

a) Which foods do you usually buy from the shops and markets?

b) Do you eat packaged food from the market or from the shops? What foods?

c) Which drinks and snacks do you consume?

d) What foods do you produce and eat (e.g. from you garden, animals you raise)?

e) Do you eat any food from the forest, any roots or anything you pick up from trees?

If yes, which one(s)?

f) Do you sometimes receive food as a gift? Which foods do you receive?

g) What do you usually eat during holidays or during any celebrations?

Is this food different from usual?

f) Is there any type of food that you rarely eat (or used to eat)

and has not been mentioned before?

h) Can you please tell how each food (mentioned by you) is usually

cooked among your community?

i) Can you please tell how each food (mentioned by you) is usually

processed among your community?

j) Can you please tell how each food (mentioned by you) is usually

stored among your community?

k) Do children, women and men eat different amounts of food? How much?

l) Are there differences in the availability of this specific food during the dry and rainy season? If yes, can you please tell me the type of foods that you find in the dry and wet season?

m) Did you see a change of the availability of this food over time?

How do you adapt to these changes? Have you changed/substituted the food you eat?

Probe questions used for the dietary survey.

a) How many meals did you (or your child) have yesterday?

Is this your (or your child's) usual number of meals?

b) What did you (or your child) eat yesterday in the morning? Can you describe what did you eat? How it was cooked? How can we measure the food that you have eaten (which tools could help to measure each food?)

Is this your (or your child's) usual meal?

c) What did you (or your child) eat yesterday in the afternoon? Can you describe what did you eat? How it was cooked? How can we measure the food that you have eaten (which tools could help to measure each food?)

Is this your (or your child's) usual meal?

d) What did you (or your child) eat yesterday in the evening? Can you describe what did you eat? How it was cooked? How can we measure the food that you have eaten (which tools could help to measure each food?)

Is this your (or your child's) usual meal?

e) Snacks? Other eating occasions? Drinks? Is this a usual day?
If no, why not?

Template for the dietary survey

Meal/time	***Food item***	***Ingredients***	***Preparation method***	***Brand name (commercial product)***	***Tools used to measure each food***	***Comments***
Breakfast						
Any snacks?						
Lunch						
Any snacks?						
Dinner						
Before bed/ bedtime snack						

Supplementary material - Chapter 4

Methods used for local, field-based sourcing of food and recipe data.

Steps in field-based sourcing of food and recipe data	Methodological Approaches	Purpose of the method
1.1 Generate list of foods	Shop and market assessment	To characterise foods and brands (if available) sold in the shops and markets.
	Focus group discussions	To investigate the meaning of food, and socio-economic and environmental factors influencing foods and food- culture.
	Individual dietary survey	To confirm and validate foods consumed
1.2 Collect recipes	Focus group discussion	To characterise cooking and storing methods, and document local recipes.
	Individual dietary survey	To validate and identify missing foods and recipes.
1.3 Document range of portion sizes and measurements	Focus group discussion	To characterise and document ranges of portion sizes and measurements used locally.
	Individual dietary survey	To explore food consumption habits in terms of portion variability.

Examples of myfood24 Ugandan recipes

Description	Translation in Rukiga	Category	SOLD	NCF	GCF	WATER	TOTNIT	PROT	FAT	CHO	KCALS	KJ
Matoke with dried beans	Akatongo kebitookye nebihimb	vegetable based dish	16.5	-	-	73.0	0.4	3.0	0.4	20.3	89.2	373.0
Matoke with fresh beans	Akatongo kebitookye nebihimb	vegetable based dish	22.7	-	-	76.3	0.4	2.4	0.3	19.3	82.3	344.3
Orange Sweet potatoes and dried beans	Akatongo kebitakuri ebyakizari	Cereal with vegetables dish	21.1	4.4	0.6	68.4	0.6	3.8	0.2	24.0	110.2	460.9
Orange Sweet potatoes and fresh beans	Akatongo kebitakuri ebyakizari	Cereal with vegetables dish	27.3	4.4	0.6	71.7	0.6	3.1	0.1	22.9	103.3	432.2
Yellow Sweet potatoes and fresh beans	Akatongo kebitakuri ebyakyinel	Cereal with vegetables dish	27.3	4.4	0.6	71.7	0.6	3.1	0.1	22.9	103.3	432.2
Yellow Sweet potatoes and dried beans	Akatongo kebitakuri ebyakinek	Cereal with vegetables dish	21.1	4.4	0.6	68.4	0.6	3.8	0.2	24.0	110.2	460.9
Irish potatoes with dried beans	Akatongo kemondi nebihimba b	Cereal with vegetables dish	-	4.4	0.6	75.7	0.6	3.6	0.2	17.2	80.8	337.9
Irish potatoes with fresh beans	Akatongo kemondi nebihimba r	Cereal with vegetables dish	6.2	4.4	0.6	79.004	0.6	2.9	0.1	16.1	73.9	309.2
Yam with dried beans	Akatongo kamatekyeri nebihim	Cereal with vegetables dish	-	-	-	64.6	0.6	3.5	0.4	28.4	123.5	516.5
Yam with fresh beans	Akatongo kamatekyeri nebihim	Cereal with vegetables dish	6.2	-	-	67.9	0.6	2.8	0.3	27.3	116.6	487.8
Pumpkin with dried beans	Akatongo kamonzi nebihimba b	vegetable based dish	4.4	-	-	85.1	0.4	2.8	0.2	8.7	44.4	185.6
Pumpkin with fresh beans	Akatongo kamonzi nebihimba n	vegetable based dish	10.6	-	-	88.4	0.4	2.1	0.1	7.7	37.5	156.9
Dried beans with green leaves	Ebihimba byomiire namababi mabisi gakinyasi	vegetable based dish	1.6	-	-	71.5	1.0	6.8	0.5	15.2	87.5	366.0

Supplementary Material - Chapter 5

Construction of the female empowerment score

Variable name	**Aggregate codes used based on UDHS responses categories**
How woman's income is used	Code 1 when: the decision is taken by the woman or jointly with partner; otherwise, code 0.
How man's income is used	Code 1 when: the decision is taken by the woman or jointly with partner; otherwise, code 0.
Large household purchases	Code 1 when: the decision is taken by the woman or jointly with partner; otherwise, code 0.
Visiting family and friends	Code 1 when: the decision is taken by the woman or jointly with partner; otherwise, code 0.
Regarding own health care	Code 1 when: the decision is taken by the woman or jointly with partner; otherwise, code 0.
Woman salary similar/higher than man salary	Code 1 when: woman earns more than man, she is sole earner; otherwise, code 0.
Woman owns a land	Code 1 when: the woman or jointly with partner or alone & jointly owns a land; otherwise, code 0.
Woman owns a house	Code 1 when: the woman or jointly with partner or alone & jointly owns a house; otherwise, code 0.
Beating allowed if: 1. Goes out without telling him [male/husband]; 2. Neglects the children; 3. Argues with him [male/husband]; 4. Refuses to have sex with him [male/husband]; 5. Burns the food	Code 1 when: the woman answered to all five questions 'No'; otherwise, code 0.

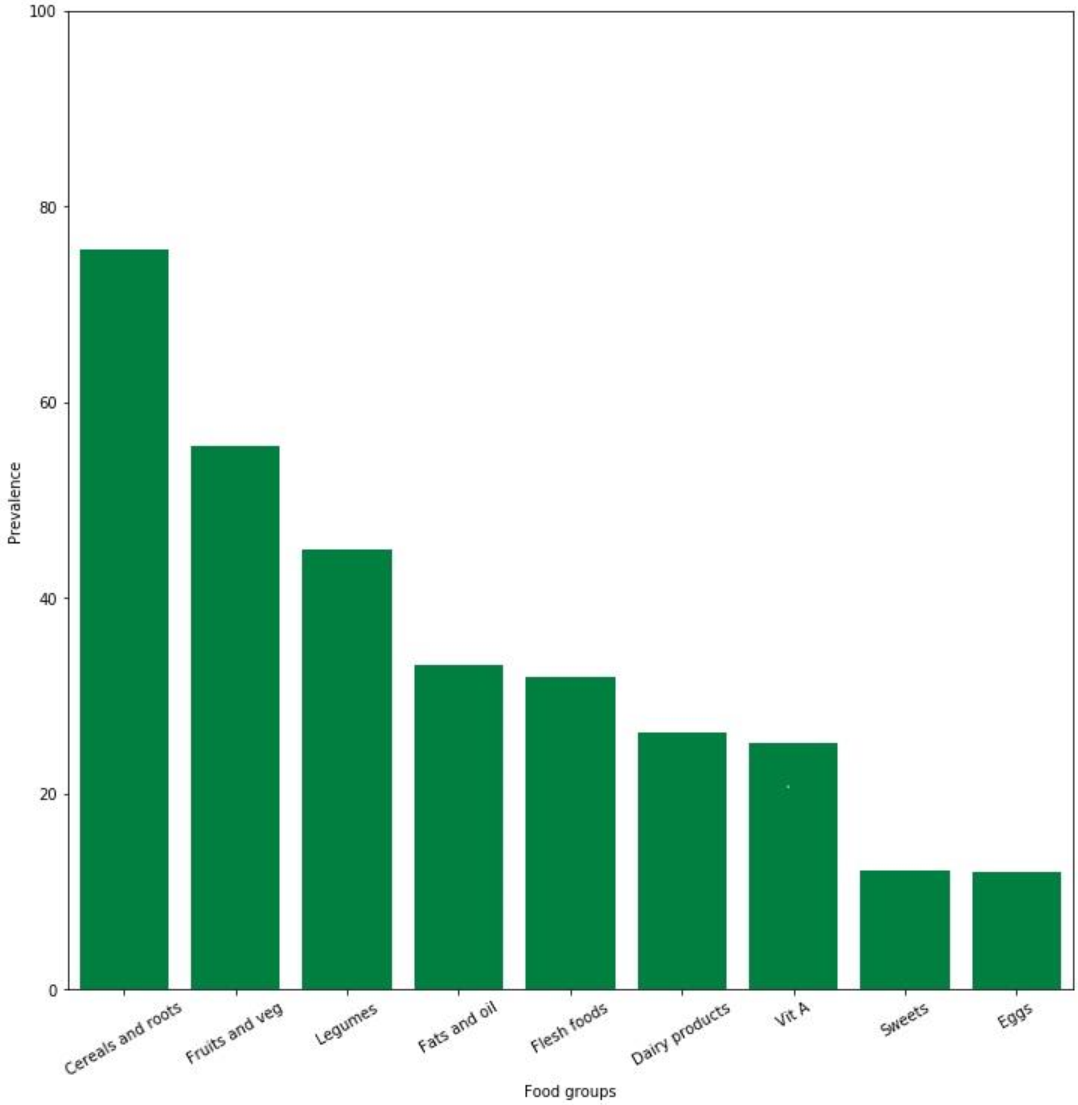
Sample characteristics of children aged 6-23 months.

	Sample N	Count (Percentage) or mean [SE]
Child characteristics		
Birth order	5485	
Firstborn		1175 (21%)
Second to fourth		2490 (45%)
Fifth and more		1820 (33%)
Birth interval (months)	5393	
Firstborn		1175 (22%)
<24		1030 (19%)
>=24		3188 (59%)
Perceived birth weight/size	5485	
Smaller than average		1342 (25%)
Average		2710 (49%)
Larger than average		1336 (24%)
Unknown		97 (2%)
Received Vitamin A in the past 6 months	5148	3291 (64%)
Received iron pills, sprinkles or syrup in the last 7 days	5148	386 (8%)
Maternal characteristics		
Age (years)	5485	
15-24		2268 (41%)
25-34		2266 (41%)
35-49		951 (17%)
Delivered at health facility	5485	4198 (77%)
Type of delivery assistance	5485	
Health professional		4198 (77%)
Traditional birth attendant		1206 (22%)
Other		81 (2%)
Caesarean Delivery	5457	401 (7%)
Occupation	4670	
Not working		158 (3%)
Manual work		3453 (74%)
Non-manual work		1059 (23%)

Currently married or living with a partner	5485	4673 (89%)
Exposure to media: at least once a week	5485	
Reading newspaper		337 (6%)
Listening to radio		2994 (55%)
Watching TV		828 (15%)
Ethnicity	4707	
Bantu		2771 (59%)
Nilotics		804 (17%)
Nile Hermits		756 (16%)
Sudanics		248 (5%)
Other		128 (3%)
Religion	5485	
Anglican		1635 (30%)
Catholic		2282 (42%)
Muslim		748 (14%)
Other religion		820 (15%)
Slept last night under mosquito net	5485	3808 (70%)
Paternal characteristics		
Age (years)	4673	
15-24		599 (13%)
25-34		2100 (45%)
>=35		1974 (42%)
Highest educational level	4550	
No education		433 (10%)
Primary		2488 (55%)
Secondary or higher		1629 (36%)
Occupation	4661	
No occupation		149 (3%)
Manual work		3453 (74%)
Non-manual work		1059 (23%)
Household characteristics		
Female household head	5485	1269 (23%)
No. of household members	5485	6.1 [2.8]
No. of children under 5	5485	1.9 [0.9]

Types of cooking fuel	5485	
Electricity, LPG, natural gas, biogas		17 (0.3%)
Wood, straw/shrubs/grass, animal dung and other		5468 (99%)
Unimproved source of drinking water	5485	1166 (21%)
Source for water not in own dwelling or yard/plot	4263	4818 (96%)
Time to get to water source (min)	4707	
0 min		3 (0.1%)
1-59 mins		3097 (57%)
>= 60 mins		2385 (44%)
Unimproved toilet facility	4707	3673 (67%)
Shared toilet with other households	4240	2082 (44%)

Percentage of frequency of foods eaten by children in the previous 24 hours.



Sensitivity analysis: results from MICE imputation and complete case-analysis for all ages with a)models for MMF and b)for MDD indicators.

a) Models for MMF

	MICE imputation								Complete case-analysis							
MINIMUM MEAL FREQUENCY	**UNADJUSTED**				**ADJUSTED**				**UNADJUSTED**				**ADJUSTED**			
All ages	**OR (95% CI)**			**p value**	**OR (95% CI)**			**p value**	**OR (95% CI)**			**p value**	**OR (95% CI)**			**p value**
Vaccination status																
Not vaccinated	1				1				1				1			
Partially vaccinated	2.91 (2.28-3.72)	2.28	3.72	<0.001	2.45 (1.89-3.17)	1.89	3.17	<0.001	0.89 (0.55-1.45)	0.55	1.45	0.65	0.87 (0.53-1.42)	0.53	1.42	0.57
Fully vaccinated	4.04 (3.15-5.19)	3.15	5.19	<0.001	3.26 (2.48-4.28)	2.48	4.28	<0.001	1.02 (0.63-1.66)	0.63	1.66	0.94	0.95 (0.58-1.57)	0.58	1.57	0.85
Female empowerment																
Very low female empowerment	1				1				1				1			
Low female empowerment	1.08 (0.94-1.25)	0.94	1.25	0.3	1.08 (0.93-1.25)	0.93	1.25	0.29	1.07 (0.88-1.30)	0.88	1.30	0.50	1.06 (0.87-1.29)	0.87	1.29	0.57
Medium female empowerment	1.03 (0.87-1.21)	0.87	1.21	0.75	1.07 (0.91-1.27)	0.91	1.27	0.41	0.97 (0.79-1.20)	0.79	1.20	0.81	1.02 (0.82-1.27)	0.82	1.27	0.84
High female empowerment	0.84 (0.63-1.13)	0.63	1.13	0.25	0.90 (0.67-1.22)	0.67	1.22	0.51	0.72 (0.51-1.01	0.51	1.01	0.06	0.78 (0.55-1.11)	0.55	1.11	0.17
Wealth index																
First wealth percentile	1				1				1				1			
Second wealth percentile	1.34 (1.13-1.59)	1.13	1.59	<0.001	1.31 (1.10-1.56)	1.10	1.56	0.003	1.40 (1.14-1.72)	1.14	1.72	0.001	1.31 (1.06-1.62)	1.06	1.62	0.01
Middle wealth percentile	1.30 (1.09-1.55)	1.09	1.55	0.004	1.25 (1.04-1.51)	1.04	1.51	0.01	1.43 (1.15-1.77)	1.15	1.77	0.001	1.33 (1.07-1.66)	1.07	1.66	0.01
Fourth wealth percentile	1.45 (1.20-1.75)	1.20	1.75	<0.001	1.43 (1.17-1.76)	1.17	1.76	<0.001	1.74 (1.37-2.22)	1.37	2.22	<0.001	1.62 (1.26-2.10)	1.26	2.10	<0.001
Highest wealth percentile	1.43 (1.19-1.72)	1.19	1.72	<0.001	1.51 (1.18-1.92)	1.18	1.92	<0.001	2.08 (1.53-2.84)	1.53	2.84	<0.001	2.13 (1.49-3.03)	1.49	3.03	<0.001
Health status																
Not sick	1				1				1				1			
Sick	1.47 (1.30-1.66)	1.30	1.66	<0.001	1.25 (1.10-1.43)	1.10	1.43	<0.001	1.09 (0.93-1.29)	0.93	1.29	0.28	1.09 (0.93-1.29)	0.93	1.29	0.29

b) Models for MDD

				MICE imputation								Complete case-analysis				
MINIMUM DIETARY DIVERSITY	**UNADJUSTED**				**ADJUSTED**				**UNADJUSTED**				**ADJUSTED**			
All ages	**OR (95% CI)**			**p value**	**OR (95% CI)**			**p value**	**OR (95% CI)**			**p value**	**OR (95% CI)**			**p value**
Vaccination status																
Not vaccinated	1				1				1				1			
Partially vaccinated	4.28 (2.95-6.19)	2.95	6.19	<0.001	4.14 (2.82-6.06)	2.82	6.06	<0.001	1.59 (0.95-2.66)	0.95	2.66	0.08	1.51 (0.89-2.56)	0.89	2.56	0.13
Fully vaccinated	3.83 (2.63-5.56)	2.63	5.56	<0.001	3.97 (2.68-5.88)	2.68	5.88	<0.001	1.22 (0.73-2.06)	0.73	2.06	0.45	1.26 (0.74-2.15)	0.74	2.15	0.39
Female empowerment																
Very low female empowerment	1				1				1				1			
Low female empowerment	0.98 (0.85-1.14)	0.85	1.14	0.8	1.00 (0.86-1.17)	0.86	1.17	0.95	1.01 (0.83-1.23)	0.83	1.23	0.89	1.04 (0.85-1.26)	0.85	1.26	0.72
Medium female empowerment	0.97 (0.82-1.15)	0.82	1.15	0.75	1.12 (0.94-1.33)	0.94	1.33	0.22	1.02 (0.83-1.26)	0.83	1.26	0.83	1.15 (0.92-1.43)	0.92	1.43	0.22
High female empowerment	0.73 (0.53-1.02)	0.53	1.02	0.06	0.92 (0.66-1.28)	0.66	1.28	0.61	0.83 (0.57-1.19)	0.57	1.19	0.31	1.01 (0.69-1.47)	0.69	1.47	0.95
Wealth index																
First wealth percentile	1				1				1				1			
Second wealth percentile	1.43 (1.18-1.73)	1.18	1.73	<0.001	1.34 (1.11-1.63)	1.11	1.63	0.03	1.39 (1.11-1.73)	1.11	1.73	0.004	1.27 (1.01-1.59)	1.01	1.59	0.04
Middle wealth percentile	1.54 (1.27-1.87)	1.27	1.87	<0.001	1.44 (1.17-1.76)	1.17	1.76	<0.001	1.63 (1.30-2.05)	1.30	2.05	<0.001	1.49 (1.18-1.87)	1.18	1.87	<0.001
Fourth wealth percentile	2.03 (1.66-2.47)	1.66	2.47	<0.001	1.80 (1.45-2.22)	1.45	2.22	<0.001	2.25 (1.77-2.85)	1.77	2.85	<0.001	1.96 (1.53-2.53)	1.53	2.53	<0.001
Highest wealth percentile	2.51 (2.06-3.04)	2.06	3.04	<0.001	2.02 (1.57-2.59)	1.57	2.59	<0.001	3.00 (2.26-3.98)	2.26	3.98	<0.001	2.53 (1.83-3.51)	1.83	3.51	<0.001
Health status																
Not sick	1				1				1				1			
Sick	1.34 (1.18-1.54)	1.18	1.54	<0.001	1.25 (1.08-1.44)	1.08	1.44	0.002	1.05 (0.89-1.24)	0.89	1.24	0.55	1.09 (0.92-1.29)	0.92	1.29	0.33

Supplementary material - Chapter 6

Focus group discussions guide questions

The questions in bold are the main ones, while the others can be asked (if necessary) to define better the main question.

i **Where do mothers get information on breastfeeding? And on complementary feeding?** Who helps mothers to learn about breastfeeding? And weaning? Do you know if there are specific courses on breastfeeding from the hospital or any other organization (e.g. NGOs) offered to any woman during pregnancy? And for weaning? Which are the courses? What do you know about HIV and breastfeeding?

ii **What determines whether a mother breastfeeds or not?** What are the reasons women in your community decide to breastfeed or not? Who? How soon after birth would a woman in your community breastfeed the baby? Is there anyone else breastfeeding the baby instead of the mother? Who?

iii **Does weather or environment affect breastfeeding or weaning?** Are there specific seasons in the year when breastfeeding or weaning are easier? Why? Are the foods used for complementary feeding different from years ago? What do you use instead now? Why? In your opinion, does this change have an impact on child growth? Why?

iv **Do you ever have problems with breastfeeding? And with complementary feeding?** Do you think some women cannot breastfeed their babies? Why? Can breastmilk not be enough for the baby? Why? If you feel you do not have enough breastmilk, what can you do to produce more? What are the barriers that could limit breastfeeding (e.g. do mothers eat enough?)? Who helps the mother during breastfeeding?

v **Is there anything that help or would help mothers with breastfeeding?** Is there anything that would help mothers breastfeed longer?

vi **When do mothers usually wean their babies?** Does a baby usually receive any other liquids (e.g. water, milk, etc.) other than breastmilk? Which ones?

Is there any special food eaten during the breastfeeding period? If so, what foods? When does usually a baby start to eat solid food? What are the first solid foods? Is there anyone else feeding the baby instead of the mother? Who? What are the barriers that could limit an appropriate weaning? Is there anything that would help mothers in having more knowledge on complementary feeding/weaning practices?

vii **Do you worry about your infants being malnourished?** Do you think there are malnourished infants in your community? How do you recognise them? What should the mother do if the child is malnourished?

Individual interviews guide questions

1. What is your ethnicity?
2. What is your age? (maternal age)
3. What age is your baby?
4. Is this your first baby?
5. If no, how many other babies have you had?
6. Do you have any twins?
7. What is your age?
8. What do you do during the day to find food or earn a wage?
9. Do you bring your child with you everywhere you go (e.g. work place, farm, etc.)?
10. Are you allowed to breastfeed your child when working? Do you breastfeed him/her at work?
11. Do you receive food from any NGOs/government?
12. Does your household own any animals? Any lands?
13. Do you have a toilet/latrine?
14. Do you have access to soap?
15. Do you have running water?
16. When do you wash your hands?

17. Where was your baby born (Hospital/Home/health centre)?
18. How was your delivery (vaginal/ c-section)?
19. Any complications during the delivery? If so, explain it please.
20. Have you ever breastfed this baby? For how long?
21. Were you and/or your baby sick at birth?
22. Was your baby sick in the first 6 months of life?
23. If s/he was sick, what did she/he have, if you know? (For example: fever, diarrhoea, vomiting, respiratory problems, skin problems, oedema, very thin, big belly (signs for malnutrition), worms, eyes problems, constipation, urinary problems, malaria…)

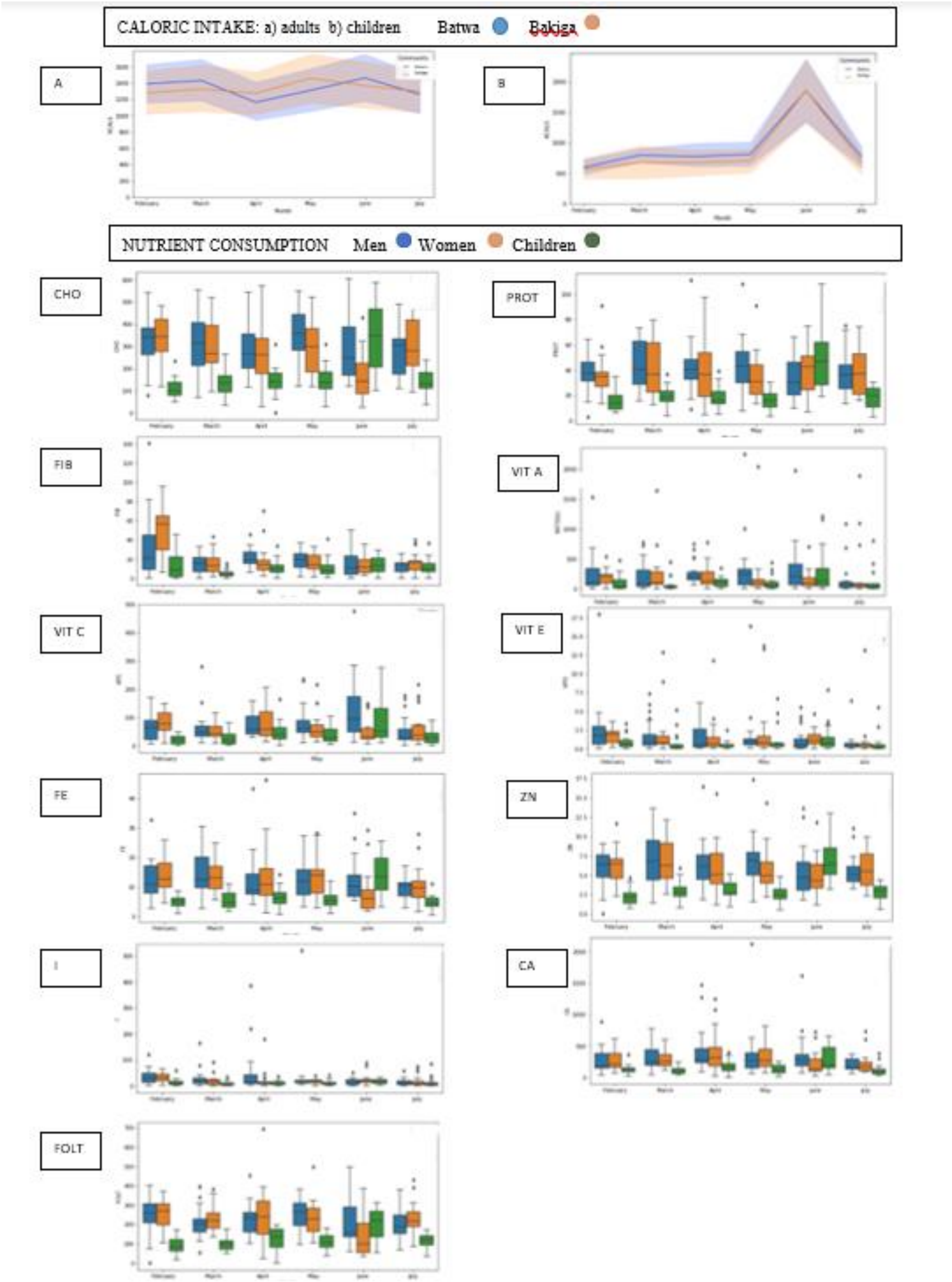
Supplementary material - Chapter 7

Tab.: Number of participants (children, women and men) who met the dietary requirements over the six months period.

Months	**Nutrients**	**CHILDREN**		**WOMEN**		**MEN**		**TOTAL** (of those meeting nutritional requirements)	
		Batwa (n=10)	*Bakiga (n=10)*	*Batwa (n=10)*	*Bakiga (n=10)*	*Batwa (n=10)*	*Bakiga (n=10)*	*Batwa (n=30)*	*Bakiga (n=30)*
February	*Kcals*	0	2	2	0	1	0	3	2
	Protein	4	6	2	1	3	0	9	7
	Iron	0	3	1	4	2	5	3	12
	Vitamin A	1	0	0	0	1	1	2	1
	Zinc	1	1	4	0	5	3	10	4
	Iodine	0	0	0	0	0	0	0	0
	Calcium	0	0	0	0	0	0	0	0
	Folate	2	4	0	0	0	1	2	5
	Vitamin C	0	1	8	5	4	7	12	13
March	*Kcals*	5	3	2	1	1	3	8	7
	Protein	9	7	4	3	4	4	17	14
	Iron	3	3	2	4	3	5	8	12
	Vitamin A	0	1	0	1	1	1	1	3
	Zinc	0	2	3	2	5	4	8	8
	Iodine	0	0	0	0	1	0	1	0
	Calcium	0	0	0	0	0	0	0	0
	Folate	1	2	0	0	0	0	1	2
	Vitamin C	0	5	4	2	5	6	9	13
April	*Kcals*	2	5	1	1	0	1	3	7
	Protein	8	8	2	4	2	1	12	13
	Iron	5	3	1	4	2	3	8	10
	Vitamin A	0	0	1	0	2	0	3	0
	Zinc	2	2	2	1	3	4	7	7
	Iodine	0	0	0	0	1	1	1	1
	Calcium	0	0	0	2	1	1	1	3
	Folate	4	6	0	1	0	1	4	8
	Vitamin C	0	3	7	1	7	6	14	10
May	*Kcals*	5	4	2	1	1	4	8	9
	Protein	6	9	1	2	0	4	7	15

	Iron	3	2	1	5	3	4	7	11
	Vitamin A	1	0	0	1	0	2	1	3
	Zinc	1	2	3	1	4	6	8	9
	Iodine	0	0	0	0	0	1	0	1
	Calcium	0	0	0	0	0	1	0	1
	Folate	3	6	0	0	0	0	3	6
	Vitamin C	0	1	5	1	7	10	12	12
June	*Kcals*	7	9	0	0	1	1	8	10
	Protein	10	10	4	2	1	1	15	13
	Iron	7	8	0	1	2	3	9	12
	Vitamin A	3	2	0	0	1	1	4	3
	Zinc	9	9	3	1	2	3	14	13
	Iodine	0	0	0	0	0	0	0	0
	Calcium	2	4	0	0	0	1	2	5
	Folate	6	9	0	0	0	2	6	11
	Vitamin C	0	7	3	2	7	9	10	18
July	*Kcals*	4	5	2	0	0	2	6	7
	Protein	7	6	3	4	0	2	10	12
	Iron	2	3	0	3	0	3	2	9
	Vitamin A	11	1	1	1	1	1	13	3
	Zinc	0	2	4	0	1	2	5	4
	Iodine	0	0	0	0	0	0	0	0
	Calcium	0	0	0	0	0	0	0	0
	Folate	2	5	0	0	0	0	2	5
	Vitamin C	0	5	4	2	3	3	7	10

Fig: Nutrients intake among children (green), women (orange) and men (blue) across months. In Fig A and B they grey area represents where the blue error bar and the orange error bar for the two ethnicities overlaps.


CALORIC INTAKE: a) adults b) children
Batwa
Bakiga
A
B
NUTRIENT CONSUMPTION
Men
Women
Children
CHO
PROT
FIB
VIT A
VIT C
VIT E
FE
ZN
I
CA
FOLT

Tab.: Mean difference between highest and lowest monthly intake estimates with CI for Batwa and Bakiga a) adults & b) children. The percentage was calculated over the lower value (value corresponding to the lowest intake of each nutrient).

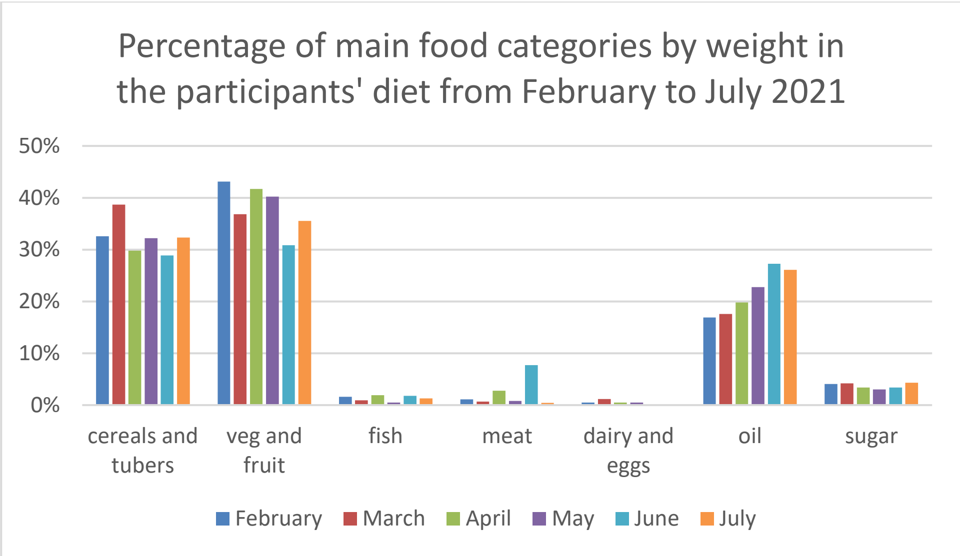
a) *Adults' nutrient intake*

Nutrients	*BATWA WOMEN*: Mean for the ↑ min and ↓ max intake	*% Difference (95% CI)*	*BAKIGA WOMEN*: Mean for the ↑ min and ↓ max intake	*% Difference with (CI)*	*BATWA MEN*: Mean for the ↑ min and ↓ max intake	*% Difference with (CI)*	*BAKIGA MEN*: Mean for the ↑ min and ↓ max intake	*% Difference with (CI)*
Carbohydrate g/d	↑ 344.6 ↓ 185.5	67% (57-76)	↑ 340.0 ↓ 158.7	74% (64-84)	↑ 357.2 ↓ 282.2	64% (53-74)	↑ 367.9 ↓ 274.9	65% (58-73)
Fat g/d	↑ 30.0 ↓ 13.3	83% (74-91)	↑ 35.6 ↓ 18.3	85% (80-90)	↑ 33.4 ↓ 16.2	89% (84-95)	↑ 33.2 ↓ 14.4	87 % (81-92)
Protein g/d	↑ 42.6 ↓ 30.2	71% (62-80)	↑ 43.8 ↓ 35.0	70% (64-77)	↑ 48.0 ↓ 32.5	76% (71-80)	↑ 50.4 ↓ 31.3	69 % (60-77)
Fibre g/d	↑ 48.5 ↓ 13.8	85% (78-92)	↑ 50.0 ↓ 14.0	88% (83-93)	↑ 24.8 ↓ 11.2	83 % (73-92)	↑ 43.0 ↓ 12.4	90% (84-961)
Iron mg/d	↑ 13.5 ↓ 8.8	71% (64-78)	↑ 17.7 ↓ 6.8	84% (76-92)	↑ 14.6 ↓ 9.4	61% (54-69)	↑ 15.3 ↓ 10.3	73% (66-80)
Vitamin A mcg/d	↑ 228.8 ↓ 98.0	91 % (83-98)	↑ 326.0 ↓ 183.8	93% (89 -97)	↑ 345.8 ↓ 161.6	91% (82-101)	↑ 471.0 ↓ 147.3	95% (93-97)
Zinc mg/d	↑ 6.6 ↓ 4.8	65% (57-72)	↑ 7.0 ↓ 4.6	68% (61-75)	↑ 7.6 ↓ 5.0	72% (66-78)	↑ 8.1 ↓ 5.0	71 % (63-79)
Iodine mcg/d	↑ 34.3 ↓ 10.9	85% (76.-93)	↑ 32.1 ↓ 18.5	86% (80-92)	↑ 66.4 ↓ 11.0	89% (82-95)	↑ 63.5 ↓ 14.9	92% (89 -95)
Calcium mg/d	↑ 274.8 ↓ 140.3	76% (70-82)	↑ 537.0 ↓ 164.4	85% (79 -90)	↑ 418.8 ↓ 166.0	74% (65-83)	↑ 487.9 ↓ 234.8	78% (69-87)
Folate mcg/d	↑ 241.2 ↓ 150.5	61% (48-75)	↑ 269.3 ↓ 115.9	81% (72-89)	↑ 246.5 ↓ 177.6	55% (47-63)	↑ 274.5 ↓ 217.6	709% (62-78)
Vitamin C mg/d	↑ 124.5 ↓ 53.7	88% (84-93)	↑ 77.8 ↓ 43.1	79.% (72-86)	↑ 109.9 ↓ 53.2	86% (75-96)	↑ 140.7 ↓ 49.3	82% (77-87)
Vitamin E mg/d	↑ 2.2 ↓ 0.3	89% (83-96)	↑ 2.3 ↓ 1.2	86% (79-93)	↑ 3.2 ↓ 0.4	95% (92-98)	↑ 2.9 ↓ 1.1	94% (89-98)

b) *Children's nutrient intake*

Nutrients	*BATWA CHILDREN*: Mean for the ↑ min and ↓ max intake	*% Difference with CI*	*BAKIGA CHILDREN*: Mean for the ↑ min and ↓ max intake	*% Difference with CI*
Carbohydrate g/d	↑ 158.4 ↓ 115.4	68 % (58-78)	↑ 141.4 ↓ 110.5	82% (73 -90)
Fat g/d	↑ 97.4 ↓ 18.3	87% (83-91)	↑ 15.8 ↓ 9.2	91% (88-94)
Protein g/d	↑ 32.5 ↓ 15.2	80% (74-85)	↑ 19.9 ↓ 15.1	80% (74-87)
Fibre g/d	↑ 16.5 ↓ 5.9	82% (75-88)	↑ 13.7 ↓ 4.3	93% (89-97)
Iron mg/d	↑ 6.2 ↓ 4.1	75% (66-83)	↑ 6.9 ↓ 5.0	83% (76-89)
Vitamin A mcg/d	↑ 161.5 ↓ 33.2	95% (92-98)	↑ 135.0 ↓ 50.6	97% (96-99)
Zinc mg/d	↑ 3.8 ↓ 2.2	75% (69-81)	↑ 3.1 ↓ 2.3	78% (71-85)
Iodine mcg/d	↑ 12.5 ↓ 7.4	86% (79-92)	↑ 20.5 ↓ 9.3	89.1% (83-94)
Calcium mg/d	↑ 161.5 ↓ 74.0	76% (69-83)	↑ 191.1 ↓ 94.2	86% (80-91)
Folate mcg/d	↑ 137.3 ↓ 89.4	65% (59-71)	↑ 117.0 ↓ 93.9	78% (70-86)
Vitamin C mg/d	↑ 73.1 ↓ 23.6	89% (85-94)	↑ 32.6 ↓ 14.3	90% (83-98)
Vitamin E mg/d	↑ 1.8 ↓ 0.4	95% (91-99)	↑ 1.0 ↓ 0.4	94% (90-97)

Fig.: Percentage of main food categories by weight in the participants' diet from February to July 2021.



Tab : Reported diet change and food availability/access to markets/shops from March 2020.

Variable	***Count adults (Percentage)***
Reported loss of taste or smell in the last month:	
Yes	10 (25)
No	30 (75)
Reported a change in the diet during Covid-19 time	
Yes	23 (57)
No	16 (40)
Difficult to say	1 (3)
Access to shops during Covid-19	
Yes	35 (87)
No	5 (13)
Access to markets during Covid-19	
Yes	27 (67)
No	13 (33)
Consumption of same food available pre-pandemic	
Yes	17 (43)
No	23 (57)
Help from humanitarian organizations to provide food	
Yes	20 (50)
No	20 (50)