Integrated Development Program Discussion Paper 3

Effects of dietary change

Synthesis across the case studies

Gideon Kruseman
Khondoker Mottaleb
Aymen Frija
Sika Gbegbelegbe
Subir Bairagi
Marco Springmann

CIMMYT
International Maize and Wheat Improvement Center

CGIAR RESEARCH PROGRAM ON Policies, Institutions, and Markets
Led by IFPRI

CGIAR

Integrated Development Program Discussion Paper 3

Effects of dietary change

Synthesis across the case studies

Principal Investigator

Gideon Kruseman

CIMMYT

Co-Investigators

Khondoker Mottaleb (CIMMYT)

Sika Gbegbelegbe (IITA)

Aymen Frija (ICARDA)

Subir Bariagi (University of Arkansas)

Marco Springmann (Oxford University)

The International Maize and Wheat Improvement Center (CIMMYT) is a non-profit international agricultural research and training organization. CIMMYT focuses on sustainable agri-food systems and improved livelihoods through research on maize, wheat and other food crops.

Applying high-quality science and strong partnerships, CIMMYT works for a world with healthier and more prosperous people, free from global food crises and with more resilient agri-food systems. Its research brings enhanced productivity and better profits to farmers, mitigates the effects of the climate crisis, and reduces the environmental impact of agriculture.

CIMMYT is a member of CGIAR, a global research partnership for a food secure future dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources.

Citation information
Kruseman G, Mottaleb KA, Frija A, Gbegbelegbe S, Bairagi S, Springmann M. 2021. Effects of dietary change - Synthesis across the case studies. Integrated Development Program Discussion Paper no. 3. El Batan, Texcoco, Mexico: International Maize and Wheat Improvement Center CIMMYT. 13 Pages.

Support

Financial support
This study was part of a project on supported by the CGIAR Research Program (CRP) for Policies, Institutions and Markets (CRP PIM) as part of the cluster of activities 1.1.1. The project name is “Effects of dietary change on the future demand for major cereals”. The project was also supported by the CRP Maize, CRP Wheat and CRP Rice through the co-funding of this project.

Declaration of interest statement

The authors declare no conflicts of interest in the publication of this research.

Purpose of the series

CIMMYT's *Integrated Development Program Discussion Paper* series publishes preliminary research results and study protocols prior to finalizing them for submission as peer-reviewed journal articles. The discussion papers are intended to solicit discussion and comments from stakeholders and peers to improve the quality of the research outputs.

The papers contain preliminary material and research results and are circulated in order to stimulate discussion and critical comment. They have not been subject to a formal external review. Any opinions stated herein are those of the author(s) and are not necessarily representative of or endorsed by CIMMYT.

Reports

001 Springmann M. 2021. Dietary adaptation mechanisms to the potential health impacts of climate related changes in micronutrients in wheat and other cereals

002 Mottaleb KA et al. 2021. Wheat Consumption Dynamics in Selected Countries in Asia and Africa: Implications for Wheat Supply by 2030 and 2050

003 Kruseman G et al. 2021. Effects of dietary change - Synthesis across the case studies

004 Amjath-Babu TS et al. 2021. Hard and Soft Climate Smart Investment in Aquaculture: Conditioning factors and decision space in a developing country context

005 Jones-Garcia E et al. 2021. Emotion classification and sentiment analysis for sustainable agricultural development; exploring available tools for analyzing African farmer interviews

006 Chamberlin J and Sumberg J.2021. Do young farmers farm differently? Evidence from sub-Saharan Africa

007 Chamberlin J. 2021. Life satisfaction of rural young people in Tanzania

Contents

Abstract

Dietary shifts such as preference from cereals toward animal proteins may reshape the global food system in the future. The food system changes may threaten the environment, changing land-use patterns and increasing GHG emissions. Therefore, a sustainable food system is needed for supplying future food demand. However, there is a gap in the food demand literature that foresee the likely composition of a future global food basket. This study fills this gap by quantifying the future trend in dietary change and its effects. It combines the insights from several case studies. The focus of these case studies were partly on trend analysis and partly on identifying the determinants and levels of key demand elasticities. The latter is crucially important as demand elasticities drive many quantitative foresight models. Several key insights stand out from this study: (i) although per capita consumption of global staple cereals is likely to decline in many countries, total demand will increase, (ii) higher demand for animal protein worldwide is expected, (iii) increased demand for quality and healthy food, and (iv) a heterogeneous reorientation of future food basket is likely, varying from Asian to African countries. The results from our study can guide policymakers to design policies that improve sustainable food production and align with increased diversified diets.

Preface

The PIM-initiated and CIMMYT-led project “Effects of dietary change on the future demand for major cereals” was a collaborative effort across the CGIAR involving researchers from CIMMYT, ICARDA, IITA, IRRI and IFPRI as well as a CRP Wheat funded contribution by Oxford University.

The objective of this project was to determine consumption pattern changes, linked to the relevant global drivers of change in some key countries. This allowed the team to explore expected changes in demand under different scenarios (urbanization, population, prices). Dietary change was analyzed according to rural-urban axis. The team used the case studies to provide well-documented examples of actual and potential dietary change.

The insights gleaned from these studies is of crucial importance for technology development for major cereals as well as providing insights into the expected pathways related to the One CGIAR impact area of nutrition and health.

Sieglinde Snapp

Director CIMMYT Integrated Development Program

1. Introduction

In foresight and ex-ante analysis, drivers of change are crucial for explaining “what if” scenarios. A number of key factors (global drivers of change, pressures, and events) shape both the future farming and consumer demand around the globe as well as the context in which they will operate. To ensure food and nutrition security, both the supply-side and the demand-side indicators are important to consider and should be well-balanced. The primary global drivers of change are climate change, demographic and economic developments. Secondary drivers of change related to the first drivers include urbanization, technological convergence, and changing political ambitions. Pressures that are the result of these global drivers include health-related issues such as enduring chronic malnutrition on one side and obesity on the other side of the spectrum, and unequal wealth and income distribution. The above-mentioned drivers, pressures, and events could force farmers, consumers, civil societies, and policymakers to reassess priorities and interventions. In the proposed study, drivers of change, pressures, and events will be analyzed separately. Within international agricultural research for development settings, the emphasis has been placed heavily on the supply-side of food security interventions. However, under the new CRP (CGIAR research program) system, research programs have shifted their focus more towards agri-food systems. This is because previously the demand-side drivers were mostly overlooked whereas more emphasis was given on the supply-side indicators. Diets are changing and will continue to change with the changes in income, demography, lifestyle, and climate. For example, in the case of maize, this results in a shift in the relative importance of the commodity for human consumption compared to animal feed. In the case of wheat, for instance, we see a marked rise in demand in societies where wheat is historically not the staple food. Moreover, gaps between economic value and nutritional value could result from contextual factors that shape the decision-making of food systems actors, related to policy, regulation, governance, or even perceptions of policymaker incentives. Urbanization trends and overall economic development will usher dietary change for both urban and rural consumers, although the nature of such changes has not been well explored to date (Tschirley et al., 2015).

Recent studies have looked into existing and potential diets and the associated impacts, including for health, environment and society (Hedenus et al., 2014; Jalava et al., 2014; Fanzo, 2015; Schader et al., 2015; de Boer et al., 2016; Springmann et al., 2016; BMGF and UKAID, 2017). Resources available in terms of land, fresh-water and key nutrients such as phosphate are becoming more scarce. An added environmental aspect of consumption patterns are the direct and indirect effects of consumption on greenhouse gas (GHG) emissions.

Currently the major (cereals, rice, wheat and maize) account for more than half of the total caloric intake globally and these cereals are the primary source of dietary energy in the low-income countries (FAO et al., 2015). The importance of these major cereals is expected to grow in the future. However, understanding the patterns of dietary change is extremely important in order to prioritize research and development efforts to ensure that both quantitative and qualitative malnutrition decreases over time.

However, the current area of arable land dedicated to the production of cereals world-wide dominates other agricultural land uses. Understanding how cereal demand is likely to develop over the next decades is therefore not a trivial matter. Global integrated assessment models such as IMPACT, GLOBIUM and MAGNET tend to use static demand elasticities in terms of income elasticities and price elasticities. Often these elasticities are taken from literature and can at times date back many years.

An update of elasticities of demand is therefore warranted. To do so two different approaches can be used. The first is a top-down macro-level approach where over time apparent demand for cereals is linked to trends in income, prices, and other key determinants of consumption such as urbanization. The second approach is a more bottom-up approach, where these same aspects are studied at a more granular level. The latter approach is more data intensive than the former, which generally relies on national level statistics, while the latter requires household level expenditure data as well as key information related to drivers of change. The comparison of the outcomes of the two approaches can help determine how demand elasticities in foresight models can and should be updated.

In an effort to contribute this area, in 2018, the CGIAR research program (CRP) on Policies, Institutions and Markets (PIM) in its cluster of activities on foresight which was part of the flagship program on "*Technological Innovation and Sustainable Intensification*" organized a series of studies on future demand of key commodities. As part of that endeavor, a project was undertaken to study the effects of dietary change on the future demand for major cereals. The overall objective of the study was to examine consumption pattern changes, linked to the relevant global drivers of change in some key countries. This allowed us to explore expected changes in demand under different scenarios (urbanization, population, prices). Dietary change was analyzed according to the rural-urban axis, for separate sub-national regions depending on context. We used the case studies to provide well-documented examples of current and potential dietary changes. The purpose of this discussion paper is to provide a synthesis of this research as well as some related studies.

In Chapter two, we discuss the different analytical approaches used to explore the future demand for major cereals. In Chapter three we provide brief background information on some of the specific geographies targeted in our studies. In Chapter 4 we highlight the main results of the case studies and in Chapter 5 we draw some overall conclusions and identify further steps for research.

2. Methods employed for analyzing cereals demand

2.1. Overview

Empirical based statistical regression models have been used extensively to analyze consumption demand. This body of work has focused on explaining and understanding current or past consumption patterns, using cross-sectional data. Whereas the focus of our studies is on changing demand as we look towards the future. Starting point for the micro-level analysis were two studies conducted with a focus on wheat (Mottaleb et al., 2018b, 2018a) and some work done in advising the Mexican government on future developments in the maize sector (Govaerts et al., 2019). For that purpose, the foresight team at CIMMYT developed a simulation model based on econometrically estimated structural equations that captured trends in maize consumption using household expenditure data linking the outcomes with key parameters that play a role in future scenarios: income levels and urbanization. The underlying logic is based on the notion that if you are able to identify a link between key drivers, impacts or responses of change for which there are future projections, you can also provide insights into the changes in demand. The key requirement is the ability to link the key change indicators to the level of analysis.

For projecting future demand, in general, either national or global agricultural sector or economy-wide models are deployed using quantitative methods offer insight into general developments in supply and demand (Hubert et al., 2010; Tilman et al., 2011; Robinson et al., 2015; Brooks and Place, 2019). One of these approaches is embodied in the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model of the global agricultural economy (Robinson et al., 2015). Foresight models, such as the IMPACT model, take changing consumption into consideration in an endogenous manner. This is done through a series of income and price elasticities at national level. The underlying logic is that these overall elasticities capture in the aggregate the intricacies of elasticities at lower levels of aggregation.

One of the ways to determine these underlying elasticities is through trend analysis. In trend analysis the long-term changes in demand are analyzed, often using time series analysis methods.

As part of the study to get a better understanding of the changing demand of major cereals various methodologies were used falling into this array of approaches just highlighted. In the following paragraphs the different approaches will be described and discussed briefly

2.1. IMPACT model

In the IMPACT model consumer demand for commodities is modeled with exogenous price and income elasticity parameters (Robinson et al., 2012). The IMPACT demand elasticities are originally based on United States Department of Agriculture–estimated elasticities and adjusted to represent a synthesis of average, aggregate elasticities for each region, given the income level and distribution of urban and rural population[1]. Over time the elasticities are adjusted to accommodate the gradual shift in demand from staples to high-value commodities like meat, especially in developing countries. This assumption is based on expected economic growth, increased urbanization, and continued

[1] The IMPACT model documentation states as reference: United States Department of Agriculture. 1998. “Commodity and Food Elasticities.” Accessed Feburary 15, 2006. http://www.ers.usda.gov/Data/Elasticities/. Unfortunately this database is no longer available. The successor database https://www.ers.usda.gov/data-products/commodity-and-food-elasticities/ , although still online, is no longer maintained.

commercialization of the agricultural sector. IMPACT treats household demand with one representative consumer per country.

Using the IMPACT model Springmann (2021) analyzed the climate-change impacts on nutrient levels in staple grains that could negatively impact mineral deficiencies amongst at-risk populations, in particular, of iron and zinc. By pairing nutritional, dietary health and dietary-scenario analyses, Springmann found that replacement of refined grains by whole grains could help compensate the climate-change-related reductions in iron and zinc concentrations in wheat, rice, maize, and improve dietary risks related to low wholegrain/fibre intake. A more comprehensive dietary-change strategy of adopting healthy and sustainable diets would impart further nutritional and health benefits, whilst also contributing to climate-change mitigation (Springmann, 2021).

The impact model is a partial equilibrium model that calculates interactions across the agri-food system through elasticities. Elasticities are crucial drivers of model outcomes. In the case of demand, economic theory postulates three elasticities that influence demand: income elasticities, own-price elasticities and cross-price elasticities. In the IMPACT model income elasticities, and own-price elasticities of demand are used. The IMPACT model does not use and cross-price elasticities of demand. The demand elasticities in IMPACT are exogenous and added to the model as parameters defined over commodity, country, and year as well as households and a concept called elasticity revision. The household concept is somewhat misleading as there is only one household defined per country. Even though the elasticities are split over urban and rural households, the values are identical.

The strength of the IMPACT model is in its ability to identify the big picture interactions in agri-food systems linked to major drivers of change. Springmann (2021) concludes that climate change is expected to have detrimental impacts on food security, including on nutrient availability, due to reductions in crop yields and nutrient concentrations of crops. Production level interventions are not sufficient to address food security complementing such strategies by interventions at the consumption level could help mitigate the nutrient impacts of climate change, whilst improving dietary health and, for the case of comprehensive dietary changes towards healthy and sustainable diets, contribute to climate-change mitigation (Springmann et al., 2018). To do so the study estimated the nutrient content of foods by pairing the consumption of each food group with its nutrient density as reported in the Global Expanded Nutrient Supply (GENuS) dataset, a global dataset of nutrient supply of 23 nutrients across 225 food categories for over 150 countries (Springmann, 2021). Springmann specified two dietary adaptation scenarios to the climate change impacts on nutrient levels. The first one included a scenario in which all grains are consumed as whole grains. The GENuS dataset account for the proportion of grains consumed as whole grains and those consumed as refined one, based on regional processing estimates (Wessells et al., 2012).

2.2. Trend analysis

Using national level data, average apparent consumption of different food items can be studied. Frija (2021a) calculated the diet composition, expressed by the average per-capita food commodities consumption for 1960 and 2018 and estimated the projected values for 2050 with a focus on Asia, Sub Sahara Africa, and North Africa. The study focused on food commodities (both crop and animal) which are essential source of protein macro nutrients which constitute 50% of human body's dry weight. The study considered a wide range of both animal and crop food and calculate the level of their integration in the average daily diet of a capita in the different considered countries. Projections were conducted based on times series data (from 1961 to 2018) and using different regression

methods which have been applied depending on the data quality for a given commodity and country, to generate future consumption values up to 2050 (Frija et al., 2021a, 2021b).

2.3. Time series analysis

Two time series analysis approaches have been used on a selected number of wheat-producing countries. The first is Vector Autoregressive (VAR) model estimation procedure, the second is the Vector Error Correction (VEC) model estimation procedure. By applying a suitability analysis of the Vector Autoregressive (VAR) model estimation procedure using Johansen's cointegration test, to determine if there was co-integration of key variables. This procedure found that for many country datasets countries' variables are cointegrated, making the application of the VAR estimation procedure unsuitable. As an alternative, the Vector Error Correction (VEC) model estimation procedure was applied. This approach was applied to wheat demand in a wide variety of countries (Mottaleb et al., 2021b).

2.4. Almost ideal demand systems combined with simulation approaches

The almost ideal demand system developed by Deaton and Muelbauer in the early 1980s (Deaton and Muellbauer, 1980) has been used extensively for demand analysis over the past four decades. This approach has been used in different ways to project future demand. An extension of the almost ideal demand system is the Quadratic Almost Ideal Demand System (**QUAIDS**) (Banks et al., 1997). It considers the existence of non-linear engel curve which is not expressed in the standard almost ideal demand system. It allows the inclusion of household characteristics. By using characteristics that can be related to general trends and drivers of change, it becomes possible to use this approach for simulating future demand.

The approach used by Mottaleb et al. (2018) for estimating demand in Bangladesh is to use Household Income and Expenditure Surveys, and applying a two-stage quadratic almost ideal system estimation procedure, the study separately estimates the expenditure elasticities for rural and urban households for five food items: rice, wheat and rice and wheat products, pulses, fish and vegetables. Second, using the estimated elasticities, projected population and the per capita GDP growth rates, this study projects the consumption of the sampled food items by 2030 (Mottaleb et al., 2018b).

In modeling demand for cereals in Uganda, Mottaleb et al. (2021) followed several steps. Mottaleb et al. assumed a rational household head who allocated the daily per capita total food budget X_{UGX} to different food items in a way that maximized utility. The allocation of the daily food budget (for the household as well as per capita) can be endogenously determined by several factors.
Thus, X_{UGX} can be a function of a number of exogenous variables. The study considered a two-stage budgeting procedure, in which it is assumed that a household first decides on the per capita daily total food budget. In the next stage, a household decides how much of the daily per capita total food budget will be allocated to each of the six food items under the assumption that prices of the food items, household demographic structure, and the major source of livelihood can affect the daily per capita budget allocation to the sampled food items.

The authors applied the endogeneity-corrected Quadratic Almost Ideal Demand System (QUAIDS) estimation approach separately for rural and urban households. From the QUAIDS model, they estimated the price and expenditure elasticities for the sampled foods and then they estimated the

aggregate demand for the sampled food items considering population projections and GDP growth rates up to 2030 (Mottaleb et al., 2021a).

Gbegbelegbe and Msukwa (2019) use the approach to analyze the effects of dietary change on the future demand for major cereals in Uganda and Nigeria, focusing on the difference between urban and rural households (Gbegbelegbe and Msukwa, 2019).

Bairagi *et al.* (2020) analyze the differences in rice food consumption patterns for urban and rural households in Vietnam using the approach. They point out that there are five important lessons that can be learned from past applications of the approach. First, elasticities are important tools for designing and reforming price and food policies globally, so demand studies are growing. Second, observe a large variation in both estimated price and income elasticities are observed across countries, so one size (fiscal policy) might not fit for all. Third, if large variation in estimates originates from methodological attributes, then the right approach, quality data and more disaggregated analysis are needed for reducing potential estimation biases. This is very important because biased estimates could lead to designing inappropriate policies. Fourth, as also pointed out by Cornelsen *et al.* (2015), cross-PE is limited in the demand literature. Finally, since many poor and developing countries have been growing tremendously in recent years, updated estimates are needed with new information to reform policies for further economic development.

Finally, Bairagi (2022) also recently estimated price and expenditure elasticities for seven food categories for rural and urban Filipino households, using Stone–Lewbel (SL) price indices and the quadratic almost-ideal demand system (QUAIDS) model.

2.5. Choice-based model: rank-ordered logistic (ROL) regression

Assuming that major cereals are homogenous commodities does not do justice to the variety within the commodities and the possible implications for changing demand. Data that allows this type of analysis is scarce and at present it has not been possible to do a comparative analysis across multiple crops. However, there is a good example of disentangling the drivers of demand for fragrant rice in South and South-East Asia (Bairagi et al., 2020a) using rank-ordered logistic regression with incomplete ranking choice data.

2.6. Ad hoc demand system analysis with simulation approaches

For the analysis of cereal consumption in Mexico as part of a foresight study into the future of the maize sector, a different approach than QUAIDS was used. The basis is still utility maximization and diminishing propensities to consume as incomes rise. Using a systems of equations consumption patterns linked to income levels differentiated by urban / rural dimension across the different regions of Mexico were analyzed and used for future projections (Kruseman, 2016; Govaerts et al., 2019).

3. Target areas of the studies

The case studies can be divided into three groups.

The first group looks at global picture using broad data sets such as the FAO food balance sheets. This allows comparison across multiple countries and years. Time series analysis and trend analysis are applicable (Frija et al., 2021a; Mottaleb et al., 2021b). The focus of these studies has been on Africa and Asia.

The second group contains country-level case studies based on much more granular datasets, often for single years or a limited number of years. Food demand elasticities are estimated with cross-sectional household-level data. By focusing on structural characteristics driving demand and relating those structural characteristics to key driver of change metrics, future simulations can be done.

The second group of studies focused on the country commodity combinations. Even when other food items were considered, the focus has been on major cereals and therefore we mention only the major cereals that were the focus of the studies.

The studies covered changes in demand for wheat in Bangladesh (Mottaleb et al., 2018b, 2018a); Rice in Vietnam (Bairagi et al., 2020b); Maize in Nigeria (Gbegbelegbe and Msukwa, 2019); Maize in Uganda (Gbegbelegbe and Msukwa, 2019; Mottaleb et al., 2021a), wheat and to some extent maize in Nepal (Mottaleb et al., 2022)); rice in the Philippines (Bairagi et al., 2022); and maize in Mexico (Govaerts et al., 2019).

The third group uses global foresight modeling tools to identify future demand-related challenges. An example of such a study is Springmann (2021) that explores the environment-nutrition nexus in changing demand at the global level with countries as the lowest level of demand aggregation.

4. Comparison and discussion of results

4.1. Trend analysis

Globally, major cereals consumption has been constantly growing and is expected to further increase by 2050. Trend analysis reveals that the most important proportion of the South Asian diet refers to major cereals (including rice, maize, barley, and wheat) (Frija et al., 2021a). In terms of diet composition, the consumption trend between 1961 and 2050 is the same for almost all countries, with increasing consumption of animal source food by 2050 (see Figure 1 below).

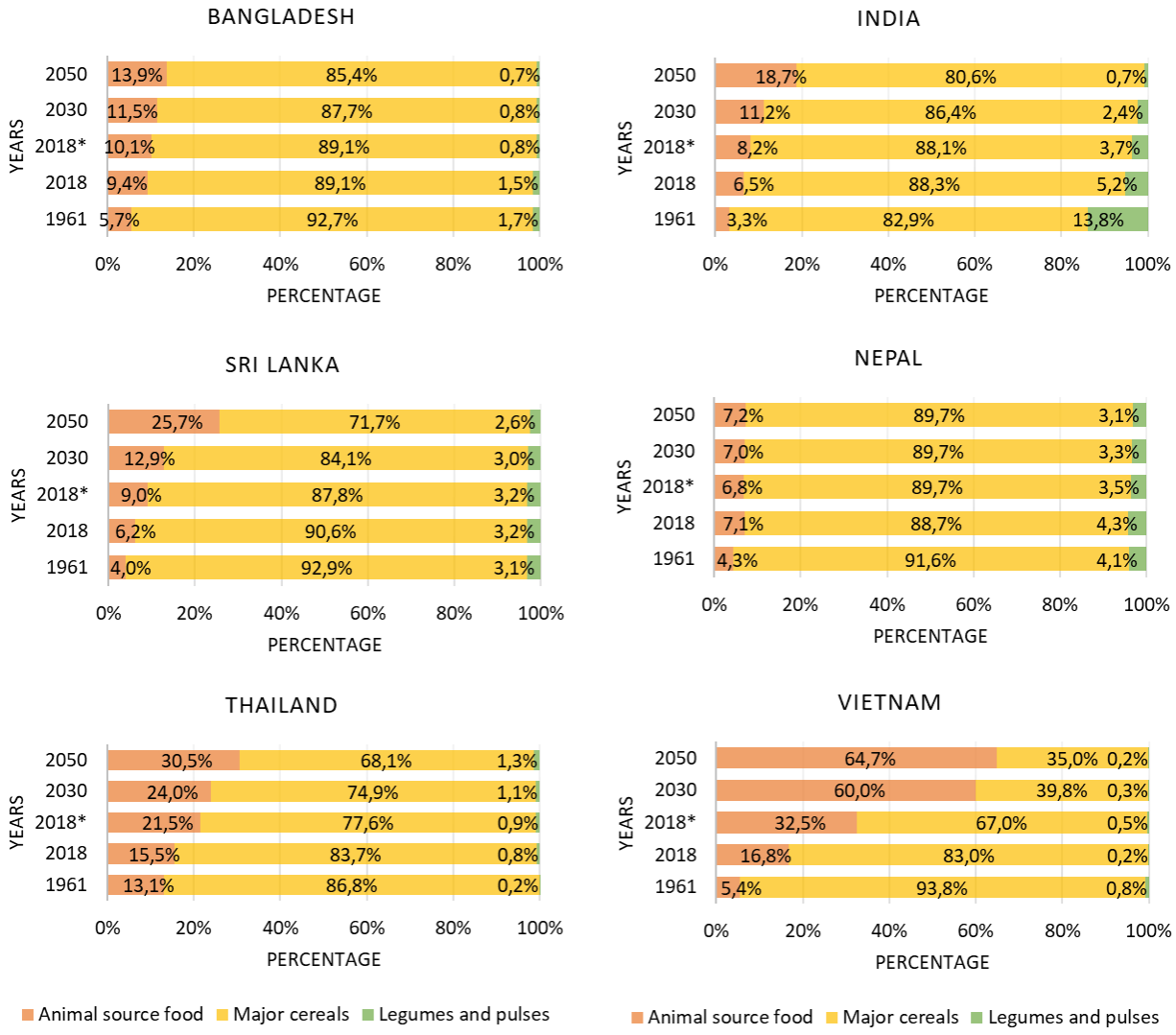

Figure 1 *Historical, present, and expected future diet composition for selected Asian countries, with relative importance of major cereals, animal source food and legumes and pulses.* (Frija et al., 2021a)

Major cereals consumption has been constantly growing and is expected to further increase by 2050. The overall diet trend in SSA is different from what we see in Asia or MENA, with decreasing relative importance of animal source food in the diet between 1961 and 2050. Mozambique is an exception for this case where the per capita consumption of animal source food is expected to increase over the years (see Figure 2 below).

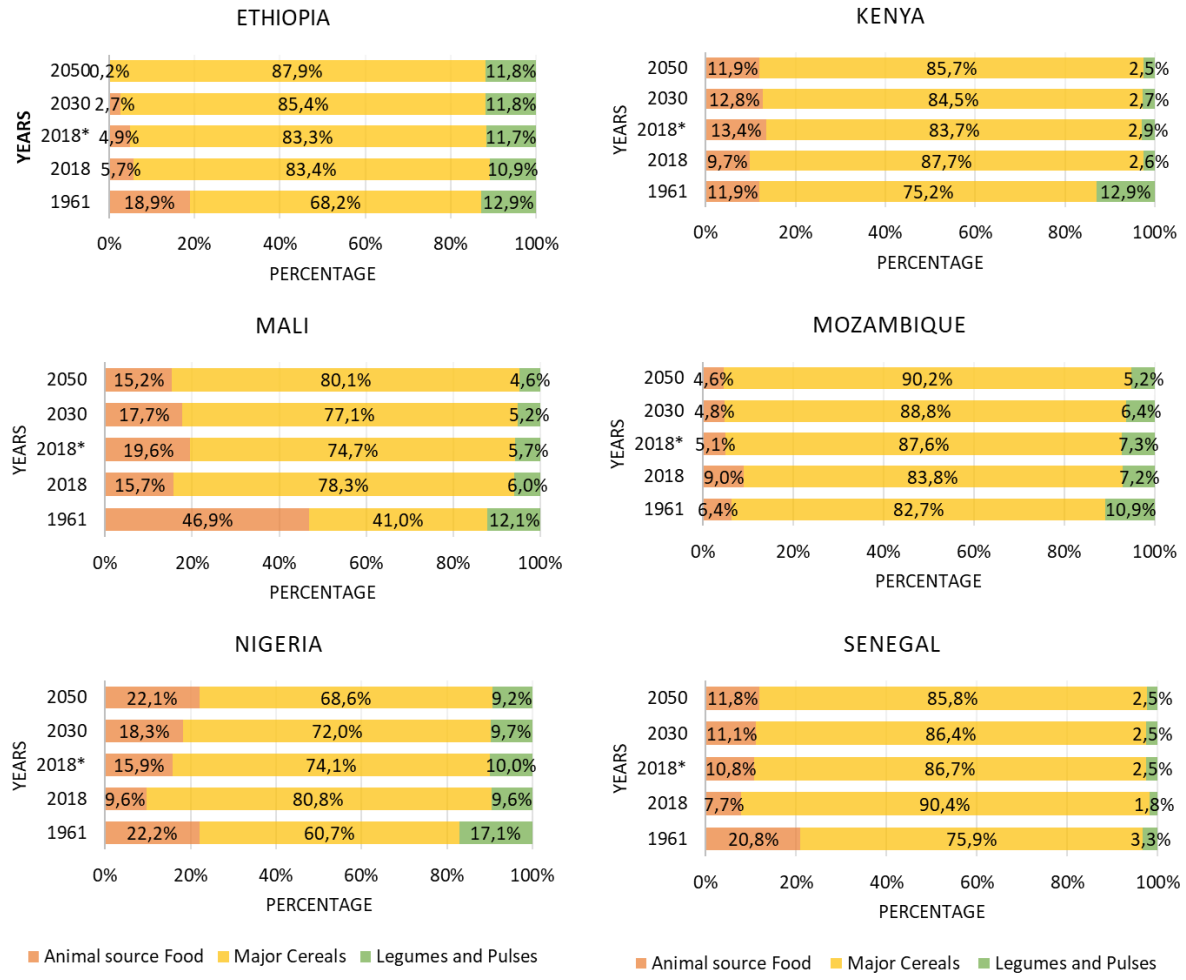

Figure 2 *Historical, present, and expected future diet composition for selected African countries, with relative importance of major cereals, animal source food and legumes and pulses.* (Frija et al., 2021a).

This analysis further showed that:

§ Per capita wheat consumption in Middle East and North African (MENA) countries is not expected to increase by 2050. The growth of wheat demand in the region is going to be mostly driven by population growth. Per capita wheat consumption is however expected to increase in many Asian and sub-Saharan African (SSA) countries.

§ While a dominant future trend of substituting grain cereals with higher-value energy-dense foods, such as fish and meat protein, is clear in most countries, the opposite trend, with the decreasing relative importance of animal source foods by 2050, has been identified in many SSA countries.

§ Per capita legume consumption has been decreasing in most analyzed MENA and SSA countries, including India.

Results of this foresight analysis help to better guide future research and development investments in food security, especially for commodities which will be highly needed for the global diet. The future growing demand for wheat for example (especially SSA and South Asia) need careful consideration for filling the agronomic and varietal research gaps in these new geographies (Frija et al., 2021b).

4.2. QUAIDS

The results from QUAIDS analyses in the different countries reveals elasticities that vary amongst regions within the countries analyzed as well as between urban and rural populations and between income groups.

Comparison of the results of the case studies calculating compensated elasticities can be observed in Table 1.

Table 1. Calculated elasticities (compensated) using the QUAIDS framework

Country	Commodity	Elasticities			
		Own-price		Expenditure (Income)	
		Rural	Urban	Rural	Urban
Bangladesh[1]	Rice	-0.23	-0.89	0.06	-0.49
	Wheat, rice and wheat products	-0.13	-0.28	-0.22	1.33
	Pulses	-0.54	-0.63	1.58	3.54
	Fish	-0.82	-0.65	3.23	2.96
	Vegetables	-0.47	-0.35	1.18	2.56
Nepal [2] (mountains)	Wheat	-0.29		0.88	0.71
	Maize, millet and other cereals	-0.16		1.02	1.95
	Rice	-0.51		0.97	0.89
	Pulses	-0.58		0.99	1.03
	Vegetables	-0.44		1.04	0.94
	Meat and fish	-0.53		1.15	1.12
Philippines[3]	Rice	-0.87	-0.90	0.11	0.07
	Other cereals	-0.68	-0.70	0.50	0.73
	Meat	-0.77	-0.78	2.03	1.94
	Fish	-1.42	-1.27	1.13	0.95
	Dairy products	-3.01	-3.24	2.14	2.18
	Fruits and vegetables	-1.07	-0.96	1.01	1.05
	Miscellaneous	-1.28	-1.32	1.37	1.33

Table 1. Calculated elasticities (compensated) using the QUAIDS framework (continued)

Country	Commodity	Elasticities			
		Own-price		Expenditure (Income)	
		Rural	Urban	Rural	Urban
Vietnam[4]	Rice	-0.31	-0.30	0.28	0.10
	Other cereals	-0.87	-0.88	0.56	0.56
	Noodles	-0.62	-0.61	0.89	0.87
	Fish	-0.32	-0.35	2.23	2.07
	Pork	-0.51	-0.50	1.17	1.17
	Chicken	-0.22	-0.09	0.59	0.49
	Eggs	-0.24	-0.13	0.77	0.72
	Fruits	-0.40	-0.61	1.51	1.30
	Vegetables	-0.76	-0.77	0.81	0.83
	Cooking oil	-0.26	-0.16	0.65	0.60
	Cooking sauce	-0.40	-0.40	0.97	0.96
	Sugar	-0.42	-0.30	1.34	1.39
	Milk	-0.11	-0.38	1.55	1.30
	Non-alcoholic drinks	-0.88	-0.88	0.68	0.66
	Alcoholic drinks	-0.22	-0.29	1.39	1.33
Uganda[5]	Matooke	-0.89	-1.00	0.36	1.01
	Cassava and potatoes	-0.74	-0.81	0.45	0.46
	Maize/coarse grains	-0.43	-0.40	1.38	1.05
	Wheat and rice	-0.24	-0.54	1.16	1.17
	Vegetables	-0.35	-0.39	1.31	1.23
	Fish and meat	-0.29	-0.27	1.27	1.15
Uganda[6]	Plantains (bunch)	-0.54	-0.33	0.56	0.39
	Plantains (heap)	NA	-0.22	NA	0.24
	Sweet potatoes (fresh)	-1.13	-0.48	0.18	0.48
	Cassava (fresh)	-0.64	-0.17	0.59	1
	Irish potatoes	-0.12	-0.41	0.34	0.17
	Rice	-0.01	-0.7	0.18	0.61
	Maize (cobs)	-0.18	-0.14	0.4	-0.02
	Maize (flour)	-0.67	-0.72	0.99	0.84
	Millet (flour)	-0.2	-0.12	0.28	0.33
	Sorghum (flour)	-0.13	NA	0.04	NA
	Sweet bananas	-0.49	0.11	0.14	-0.08
	Chapati	-0.55	-0.24	0.09	0.5
	Cassava (flour)	-0.07	-0.12	0.03	0.21
	Loaf	0.92	-0.47	-0.07	0.66
	Bun	NA	-0.03	NA	-1.02

Table 1. Calculated elasticities (compensated) using the QUAIDS framework (continued)

Country	Commodity	Elasticities			
		Own-price		Expenditure (Income)	
		Rural	Urban	Rural	Urban
Nigeria[7]	Yam flour	NA	2.1	NA	0.84
	Yam roots	0.46	2.74	2.4	1.92
	Cassava flour	0.67	0.35	0.94	0.96
	Gari	-0.22	-0.3	0.97	0.41
	Cocoyam	1.59	2.27	2.03	0.74
	Plantains	0.95	0.15	0.48	6.13
	Sweet potato	-0.74	-0.3	0.88	1.05
	Rice	-0.36	0.21	1.35	-0.29
	Wheat flour	NA	-0.57	NA	3.33
	Millet	-0.17	-0.58	-0.34	-0.6
	Maize	-0.7	-0.32	0.82	0.9
	Sorghum	-0.27	-0.44	-0.37	1.27
	Maize flour	2.93	-0.25	-0.58	0.19

Notes : [1] 2000, 2005, and 2010 average (Mottaleb et al. 2018b); [2] 1994, 2004, and 2011 average (Mottaleb et al. 2022); [3] 2006, 2009, 2012, 2015, and 2018 average (Bairagi et al. 2022); [4] 2012, 2014, and 2016 average (Bairagi et al. 2020); [5] 2010-11, 2013-14, and 2015-16 average (Mottaleb et al. 2021); [6] Gelegbelegbe and Msukwa (2019); [7] Gelegbelegbe and Msukwa (2019).

In projecting demand for the sampled food items in 2030 and 2050, these studies used the weighted average of the elasticities across the groups identified. Gbegbelegbe and Msukwa (2019) for instance find that urban demand for rice would be more than 50% that of rural demand by 2030 in Nigeria. By contrast, in Uganda, the demand for maize would be more than 3 times higher in rural areas compared to urban areas by 2030. These results imply that rural development in Uganda should put an emphasis on raising land productivity whereas in Nigeria, rural development should raise the productivity of both agricultural land and labor, which are likely to become scarce in the future (Gbegbelegbe and Msukwa, 2019).

Mottaleb et al. (2022) find that that the consumption demand of the sampled commodities would increase with the GDP and population growth in Nepal. For example, by 2050, the demand for wheat, maize, and rice will increase by 43%, 58%, and 34%, respectively, from the consumption level in 2016-18. This study also demonstrates that the consumption demand for noncereal food items such as pulses, vegetables, meat and fish would also increase by 2030 and 2050 than the 2016-18 level. Based on the findings, this study strongly suggests policymakers to invest both in cereal and noncereal subsectors of agriculture, firstly to combat extreme poverty and hunger in Nepal, and secondly to ensure income of the rural agricultural households, as more than 66% of the employed labor force in Nepal is currently engaged in agriculture.

Mottaleb et al (2018a; 2018b) find that in 2030 both rural and urban households in Bangladesh will consume more wheat, pulses and fish, but the urban households will consume less rice compared to the current levels of consumption in 2015. They find that with the increase in income and urbanization, this traditional rice-consuming country is increasingly consuming more wheat. The

changes in the relative consumption in Bangladesh are prominent both in rural and urban areas. The literature often is based on the premise that with increasing income, households switch from staple cereals to high food-value items. The studies highlight the need to also consider within-staple substitution.

Bairagi (2020b) find a large variation in the estimated price elasticities (–0.05 to –0.88) and expenditure elasticities (–0.16 to 2.56) in Vietnam. Food types, urban status and income groups can explain this variation. We also find that the staple food, rice, is already an inferior good for rich urban households in Vietnam. Moreover, food preferences are evolving away from rice but towards animal proteins (fish, pork, chicken, eggs and milk), fruits and vegetables, irrespective of urban status and income groups. As the Vietnam economy continues to grow with a doubling of gross domestic product (GDP) in the next decade, per capita rice consumption in both urban and rural areas and across different income groups will continue to decline, whereas demand for other high-value products will rise.

How these results compare to elasticities used in the IMPACT model can be observed in Table 2.

Table 2. Elasticities used in the IMPACT model

Country	Commodity	Elasticities	
		Own-price	Income
Bangladesh	Maize	-0.26	0.19
	Rice	-0.25	0.07
	Wheat	-0.34	0.37
Nepal	Maize	-0.27	0.20
	Rice	-0.26	0.05
	Wheat	-0.34	0.42
Philippines	Maize	-0.17	-0.06
	Rice	-0.21	0.02
	Wheat	-0.38	0.40
Vietnam	Maize	-0.34	0.33
	Rice	-0.25	-0.03
	Wheat	-0.39	0.53
Nigeria	Maize	-0.40	0.18
	Rice	-0.48	0.36
	Wheat	-0.44	0.42
Uganda	Maize	-0.38	0.17
	Rice	-0.46	0.37
	Wheat	-0.45	0.45

There are clear discrepancies between the elasticities used in the IMPACT model and those calculated using the QUAIDS approach and granular household consumption data. The minor changes over time in the elasticities in the IMPACT model provide a range of values that do not include the calculated elasticities in the case studies.

5. Outlook and opportunities

Mottaleb et al. (2022) find that aggregate demand for both cereal and non-cereal food items will increase. Unlike some previous studies (e.g. Pingali, 2007; Pingali et al., 2019), they conclude that it is important to invest in both cereals and non-cereal food crops, including pulses and vegetables, to ensure basic food security and to nurture human health. Interestingly, compared to coarse rice and maize, wheat is an income elastic food item. With increases in income and urbanization, and lifestyle changes, the demand for fine rice and wheat will increase across Asia and Africa (Gandhi et al., 2004; Nagarajan, 2005; Mason et al., 2015; Mottaleb et al., 2018c).

Frija et al. (2021a) concludes that future diets will evolve differently across regions and countries. While a dominant pattern of the substitution of grain cereals with higher-value energy-dense foods, such as fish and meat protein, is clear in most studied countries, still other specific trends are identified, especially in SSA where the future consumption of meat products will be growing at relatively lower rates compared to other cereals and dry legumes. Another trend is also related to the increasing future demand of wheat in most analyzed countries and regions where wheat is expected to take a higher share of the diet in most of the countries by 2050.

The set of studies synthesized here present a step in identifying the pathways of how drivers of change shape the demand for major cereals, based a number of case studies. The next step entails comparing to other analyses and filling in the key knowledge gaps in order to improve the demand equations in quantitative foresight models. The insights gleaned from these studies can also inform policy debates related to food and nutrition security.

References

Bairagi, S., Demont, M., Custodio, M. C., and Ynion, J. (2020a). What drives consumer demand for rice fragrance? Evidence from South and Southeast Asia. *Br. Food J.* doi:10.1108/bfj-01-2019-0025.

Bairagi, S., Mohanty, S., Baruah, S., and Thi, H. T. (2020b). Changing food consumption patterns in rural and urban Vietnam: Implications for a future food supply system. *Aust. J. Agric. Resour. Econ.* doi:10.1111/1467-8489.12363.

Bairagi, S., Zereyesus, Y. A., Baruah, S., and Mohanty, S. (2022). Structural Shifts in Food Basket Composition of Rural and Urban Philippines: Implications for the Food Supply System. *PLoS One* accepted.

Banks, J., Blundell, R., and Lewbel, A. (1997). Quadratic Engel curves and consumer demand. *Rev. Econ. Stat.* 79, 527–539.

BMGF, and UKAID (2017). Agriculture for improved nutrition: a future research agenda. Available at: https://www.anh-academy.org/sites/default/files/Agriculture for Improved Nutrition-A Future Research Agenda.pdf.

Brooks, K., and Place, F. (2019). Global food systems: Can foresight learn from hindsight? *Glob. Food Sec.* 20, 66–71. doi:10.1016/j.gfs.2018.12.004.

de Boer, J., de Witt, A., and Aiking, H. (2016). Help the climate, change your diet: A cross-sectional study on how to involve consumers in a transition to a low-carbon society. *Appetite* 98, 19–27. doi:10.1016/j.appet.2015.12.001.

Deaton, A., and Muellbauer, J. (1980). An almost ideal demand system. *Am. Econ. Rev.* 70, 312–326.

Fanzo, J. (2015). Ethical issues for human nutrition in the context of global food security and sustainable development. *Glob. Food Sec.* 7. doi:10.1016/j.gfs.2015.11.001.

FAO, IFAD, and WFP (2015). Achieving Zero Hunger. The Critical Role of Investments in Social Protection and Agriculture. Rome.

Frija, A., Ouerghemmi, H., and Mottaleb, K. A. (2021a). Dietary change in Asia, Sub Sahara Africa, and North Africa: historical changes and future food consumptions perspectives. Cairo, Egypt Available at: https://hdl.handle.net/20.500.11766/66832.

Frija, A., Tadesse, W., Bishaw, Z., Yigezu, Y., Devkota, M., and Dessalegn, B Rischkowsky, B Ouerghemmi, H Megenasa Biradar, C Wery, J. (2021b). The Future of Wheat Research and Production in Sub-Saharan Africa. Beirut, Lebanon Available at: https://hdl.handle.net/20.500.11766/66804.

Gandhi, V. P., Zhou, Z.-Y., Mullen, J., Zhang-Yue Zhou, and Mullen, J. (2004). India's Wheat Economy: Will Demand Be a Constraint or Supply? *Econ. Polit. Wkly.* 39, 4737–4746. doi:https://www.jstor.org/stable/4415713.

Gbegbelegbe, S., and Msukwa, W. (2019). Effects of dietary change on the future demand for major cereals – case study for Uganda and Nigeria. Lilongwe, Malawi.

Govaerts, B., Chávez, X., Fernández, A., Vega, D., Vázquez, O., Pérez, M., et al. (2019). *Maíz para México*. , ed. Rebeca López Perea Texcoco: CIMMYT Available at: https://repository.cimmyt.org/handle/10883/20219.

Hedenus, F., Wirsenius, S., and Johansson, D. J. A. (2014). The importance of reduced meat and dairy consumption for meeting stringent climate change targets. *Clim. Change* 124, 79–91. doi:10.1007/s10584-014-1104-5.

Hubert, B., Rosegrant, M., van Boekel, M. A. J. S., Ortiz, R., and Ortiz, R. (2010). The future of food: Scenarios for 2050. *Crop Sci.* 50, 33–50. doi:10.2135/cropsci2009.09.0530.

Jalava, M., Kummu, M., Porkka, M., Siebert, S., and Varis, O. (2014). Diet change—a solution to reduce water use?

Environ. Res. Lett. 9, 074016. doi:10.1088/1748-9326/9/7/074016.

Kruseman, G. (2016). Patronos de consumo de maíz en Mexico 2012-2013. El Batan, Texcoco, Mexico.

Mason, N. M., Jayne, T. S., and Shiferaw, B. (2015). Africa's Rising Demand for Wheat: Trends, Drivers, and Policy Implications. *Dev. Policy Rev.* 33, 581–613. doi:10.1111/dpr.12129.

Mottaleb, K. A., Fatah, F. A., Kruseman, G., and Erenstein, O. (2021a). Projecting food demand in 2030: Can Uganda attain the zero hunger goal? *Sustain. Prod. Consum.* 28, 1140–1163. doi:10.1016/J.SPC.2021.07.027.

Mottaleb, K. A., Rahut, D. B., Kruseman, G., Abdul Fatah, F., and Erenstein, O. (2022). Future Food Demand: Implications for Nepal. *Food Energy Secur.* accepted.

Mottaleb, K. A., Rahut, D. B., Kruseman, G., and Erenstein, O. (2018a). Changing Food Consumption of Households in Developing Countries: A Bangladesh Case. *J. Int. Food Agribus. Mark.* 30, 156–174. doi:10.1080/08974438.2017.1402727.

Mottaleb, K. A., Rahut, D. B., Kruseman, G., and Erenstein, O. (2018b). Evolving food consumption patterns of rural and urban households in developing countries: a Bangladesh case. *Br. Food J.* 120, 392–408. doi:10.1108/BFJ-12-2016-0620.

Mottaleb, K. A., Rahut, D. B., Kruseman, G., and Erenstein, O. (2018c). Wheat production and consumption dynamics in an Asian rice economy: The Bangladesh case. *Eur. J. Dev. Res.* doi:10.1057/s41287-017-0096-1.

Mottaleb, K. A., Sonder, K., and López Ridaura, Santiago Frija, A. (2021b). Wheat Consumption Dynamics in Selected Countries in Asia and Africa: Implications for Wheat Supply by 2030 and 2050. El Batan, Texcoco, Mexico.

Nagarajan, S. (2005). Can India produce enough wheat even by 2020? *Curr. Sci.* 89, 1467–1471. Available at: http://www.jstor.org/stable/24110907.

Pingali, P. (2007). Westernization of Asian diets and the transformation of food systems: Implications for research and policy. *Food Policy* 32, 281–298. doi:https://doi.org/10.1016/j.foodpol.2006.08.001.

Pingali, P., Aiyar, A., Abraham, M., and Rahman, A. (2019). *Transforming Food Systems for a Rising India*. Palgrave S. , eds. P. Pingali, A. Aiyar, M. Abraham, and A. Rahman New York doi:10.1007/978-3-030-14409-8.

Robinson, S., Daniel Mason-D'Croz, Islam, S., Sulser, T. B., Robertson, R., Zhu, T., et al. (2012). International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) : Model Description. Washington D.C. doi:DOI: 10.13140/RG.2.1.4865.1607.

Robinson, S., Mason-D'croz, D., Islam, S., Sulser, T. B., Robertson, R., Zhu, T., et al. (2015). The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) Model Description for Version 3. Washington DC doi:10.13140/RG.2.1.4865.1607.

Schader, C., Muller, A., Scialabba, N. E.-H., Hecht, J., Isensee, A., Erb, K.-H., et al. (2015). Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability. *J. R. Soc. Interface* 12. Available at: http://rsif.royalsocietypublishing.org/content/12/113/20150891.abstract.

Springmann, M. (2021). Dietary adaptation mechanisms to the potential health impacts of climate related changes in micronutrients in wheat and other cereals. El Batan, texcoco, Mexico Available at: https://repository.cimmyt.org/handle/10883/21778.

Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H. C. J., Gollin, D., et al. (2016). Global and regional health effects of future food production under climate change: a modelling study. *Lancet*. doi:10.1016/S0140-6736(15)01156-3.

Springmann, M., Wiebe, K., Mason-D'Croz, D., Sulser, T. B., Rayner, M., and Scarborough, P. (2018). Health and

nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail. *Lancet Planet. Heal.* 2, e451–e461. doi:10.1016/S2542-5196(18)30206-7.

Tilman, D., Balzer, C., Hill, J., and Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad. Sci. U. S. A.* 108, 20260–4. doi:10.1073/pnas.1116437108.

Tschirley, D. L., Snyder, J., Dolislager, M., Reardon, T., Haggblade, S., Goeb, J., et al. (2015). Africa's unfolding diet transformation: implications for agrifood system employment. *J. Agribus. Dev. Emerg. Econ.* 5, 102–136.

Wessells, K. R., Singh, G. M., and Brown, K. H. (2012). Estimating the Global Prevalence of Inadequate Zinc Intake from National Food Balance Sheets: Effects of Methodological Assumptions. *PLoS One* 7, e50565. doi:10.1371/JOURNAL.PONE.0050565.

Notes

CGIAR

CIMMYT MR
International Maize and Wheat Improvement Center

CIMMYT Headquarters:
Apdo. Postal 041, C.A.P. Plaza Galerías,
Col. Verónica Anzures, 11305 CDMX, México
Email: cimmyt@cgiar.org
www.cimmyt.org