VOICE FOR CHANGE PARTNERSHIP (V4CP)

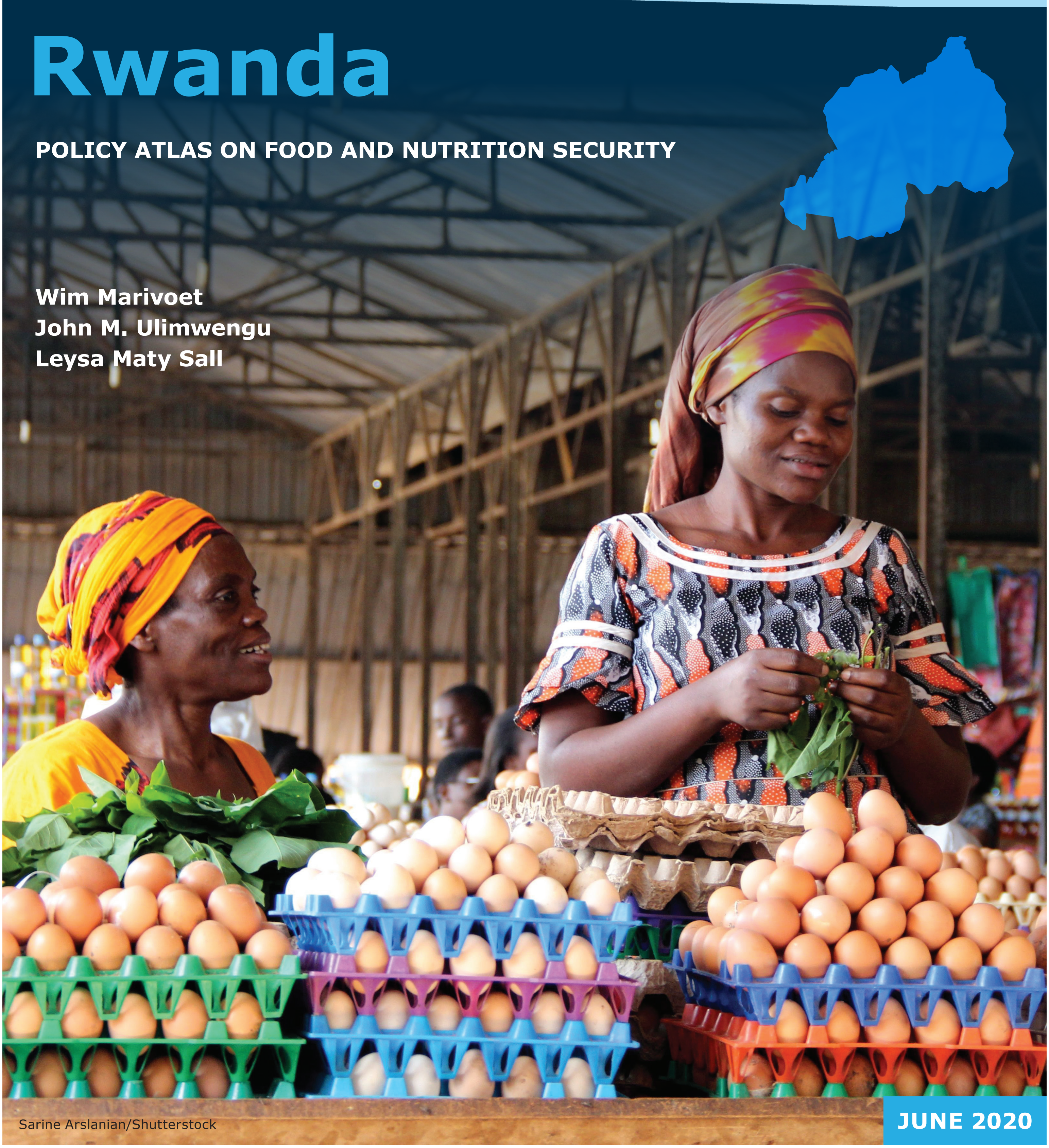
SNV

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI

Rwanda

POLICY ATLAS ON FOOD AND NUTRITION SECURITY

Wim Marivoet
John M. Ulimwengu
Leysa Maty Sall



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VOICE FOR CHANGE PARTNERSHIP (V4CP)

The Voice for Change Partnership (V4CP) is a multisectoral programme funded by the Dutch Ministry of Foreign Affairs (DGIS), operated jointly by the Netherlands Development Organization (SNV) and the International Food Policy Research Institute (IFPRI), and implemented in six countries: Burkina Faso, Ghana, Honduras, Indonesia, Kenya and Rwanda. The V4CP supports advocacy by Civil Society Organizations (CSOs) in order to influence policies and decisions. By enhancing CSO capacities in leadership, knowledge development, advocacy skills, and organizational sustainability, CSOs are empowered to speak with a greater voice. The V4CP trains CSO members to use research evidence, data and case studies to back up their advocacy strategies. The V4CP tackles four issues—food and nutrition security, resilience, renewable energy, and water, sanitation and hygiene (WASH)—while addressing gender imbalance and climate change mitigation. By collaborating with national and international partners, different levels of government, and the private sector, CSOs contribute to improving the "enabling environment". Strengthening the voice of CSOs in policy creation and the implementation of services ensures that the interests of communities represented by CSOs are better served.

ACKNOWLEDGEMENTS

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Chapter 1

FROM RESOURCES TO POLICYMAKING: A GEOGRAPHICALLY DISAGGREGATED JOURNEY

1.1. MAPS AS POWERFUL TOOLS FOR ADVOCACY

A popular saying states that "a picture is worth a thousand words." Maps are pictures of our world and its conditions. They illustrate how conditions in one area relate to neighbouring areas. Maps can display political boundaries, roads, population, health status, climate conditions, natural resources, poverty, education rates, or economic activities such as crop production. They illustrate information about locations, show spatial patterns, and can be used to compare patterns between different physical characteristics or social phenomena.

Because maps help us understand the **spatial relationships** of different phenomena or conditions, they are useful for understanding where to target our attention and to set priorities accordingly. Since maps can interact with various types of data, they help us design more targeted and comprehensive programs by illustrating where needs are most severe, which bottlenecks hinder progress, and how different challenges relate geographically to one another. To inform time-constrained policymakers, maps can be powerful tools to single out a particular issue and what it takes to address it, in a concise and attractive way.

The maps in this policy atlas use data and statistics on agriculture, food consumption, and nutrition to consider geographically-sensitive strategies to improve **food and nutrition security (FNS).** They offer a one-time snapshot of realities that are constantly evolving and thus subject to change when events occur or more accurate data become available. For the latest maps, please consult the ReSAKSS eAtlas country webpage of Rwanda (eatlas.resakss.org/Rwanda/en), which also provides spatial data and maps beyond those covered in this report.

Box 1.1. Limitations of a spatial approach

Geographic representations can be misleading because surface areas do not necessarily equate with population numbers—especially when comparing vast yet scarcely populated areas with small densely urban settlements. Rural areas typically dominate maps, while densely-populate urban centres may appear insignificant despite their significance for large numbers of people. In a similar vein, maps often only display averages for a given administrative unit—such as a district or region—thereby ignoring dispersion or inequality within that unit. For these reasons, the spatial approach is but one of several methods to construct an appropriate level of information to inform policy decisions.

1.2. CIVIL SOCIETY ORGANISATIONS WORKING UNDER V4CP IN RWANDA

The CSOs working under V4CP in Rwanda represent the interests of various groups and communities such as smallholder farmers, food processors, entrepreneurs, development and environmental groups. By fostering collaboration among CSOs and relevant stakeholders, CSOs influence agenda-setting and hold the government and private sector accountable for their promises and actions. The V4CP Programme in Rwanda focuses exclusively on food and nutrition security.

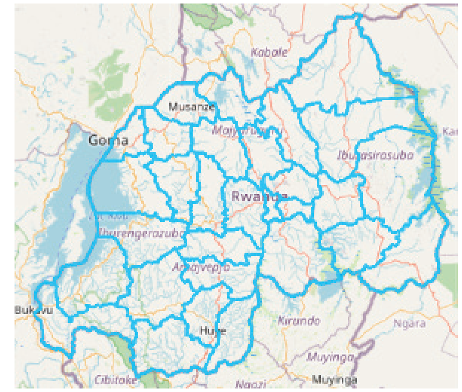
The following six CSOs operate under the V4CP programme in Rwanda: Caritas Rwanda, Scaling Up Nutrition (SUN) Alliance, Rwanda Development Organisation (RDO), IMBARAGA, Rwanda Consumers' Rights Protection Organisation (ADECOR) and DUHAMIC-ADRI. The main advocacy goal of these CSOs centres around four sub-themes. These include: (i) increased food production and consumption; (ii) food fortification; (iii) nutrition budget allocation; and (iv) coordination. This policy atlas mainly provides evidence to support the advocacy agenda of CSOs working on the first three sub-themes.

Box 1.2. provides a short description of each CSO with their main geographic target zones.

Box 1.2. Description and target districts of CSOs under V4CP Programme

Caritas Rwanda is a non-governmental organisation which coordinates all the actions carried out by the Church in the areas of social assistance, healthcare and development. Its vision is to achieve a society that provides human dignity to every person. With its extensive network of volunteers, Caritas Rwanda assists and empowers vulnerable people in their fight against discrimination, poverty, sickness and injustice.

Scaling Up Nutrition (SUN) Alliance is an umbrella of civil society organisations in Rwanda to promote nutrition-sensitive and -specific actions. The primary activity of the SUN Alliance is to strengthen the coordination among nutrition actors and stakeholders, through tracking results, aligning strategies and programs, and pooling resources of its members with the overall objective to eliminate all forms of malnutrition.



Rwanda Development Organisation (RDO) is a non-profit and non-governmental organisation established in 1995 to help spur social and economic development in Rwanda. Its vision is to ensure that all Rwandans are in control of their own destiny and enjoy a decent standard of living. To achieve this, RDO works to empower partner communities, improve human capital, increase food and nutrition security, and establish market linkages within an environmentally sustainable environment.

IMBARAGA is a national organisation of farmers created in 1992 in Rwanda. Its mandate is to defend the interests of an estimated 27,300 farmers located in 25 districts across the country and improve their socio-economic living conditions. With its vision to make every member "a professional farmer and change maker", IMBARAGA aims to increase farmers' productivity & competitiveness through capacity building and protect their social and economic rights through its advocacy work.

Rwanda Consumers' Rights Protection Organisation/Association pour la Défense des droits des Consommateurs au Rwanda (ADECOR) is a local non-governmental organisation dedicated to reducing poverty and injustice while promoting and protecting consumers' rights, especially for the poorest people. Adopting a human rights-based approach in mobilising and empowering citizens, ADECOR's advocacy work mainly focuses on agriculture, food safety, food security and nutrition.

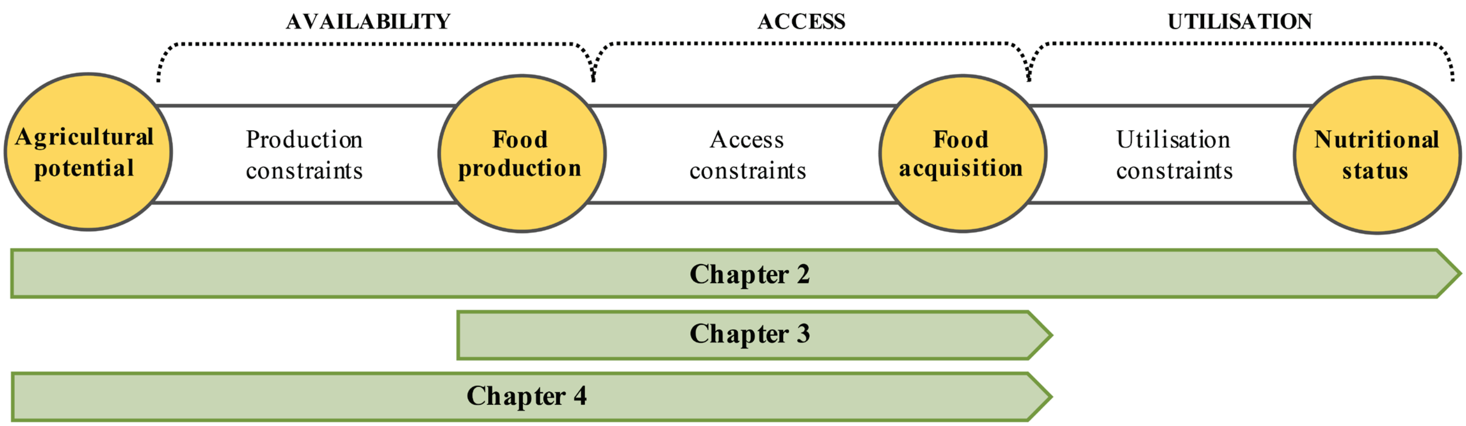
DUHAMIC-ADRI is a non-profit association, initiated at the local level and currently operating throughout Rwanda. Its overall mission is to help and assist farmers organise themselves to overcome marginalisation in rural areas. To achieve this, DUHAMIC-ADRI stimulates the creation and consolidation of local associations, cooperatives and farmers' groups; strengthens their organisational capacity; and supports their wide range of activities.

1.3. OBJECTIVE AND OVERVIEW

This policy atlas utilises maps to investigate **how nutrition, agriculture and FNS interventions could most effectively be targeted** in Rwanda. Future CSO advocacy strategies could be strengthened and enriched with spatial information that indicates *where* policy efforts would be most effective, addressing bottlenecks faced by the most deprived communities, reducing disparities, or helping zones meet their full potential.

The conceptual framework used in this policy atlas is based on the sequential pillars of food and nutrition security (FNS), typically labelled as **availability, access and utilisation**. For people to "have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996), the **constraints** linked to each pillar should be eliminated or adequately addressed. Figure 1.1. illustrates the sequential or hierarchical nature of these constraints, all having an impact on final nutritional outcomes. To improve nutrition, a population should first be able to produce enough food, which is contingent upon the level of agricultural potential combined with production constraints faced by farmers. Whereas biophysical constraints (such as rainfall, temperature and soil types) determine agricultural potential, *production constraints* refer to all sorts of suboptimal farming inputs and technologies (such as inferior seeds, or lack of agricultural extension). Next, households should be able to acquire diverse food items, which depends on the amount and variety of food produced along with various *access constraints*, such as low-quality transportation and storage infrastructure or economic constraints like limited purchasing power or trade restrictions. Once households acquire food, food must be properly prepared and allocated to each family member, and consumed in hygienic and healthy conditions—which are all various types of *utilisation constraints*.

Figure 1.1. Overall framework and conceptual location of each chapter



Source: Authors.

Each chapter of this policy atlas focuses on a different conceptual part within the overall framework. Chapter 2 evaluates the degree of constraints at district level along the full FNS pathway by comparing actual data on local agricultural potential, food production, food acquistion and nutrition status. Chapter 3 explores the bottlenecks faced by households in Rwanda to acquire enough healthy food. By focusing on nutrients essential for human health, this chapter identifies target districts and foods for improving either agricultural production, market integration, post-harvest handling, or household food budget allocation. Chapter 4 deepens the previous analysis by identifying optimal diets per price zone before determining the type of district and national policies needed to produce and consume such diets. This chapter also relies on crop suitability analyses to locate potential areas for increased food production. Chapter 5 summarises the overall findings and how they should inform policymaking in Rwanda.

At the end of each chapter, we provide a short advocacy note with key messages that indicate how findings could best guide future policies. Throughout the policy atlas, explanatory boxes, key word lists and infographics contexualize each chapter.

Chapter 2

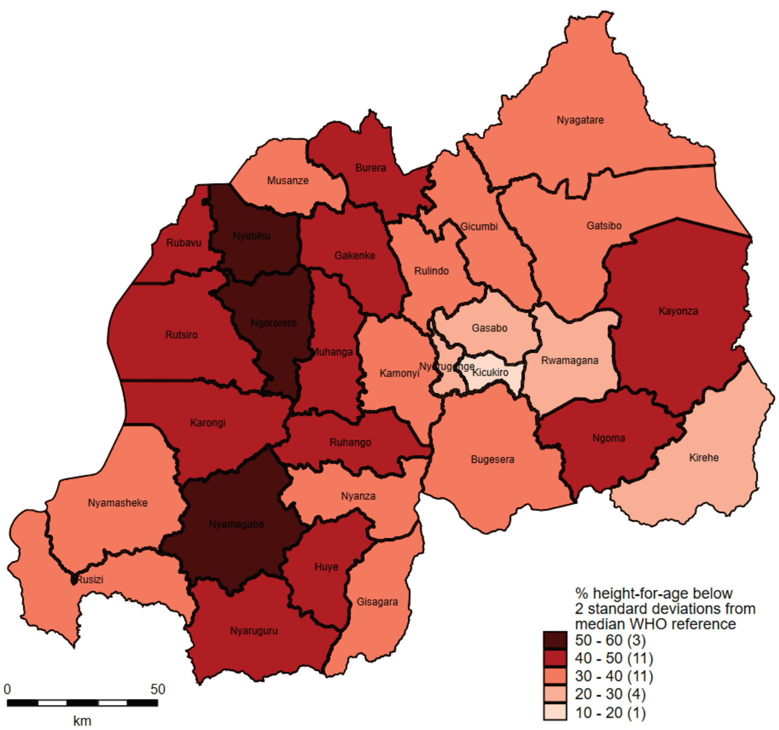
COMPREHENSIVE TYPOLOGY FOR FOOD AND NUTRITION SECURITY INTERVENTIONS

2.1. INTRODUCTION

This chapter presents a comprehensive **typology** to identify possible food and nutrition security (FNS) interventions in Rwanda. We start by identifying the districts of Rwanda with the poorest nutritional outcomes. In the following sections, we apply the typology to explore interventions that could improve outcomes by comparing four indicators within each district: *agricultural potential, food production, food acquisition and nutrition outcomes*. By comparing these indicators, we identify the districts that could benefit most from efficiency improvements in *production, access or utilisation*. This chapter ends by offering policy recommendations and illuminates how geographically-specific analysis can guide the design of FNS interventions.

Figure 2.1. presents the **spatial distribution** of chronic malnutrition among children below the age of 5 years in Rwanda in 2014/15.

Figure 2.1. Prevalence of stunting among children (<5 years) in Rwanda (2014/15)



Source: Authors with data from DHS (2014/15).

Despite considerable progress over the last ten years, a national average stunting level of 37.9% remains undeniably problematic (DHS 2014/15). Further, as shown in Figure 2.1., higher stunting levels are mainly observed in the western part of the country and are particularly high in the districts of Nyamagabe, Ngororero and Nyabihu with prevalence levels well above 50%. In the centre, around the capital city of Kigali, chronic malnutrition is distinctively lower with less than 30% of the child population being affected. It is only in the district of Kicukiro that stunting is lower than 20%. To address differences in nutrition status across the country, it is thus important to design policy interventions that account for **spatial heterogeneity**.

Key Words

Typology a reduction of real-world complexity to types; classification

Spatial Distribution the study of phenomena and their physical locations; the graphic display of that information

Spatial Resolution the number of pixels used to create an image (e.g. of the earth's surface). A higher number (of smaller) pixels shows more resolution and definition; fewer, larger pixels shows less

Remote Sensing scanning the earth from high altitude (i.e. satellite) to gather information

Spatial Heterogeneity the uneven distribution of a trait across districts

Conceptual Framework the way ideas are organized; a structure used to relate different concepts and show their orientation toward a shared goal

Transaction Costs costs associated with the exchange of goods/services across time, place and markets, but distinct from the actual production cost

Indicator a measurable unit that serves as a gauge or symbol to indicate the condition of something

Scatterplot a data visualization that shows the relationship between two variables. It uses dots to represent numeric values (one variable plotted along the x-axis, and the other along the y-axis)

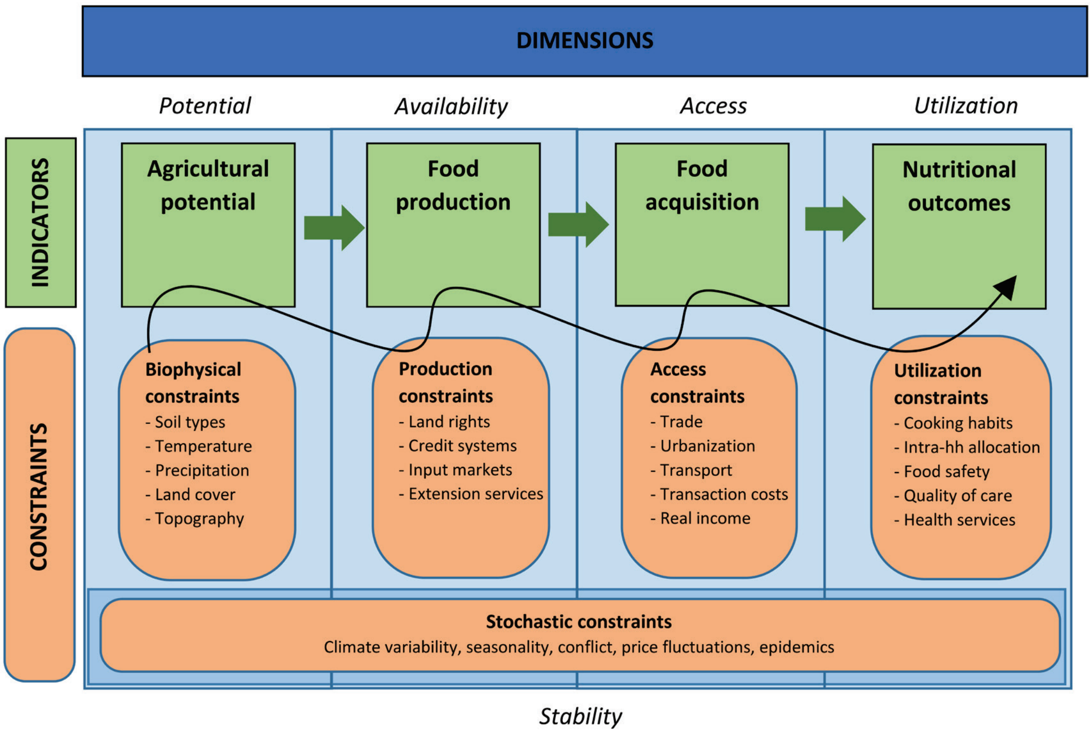
Absolute benchmark is based on an exact target

Relative benchmarks compare entities' performance to each other

2.2. CONCEPTUAL FRAMEWORK

To guide policies and programs that address food and nutrition insecurity throughout the country, it is helpful to consider the pathway from agricultural potential to nutrition status. The **conceptual framework** laid out in Figure 2.2. shows four dimensions of FNS. The dimensions flow chronologically with each step facing constraints. For example, with respect to food production, farmers need access to land, knowledge, credit, seeds and fertilizer to be able to tap into the agricultural potential of their land. Further down the chain, even if food is sufficiently produced, families might be constrained due to all sorts of **transaction costs**, such as trade barriers or poor transportation infrastructure that results in higher local prices. Nutrition outcomes could also be affected by utilisation constraints such as lack of food safety or culinary habits, intra-household allocations, or health and sanitation conditions.

Figure 2.2. Conceptual pathway from agricultural potential to nutrition outcomes



Source: Authors adapted from Pangaribowo et al. (2013).

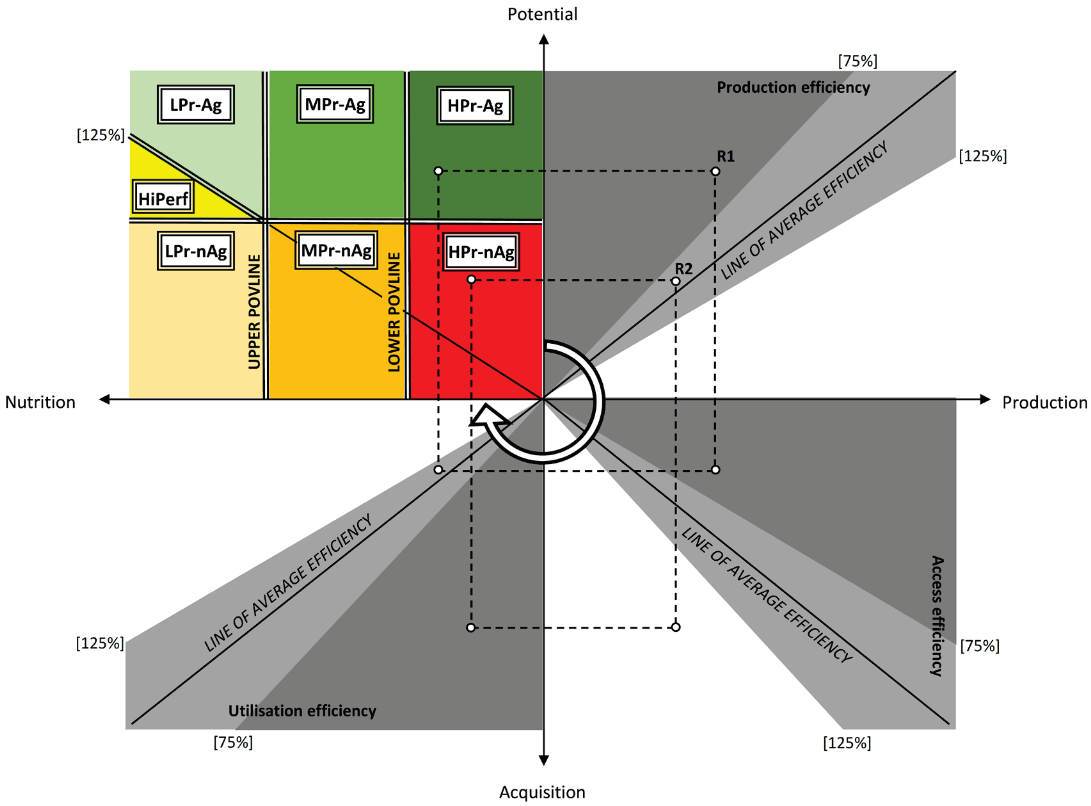
By assigning one **indicator** for each of the four sequential FNS dimensions (see the green boxes in Figure 2.2.), the typology helps point out where and which type of intervention would be most effective at improving the nutrition status of the Rwanda population. The typology classifies each district's efficiency at transforming:

(i) agricultural potential into food production (*production efficiency*)
(ii) food production into food acquisition (*access efficiency*)
(iii) food acquisition into nutrition outcomes (*utilisation efficiency*).

To estimate these three efficiency types, we create a diagram that links all the indicators. The diagram (see Figure 2.3.) displays each indicator on a different axis, thus creating a four-dimensional diagram. Starting from the axis measuring agricultural potential (top vertical axis), this diagram should be read clock-wise. The upper-right panel describes the relationship between agricultural potential and food production. In this panel, the diagonal line of average efficiency indicates the level of food production one can *expect* based on each area's agricultural potential. In a similar vein, the diagonal of *access efficiency* (lower-right panel) reflects the *expected* levels of food acquisition based on a district's level of food production. Finally, *utilisation efficiency* (lower-left panel) represents the *expected* levels of nutrition status for every level of food acquisition. These three efficiencies compare districts in Rwanda to each other, which means the *expected levels* are all based on a *relative comparison to the other districts*.

By drawing a "fork" around the lines of average efficiency, we can define three levels of efficiency: above average, below average and average. When data observations fall *within* the "fork", efficiency is average. For example, for districts (represented by dots) that fall within the "fork" of production efficiency (upper-right panel), the level of food production is roughly what you would expect based on their agricultural potential (that is under prevailing average production constraints characterizing the country). However, when data observations fall outside this "fork" range, food production performance is either worse or better than what is (on average) observed throughout the country. In this way, we classify districts that perform better than 125% of the country average as "above average" (represented by the white space in the quadrants in Figure 2.3.). We classify districts that perform worse than 75% of the country average as "below average" (dark grey space); and "average" districts fall within the 75-125% "fork" range (light grey space). The same relative benchmarking of "above average", "below average" and "average" applies to *access efficiency* (lower-right panel) and utilisation efficiency (lower-left panel).

Figure 2.3. Combined diagram of FNS dimensions



Notes: LPr, MPr, HPr respectively stand for low-, medium- and high-priority nutrition areas; Ag and nAg refer to higher (Ag) and lower (nAg) agricultural potential; HiPerf stands for high-performance areas. "Povline" refers to poverty line.
Source: Authors.

The upper-left panel in Figure 2.3. shows poverty lines for low-, medium-, and high-priority nutrition areas. In addition, the upper-left panel distinguishes between areas with higher and lower agricultural opportunities.[1] Based on these definitions, there are seven intervention types, which emerge by combining the three priority levels—High Priority area (HPr), Medium Priority area (MPr), and Low Priority area (LPr)—and two levels of agricultural potential—either higher agricultural potential (Ag) or lower potential (nAg).[2] Within the category of "low priority areas with higher agricultural potential (LPr-Ag)," one can further classify areas as "high-performance (HiPerf)" when their overall efficiency level is higher than 125% of the country's average. These areas could serve as examples to others and may not be suitable for an FNS intervention since they already perform well in converting agricultural potential in nutrition outcomes.

Combining all information, the four-dimensional diagram underneath this typology depicts two sorts of benchmarking:

1) The upper-left panel applies an **absolute benchmark** to show the *level of nutrition-poverty urgency*. This panel also identifies whether *a focus on agricultural production* is warranted;

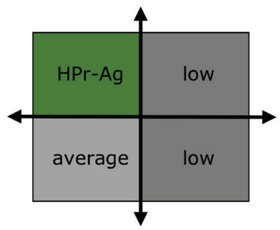
2) The other three panels apply **relative benchmarking** by comparing each district's performance with expected outcomes while roughly detailing where, along the pathway from agricultural potential to nutrition status, the biggest gains can be realised in terms of reducing production, access, or utilisation constraints.

[1] This distinction is based on the level of agricultural potential which corresponds with the intersection of the upper-bound poverty line and the line representing 125% of the average efficiency between potential and nutrition. This means that areas with an agricultural potential below this threshold will not reach a nutritional status above the upper-bound poverty line, unless they perform better than 125% of what is, on average, observed in the country.
[2] These types are much inspired by the work of Torero (2014).

Box 2.1. Typology examples

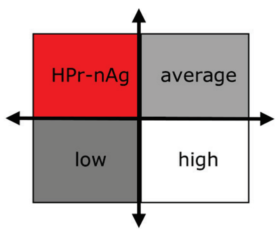
This box discusses the typology profile of two fictitious regions, R1 and R2, capturing data observations for various dimensions in Figure 2.3. Each region is represented by four data points, according to its values for each of the four dimensions. The precise location of data points within each of the panels thus characterises the region. The upper-left panel defines the priority level, with darker colours (green or red) indicating higher urgency, while the other panels provide insight on what type of intervention would be most effective to improve nutrition outcomes.

R1



R1 is a "high-priority region with higher agricultural potential (HPr-Ag)" because the nutrition status of its population is low while agricultural potential is high. To improve nutrition outcomes in this region, most attention should go to removing production and access constraints, as efficiency for both dimensions is lower than what is (on average) observed across the country. Utilisation efficiency is average and therefore is considered a less critical bottleneck.

R2



R2 is a "high-priority region with lower agricultural potential (HPr-nAg)" because both the nutrition status of its population and agricultural potential is low. In contrast to R1, we cannot expect major nutrition improvements to result from removing production constraints because the region's agricultural potential is low and its production efficiency is already average. Neither can we expect major nutrition benefits due to improving access to food because the region's efficiency is already higher than average in the country. To improve nutrition outcomes, R2 should mainly focus on reducing utilisation constraints, as efficiency for this dimension is low.

2.3. DATA ON FOOD AND NUTRITION SECURITY

Based on the conceptual framework above and relying on various data sources, we construct a key variable indicator for each FNS dimension.[3] For quick reference, Table 2.1. summarises the indicators for each dimension and provides some descriptive statistics.

To estimate agricultural potential of each district in Rwanda, we consider how many kilocalories could be produced from all available arable land, essentially translating hectares into a kilocalorie equivalent. For agricultural land estimates, we rely on two **remote sensing** satellite data sources. The first source identifies all land used for agriculture in 2015, at 30m pixel **spatial resolution** (Xiong et al., 2017). The second source (Hansen et al., 2013) indicates the amount of forest cleared between 2000 and 2015, assuming that this land was cleared for agriculture (de la Paix, Lanhai, Xi, Ahmed, & Varenyam, 2013). We use these satellite data to create a map of (immediately) arable land countrywide. We assign each arable land pixel a cultivated crop (maize, sorghum, rice, cassava, sweet potato, Irish potato, tarot, banana, groundnut and soya bean) proportional to its share in the country's poverty basket, as defined by NISR (2015). Using optimal yield data (which assumes proper fertilization, good agronomic practices and rainfed conditions) from the Ministry of Agriculture (FAO, 2003), each assigned arable pixel of corresponding crop is then converted to estimate crop production and corresponding kilocalories.[4] For each district, we sum up the total potential kilocalorie production of all pixels before dividing by the number of people living in that district, which then gives us the potentially-available kilocalories per person.

To derive an indicator for food production, we rely on district statistics of *actual* agricultural production in 2017 (seasons A and B) obtained from NISR (2017a, 2017b). We convert these 2017 production statistics for the most important cereals, tubers and pulses into kilocalories using the same food composition data as above (Stadlmayr et al., 2012). Again, for each district, we then divide the total kilocalorie production by the population of that district resulting in actual available kilocalories per person at the district level. Due to data limitations, we exclude agricultural production from animal sources, such as meat, fish, milk and eggs. To represent food acquisition, we use the WFP's Food Consumption Score (FCS) from the Comprehensive Food Security and Vulnerability Analysis (CFSVA) of 2015. Based on recall data of food group consumption in the past 7 days, this composite score takes into account dietary diversity, food frequency, and relative nutritional importance of different food groups (WFP, 2008). For each district, we calculate the percentage of households with an acceptable score (i.e. above 35.5, according to World Food Programme's recommendations). For nutrition, we rely on data from the Demographic and Health Survey (DHS) of 2014/15. We define our

[3] We employ data indicators from different time periods, based on most recent availability; we assume that the geographical structure of older data remains constant over time.
[4] Based on food composition data compiled by Stadlmayr et al. (2012).

nutrition indicator as the percentage of under-five-years old children who are non-stunted (i.e. have a height-for-age ratio *above* the malnutrition cut-off for the reference population).

Table 2.1. Descriptive statistics of key FNS indicators for Rwanda (2014-2017)

Indicator	Indicator components	Obs.	Mean	Min	Max
Potential	Immediately arable land (km^2)	30	518.5	19.0	1361.7
	Daily potential kilocalorie production per person	30	2502.8	84.5	4565.0
Production	Daily kilocalorie production per person	30	1553.8	145.8	2668.0
Acquisition	% of households with FCS below 35.5	30	28.5	2.1	62.5
	% of households with FCS above 35.5	30	71.5	37.5	97.9
Nutrition	% of stunted children (<5 years, below -2 standard deviations of the median height-for-age of the reference population)	30	38.7	17.0	59.0
	% of non-stunted children (<5 years, above -2 standard deviations of the median height-for-age of the reference population)	30	61.3	41.0	83.0

Source: Authors with data from Brown de Colstoun et al. (2017); CFSVA (2015); DHS (2014/15); FAO (2003); Hansen et al. (2013); NISR (2015, 2017a, 2017b); Pekel et al. (2016); Stadlmayr et al. (2012); UNEP-WCMC (2018); Xiong et al. (2017).

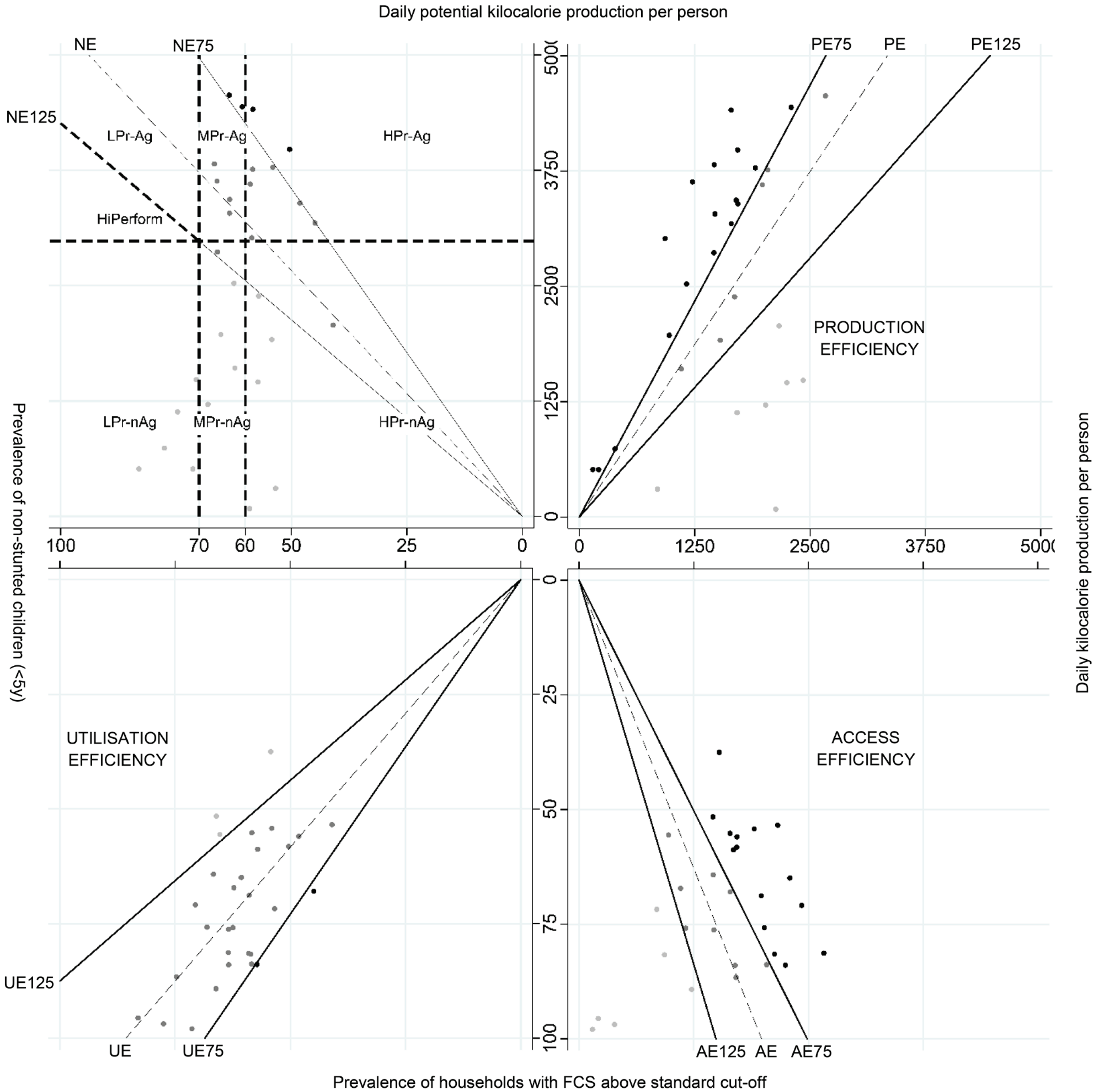
2.4. TYPOLOGY OUTCOMES

Having defined and estimated indicators for each FNS dimension for each district in Rwanda, Figure 2.4. presents the four-dimensional diagram loaded with real data. This diagram consists of four **scatterplots** where each dot represents a district and its corresponding pair of values for both constituent indicators. Figure 2.5. adds the spatial dimension by presenting four country maps, each covering a quadrant from Figures 2.3. and 2.4., showing level of production, access or utilisation efficiency and one with colours representing the intervention types. For the three efficiency types (panel b, c and d), the lightest grey colour indicates districts with “better than average” efficiency while the black colour refers to districts characterised by “worse than average” efficiency. The latter districts would be potential candidates for targeted interventions to improve production, access or utilisation efficiency. Panel (a) combines nutrition priority levels of districts with relative agricultural potential of that district, displaying the seven intervention types.

We observe 14 high-priority districts, six with lower agricultural potential and eight with stronger agricultural potential. Among those with fewer agricultural opportunities, we find two districts in the eastern part of the country (Ngoma and Kayonza) and four in the northwestern part (Rutsiro, Nyabihu, Burera and Rubavu), bordering Uganda and the Democratic Republic of the Congo. On the other hand, the high-priority districts endowed with higher agricultural potential are all clustered in the western part of the country, stretching from Gakenke in the north to Nyaruguru in the south.

Although these districts all need urgent nutrition interventions (based on child stunting levels), the type of optimal intervention will depend upon their location. Many high-priority districts suffer from severe access constraints—an observation which equally applies to many other districts and which corroborates with the adverse topography of the country. Closer to Kigali, this constraint appears less problematic. For most high-priority districts endowed with higher agricultural potential, these constraints are coupled with high production inefficiencies in Nyamagabe, Karongi, Nyaruguru and Gakenke, and with severe utilisation constraints in Kayonza. In contrast, access inefficiencies are less crucial in Huye and Ngororero. For these high-priority districts, severe production constraints are the most critical bottleneck combined with low utilisation efficiency in Ngororero. Remarkably, inefficiencies in utilisation do not vary much across districts, as only five districts perform substantially better or worse than the country’s average.

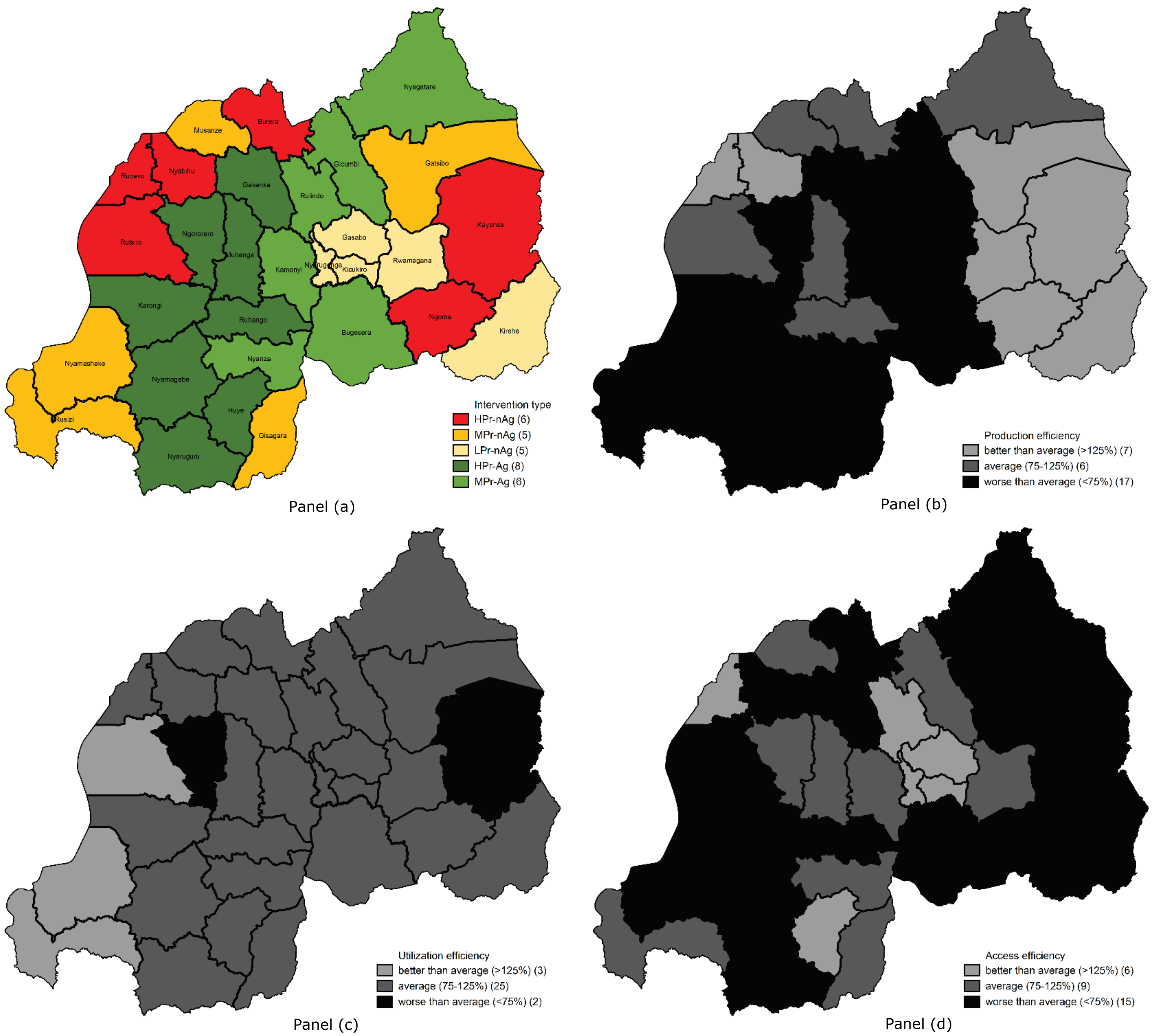
Figure 2.4. Combined scatterplot with district data, Rwanda (2014-2017)



Notes: LPr, MPr, HPr respectively stand for low-, medium- and high-priority districts for nutrition; Ag and nAg refer to higher and lower agricultural potential; HiPerform stands for high-performance districts. PE, AE, UE and NE are estimated lines based on population-weighted OLS regressions with intercept through the origin, respectively having a slope of 1.497, 19.892, 1.167 and 0.019. The E75 and E125 lines are derived from the previous lines with slopes being 75% and 125% the size of the estimated slopes.

Source: Authors with data from Brown de Colstoun et al. (2017); CFSVA (2015); DHS (2014/15); FAO (2003); Hansen et al. (2013); NISR (2015, 2017a, 2017b); Pekel et al. (2016); Stadlmayr et al. (2012); UNEP-WCMC (2018); Xiong et al. (2017).

Figure 2.5. Districts by intervention type and efficiency level, Rwanda (2014-2017)



Notes: LPr, MPr, HPr respectively stand for low-, medium- and high-priority districts; Ag and nAg refer to higher and lower agricultural potential.
Source: Authors with data from Brown de Colstoun et al. (2017); CFSVA (2015); DHS (2014/15); FAO (2003); Hansen et al. (2013); NISR (2015, 2017a, 2017b); Pekel et al. (2016); Stadlmayr et al. (2012); UNEP-WCMC (2018); Xiong et al. (2017).

2.5. LINKING TYPOLOGY TO POLICY

Despite its broad perspective, the typology elaborated in this chapter is useful in identifying various clusters of Rwanda districts that suffer mostly from production, access and utilisation inefficiencies. Within the current policy framework of highly decentralised development strategies, this relative benchmarking exercise is not only useful to directly inform future district policies but also to assure coherence and to capture synergy at the more national level.

Table 2.2. summarises the exact inefficiency profile observed for each cluster of high-priority districts in Rwanda. Based on this classification, the country's fourth generation PSTA (MINAGRI, 2018a) could be substantially improved with geographical targeting of key investments. For example, various sub-components under priority area 1 (innovation and extension) and 2 (productivity and resilience) which aim to improve agricultural productivity, have little or no spatial focus and should be more explicitly geared towards the high-priority districts of Huye, Nyamagabe, Gakenke, Karongi, Nyaruguru and Ngororero. Likewise, investment plans

proposed under priority area 1 (innovation and extension) and 3 (inclusive markets and value addition), which aim to improve linkages between production and processing while increasing knowledge and technology, do not explicitly target the districts of Nyamagabe, Gakenke, Karongi, Nyaruguru, Ngoma, Rutsiro, Nyabihu, Burera, Ruhango and Kayonza, which mostly suffer from market inefficiencies. Finally, to address the utilisation constraints characterising the districts of Kayonza and Ngororero, PSTA4 is not only spatially underspecified, its investment focus does not really cover the utilisation dimension of FNS—despite the holistic approach taken and the willingness to work across sectors. Table 2.2. also presents areas where PSTA4 aligns reasonably well with the inefficiency profile of high-priority districts. This alignment however mainly concerns investments in cash crop productivity as well as extension of irrigation schemes, the latter being spatially determined by the presence of waterbodies.

Table 2.2. Efficiency profile of high-priority districts in Rwanda (2014-2017) versus PSTA

District	Agricultural potential	Efficiency: Production	Efficiency: Access	Efficiency: Utilisation	Strategic Plan for Agricultural Transformation (PSTA) (cf. Annex 7: Government Plan Targets)
Huye	higher	**low**	high	medium	Increased area and productivity of coffee production in Huye
Nyamagabe, Gakenke, Karongi, Nyaruguru	higher	**low**	**low**	medium	Increased area and productivity of coffee production in Nyamagabe and Gakenke; increased area of irrigated land in Nyamagabe and Nyaruguru; increased area of tea production in Karongi and Nyaruguru
Ngoma, Rutsiro, Nyabihu, Burera, Ruhango	lower/higher	medium/ high	**low**	medium/ high	Increased area of irrigated land in Ngoma and Ruhango
Kayonza	lower	high	**low**	**low**	Increased area of irrigated land in Kayonza
Ngororero	higher	**low**	medium	**low**	Not mentioned in PSTA
Rubavu, Muhanga	lower/higher	medium/ high	medium/ high	medium	Increased area of irrigated land in Muhanga

Notes: The defining set of inefficiencies for each cluster of high-priority districts is indicated in bold.
Source: Authors with data from Brown de Colstoun et al. (2017); CFSVA (2015); DHS (2014/15); FAO (2003); Hansen et al. (2013); MINAGRI (2018); NISR (2015, 2017a, 2017b); Pekel et al. (2016); Stadlmayr et al. (2012); UNEP-WCMC (2018); Xiong et al. (2017).

ADVOCACY NOTE ON CHAPTER 2

The typology results of this chapter may be useful to the advocacy work of CSOs in Rwanda in at least two ways. First, they facilitate advocating for more geographically-sensitive FNS policies that heed the differences across districts. Second, the results help us to question or challenge investments that fail to target the most critical bottlenecks to improving nutrition outcomes.

Two basic questions should be raised when evaluating current or future government FNS policies:

1) What type of bottleneck does this policy address? Is it a production, access or utilisation challenge (constraint)?
2) Which area, region or district of the country does this policy target?

POSSIBLE ACTIONS

- If policies lack geographic targeting, CSOs can reference Table 2.2., which lists high-priority districts and their most critical bottlenecks.
- If the policy does explicitly mention target areas, then:
    - CSOs could ensure that priorities align with those summarised in Table 2.2.
    - When policies target low- or medium-priority districts, CSOs could redirect attention toward high-priority areas. Alternatively, CSOs could request guarantees that investments in low-priority districts will benefit surrounding high-priority districts.
    - When policies in high-priority districts do not prioritise the most critical bottlenecks, CSOs could request a reorientation so that interventions first address the most urgent challenges.

Chapter 3

NUTRIENT ADEQUACY MAPS FOR TARGETED POLICY INTERVENTIONS

3.1. INTRODUCTION

This chapter presents a series of **nutrient adequacy** maps to help understand, identify and locate the major challenges behind the country's insufficient or unbalanced food intake. The maps show food production and consumption data converted into corresponding calorie and nutrient amounts, comparing them with the nutrition requirements of each district's population. The adopted method roughly aligns with the food system approach currently advocated by many researchers and development partners (Ericksen, 2008; Gillespie & van den Bold, 2017; Global Panel on Agriculture and Food Systems for Nutrition, 2016; Jones & Ejeta, 2015; Pinstrup-Andersen, 2013; Stephens, Jones, & Parsons, 2018; Tendall et al., 2015). In this chapter we focus on total calories consumed (energy intake) as well as a set of **micronutrients** associated with "hidden hunger" when they are insufficiently consumed. These include calcium, iron, zinc, folate, vitamin B12 and vitamin A. Even without the obvious signs of malnutrition like stunting or "felt" hunger pangs, micronutrient deficiencies affect a person's well-being and development, and can lead to mental and cognitive impairment, poor health, low productivity, even death. By comparing nutrient consumption adequacy with the locally available food items that contain essential micronutrients, we can strategically design FNS policies.

Figure 3.1. presents the overall challenge of Rwanda's undernutrition, expressed both in terms of *diet quantity* and *quality*.

Key Words

Nutrient adequacy sufficient intake of essential nutrients based on individual requirements for optimal health

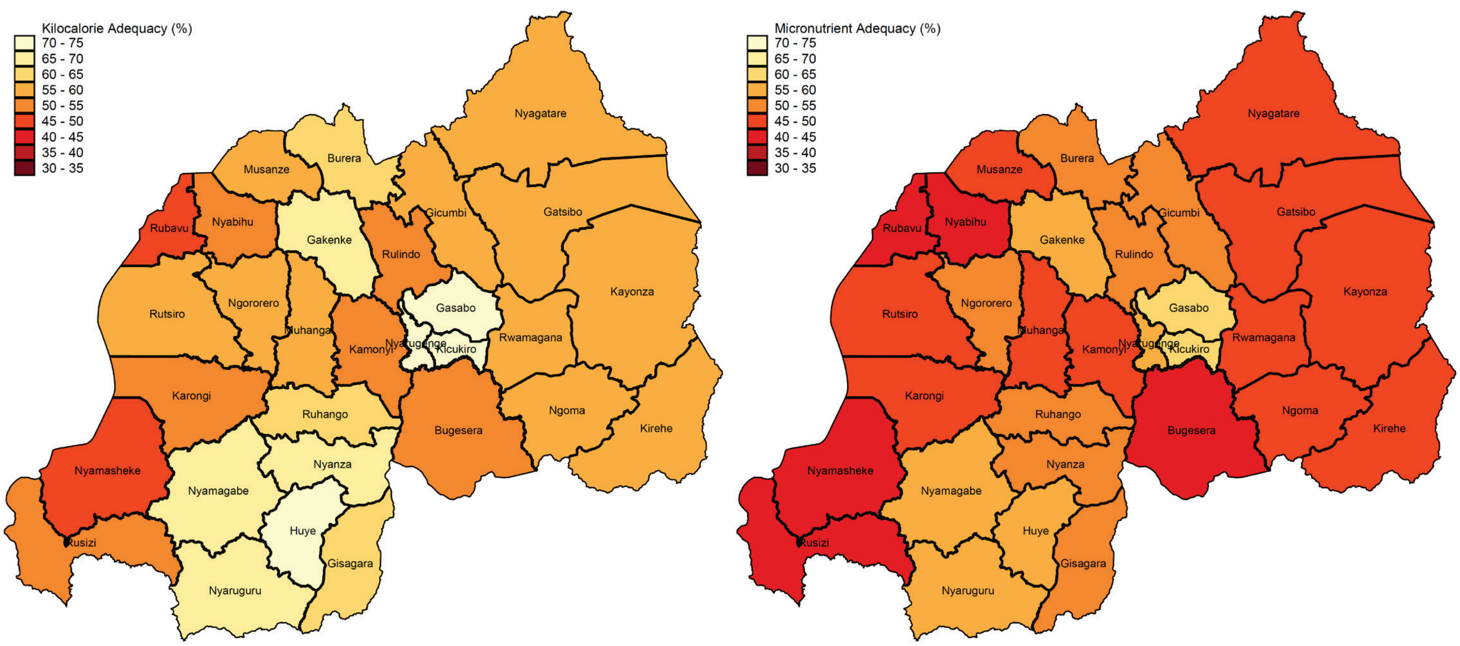
Micronutrients essential elements required in small quantities; vitamins and minerals are two distinct sets of micronutrients

Demand constraint a limitation defined by consumers' ability to afford, or willingness to pay for a certain commodity

Adult-male equivalence a concept to standardise nutrition requirements across population groups

Sampling weights values associated with data observations that ensure that survey statistics are representative of the population

Figure 3.1. Diet quantity and quality, Rwanda (2013/14)



Source: Authors with data from EICV4 (2013/14).

Whereas diet quantity refers to a sufficient intake of kilocalories, diet quality looks at intake of micronutrients. In this chapter we define nutrition adequacy at the "household level," which means that the required number of kilocalories or micronutrients for each household depends on size and demographic structure of the family. To obtain mean adequacy rates for each district, we first cap energy and nutrient household adequacies at 100% (since 100% means sufficient intake). Diet quantity is straightforward since it depends only on total kilocalories; for diet quality, we apply the same procedure for each micronutrient individually before computing the arithmetic mean at the household level, also known as the mean adequacy ratio (MAR).

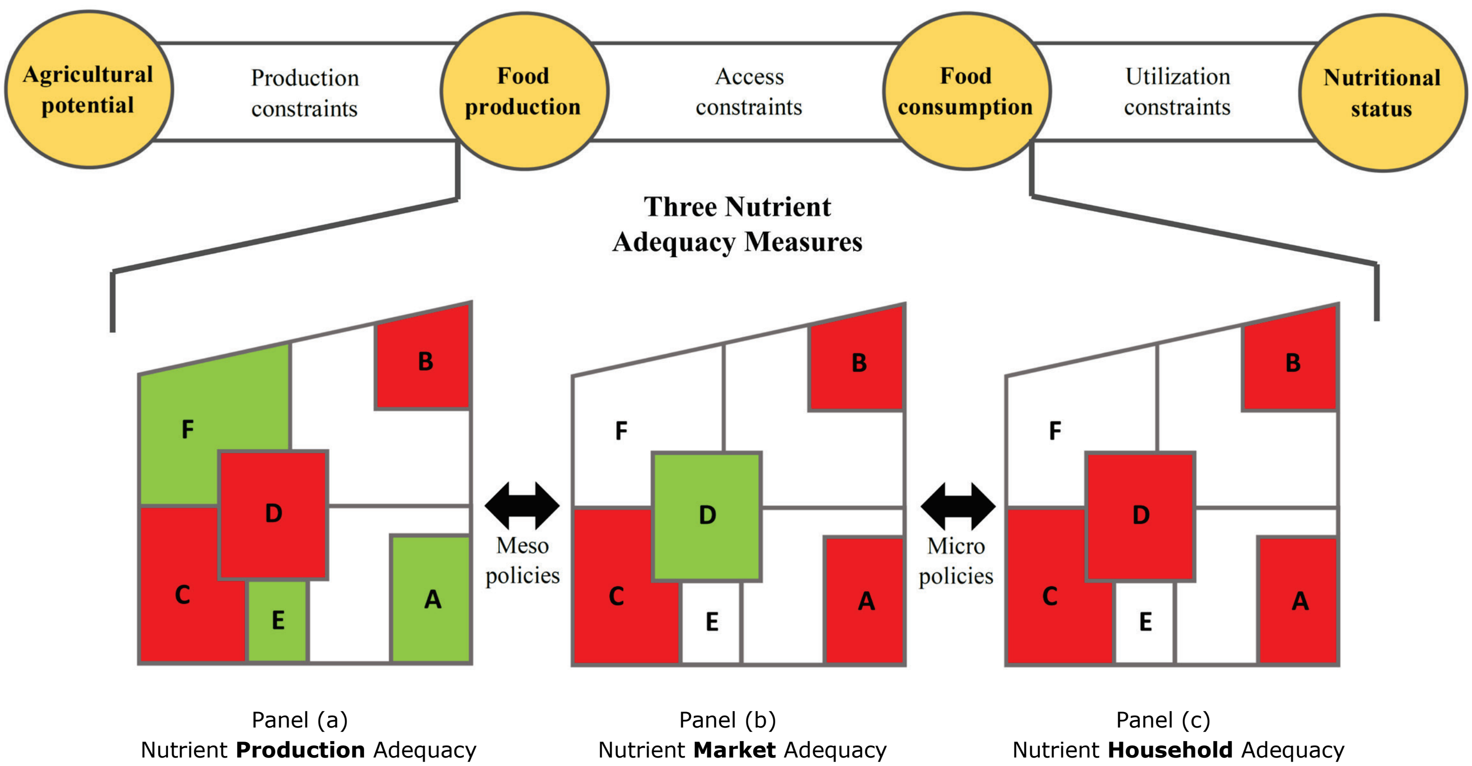
The left-hand side map of Figure 3.1. shows that food energy intake is relatively better in the three districts composing Kigali city as well as in Huye with adequacy levels above 70%. In contrast, households living in Nyamasheke and Rubavu in the country's west are doing much worse and reach at best 50% of their recommended intake. In terms of micronutrients (right-hand side map of Figure 3.1.), the situation is more precarious, with generally lower adequacy levels but with largely the same spatial distribution: diets in Kigali are more diversified, while those in various districts in the west as well as in Bugesera are characterised by a lack of essential micronutrients.

3.2. CONCEPTUAL FRAMEWORK

To generate evidence on the causes and related opportunities to address the spatial heterogeneity in food-intake deficiency, we map three distinct nutrient adequacy measures for food energy and micronutrients. The first measure, *nutrient production adequacy*, quantifies the district's agricultural production capacity to meet the minimal energy and nutrient requirements of its population. The second measure, *nutrient market adequacy*, indicates the aggregate accessibility of calories and nutrients, based on the district's population food needs. The third measure, *nutrient household adequacy*, addresses the unequal access among households within each district. By comparing the three nutrient adequacy maps and by connecting them to their corresponding food sources, we can strategically design and evaluate FNS policies.

The green colour in Figure 3.2. indicates nutrient surplus in an area, red indicates a deficit, and white indicates self-sufficiency. Panel (a) in Figure 3.2. shows three areas with insufficient nutrient production (areas B, C and D). Increasing nutrient production in these areas might be an appropriate policy strategy, but it is important to explore additional challenges and opportunities first. For example, look at area D in panels (a) and (b). Even though area D does not produce enough nutrients, its neighbouring areas E and F have production surpluses—the market in area D is *not* nutrient deficient, perhaps thanks to successful market integration with areas E and F. Given its location, area C might seek similar forms of market integration with areas E and F.

Figure 3.2. Three nutrient adequacy measures to identify and locate bottlenecks to food security



Note: White indicates self-sufficiency, green indicates surplus and red indicates deficiency.
Source: Authors.

Now look at area A in panels (a) and (b). Area A *produces* enough nutrients, but markets in area A do not sell enough to keep the local population healthy. We call this "nutrient loss." It occurs when nutrients produced locally are traded or sold outside the area, or when post-harvest losses prevent those nutrient-rich foods from making it to local markets. Fixing the nutrient loss may require revising commercial or trade policies, improving transport infrastructure to better link markets to producers, or by investing in storage and processing capacity.

Finally, let us compare area D in panels (b) and (c). Although enough nutrients make it to the market (panel b), households still lack adequate nutritious food (panel c). Why would this be? Perhaps the nutritious food is simply unaffordable for households; or perhaps people lack nutrition knowledge and therefore ignore important nutrient-rich food. We call these obstacles **demand constraints** since they do not depend on the suppliers, but on the consumers demanding food products. Fixing these challenges might require nutrition-sensitive social protection schemes that help supplement income, or behavioural change campaigns that promote nutrient-rich foods or nutrition education.

3.3. DATA

The data used in this chapter come from various sources but each source allows us to compute estimates of nutrient adequacy for the 30 districts of Rwanda. For production adequacy, we rely on the official production statistics of the agricultural year 2016-2017 (season A and B combined) provided by the National Institute of Statistics of Rwanda (NISR, 2017a). These comprise data on 4 main cereals (maize, sorghum, rice and wheat), 5 tubers (cassava, Irish potato, sweet potato, tarot and cooking banana), 4 pulses (beans, peas, groundnuts and soya beans) as well as sweet and beer bananas, and aggregate production estimates on other fruit and vegetables.[5] Using food composition data compiled for nine African countries (Stadlmayr et al., 2012), we convert production quantities into kilocalories and other nutrient equivalents and aggregate by district. We estimate the ratio of production adequacy by dividing the food energy and nutrient production levels by their respective required intakes according to each district's demographic makeup. We use the same approach for market adequacy, based on food consumption data obtained from the Integrated Household Living Conditions Survey (EICV4) conducted in 2013/14 (NISR, 2016). This survey combines different sources of food consumption, such as purchases and own production. In total, more than 120 food items are covered. Quantities of food consumption are estimated by imputing regional food prices. Using the same food composition data (Stadlmayr et al., 2012), we derive aggregate nutrient consumption by district and divide it by the district's required intake levels. We derive household adequacy from the same household consumption survey, estimated at the household level by considering the family's required intake (capping all values above 100%), then averaging household ratios by district. The required intake levels for each household and district are determined using the common **adult-male equivalence** approach combined with population **sampling weights**. Each of the three measures is a ratio, where 100% reflects adequacy, and values below (above) 100% point to deficiency (surplus). The colour scheme applied throughout this chapter is pale yellow for adequacy, green for surplus and red for deficiency.

3.4. NUTRIENT ADEQUACY

Table 3.1. provides an overview of absolute gaps in nutrient production and consumption, compared to recommended intake levels as well as the three nutrient adequacy measures.

Table 3.1. National food energy and nutrient adequacy levels based on production, consumption and recommended intake, Rwanda (2013-2017)

	Production per day, AME	Consumption per day, AME	Recommended intake per day, AME	National Production Adequacy (%)	National Market Adequacy (%)	National Household Adequacy (%)
Kilocalories (kcal)	2077.6	1696.0	2750.0	75.5	61.7	59.5
Protein (g.)	(47.6)	50.5	50.0	(95.2)	101.0	79.3
Calcium (mg.)	(370.0)	484.3	1000.0	(37.0)	48.4	47.6
Iron (mg.)	12.8	13.0	27.4	46.8	47.4	47.7
Zinc (mg.)	7.2	7.2	14.0	51.2	51.5	50.4
Folate (mcg.)	490.7	706.2	400.0	122.7	176.6	92.3
Vitamin B12 (mcg.)	(0.0)	0.3	2.4	(0.0)	11.4	9.9
Vitamin A (mcg.)	(342.7)	376.9	600.0	(57.1)	62.8	56.8

Notes: In absence of reliable statistics on meat, fish, dairy and palm oil production, the corresponding values for protein, calcium, vitamin B12 and vitamin A are put in brackets.
Source: Authors with data from EICV4 (2013/14) and NISR (2017).

[5] We were unable to obtain reliable statistics on meat, fish and dairy production, which will render the nutrient production measures of protein, calcium and vitamin B12 much less accurate. The same is true for palm oil with respect to vitamin A related measures.

Apart from folate and protein where households reach at least 80% of the recommended levels, the average Rwandan diet looks very dismal. Average vitamin B12 adequacy is extremely low (10%) while for most other micronutrients, households barely reach half of their recommended intake levels: 48% for calcium and iron, 50% for zinc and 57% for vitamin A. With an average kilocalorie adequacy level at 60%, hunger, in addition to micronutrient deficiency, remains a daily reality for many Rwandese families.

Insufficient production of food items containing the necessary nutrients is certainly one key explanation for the low intake levels observed. This is certainly true for iron and zinc, which have production adequacies of barely 50%, and to a lesser extent for kilocalories (around 76%). The same holds true for calcium and vitamin B12 despite limited production statistics (see above).

Given data limitations, it is also difficult to assess the precise magnitude of nutrient losses between production areas and markets. However, with respect to food energy, there are significant losses as the country's market adequacy is substantially lower than its production adequacy (62% versus 76%). Interestingly, the Rwanda market appears to be supplied by imported food items rich in folate given that the national market adequacy significantly exceeds the nutrient's production adequacy.

By comparing nutrient market and household adequacies, we observe demand problems for protein, folate and to a lesser extent vitamin A. For vitamin A, which is typically found in fruit and vegetables, a lack of knowledge about the nutritional value of vitamin A may explain why household intake is deficient. For protein and folate, found mostly in more expensive food items such as meat, fish and pulses, unaffordability may be a more straightforward explanation behind deficient intakes.

Figure 3.3. displays the same three adequacy measures for each of the six micronutrients covered in this chapter, illustrated geographically by district.

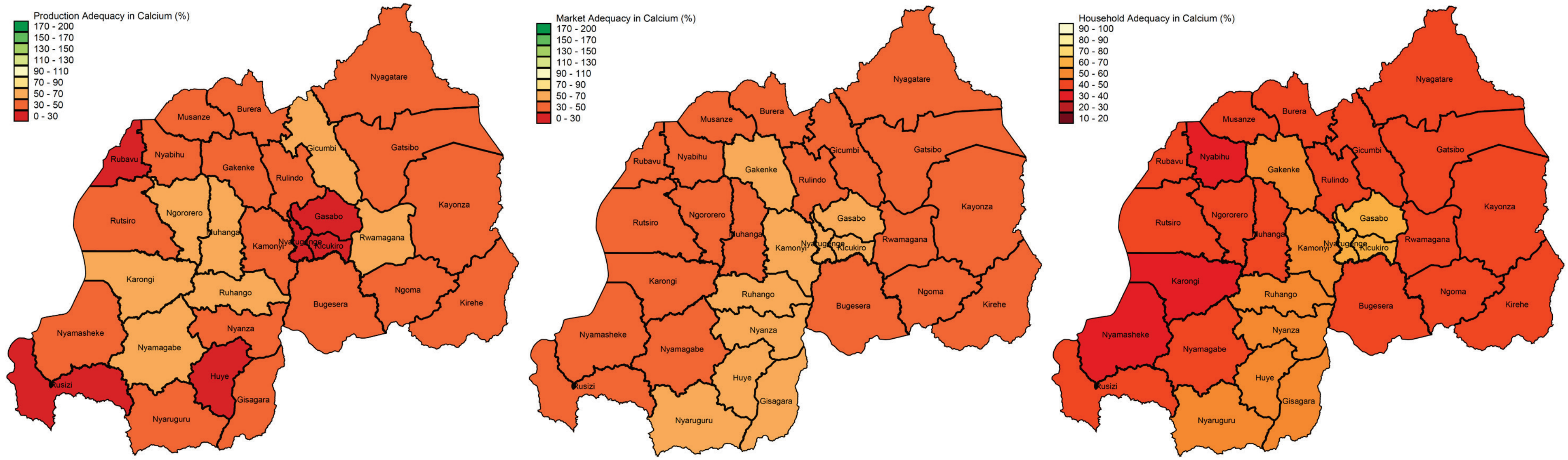
For the most critical nutrient deficiency, *vitamin B12* (see panel e), the same spatial outlook applies to the majority of districts: low production of food items containing this nutrient (left-hand side map), resulting in deficient market supply (middle map) and low corresponding adequacies observed at the household level (right-hand side map). Kigali is a minor exception with slightly better nutrient market and household adequacy levels for its three constituent districts.

For *calcium* (see panel a), *iron* (see panel b) and *zinc* (see panel c), the nutrient adequacy measures depict a highly similar pattern. For each nutrient, the more densely populated districts of Kigali have lower production adequacies. The same observation also applies to Rusizi for all three nutrients, Huye for calcium and iron, and Rubavu for calcium. In contrast, slightly higher production performances are recorded in various districts scattered throughout the country with Nyagatare and a couple of other districts in the north doing noticeably better in terms of iron and zinc production. These spatially unequal production adequacies are roughly levelled out in terms of market access, which points to some degree of market integration between production sites and consumption centres. There is still significant geographical diversity when analysing nutrient household adequacies, with Kigali generally performing better while Nyamasheke and Rusizi are doing worse for at least two out of three nutrients. Demand constraints, either in terms of unaffordability or lack of knowledge on nutrition, may be the underlying causes behind these lower intakes.

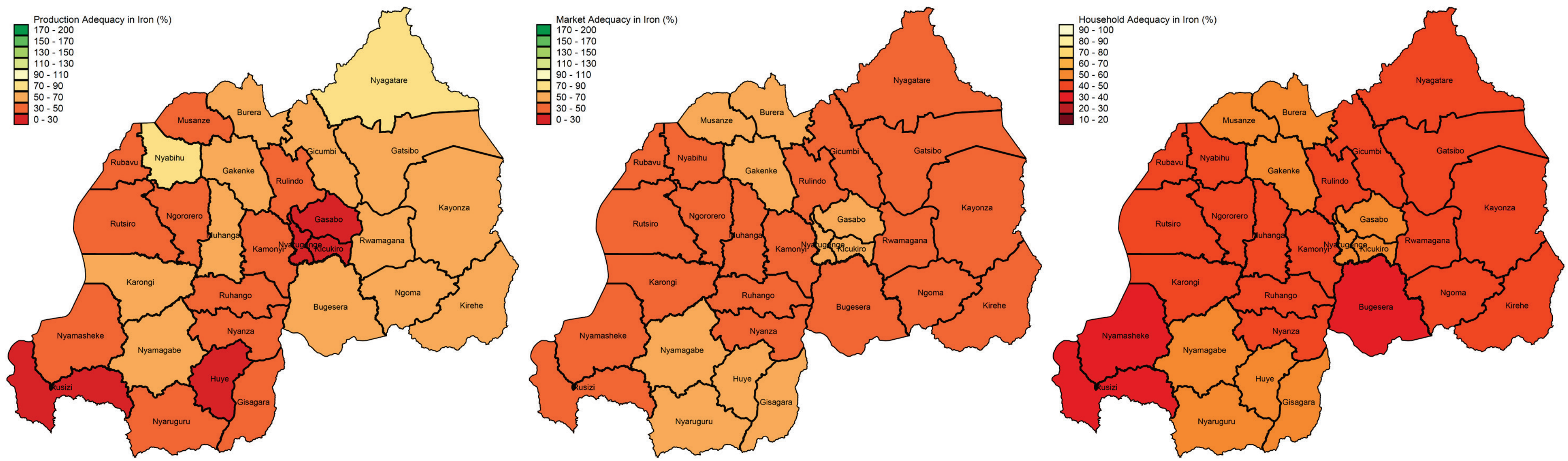
For *vitamin A* (see panel f), we observe a different spatial combination of nutrient adequacies. Although the districts of Kigali combined with Rusizi and Huye are again far from producing enough vitamin A to feed their respective populations, various districts (mainly in the country's south) are roughly self-sufficient. This may be due to the more favourable biophysical conditions of those areas for growing crops rich in vitamin A (such as sweet potato). Compared to calcium, iron and zinc, market integration of foods containing vitamin A is lower, with Bugusera and three districts in the north being the most undersupplied. In the next section, we link this difference in performance to higher levels of perishability of food items rich in this nutrient.

Compared to all other micronutrients, *folate*-rich foods (see panel d) are a lesser nutrition priority. On average, Rwanda produces enough folate to properly feed its population and districts without sufficient local production (again Kigali, Rusizi, Huye and Rubavu) seem to be well connected to surrounding rural production zones or to markets abroad. Given these favourable market conditions, nutrient household adequacies are well above 90% for most districts and only a few districts perform slightly worse.

Figure 3.3. Micronutrient production, market and household adequacies at district level, Rwanda (2013-2017)

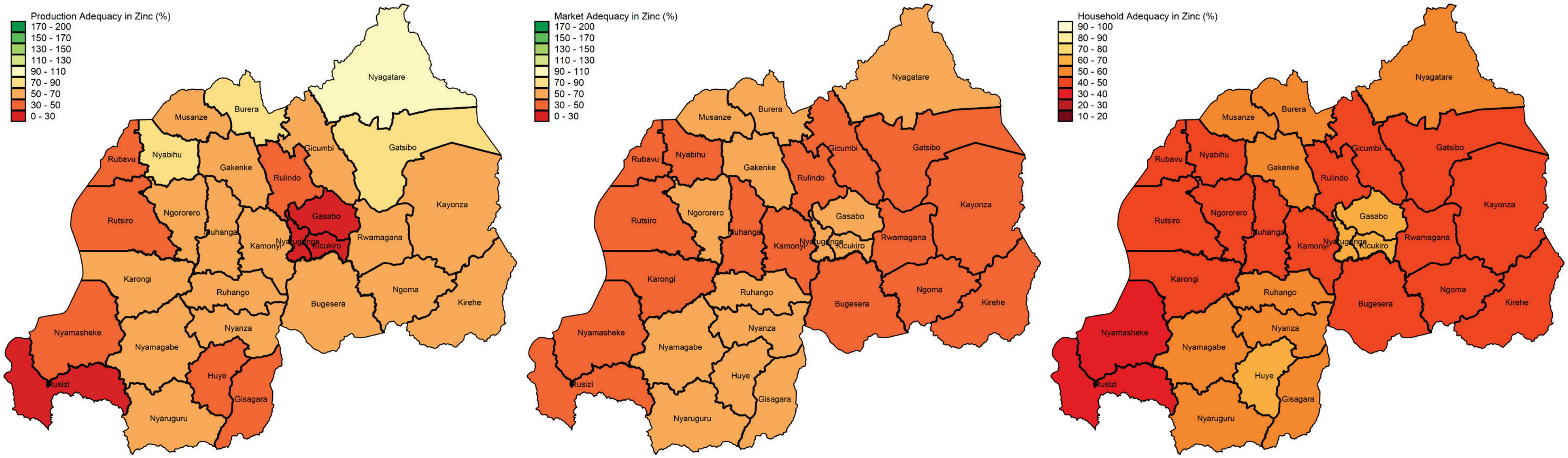


Panel (a): Calcium adequacy

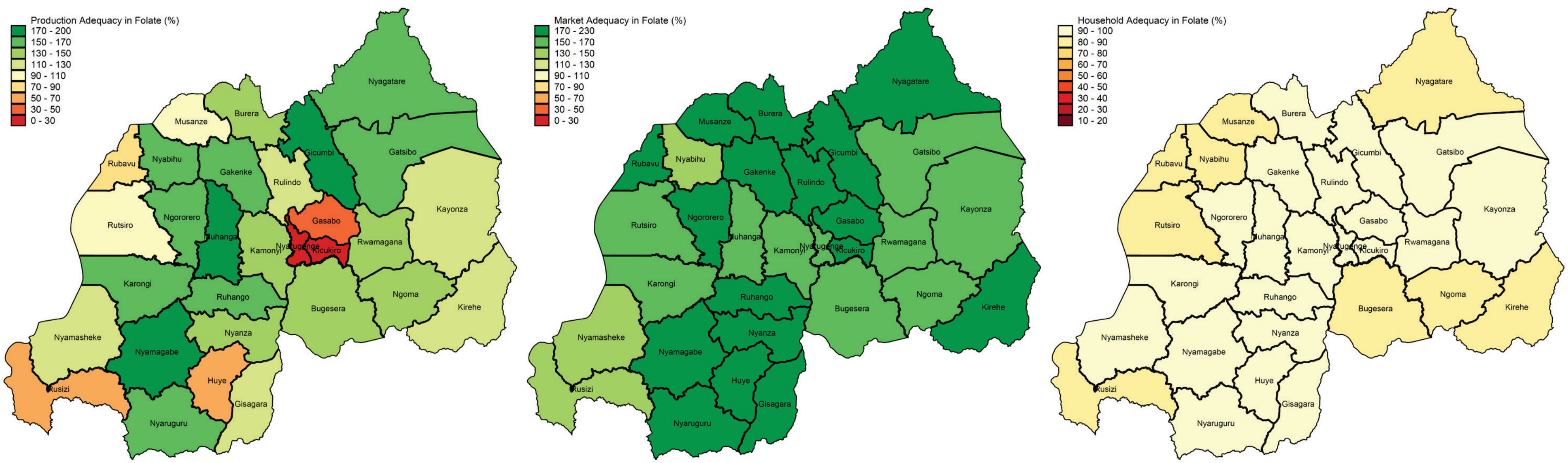


Panel (b): Iron adequacy

Figure 3.3. Continued

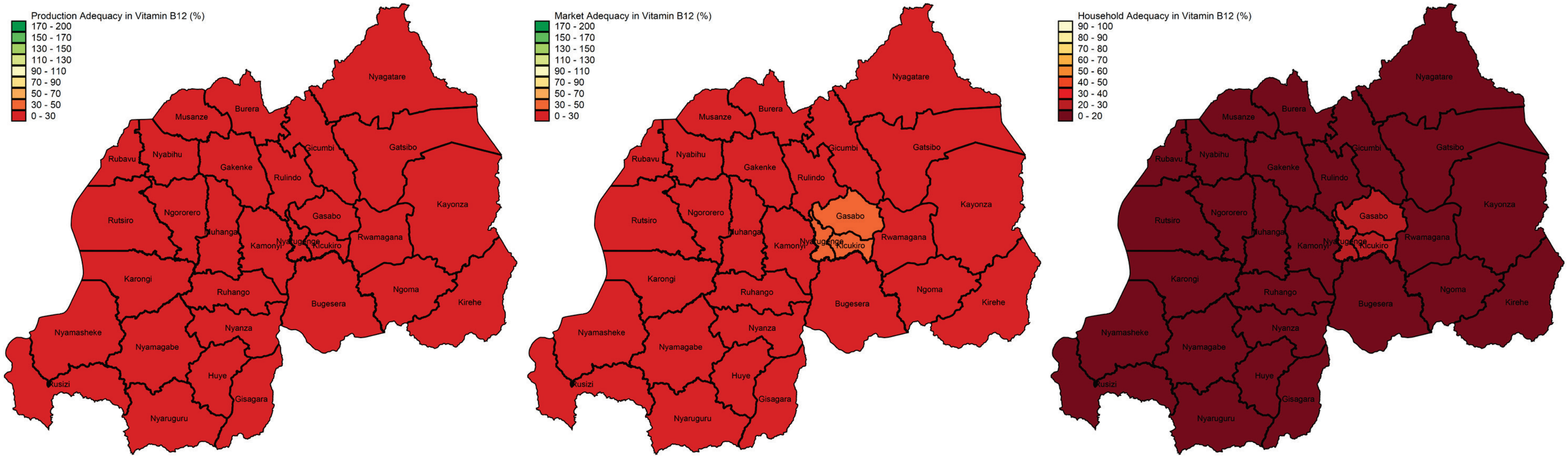


Panel (c): Zinc adequacy

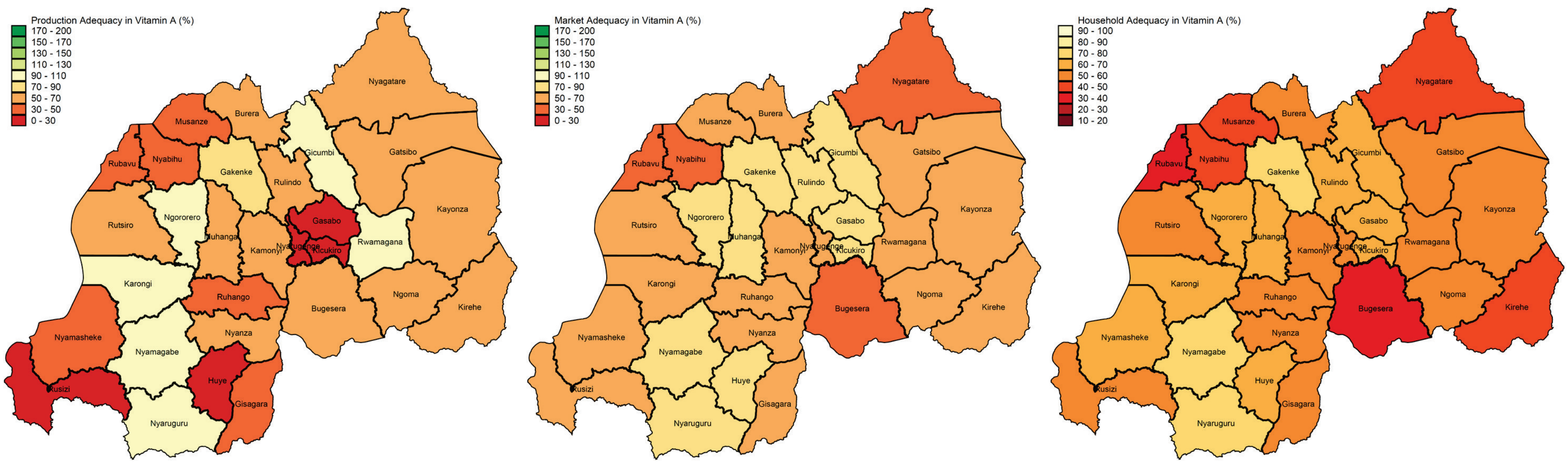


Panel (d): Folate adequacy

Figure 3.3. Continued



Panel (e): Vitamin B12 adequacy



Panel (f): Vitamin A adequacy

Source: Authors with data from EICV4 (2013/14) and NISR (2017).

3.5. FROM NUTRIENT DEFICIENCIES BACK TO FOOD AND TARGETED POLICIES

In this section, we shift focus to the actual food items that supply micronutrients, considering policy recommendations that could help increase production, reduce nutrient loss and improve consumer access to healthy foods. In real life people grow and buy actual foods—not micronutrients. For each nutrient covered in this chapter, Table 3.2. presents the five most important national food items according to two criteria:

1) current share in overall nutrient intake (%) (left-hand side column)
2) cheapest prices per nutrient (expressed in *Rwanda Francs* (RwF) (right-hand side column)

Table 3.2. also identifies the nutritional content per 100 gr edible portion of each food item (Stadlmayr et al., 2012) and its food budget share.

To address vitamin B12 deficiency, the country should dramatically produce more animal products, so they become much more available and affordable on the market. Currently, more than 95% of overall vitamin B12 intake is obtained through the consumption of dairy products (i.e. fresh and curdled milk), for which no cost-effective alternative exists as largely the same food items rank best in both top-5 lists of Table 3.2. In absence of such alternatives and given current sub-optimal production, policy-makers should consider strategies to fortify food with vitamin B12 or provide vitamin B12 supplements to the population.

The similar spatial profile for calcium, iron and zinc as discussed in the previous section stems from the fact that roughly the same food sources are responsible for intakes of all three nutrients (see left-hand side of Table 3.2.). Indeed, dry beans account for the highest share in nutrient intake, followed by sweet potato, amaranth, Irish potato and cassava flour. The dry condition of beans and cassava flour, which facilitates transportation and trade, might explain the higher levels of market integration for each of the three nutrients. As a result, the location for increased production of food crops rich in calcium, iron and zinc or the location of cross-border entry points seems less important. When increased production is not feasible in the short run (perhaps due to bio-physical constraints), it is worth considering small modifications to the daily food basket. The right-hand side of Table 3.2. indicates that perhaps soya bean (dry and flour) is a cost-effective alternative given its low nutrient price and high nutritional density. In addition, cassava leaves have low nutrient prices for both calcium and iron too, while the consumption of curdled and fresh milk could further increase the uptake of calcium in a cost-effective way. As observed above, dairy products are equally important for vitamin B12. As such, slight changes in food budget allocations might increase the uptake of calcium, iron and zinc considerably. Further, policies in Rwanda should not only examine to what extent people would be receptive to changing their food preferences, but also subsequently promote the production of these alternative food crops.

The difficulties of perishability, highlighted in the previous section, are apparent in Table 3.2.: both of the top-5 lists of vitamin A food items include highly perishable foods (such as dark-green leafy vegetables, tubers and fruit). Therefore, investing in transportation infrastructure to reduce travel time between harvest and consumption or the development of storage and processing capacities are policies worth considering to improve the distribution of vitamin A, especially to the more northern districts. Moreover, demand problems associated with vitamin A should be tackled by informing the population about the nutritional value of vitamin A rich food items while highlighting some economically viable alternatives, such as spinach, mangos and carrots. In fact, the latter three food items all have nutrient prices (substantially) below that of sweet potato, which is currently the most important source of vitamin A. Therefore, a higher budget share devoted to spinach, mangos and carrots might considerably increase nutrient adequacy levels.

While working to increase agricultural production of some crops, improve distribution efficiency for others and promote more nutritious diets, social protection schemes (such as food or cash transfers) should be considered in the short run to assure minimal intakes of essential nutrients for the most undernourished households in Rwanda.

Table 3.2. Top-5 food items according to nutrient share and price, Rwanda (2013/14)

	Food item	Nutrient intake share	Price per nutrient (RwF)	Nutrient content 100gr	Food budget share	Food item	Nutrient intake share	Price per nutrient (RwF)	Nutrient content 100gr	Food budget share
Calorie	Dry beans	19.7%	0.12	337.7	14.1%	Dry maize (grain)	2.2%	0.06	351.0	0.8%
	Sweet potato	18.6%	0.11	115.5	12.9%	Sorghum	0.6%	0.09	344.0	0.3%
	Cassava (flour)	10.5%	0.09	335.0	5.7%	Cassava (flour)	10.5%	0.09	335.0	5.7%
	Irish Potato	8.6%	0.23	80.0	12.1%	Sorghum (flour)	1.6%	0.10	347.0	1.0%
	Banana - cooking	8.5%	0.17	140.0	8.7%	Avocado	1.4%	0.10	154.0	0.9%
Protein	Dry beans	44.6%	1.72	22.7	14.1%	Soya Flour	2.4%	1.49	34.5	0.6%
	Sweet potato	8.1%	8.71	1.5	12.9%	Soya (dry)	0.2%	1.51	32.0	0.0%
	Irish Potato	6.8%	9.76	1.9	12.1%	Dry beans	44.6%	1.72	22.7	14.1%
	Fresh beans	5.5%	3.34	7.8	3.4%	Dry maize (grain)	2.0%	2.20	9.1	0.8%
	Corn (flour)	5.3%	4.10	9.5	4.0%	Sorghum	0.6%	2.84	10.5	0.3%
Calcium	Dry beans	22.4%	0.28	142.2	14.1%	Amaranth	16.7%	0.05	380.0	1.8%
	Amaranth	16.7%	0.05	380.0	1.8%	Cassava leaves	5.3%	0.10	276.1	1.2%
	Sweet potato	13.7%	0.41	31.5	12.9%	Curdled Milk	2.9%	0.18	121.0	1.2%
	Cassava (flour)	11.7%	0.21	137.5	5.7%	Fresh milk	7.3%	0.19	120.0	3.2%
	Fresh milk	7.3%	0.19	120.0	3.2%	Soya (dry)	0.1%	0.21	231.6	0.0%
Iron	Dry beans	34.2%	5.46	7.2	14.1%	Amaranth	8.3%	2.89	6.2	1.8%
	Sweet potato	14.5%	11.80	1.1	12.9%	Cassava leaves	3.2%	4.98	5.5	1.2%
	Amaranth	8.3%	2.89	6.2	1.8%	Dry beans	34.2%	5.46	7.2	14.1%
	Irish Potato	7.6%	21.10	0.9	12.1%	Dry maize (grain)	1.7%	6.08	3.3	0.8%
	Fresh beans	4.6%	9.67	2.7	3.4%	Soya (dry)	0.1%	6.21	7.8	0.0%
Zinc	Dry beans	35.4%	13.50	2.9	14.1%	Soya (dry)	0.1%	10.20	4.7	0.0%
	Sweet potato	13.1%	33.27	0.4	12.9%	Dry maize (grain)	2.2%	12.39	1.6	0.8%
	Irish Potato	7.8%	52.44	0.4	12.1%	Soya Flour	1.7%	13.14	3.9	0.6%
	Corn (flour)	6.0%	22.50	1.7	4.0%	Dry beans	35.4%	13.50	2.9	14.1%
	Cassava (flour)	4.9%	39.64	0.7	5.7%	Sorghum (flour)	2.0%	16.44	2.1	1.0%
Folate	Dry beans	52.6%	0.09	433.7	14.1%	Dry beans	52.6%	0.09	433.7	14.1%
	Sweet potato	17.4%	0.25	52.0	12.9%	Soya (dry)	0.1%	0.13	375.0	0.0%
	Fresh beans	3.9%	0.29	89.7	3.4%	Green pea (dry)	0.3%	0.13	510.0	0.1%
	Irish Potato	3.9%	1.05	17.5	12.1%	Soya Flour	1.5%	0.15	345.0	0.6%
	Cassava (flour)	3.1%	0.62	47.0	5.7%	Spinach	0.1%	0.19	176.0	0.1%
Vitamin B12	Fresh milk	76.7%	38.22	0.6	3.2%	Fresh milk	76.7%	38.22	0.6	3.2%
	Curdled Milk	18.7%	57.35	0.4	1.2%	Curdled Milk	18.7%	57.35	0.4	1.2%
	Eggs	1.9%	195.42	0.9	0.4%	Sheep/mutton/lamb meat	0.1%	164.08	2.9	0.0%
	Goat meat	0.7%	245.66	1.1	0.2%	Eggs	1.9%	195.42	0.9	0.4%
	Fish (fresh/frozen)	0.7%	609.16	0.6	0.5%	Goat meat	0.7%	245.66	1.1	0.2%
Vitamin A	Sweet potato	45.7%	0.19	69.2	12.9%	Amaranth	16.1%	0.07	240.7	1.8%
	Amaranth	16.1%	0.07	240.7	1.8%	Spinach	0.4%	0.08	409.0	0.1%
	Banana - cooking	10.7%	0.54	43.0	8.7%	Cassava leaves	8.3%	0.10	285.6	1.2%
	Cassava leaves	8.3%	0.10	285.6	1.2%	Mangos	2.0%	0.11	206.7	0.3%
	Tomatoes	3.1%	0.51	52.0	2.3%	Carrots	2.1%	0.15	713.3	0.5%

Note: The grey-shaded columns represent the two ranking variables used to derive top-5 lists of food items for each nutrient.
Source: Authors with data from EICV4 (2013/14).

ADVOCACY NOTE ON CHAPTER 3

Let us consider some key advocacy messages from this analysis:

1. Rwanda's population suffers from micronutrient deficiency, also known as "hidden hunger," which can cause severe cognitive and physical health, and human development problems.
2. The causes behind Rwanda's hidden hunger depend both on geographic location, the type of micronutrient, and corresponding food sources that supply that micronutrient.
3. To address hidden hunger, policy interventions should be geographically-sensitive and tailored to specific foods.
4. The table below summarises the main findings per micronutrient, starting with vitamin B12 which has the lowest national nutrient adequacy. Proposed priority actions are **in bold** and underlined text roughly indicates priority locations.

Nutrient	National Household Adequacy	Targeted policy interventions
Vitamin B12	9.9%	- **Increase availability of animal-based food items** across the entire country - **Fortify foods with vitamin B12** or **provide vitamin B12 supplements** across the entire country
Calcium, Iron, Zinc	47.6-50.4%	- **Increase availability of dry beans, sweet potato, amaranth, Irish potato and cassava flour** across the entire country and especially in Rusizi, Huye and Rubavu - **Increase nutrition awareness** of cost-effective food items rich in calcium, iron or zinc, such as soya beans and cassava leaves
Vitamin A	56.8%	- **Increase horticultural production** (rich in vitamin A) in districts with appropriate biophysical conditions, and especially in Huye and Rusizi - **Strengthen value chains of horticultural products** by investing in transportation, storage and processing infrastructure to better handle perishable food items - **Increase nutrition awareness** of cost-effective food items rich in vitamin A, such as spinach, mango and carrot
Folate	92.3%	- No priority
All nutrients	---	- **Implement social protection programs** in the short run to guarantee a minimal intake of key nutrients to the most undernourished households, a large share of which live in the districts of Bugesera, Nyabihu, Nyamasheke, Rusizi and Rubavu

Chapter 4

MAKING AGRICULTURAL AND RELATED POLICIES MORE NUTRITION-SENSITIVE

4.1. INTRODUCTION

Rwanda is still struggling with high levels of malnourishment despite solid economic growth, improved access to schooling and basic infrastructure such as water, sanitation and electricity (WBG, 2018; WDI, 2019; Weatherspoon, Miller, Ngabitsinze, Weatherspoon, & Oehmke, 2019). For example, the chronic malnutrition (or stunting) prevalence rate for children younger than five was 37.9% in 2014/15 (DHS 2014/15). Figure 4.1. presents the spatial distribution of child stunting; only in Kicukiro (one of three districts composing Kigali) is the prevalence rate is below 20%. In three of its neighbouring districts and in Kirehe it falls between 20% and 30%. Surrounding areas have poorer outcomes: 14 districts (predominantly) in the western part of the country have stunting levels above 40%, and stunting is most problematic in Nyabihu, Ngororero and Nyamagabe, with rates above 50%.

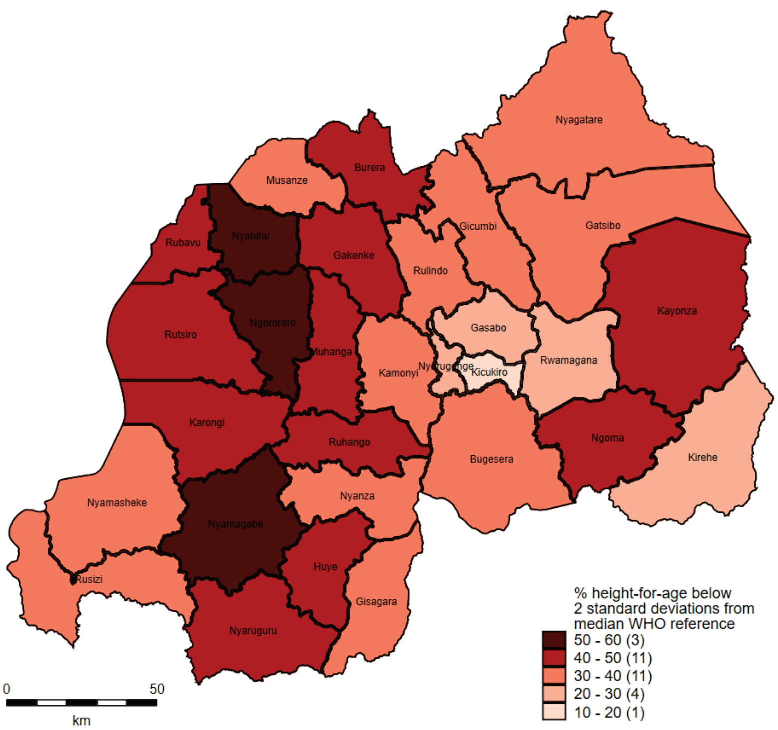
Key Words

Diet optimization procedure to identify the optimal diet according to a particular diet characteristic (e.g. its cost) while meeting a set of requirements (often in terms of nutrient intake)

Linear programming technique based on linear mathematical relations to run a diet optimization procedure

Nutrient allocation frontier the limits of maximum efficiency for attaining nutrient adequacy for any given budget level

Figure 4.1. Chronic malnutrition among children below the age of five years, Rwanda (2014/15)



Source: Authors with data from DHS (2014/15).

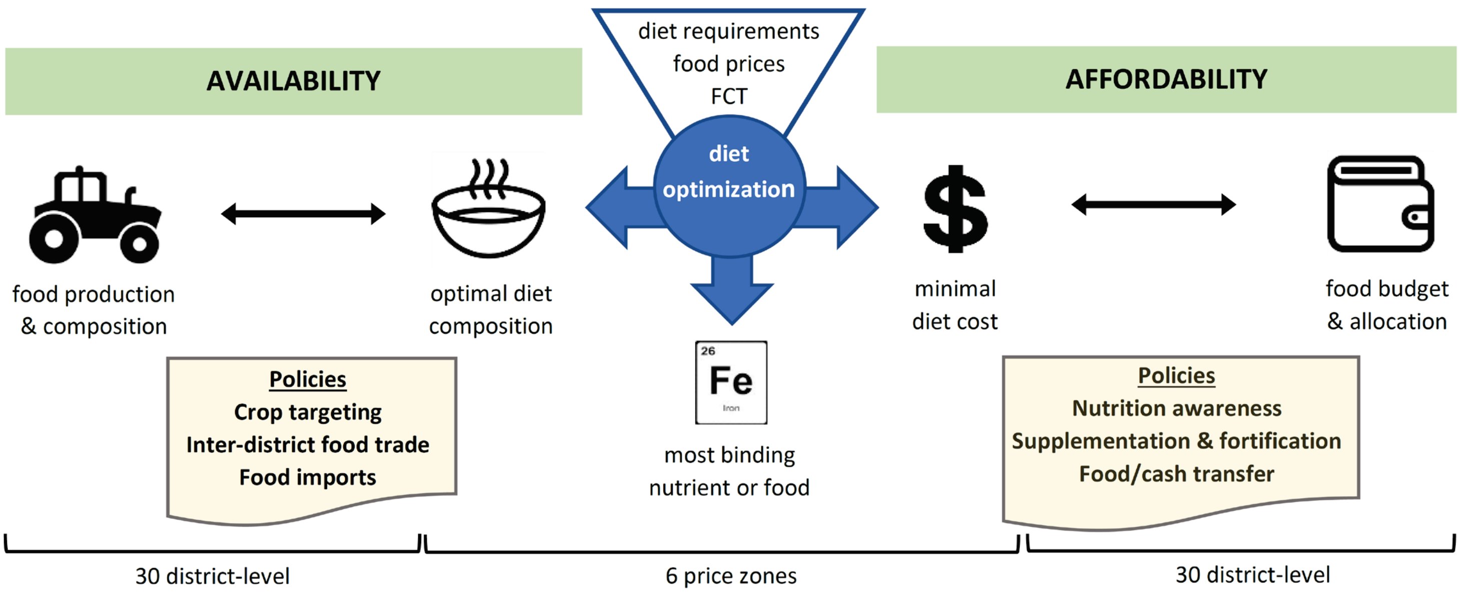
According to the basic framework of malnutrition developed by UNICEF (1992), chronic malnutrition is the combined result of inadequate dietary intake and disease, both being immediate and interrelated causes. Although collaboration between health and agriculture sectors should be encouraged where politically feasible, this chapter focuses on the food dimension and the role of agricultural and related policies in reducing stunting in Rwanda. More particularly, it identifies areas for improvement and presents policy recommendations to make the country's food and nutrition security policies more geographic- and nutrition-sensitive.

To understand how food and nutrition security policies can reduce malnutrition, we rely on **diet optimization** techniques. Such techniques identify the cheapest diet possible that provides both enough calories (diet quantity) and a sufficiently diverse balance of macro- and micronutrients (diet quality). To achieve the most cost-effective diet for local populations, the corresponding food items should be both available and affordable. These two dimensions are interrelated: an increase in food availability—through increased production, trade or imports—will lower corresponding prices, which in turn will make food more affordable to households. Knowing the optimal composition of a low-cost diet, its cost and most urgently-needed nutrients can improve the design of food and nutrition security policies, such as nutrition-awareness campaigns, nutrient supplementation and food fortification, nutrition-sensitive social protection, trade and agricultural policies. In this chapter, we focus on agricultural policies, namely the Crop Intensification Program (CIP) and the fourth Strategic Plan for Agricultural Transformation in Rwanda (PSTA4) (MINAGRI, 2011, 2018b).

4.2. METHODOLOGY AND DATA

As illustrated in Figure 4.2., this analysis identifies cost-effective diets for each of the six price zones of the country. This identification is the result of a diet optimization algorithm based on **linear programming** (van Dooren, 2018) that uses local food prices, food composition tables (FCT) and nutrient requirements or dietary guidelines as three basic inputs. The output of this optimization procedure is also threefold. First, it provides the optimal diet composition, that is the precise daily quantities (in grams) of each food component needed to meet all nutrient requirements at the lowest cost. Second, it yields the corresponding daily cost of obtaining such a diet, expressed in Rwanda Francs (RwF). And third, it allows us to extract the most binding nutrient or food item—that is the nutrient or item whose threshold is exactly met when consuming the cost-effective diet as opposed to other nutrients or items which exceed their respective threshold.

Figure 4.2. Diet optimization: inputs, outputs and potential policy insights



Source: Authors.

Different diet optimization techniques exist (see Cost of Nutritious Diets Consortium 2018). Although these techniques are similar in estimating the diet-optimal output characteristics, they differ in terms of precise input data used, as well as their final application. Regarding input data, the most important difference relates to setting diet requirements. These can vary by population subgroups targeted, nutrients or food groups considered, thresholds applied, restrictions of nutrient interaction or balance, and cultural or palatability constraints. The approach adopted in this note draws much inspiration from Cost of the Diet and Fill the Nutrient Gap tools developed by Save the Children UK and World Food Programme, respectively. We apply our analysis to the entire population of Rwanda and define four different scenarios of increasingly stringent diet constraints. This leads to more expensive and more realistic optimal diets. Comparing results across different scenarios also provides insight into the underlying structure of the country's food system.

The first diet scenario imposes a threshold only on food energy using the estimated average requirement (EAR) for an adult male equivalent (AME) aged 30 years old and with a physical activity level equal to 1.75. As summarised in Table 4.1., this EAR amounts to 2,750 kcal and corresponds to the caloric intake level at which the needs of 50% of the population are met (FAO, 2001b). The second scenario is based on the previous scenario and in addition requires that the macronutrient sources of energy are adequately balanced. The intervals of macronutrient balance are typically defined as follows: 15-30% (fat), 55-75% (carbohydrate) and 10-15% (protein) (WHO/FAO, 2003). This scenario also restricts sugar consumption to a maximum of 10% of all calorie intake and the total daily portion size to 3 kg.[6] The third scenario introduces a series of key micronutrients, each with their recommended dietary allowance (RDA) and tolerable upper limits (UL) (Omiat & Shively, 2017; WHO/FAO, 2004). Unlike the calorie threshold, RDA is more stringent and provides the intake level at which the needs of 97.5% of the population are met.[7] The fourth diet scenario introduces cultural acceptability or palatability constraints. In the absence of clear guidelines, diets are required to include each of the 10 most important food items consumed by the middle 50% of the population in each price zone, up to at least 75% of the average budget share observed. The latter scenario assures that diets, although nutritious in all clinical aspects, are not completely unfamiliar to the culinary habits of the Rwandese population.

Table 4.1. Four diet scenarios with corresponding characteristics and thresholds

<table>
<tr><th>Scenario</th><th>Characteristics</th><th>Thresholds

per day, AME</th></tr>
<tr><td>Diet 1: Energy</td><td>- Food energy adequacy (EAR)</td><td>- 2,750 kcal (30 years, 60 kg, PAL 1.75)</td></tr>
<tr><td>Diet 2: Macronutrients</td><td>- Diet 1
- Macronutrient balance
- Total portion limit
- Sugar limit</td><td>- above constraints
- 15-30% (fat); 55-75% (carbohydrate); 10-15% (protein)
- <3,000 gram
- <10% (sugar)</td></tr>
<tr><td>Diet 3: Micronutrients</td><td>- Diet 2
- Micronutrient adequacy (RDA)
- Micronutrient upper limits (UL)</td><td>- above constraints
<table>
<tr><th></th><th>RDA</th><th>UL</th></tr>
<tr><td>Calcium (mg.)</td><td>1,000</td><td>2,500</td></tr>
<tr><td>Iron (mg.)</td><td>27.4</td><td>45</td></tr>
<tr><td>Zinc (mg.)</td><td>14</td><td>40</td></tr>
<tr><td>Folate (mcg.)</td><td>400</td><td>1,000</td></tr>
<tr><td>Vitamin B12 (mcg.)</td><td>2.4</td><td>-</td></tr>
<tr><td>Vitamin A (mcg.)</td><td>600</td><td>3,000</td></tr>
</table></td></tr>
<tr><td>Diet 4: Acceptability</td><td>- Diet 3
- Cultural acceptability</td><td>- above constraints
- >= 75% of average budget share spent on each of the 10 most important locally-produced food items by all households between 25-75% of food budget distribution per AME</td></tr>
</table>

Source: Authors.

After estimating the four diet scenarios we compare the latest and most advanced version with actual food production and its composition upstream, and with actual household food budgets and their allocation downstream (see Figure 4.2.). As such, we gain insight into the type of policies that could make the food system more nutrition-sensitive.

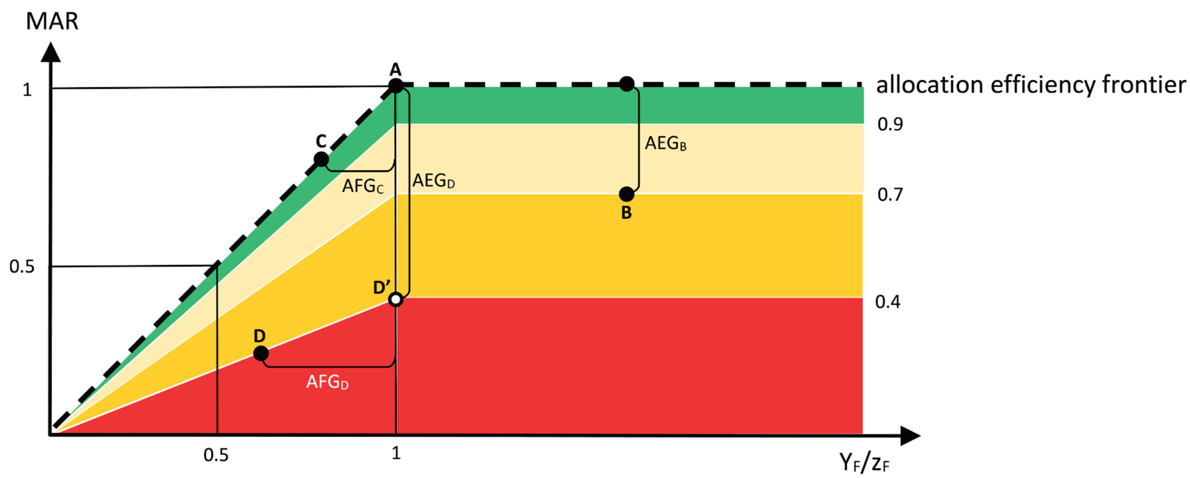
We can estimate affordability and allocation efficiency of household food budgets by comparing optimal with actual costs and allocations. Figure 4.3. captures both dimensions: it measures affordability on the X-axis as the ratio of the food budget (Y_F) over the minimal cost of a nutritious diet (z_F), with one as the threshold between affordability and unaffordability. The more the ratio exceeds (falls below) one, the more the diet is (un)affordable to households. Allocation efficiency is largely based on the mean adequacy ratio (MAR), which is the arithmetic average of all energy and nutrient adequacies used in the diet optimization algorithm and measured along the Y-axis. Given that individual adequacies are capped at 100%, MAR is also confined between zero and one. For all affordability levels above one, we simply measure household allocation efficiency by MAR. For affordability levels below one, however, MAR levels are constrained by their corresponding affordability levels. In fact, each food budget below the cost of the optimal diet can at best yield a MAR level equal to its affordability level. This is achieved only when the food budget follows the same proportional allocation as the optimal diet. For example, with a food budget half the cost of the optimal diet (that is Y_F/z_F=0.5), one can access half the portion size of all food items within that diet and thus reach only half of the recommended intake level for each individual nutrient, which results in a MAR level of 0.5. Therefore, the highest allocation efficiency is presented by the dashed line in Figure 4.3., where MAR equals the affordability level for Y_F/z_F below one and equals one for Y_F/z_F above one. The full allocation efficiency space is then defined proportional to this **nutrient allocation frontier** as shown by the green-to-red colour scheme.

Combining information on affordability and allocation efficiency is useful to guide the design of FNS policies. A key reference point in this respect is household A in Figure 4.3.; household A can barely afford a nutritious diet but its budget allocation is 100% efficient. As a result, all family members of household A have access to all nutrients they need, as reflected in MAR equal to one.

[6] Due to lacking data on sugar as part of the carbohydrate content in all food items, calculations on maximum sugar intake are based only on energy obtained from the food item "sugar", resulting in a less binding sugar constraint overall.
[7] For dietary iron and zinc, bioavailability levels are assumed at 5% and 15% respectively.

The same applies to households located on the dashed line to the right of household A: they can both afford and choose to consume a fully nutritious diet. This context does not require much policy attention. In contrast, households B, C and D not only perform worse than household A in nutritional terms, each of them also requires a different set of policies. Household B for example has more than enough financial resources to meet the household's nutrient requirements yet its MAR is only 0.7. To overcome this allocation efficiency gap (AEG_B), policies should aim at changing food choice behaviour and increasing nutrition awareness, or, if that is not feasible, introducing supplementation or food fortification schemes based on currently preferred food items. Despite optimal food choices, household C simply lacks the required food budget to obtain a nutritious diet. This requires policies that close the household's affordability gap (AFG_C). In fact, contingent upon the same allocation preference, household C will reach the same nutrition status as household A if provided with the required additional resources (AFG_C) either in cash or in-kind. Finally, the situation of household D is a combination of challenges faced by the previous two households, that is a sub-optimal food choice combined with insufficient financial resources. A combination of corresponding policies is thus required to overcome the household's allocation efficiency gap (AEG_D) and affordability gap (AFG_D). In this scenario, any cash transfer *should* be accompanied by an awareness campaign to avoid that the situation of household D only improves to D' instead of a situation similar to household A. If the impact of an awareness campaign is too uncertain, a policy could transfer food that mimics the composition of the optimal diet.

Figure 4.3. Affordability and allocation efficiency



Source: Authors.

Other nutrient-sensitive policies can be identified in relation to agriculture and food distribution. After scaling-up the optimal diet to reflect annual food needs of districts, one can estimate differences between required food availability and local agricultural production. This information can then be used to identify crops and food items that could be subject to increased production (in cases where appropriate biophysical conditions exist) or inter-district trade (to match shortage and excess production across districts). Promoting local food production and exchange has the double advantage of strengthening rural livelihoods while making food available at lower prices—both which increase food purchasing power. Strategies of domestic food self-sufficiency should however be evaluated against the advantages and risks of relying on food imports, which may be cheaper but also more volatile. Beyond the sterile opposition of autarky versus free trade, Clapp (2017) cites a number of instances when the pursuit of food self-sufficiency makes sense—many of which apply to Rwanda. The country is currently implementing several programs on crop selection and agricultural intensification, such as CIP and PSTA4, each of which could benefit from insights obtained through this type of analysis.

The data used in this chapter come from various sources. Diet requirements summarised in Table 4.1. are based on recommended intake levels by age/sex as defined by the most recent FAO/WHO/UNU Joint Panels (FAO, 2001; WHO/FAO, 2004; WHO, 2007). Food composition data are obtained from FCT compiled for nine African countries (Stadlmayr et al., 2012). Standardised food prices for each of the six price zones are derived from the Integrated Household Living Conditions Survey (EICV4) conducted in 2013/14 (NISR, 2016). The latter source also contains the required data on household budgets and their allocation over more than 120 food items to derive measures of diet affordability and allocation efficiency. In addition, EICV4 provides required sampling weights to scale up the optimal diet to match food needs of each district's population. This information is then compared to official district-level production statistics of the agricultural year 2016-17 (season A and B combined) provided by the National Institute of Statistics of Rwanda (NISR, 2017a). To identify potential areas for increased agricultural production, we rely on a comprehensive land classification study conducted by Verdoodt and Van Ranst (2003). Based on climate, topography and soil data, this study provides detailed maps combining actual and potential suitability classes for the cultivation of various crops typically grown in Rwanda.

4.3. RESULTS

Diet optimization

Table 4.2. presents cost and composition of optimal diets specific to each price zone for each of the four scenarios described above. With only a minimal food energy requirement, the first diet scenario simply selects one food item with the cheapest calories, which follows from the combination of calorie content and corresponding price. In all price zones, the cheapest calories are found in dry maize grains, for which consuming 783 grams exactly yields the daily energy threshold of 2,750 kcal per AME. Given prevailing prices, this one-item diet would cost 157 RwF in four out of six price zones, while being more expensive in Rural Southern (196 RwF) and cheaper in Rural Northern (141 RwF). As discussed below, the latter observation stems from higher local maize production, especially in Nyagatare.

Considering macronutrient requirements, the second scenario uniformly adds avocado to the diet in all price zones. This is due to the fact that maize has a slight macronutrient imbalance which is most cost-effectively compensated through the consumption of avocado. In fact, maize contains slightly too much energy from carbohydrates and too little from fats, while avocado is extremely fatty and low in carbohydrates. As a result, adding 129 grams of avocado while reducing maize consumption to 741 gram restores the macronutrient balance in all price zones. Given higher prevailing avocado prices in urban areas, the diet cost increases more in Kigali and other urban price zones compared to rural areas.

Imposing minimum and maximum cut-offs for six micronutrients makes optimal diets more diversified and more expensive. Increases in diet cost are significant and range from 36% in Rural Southern (that is from 198 RwF to 270 RwF) to 67% in Kigali, an increase from 174 RwF to 290 RwF. In contrast, increases in diet diversification are less pronounced and mainly involve the same food items with exact quantities determined by prevailing food prices but all yielding a total food portion of roughly 1.2 kg. Dry grain maize continues to provide the lion share of calories and is also a main source of iron, zinc and to a lesser extent folate. Fresh milk is solely responsible for critical intakes of vitamin B12, which is a vitamin only found in animal-based food items. In addition, milk also accounts for roughly half of all calcium intake while the other half is provided by amaranth or cassava leaves—these dark green leafy vegetables are also a main source of vitamin A. The most constraining requirements in each price zone relate to food energy, folate, vitamin A and vitamin B12, while iron content of each optimal diet exceeds its corresponding threshold. Compared to the previous diet scenario, and except for Rural Northern, avocado is no longer part of any optimal diet, indicating that maize's macronutrient imbalance is restored by the combination of selected food items.

Accounting to some degree for prevailing food preferences, we observe that optimal diets under the fourth scenario again become more diversified and more expensive. Increases in diet cost are less pronounced compared to the shift from the second to third scenario and range between 8% in Rural Southern and 28% in Rural Northern. Regarding diversification, there is a substantial increase in the number of food items considered in each optimal diet: from at most six items under scenario three to at least thirteen items under scenario four. To some extent, this is not surprising given that cultural acceptability and palatability constraints have been introduced by forcing the optimization algorithm to include at least 10 items. It also indicates that current food preferences of Rwandese households are often not cost-effective in meeting their nutritional requirements. Such preferences mainly include various roots and tubers, such as Irish potato, sweet potato, cassava and cooking banana. Despite shortcomings and arbitrary choices in the fourth diet scenario, it appears that one can be adequately nourished in Kigali with only 316 RwF (USD 0.46) per day while even lower budgets suffice in other price zones of Rwanda.

Table 4.2. Composition and cost of four diet scenarios per price zone, Rwanda (2013/14)

	Kigali		Other urban		Rural Southern		Rural Western		Rural Northern		Rural Eastern	
	Item	gram	Item	gram	Item	gram	Item	gram	Item	gram	Item	gram
Diet 1	Dry maize (grain)	783	Dry maize (grain)	783	Dry maize (grain)	783	Dry maize (grain)	783	Dry maize (grain)	783	Dry maize (grain)	783
	Cost in RwF	**157**	**Cost in RwF**	**157**	**Cost in RwF**	**196**	**Cost in RwF**	**157**	**Cost in RwF**	**141**	**Cost in RwF**	**157**
Diet 2	Dry maize (grain)	741	Dry maize (grain)	741	Dry maize (grain)	741	Dry maize (grain)	741	Dry maize (grain)	741	Dry maize (grain)	741
	Avocado	129	Avocado	129	Avocado	129	Avocado	129	Avocado	129	Avocado	129
	Cost in RwF	**174**	**Cost in RwF**	**168**	**Cost in RwF**	**198**	**Cost in RwF**	**161**	**Cost in RwF**	**149**	**Cost in RwF**	**161**
Diet 3	Dry maize (grain)	672	Dry maize (grain)	663	Dry maize (grain)	668	Dry maize (grain)	665	Dry maize (grain)	672	Dry maize (grain)	670
	Fresh milk	400	Fresh milk	400	Fresh milk	400	Fresh milk	400	Fresh milk	400	Fresh milk	400
	Amaranth	132	Amaranth	96	Amaranth	133	Cassava leaves	68	Amaranth	132	Amaranth	102
	Dry beans	13	Soya (dry)	30	Soya (dry)	23	Amaranth	60	Dry beans	17	Dry beans	15
	Soya Flour	9	Carrots	13			Soya (dry)	16	Avocado	10	Soya (dry)	11
							Dry beans	3	Soya Flour	4	Carrots	11
	Cost in RwF	**290**	**Cost in RwF**	**247**	**Cost in RwF**	**270**	**Cost in RwF**	**227**	**Cost in RwF**	**204**	**Cost in RwF**	**243**
Diet 4	Dry maize (grain)	602	Dry maize (grain)	515	Dry maize (grain)	518	Dry maize (grain)	451	Dry maize (grain)	454	Dry maize (grain)	422
	Fresh milk	400	Fresh milk	400	Fresh milk	397	Fresh milk	400	Fresh milk	400	Fresh milk	400
	Amaranth	131	Irish Potato	90	Sweet potato	163	Sweet potato	265	Sweet potato	294	Cooking banana	183
	Irish Potato	69	Cooking banana	77	Amaranth	103	Irish Potato	101	Irish Potato	136	Sweet potato	96
	Cooking banana	31	Sweet potato	72	Cassava (root)	52	Cooking banana	46	Amaranth (large)	59	Cassava (root)	65
	Dry beans	21	Amaranth	50	Avocado	37	Dry beans	40	Dry beans	47	Irish Potato	61
	Cassava (flour)	20	Dry beans	48	Dry beans	36	Cassava (root)	40	Cooking banana	39	Dry beans	59
	Soya Flour	18	Avocado	36	Irish Potato	33	Avocado	39	Soya Flour	30	Amaranth	43
	Sweet potato	16	Cassava (root)	23	Cassava (flour)	26	Maize (fresh)	36	Avocado	30	Soya (dry)	38
	Cassava (root)	8	Cassava (flour)	22	Soya (dry)	21	Soya (dry)	33	Cassava (root)	24	Avocado	37
	Avocado	7	Fresh bean	20	Cooking banana	20	Fresh bean	28	Maize (fresh)	21	Maize (fresh)	33
	Maize (fresh)	3	Soya (dry)	19	Tarot/amateke	15	Cassava (flour)	22	Fresh bean	20	Cassava (flour)	30
	Fresh bean	3	Carrots	19	Fresh bean	12	Tarot/amateke	18	Amaranth (small)	14	Fresh bean	27
			Amaranth	16	Maize (fresh)	8	Amaranth	36	Corn (flour)	11	Carrots	24
			Corn (flour)	13	Curdled Milk	5	Cassava leaves	15	Cassava (flour)	8	Corn (flour)	16
							Carrots	10				
	Cost in RwF	**316**	**Cost in RwF**	**287**	**Cost in RwF**	**292**	**Cost in RwF**	**271**	**Cost in RwF**	**261**	**Cost in RwF**	**302**

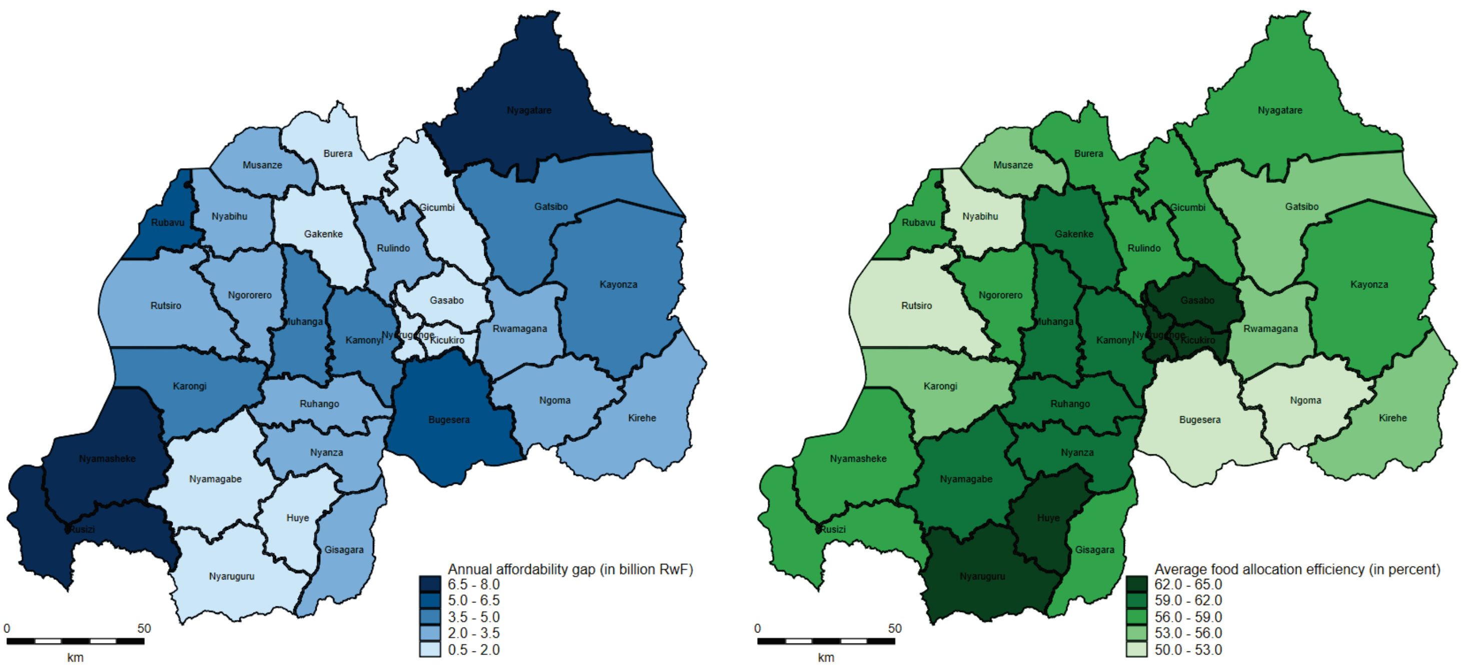
Source: Authors with data from EICV4 (2013/14).

Affordability analysis

Relying on optimization results of the fourth diet scenario, Figure 4.4. presents total affordability gap and average allocation efficiency by district. The total affordability gap is the sum of all shortfalls between the optimal diet cost and the daily food budget of households located in corresponding price zones. The gap represents the total amount of financial resources needed to allow every household to purchase the most cost-effective diet. As such, it combines information on relative budget gaps and demographic weight observed across districts. Overall, the country would need 94 billion RwF per year to provide every Rwandese household with additional resources to meet all nutritional requirements. According to the left-hand side map of Figure 4.4., most of the budget would flow to Nyagatare, Nyamasheke and Rusizi for which the affordability gap falls within 6.5 to 8.0 billion and to a lesser extent to Bugesera and Rubavu with gaps between 5.0 and 6.5 billion. On the other side of the scale, we identify nine districts whose annual affordability gap is lower than 2.0 billion. Despite their demographic weight, the three districts of Kigali (Gasabo, Kicukiro and Nyarugenge) require the least resources (less than 0.7 billion RwF), which indicates that most households have a food budget close to or higher than the cost of the optimal diet.

The right-hand side map of Figure 4.4. shows how efficiently households allocate their food budget in terms of meeting their nutritional requirements. To this end, household-level allocation efficiencies are simply averaged by district. Again, the three districts of Kigali together with Huye and Nyaruguru perform best, with average allocation efficiencies above 62%. With percentages below 53%, we observe the least efficient food allocations in Nyabihu, Ngoma, Rutsiro and Bugesera—these stem from food choices that negatively impact calcium, iron, zinc, vitamin B12 or vitamin A intake.

Figure 4.4. Affordability gap and food allocation efficiency



Source: Authors with data from EICV4 (2013/14).

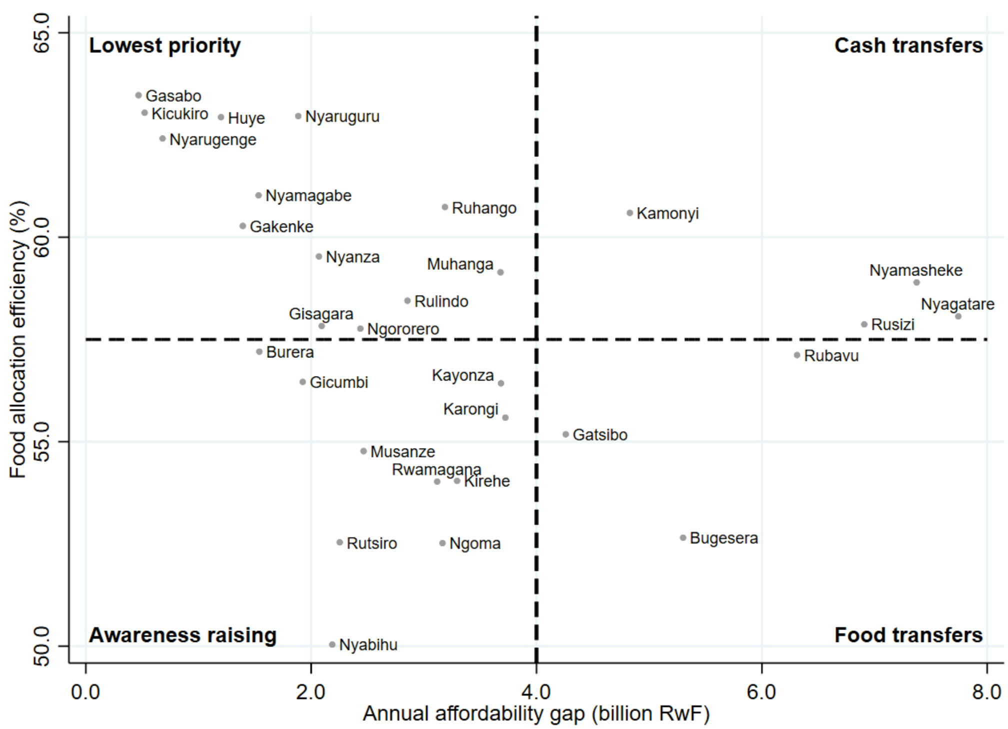
To flesh out the types of policies and immediate social protection needed to improve FNS in Rwanda, we combine dimensions of food affordability and allocation efficiency. The upper-left quadrant of Figure 4.5. contains districts with smaller food affordability gaps and higher food allocation efficiency. Households in those districts not only have a higher food budget on average, they also make better use of it by attaining higher nutrient adequacies. As a result, districts located in this quadrant require less policy attention. In line with the discussion above, the most representative cases are the three districts of Kigali as well as Huye and Nyaruguru. Despite their performance, households in districts located in the upper-left quadrant still suffer from important budget gaps and allocation inefficiencies.

Households that live in districts located in the bottom-left quadrant equally have smaller food budget gaps, yet they perform worse in terms of food allocation efficiency. In other words, these households could reach similar nutrient adequacy levels compared to those in the upper-left quadrant but have made less nutritious food choices. Therefore, policies should focus on raising awareness on which food items to consume to reduce key nutrient deficiencies. In circumstances where food preferences are overly sticky, nutrient supplementation or food fortification might be other appropriate responses. The Nyabihu district might be particularly well suited to this type of intervention since its annual affordability gap is close to 2 billion RwF and its allocation efficiency as low as 50%.

The upper-right quadrant contains districts characterised by larger affordability gaps and higher food allocation efficiencies. When provided with increased financial resources, households in those districts are likely to attain significantly higher nutrient adequacies provided they maintain similar allocation patterns. Policies could thus focus on closing household budget gaps through cash transfers or other financial measures such as tax reductions. Households in Kamonyi might be most eligible for these types of measures given their allocation efficiency above 60% and their combined budget gap close to 5 billion RwF per year.

The bottom-right quadrant contains districts with larger affordability gaps and lower food allocation efficiencies. Households living in those districts not only often lack the financial resources to be well-nourished, their food choices are also less cost-effective in terms of attaining nutrient adequacy. In such circumstances, nutrition-awareness campaigns should accompany cash transfers so that increased budgets are more efficiently allocated on food items rich in key nutrients. Alternatively, nutrient-dense food could also be provided directly to households. With an accumulated budget gap over 5 billion RwF and an average allocation efficiency below 55%, households in Bugesera are most eligible to receive this type of policy support.

Figure 4.5. Affordability gap and food allocation efficiency



Source: Authors with data from EICV4 (2013/14).

Availability analysis

This section focuses on longer-term and more structural policies to optimise local food availability through agricultural development and inter-district food trade. To do so, we compare agricultural production statistics of 2016-17 with required food quantities corresponding to the fourth optimal diet scenario. Using population sampling weights of the EICV4 (2013/14) and an annual growth rate of 2.6% to synchronize production and consumption data (NISR 2014:9), these food quantities are obtained after upscaling the optimal diet of each price zone. The first two columns of Table 4.3. present annual domestic production and required food availability for all diet-optimal crops for which production data were available. The third column of Table 4.3. presents the nutrient self-sufficiency ratio (SSR) defined as the ratio of domestic food production over domestic food availability (FAO, 2001a). The nutrient SSR replaces *actual* by *required* domestic food availability, which is the cheapest amount of food to meet all nutrient and cultural requirements as summarised under the fourth diet scenario. If nutrient SSR is below 100%, the country falls short in producing the required food quantities while percentages above 100% point to excess production. The last column of Table 4.3. provides an absolute estimate of annual excess production, which is calculated by subtracting required availability from annual domestic production. Positive volumes point to surpluses and negative values to shortfalls.

For all eight food items considered, Rwanda's domestic agricultural production markedly differs from the required diet-optimal food quantities. Whereas the production of cereals and soya beans is highly deficient, all other crops in Table 4.3. are produced in abundance. More specifically, only 32% of required cereals and 20% of required soya beans are domestically produced, generating an annual deficit of more than 1.1 million tons for cereals and around 93,000 tons for soya. On the other hand, homegrown production exceeds required quantities by around factor two for cassava and sweet potato, by almost factor three for Irish potato and cooking banana and is approximately seven and nine times higher for fresh beans and tarot, respectively. Total excess production for all roots and tubers combined amounts to 1.7 million tons per year while cooking bananas and fresh beans add another annual surplus of around 857,000 tons.

Despite their absolute numbers in metric tons, it is important to note that surplus production of roots and tubers can only very partially compensate for shortfalls in cereal production. First, statistics of root and tuber production are in fresh condition, containing on average 70% water and 15% inedible parts, as compared to cereals measured in dried and fully edible grain kernel condition. As a result, expressed in dry edible matter, deficit production of cereals remains above 1 million tons while surpluses of roots and tubers shrink from 1.7 million tons to only 432,000 tons. Second, even if total dry edible weight would be equal, the nutrient composition and cost of cereals are different from those observed for roots and tubers, which is basically reflected in the different shares of each crop within the optimal diets.

Simply stated, Rwanda should aim at producing and consuming more cereals, especially maize, while paying less attention to the production of roots and tubers. This recommendation however is based on an all things equal viewpoint. In reality, uneven changes in food supply and demand may affect prices to the extent that shares of certain crops within optimal diets change significantly. Furthermore, actual food availability in the country is also determined by food imports and food exports while the present analysis is limited to only eight food items, thus discarding information on milk, amaranth, dry beans, avocado and carrots, for which we faced data issues. In addition, increasing agricultural production is contingent upon appropriate crop-specific biophysical conditions such as climatic, landscape and soil characteristics. In the case of increased maize production, Verdoodt and Van Ranst (2003) indicate that actual suitability is at best moderate for the eastern part of the country due to adverse topography of western highlands. However, after terracing and adequate fertilisation, maize could be potentially grown throughout the country.

Table 4.3. Nutrient self-sufficiency ratio (SSR) and excess production of diet-optimal food quantities, Rwanda (2017)

Food item	Domestic production per ton/year (1)	Required availability per ton/year (2)	Nutrient SSR percent (1)/(2)	Excess production per ton/year (1)-(2)
Cereals	546,080	1,691,358	32	-1,145,278
Cassava	1,040,944	511,817	203	529,127
Irish potato	774,584	267,207	290	507,377
Sweet potato	1,054,794	568,858	185	485,936
Tarot	224,359	24,269	924	200,091
Cooking banana	724,166	251,441	288	472,724
Soya beans	23,285	116,386	20	-93,102
Fresh beans	451,340	67,050	673	384,290

Note: Cereal domestic production combines statistics on maize, sorghum, rice and wheat while required quantities involve just maize as being the only cereal selected through diet optimization. Therefore, nutrient SSR and excess production underestimate true deficiency levels.
Source: Authors with data from EICV4 (2013/14) and NISR (2017).

The maps in Figure 4.6. display district-level excess production for each of the eight food items considered above. As such, we can see whether local agricultural production is sufficient to meet nutrient requirements of any given district population but also whether excess production could help reduce food deficiencies in neighbouring districts. For cereals, panel (a) of Figure 4.6. shows that only Nyagatare produces a surplus of between 21,000 and 42,000 metric tons. All other districts register a shortfall, which is moderate for Gatsibo and Kirehe (below 21,000 tons), substantially higher in eleven districts mainly in the western part of the country (between 42,000 and 63,000 tons) and close to 112,000 tons in Gasabo. Because of actual suitability conditions (Verdoodt & Van Ranst, 2003), the Eastern Plateau located east of Gasabo could become an important production centre for maize, especially to address deficits in the three highly populated districts of Kigali. To reduce maize deficits in the western part of the country, either the same production hub could be relied upon, requiring perhaps additional market integration measures, or other hubs need to be developed. The latter might require substantial land management in terms of terracing and fertilisation but could then become highly suitable for the cultivation of maize, in particular the agricultural zones of Imbo, Impara and Central Plateau.

Figure 4.6. Excess production by district, Rwanda (2017)

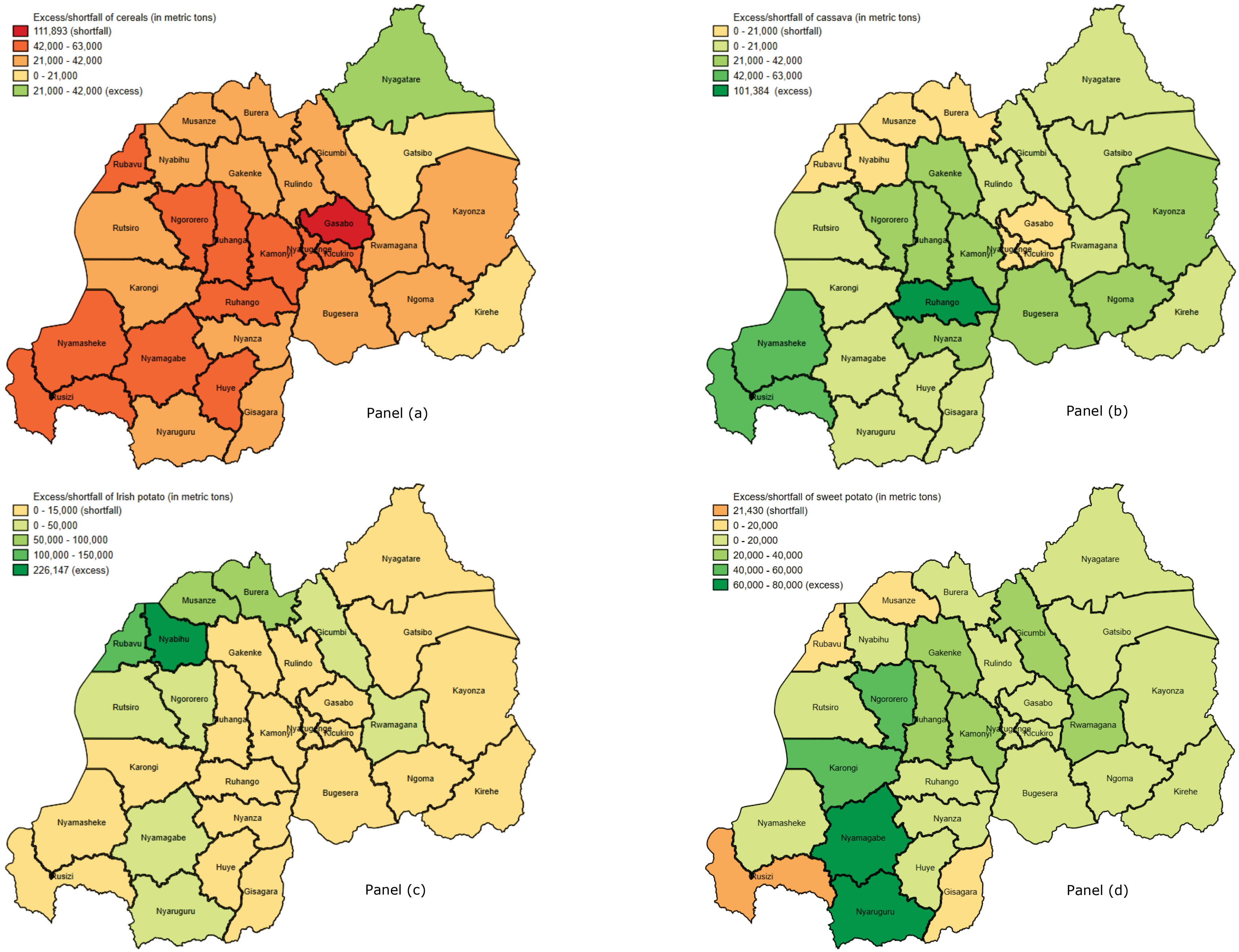
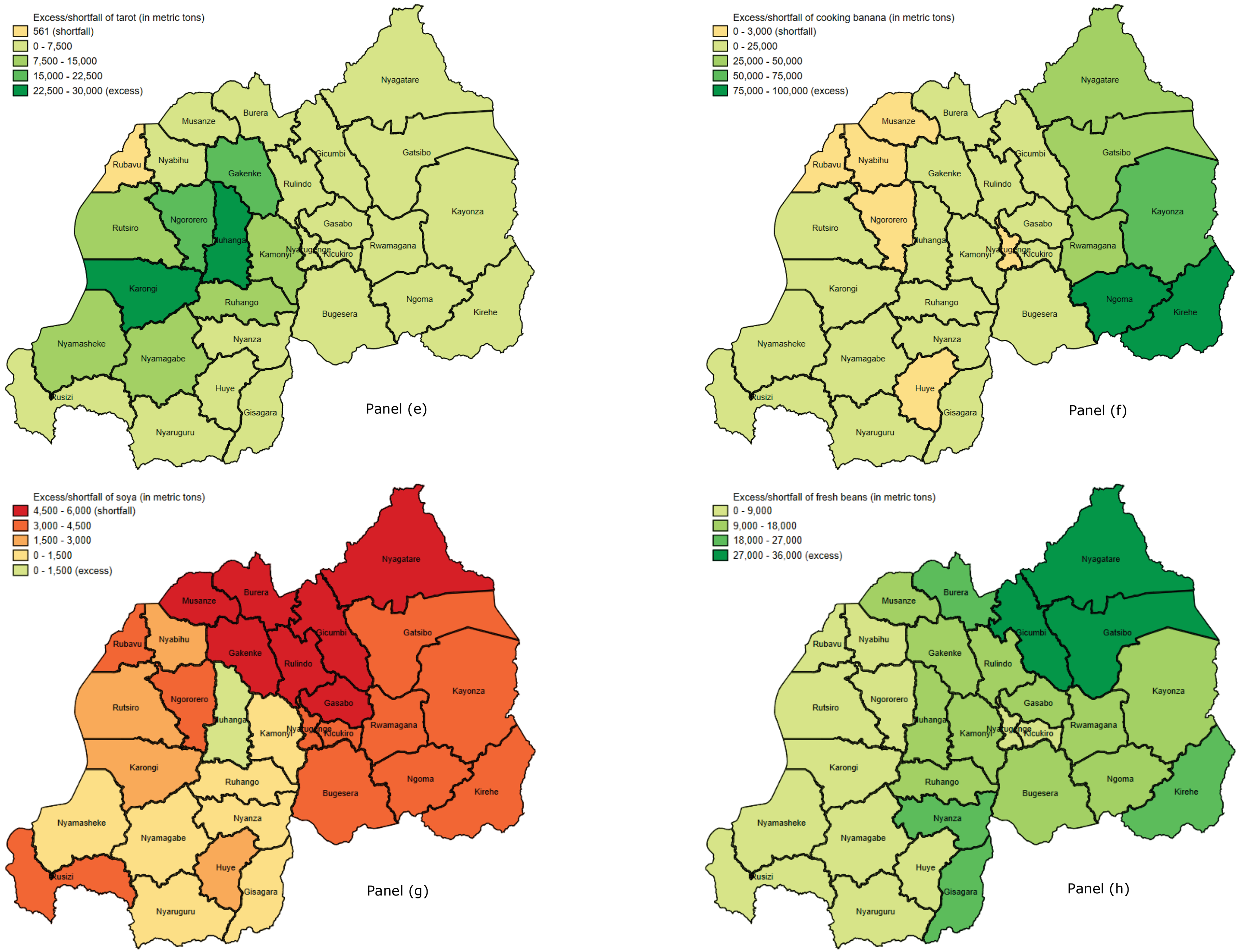


Figure 4.6. Continued



Source: Authors with data from EICV4 (2013/14) and NISR (2017).

Rwanda is also deficient in the production of soya beans—though to a much lesser extent in absolute terms. Following panel (g) of Figure 4.6., again only one district, Muhanga, is able to generate a small surplus (less than 1,500 tons) while many districts in the northern and eastern part of the country record relatively large shortfalls (between 3,000 and 6,000 tons). The same crop suitability limitations roughly apply as those for maize (Verdoodt & Van Ranst, 2003). Under actual conditions, the Eastern Plateau combined with Eastern Savannah and the land of Bugesera are most suitable for the cultivation of soya beans. These agricultural zones are also well situated to reduce the largest soya bean deficits of the country, yet additional market measures should be considered to assure that the most remote soya-deficient districts, such as Burera, Musanze and Gakenke, benefit from this surplus. Alternatively, productivity in Muhanga and neighbouring districts within Central Plateau and Granitic Ridge could be increased through better land management in order to address the more substantial deficits observed in northern districts and the remaining smaller deficits in the southwestern part of the country. For Rusizi in particular, deficits could best be addressed by increased local production because large plots of land are already moderately suitable or, after correct land management, could even become highly suitable for the cultivation of soya beans.

With respect to the remaining six crops—cassava, Irish potato, sweet potato, tarot, cooking banana and fresh beans—the main issue is not production but rather its accurate distribution across districts to assure that people have access to their required diet-optimal quantities. In panel (b) of Figure 4.6., we note relatively small shortfalls of cassava (less than 21,000 tons) in the three districts of Kigali as well as in four northern districts stretching from Rubavu to Burera. The latter deficits could be easily addressed through excess supply originating from neighbouring Ngororero and Gakenke. The districts of Kigali could profit from excess production realised in surrounding districts, mainly Kamonyi and Bugesera. A bit further located from Kigali is Ruhango, which appears to be the hot spot of cassava with an excess production of more than 100,000 tons.

In terms of Irish potato, panel (c) of Figure 4.6. shows a large number of districts recording a relatively small deficit of below 15,000 tons. The same four northern districts that were deficient in local cassava production are generating the most surplus, ranging from 50,000 to 100,000 tons in Burera and Musanze and from 100,000 to 150,000 tons in Rubavu, and reaching an excess production of more than 200,000 tons in Nyabihu. Given the spatial concentration of excess Irish potato production, adequate policy measures should be implemented to securely supply the various crop-deficient districts scattered across the country. Alternatively, another production hub for Irish potato could be developed in the southern part of the Congo-Nile Water-shed Divide, which covers the districts of Nyamasheke and Rusizi, each having large plots of land with very suitable biophysical conditions as long as soil fertility and land erosion can be controlled.

Deficit production of sweet potato (see panel d) is limited to only four districts, with shortfalls below 20,000 tons in Rubavu, Musanze and Gisagara and slightly more pronounced in Rusizi. To address these shortages, many districts could supply these four districts with their excess production. Surpluses are especially high in Nyaruguru and Nyamagabe, ranging from 60,000 to 80,000 tons, and are therefore well situated to address shortages in neighbouring Rusizi.

According to panel (e) of Figure 4.6., there is only one district, Rubavu, which faces a minor deficit (below 600 tons) in local tarot production while all other districts produce more than their corresponding diet-optimal quantities. As a result, distribution concerns are limited to securely supply tarot to Rubavu, perhaps originating from Rutsiro or Ngororero, located to the district's south. The biggest excess production hubs are Muhanga and Karongi each generating more than 22,500 tons of tarot in surplus.

Regarding cooking banana, panel (f) of Figure 4.6. indicates minor shortfalls (below 3,000 tons) in six districts mainly located in the western part of the country. These shortages could be easily reduced by using the small surpluses of surrounding districts or by relying on substantial excess production generated in the country's southeast. In fact, most excess production appears to be concentrated in only three districts, Kayonza, Ngoma and Kirehe, with volumes far exceeding 50,000 tons. Given the relative distance between deficient and surplus generating districts, additional market integration measures should be considered. An alternative approach is to produce more cooking banana in the northern part of Central Plateau (more specifically in Gakenke district) as well as along the northern Kivu Lake borders in Rubavu. Both areas are closely located to banana-deficient districts and have the potential to become moderately or highly suitable for the cultivation of bananas.

With respect to fresh beans, panel (h) of Figure 4.6. shows that none of the 30 districts are producing less than their required diet-optimal quantities. This means that, in addition to production, no pressing distribution concerns exist for this crop. However, there is substantial variation in excess production, which increases from the southwestern to the northeastern part of the country. Most excess production is generated in Gicumbi, Gatsibo and Nyagatare, each recording more than 27,000 tons in surplus.

For all crops except cereals and soya beans, large volumes of excess production are concentrated in specific districts. As a matter of fact, it looks like available arable land has been purposely or *de facto* allocated to certain crops. Relying again on Verdoodt and Van Ranst (2003), this allocation of land aligns reasonably well with actual and potential suitability for the cultivation of Irish potato, sweet potato, fresh beans and bananas but could be improved for cassava and tarot. For both tubers, the most suitable locations are in the agricultural zones of Bugesera, Eastern Plateau and Eastern Savannah as opposed to the current production hubs in Ruhango for cassava and Karongi and Muhanga for tarot.

4.4. POLICY IMPLICATIONS

The present analysis is closely related to various ongoing policies in Rwanda. In addition to the overall vision in the National Agriculture Policy (NAP) (MINAGRI, 2017), the effective implementation of agricultural policies lies with the country's four Strategic Plans for Agriculture Transformation (PSTA). The latest version (PSTA4) outlines priority investments and resources needed for the agriculture sector for the period 2018-2024 (MINAGRI, 2018b). Since 2007, one of the flagship programs under PSTA is the Crop Intensification Program (CIP). The aim of this program is to double productivity levels of nine priority crops (including maize, wheat, rice, Irish potato, beans, cassava, banana, soya bean and sunflower) while upgrading corresponding food value chains (MINAGRI, 2011).

PSTA4 provides a series of projections on domestic calorie, protein, iron and calcium availability following targeted yield improvements. In addition, a national calorie-sufficient food basket has been defined that can be used in combination with population projections to estimate "whether or not Rwanda would be a net importer or net exporter of each product" (MINAGRI 2018:77). The methodology adopted in this chapter is similar but provides for various improvements. First, the identification of optimal food baskets goes beyond concerns of calorie sufficiency and local preferences to consider adequate intakes of key macro- and micronutrients. Second, the selected food baskets are cost-effective with respect to prevailing food prices in each of the six price zones. Third, compared to a national perspective, the present analysis estimates food self-sufficiency at the district level and at the same time identifies opportunities for increased domestic market integration.

The CIP includes aspirations for more spatially-targeted policies, especially with respect to developing regional "bread baskets". These food production hubs should be identified following three criteria: (i) agronomic potential of the area, (ii) accessibility to national and regional markets and (iii) population density (MINAGRI 2011:36-37). Although each of these criteria makes perfect sense, the ultimate objective appears to receive little attention within the strategy, or at least is not quantified. The policy should specify the type and size of bread basket regions, and corresponding value chains that should be developed to address the nutritional challenges of the country. To make agriculture and its related policies truly nutrition-sensitive it is important to include information on nutrient requirements (or deficiencies) when choosing priority crops and setting targets for related production. This being said, with the exception of wheat, rice and sunflower, the selected priority crops under CIP match reasonably well with the core ingredients of the cost-optimal diet under the fourth scenario.

The development of bread baskets and the analysis of inter-district food trade also neatly match the need to adopt a food system or value chain perspective highlighted in PSTA4 and CIP reports (MINAGRI, 2011, 2018b). This requires paying attention to various market integration measures such as investments in transport, storage and processing infrastructure to mitigate post-harvest losses and properly conserve nutrient quality in foods, as well as to affordability and consumer preferences. Upgrading value chains may increase income opportunities for actors along the chain, as envisioned by the second strategic impact area of PSTA4; it may also affect food prices down the chain, especially in areas located further away from the targeted bread baskets. Depending upon location and context, people's ability to access a nutritious diet may vary. In addition, people might be insufficiently aware of nutritional values and health risks of certain diets resulting in sub-optimal food budget allocations. Apart from food production and availability, effective FNS policies should therefore include information on people's food affordability and allocation efficiency.

In summary, with reference to the mid-term evaluation of CIP in 2011, the focus should *not* shift "from producing enough to producing surplus" (MINAGRI, 2011) but rather to producing adequate food quantities to assure a nutritious and cost-effective diet for all, while providing social protection measures and nutrition awareness to the most vulnerable households in Rwanda.

ADVOCACY NOTE ON CHAPTER 4

Key messages from this chapter:

1. One can be adequately nourished in Kigali with only 316 RwF per day (in 2013/14 prices) while even lower budgets suffice in other price zones of Rwanda.
2. Despite this acceptable cost, the country would still need 94 billion RwF per year (in 2013/14 prices) to make every Rwandese household meet its nutrient requirements. The biggest budget gaps are found in Nyagatare, Nyamasheke and Rusizi and to a lesser extent in Bugesera and Rubavu.
3. More nutritious food could enter current food baskets across all districts of the country. With rates below 53%, food allocation efficiency is however lowest in Nyabihu, Ngoma, Rutsiro and Bugesera.
4. Crossing food affordability and allocation efficiency, Figure 4.5. indicates which type of policy support is suitable for each district—ranging from nutrition awareness to food and cash transfers.
5. From the optimal-diet viewpoint, Rwanda should produce substantially more cereals and pulses (especially maize and soya) in areas with apt biophysical conditions and pay less attention to the production of roots and tubers.
6. PSTA4 projections of domestic calorie and nutrient availability, and CIP identifications of bread baskets could be improved with more spatial detail and additional information on cost effectiveness and nutrient sensitivity.
7. Accompanying measures, such as investments in transportation, storage and processing infrastructure, should be taken to promote inter-district food trade between selected production hubs and final consumption centres.

Chapter 5

BOTTLENECKS AND LOCATION-SPECIFIC ADVOCACY SOLUTIONS

The basic premise of this policy atlas is that **agricultural transformation takes place in a heterogeneous context**. By being geographically sensitive and taking account of biophysical, economic and social variations across the country, policy design and implementation could be more effective. While this viewpoint became part of mainstream development discourse several decades ago, tools that can handle heterogeneity have remained rare. In this policy atlas, we rely on maps to highlight and describe heterogeneity, identify bottlenecks and to suggest location-specific advocacy solutions.

Maps are powerful tools to capture heterogeneity, prioritise and develop an advocacy strategy. By disaggregating data by a country's administration units (i.e. regions, districts), different data, such as food production, consumption or climate data, can be combined in the same analysis—even though they may be measured in very different ways. Maps allow data and findings to be summarised in a concise visual picture, in contrast to a table that would require many rows (one for each district) and be unattractive and unable to display spatial relationships. Finally, maps can tell a convincing story instantly, which is an important feature when dealing with time-constrained policy makers.

Now, what is the story told by this policy atlas?

Child stunting and hidden hunger are serious challenges in most districts of Rwanda. Stunting rates are above 30% in 25 out of 30 districts, and key micronutrient adequacies on average fall below 57% (except for folate). Vitamin B12 is clearly most problematic, with a national adequacy rate of 9.9%. Intakes of calcium, iron, zinc, and vitamin A are higher, ranging between 47.6% and 56.8%. Because adequately consuming micronutrients leads to better nutrition outcomes, addressing hidden hunger could be an important advocacy topic for CSOs. Since many donors and development agencies nowadays require interventions to be "nutrition-sensitive," CSOs could help harmonise government efforts along the full food system, from production to final consumption.

As mentioned in the introduction, the CSOs working under the V4CP programme cover several parts of the food system. If their focus is on increasing and diversifying agricultural production, then most attention should go to removing **production constraints** in the high-priority districts of **Huye, Nyamagabe, Gakenke, Karongi, Nyaruguru and Ngororero**. While other districts may suffer equally from low production efficiency, the effect on final nutrition outcomes is smaller. In a similar vein, there may be other high-priority districts that could also benefit from increasing production efficiency, but other bottlenecks appear more critical.

Given the high child stunting levels throughout the country and irrespective the benefits of removing relative production inefficiencies, a more comprehensive agriculture development strategy is required to address the nutritional challenges of Rwanda. According to the nutrient adequacy analysis in Chapter 3, the production of vitamin B12 is very low in Rwanda, resulting in equally low intake rates among the local population. Increasing the availability of meat and dairy products across the entire country could thus help increase the intake of vitamin B12. In addition, under current food preferences, increasing the availability of dry beans, sweet potato, amaranth, Irish potato and cassava flour will likely increase the uptake of calcium, iron and zinc across the entire country and especially in Rusizi, Huye and Rubavu. To reduce vitamin A deficiency, districts with appropriate biophysical conditions should aim at increasing their production of various horticultural foods.

Following the identification of cost-optimal diets, the spatial analysis in Chapter 4 further explored the possible location of bread baskets based on crop suitability criteria and observed production shortages to meet all nutritional requirements of the population. Following this viewpoint, Rwanda should produce substantially more cereals and legumes (especially maize and soya) and pay less attention to the production of roots and tubers. Various districts in the eastern part of the country are currently suitable for the cultivation of maize and soya beans while substantial land management in the form of terracing and fertilisation is required to render areas in the western part equally suitable.

In addition to production inefficiencies impeding FNS and following the country's adverse topography, many districts in Rwanda face **access constraints**. These constraints appear most critical in the high-priority districts of **Nyamagabe, Gakenke, Karongi, Nyaruguru, Ngoma, Rutsiro, Nyabihu, Burera, Ruhango and Kayonza**. Depending on the selection and location of bread baskets, adequate market integration measures should be adopted to secure supplies to districts characterised by production shortages while upgrading the corresponding food value chain. These measures include investments in transportation, storage and processing infrastructure to reduce transport time or increase shelf life of foods, especially those that are highly perishable such as horticultural products.

Utilisation constraints appear critical to only two districts suffering from the highest child stunting levels, which are **Kayonza and Ngororero**. In these districts, access to a diverse range of food items is less important than how the foods are utilised at the household level to generate nutrition outcomes. Apart from culinary practices and intra-household allocation, nutritional health outcomes also depend on healthcare, water and sanitation infrastructure and practices.

Not all targeting should be driven by geographic location. Large numbers of deprived and malnourished people may live in districts with average performances that appear less critical due to pronounced intra-district inequality. Addressing FNS bottlenecks may take time. In the short run **social protection programs** could guarantee minimal intake of key nutrients for the most under-nourished households, a large share of which live in Bugesera, Nyabihu, Nyamasheke, Rusizi and Rubavu. Depending on level and allocation of current food budgets, these programs could take the form of food transfers, cash transfers or **nutrition awareness campaigns**. Given the low budget allocation efficiencies observed throughout the country, the latter campaigns might be an effective and efficient strategy to improve the quality of diets consumed by Rwandan households. From a national perspective and more closely related to current preferences, consuming more soya beans and cassava leaves will increase the intake of calcium, iron and zinc. To reduce vitamin A deficiency, more spinach, mango and carrot could be consumed. A more substantial shift in food preferences involves the substitution of various roots and tubers with maize products—since maize is a cost-effective source of energy, iron, zinc and folate. Milk and dark green leafy vegetables are two other cost-effective ingredients that provide the majority of required vitamin B12, calcium and vitamin A intake. Given its low intake across the country, it is also worth investigating possible strategies of vitamin B12 food fortification and supplementation.

Various key **policies and programs on agriculture and food security could be made more nutrition-sensitive and enriched with more spatial detail**. The maps in this policy atlas could thus help CSOs prioritise selection of advocacy topics and corresponding strategies to inform policies on how to best address location-specific bottlenecks across the country.

REFERENCES

Brown de Colstoun, E. C., Huang, C., Wang, P., Tilton, J. C., Tan, B., Phillips, J., … Wolfe., R. E. (2017). *Global Man-made Impervious Surface (GMIS) Dataset From Landsat*. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/https://doi.org/10.7927/H4P55KKF

Clapp, J. (2017). Food self-sufficiency: Making sense of it, and when it makes sense. *Food Policy*, *66*, 88–96. https://doi.org/10.1016/j.foodpol.2016.12.001

Cost of Nutritious Diets Consortium. (2018). *Indicators and tools for the cost of nutritious diets*. Boston, MA: Tufts University.

de la Paix, M. J., Lanhai, L., Xi, C., Ahmed, S., & Varenyam, A. (2013). Soil degradation and altered flood risk as a consequence of deforestation. *Land Degradation and Development*, *24*(5), 478–485. https://doi.org/10.1002/ldr.1147

Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change*, *18*, 234–245. https://doi.org/10.1016/j.gloenvcha.2007.09.002

FAO. (2001a). *Food balance sheets: A handbook*. Rome: Food and Agricultural Organization of the United Nations. Retrieved from http://faostat3.fao.org/browse/FB/FBS/E

FAO. (2001b). *Human energy requirements; Report of a Joint FAO/WHO/UNU Expert Consultation*. Rome: Food and Agricultural Organization of the United Nations.

FAO. (2003). *Republique Rwandaise: Cadre Strategique General des Interventions dans le Secteur Agricole*. Kigali: Food and Agricultural Organization of the United Nations.

Gillespie, S., & van den Bold, M. (2017). Agriculture, Food Systems, and Nutrition: Meeting the Challenge. *Global Challenges*, *1*(3), 1–12. https://doi.org/10.1002/gch2.201600002

Global Panel on Agriculture and Food Systems for Nutrition. (2016). *Food systems and diets: Facing the challenges of the 21st century*. London. https://doi.org/http://glopan.org/sites/default/files/ForesightReport.pdf

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., … Townshend, J. R. G. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science*, *342*(November), 850–853. https://doi.org/10.1126/science.1244693

Jones, A. D., & Ejeta, G. (2015). A new global agenda for nutrition and health: the importance of agriculture and food systems. *Bulletin World Health Organization*, *94*(December), 228–229. https://doi.org/10.2471/BLT.15.164509

MINAGRI. (2011). *Strategies for Sustainable Crop Intensification in Rwanda, Shifting focus from producing enough to producing surplus*. Kigali: Ministry of Agriculture and Animal Resources of Rwanda.

MINAGRI. (2017). *National Agriculture Policy*. Kigali: Ministry of Agriculture and Animal Resources of Rwanda.

MINAGRI. (2018a). *Strategic Plan for Agricultural Transformation 2018-24 (Draft: June 2018)*. Kigali: Ministry of Agriculture and Animal Resources of Rwanda.

MINAGRI. (2018b). *Strategic Plan for Agriculture Transformation 2018-24 (Planning for Wealth)*. Kigali: Ministry of Agriculture and Animal Resources of Rwanda.

NISR. (2014). *Fourth Population and Housing Census, Rwanda, 2012: Final results, Main indicators report*. Kigali: National Institute of Statistics of Rwanda.

NISR. (2015). *Rwanda Poverty Profile Report: Integrated Household Living Conditions Survey 2013/14*. Kigali: National Institute of Statistics of Rwanda.

NISR. (2016). *Rwanda - Integrated Household Living Conditions Survey (EICV4), 2013-2014, Cross-Sectional Sample*. Kigali: National Institute of Statistics Rwanda (NISR) - Ministry of Finance and Economic Planning. Retrieved from http://microdata.statistics.gov.rw/index.php

NISR. (2017a). Seasonal Agricultural Survey - 2017. Retrieved November 15, 2018, from http://www.statistics.gov.rw/datasource/seasonal-agricultural-survey-2017

NISR. (2017b). Seasonal Agricultural Survey Report - Season A, 2017. Retrieved March 28, 2018, from http://www.statistics.gov.rw/publication/seasonal-agricultural-survey-report-season-2017

NISR. (2017c). Seasonal Agricultural Survey Report - Season B, 2017. Retrieved March 28, 2018, from http://www.statistics.gov.rw/publication/seasonal-agricultural-survey-report-season-b-2017

Omiat, G., & Shively, G. (2017). Charting the cost of nutritionally-adequate diets in Uganda, 2000-2011. *African Journal of Food, Agriculture, Nutrition and Development*, *17*(01), 11571–11591. https://doi.org/10.18697/ajfand.77.16340

Pangaribowo, E. H., Gerber, N., & Torero, M. (2013). *Food and nutrition security indicators: A review* (ZEF Working Paper No. 108). Bonn. https://doi.org/ISSN 1864-6638

Pekel, J.-F., Cottam, A., Gorelick, N., & Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. *Nature*, *540*(418–422). https://doi.org/https://doi.org/10.1038/nature20584

Pinstrup-Andersen, P. (2013). Nutrition-sensitive food systems: From rhetoric to action. *The Lancet*, *382*, 375–376. https://doi.org/10.1016/S0140-6736(13)61053-3

Stadlmayr, B., Charrondiere, R. U., Enujiugha, V. N., Bayili, R. G., Fagbohoun, E. G., Samb, B., … Burlingame, B. (2012). *West African Food Composition Table*. Rome: Food and Agricultural Organization of the United Nations. Retrieved from http://www.fao.org/docrep/015/i2698b/i2698b00.pdf

Stephens, E. C., Jones, A. D., & Parsons, D. (2018). Agricultural systems research and global food security in the 21st century: An overview and roadmap for future opportunities. *Agricultural Systems*, *163*, 1–6. https://doi.org/10.1016/j.agsy.2017.01.011

Tendall, D. M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q. B., … Six, J. (2015). Food system resilience: Defining the concept. *Global Food Security*, *6*(October), 17–23. https://doi.org/10.1016/j.gfs.2015.08.001

Torero, M. (2014). Targeting investments to link farmers to markets: a framework for capturing the heterogeneity of smallholder farmers. In P. B. R. Hazell & A. Rahman (Eds.), *New Directions for Smallholder Agriculture*. Oxford: Oxford University Press. https://doi.org/10.1093/acprof

UNEP-WCMC. (2018). Protected Area Profile for Rwanda from the World Database of Protected Areas. Retrieved March 28, 2018, from www.protectedplanet.net

UNICEF. (1992). *Food, Health and Care - the UNICEF Vision and Strategy for a World Free from Hunger and Malnutrition*. New York:

UNICEF.
van Dooren, C. (2018). A Review of the Use of Linear Programming to Optimize Diets, Nutritiously, Economically and Environmentally. *Frontiers in Nutrition*, *5*(48), 1–15. https://doi.org/10.3389/fnut.2018.00048
Verdoodt, A., & Van Ranst, E. (2003). *A Large-Scale Land Suitability Classification for Rwanda*. Ghent (Belgium): Laboratory of Soil Science, Ghent University.
WBG. (2018). *Rwanda Economic Update. Tackling Stunting: An Unfinished Agenda*. Kigali: World Bank Group. Retrieved from http://documents.worldbank.org/curated/en/360651529100512847/pdf/127256-NWP-P164510-PUBLIC-Rwanda-Economic-Update-ed-no-12-June-2018.pdf
WDI. (2019). *World Development Indicators*. Washington, DC: World Bank.
Weatherspoon, D. D., Miller, S., Ngabitsinze, J. C., Weatherspoon, L. J., & Oehmke, J. F. (2019). Stunting, food security, markets and food policy in Rwanda. *BMC Public Health*, *19*(882), 1–13. https://doi.org/10.1186/s12889-019-7208-0
WFP. (2008). *Food Consumption Analysis, Calculation and use of the food consumption score in food security analysis*. Rome: World Food Programme, Vulnerability Analysis and Mapping Branch (ODAV).
WHO/FAO. (2003). *Diet, Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO Expert Consultation*. Geneva: World Health Organization.
WHO/FAO. (2004). *Vitamin and Mineral Requirements in Human Nutrition*. Geneva/Rome: World Health Organization, Food and Agricultural Organization of the United Nations.
Xiong, J., Thenkabail, P. S., Tilton, J. C., Gumma, M. K., Teluguntla, P., Oliphant, A., … Gorelick, N. (2017). Nominal 30-m cropland extent map of continental Africa by integrating pixel-based and object-based algorithms using Sentinel-2 and Landsat-8 data on Google Earth Engine. *Remote Sensing*, *9*(10), 1–27. https://doi.org/10.3390/rs9101065

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About the Authors

Wim Marivoet is Research Fellow, **John M. Ulimwengu** is Senior Research Fellow, and **Leysa Maty Sall** is research analyst in the West and Central Africa Office of the International Food Policy Research Institute (IFPRI). This policy atlas has been prepared in close collaboration with the ReSAKSS eAtlas technical team led by Mohamed Abd Salam El Vilaly and Racine Ly, and with Paul Guthiga (ReSAKSS-ECA). The authors wish to acknowledge the input of many participants who contributed to the discussion at various in-country workshops (2018-2020). They are also grateful to Fernando Sedano and Claude Bizimana for their assistance with data analysis and commenting on individual chapters, and to Julie Kurtz and Fleur Wouterse for copy-editing and final revision.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
A member of the CGIAR Consortium | A world free of hunger and malnutrition
West and Central Africa Office | Lot #2 Titre 3396 - BP 24063, Dakar-Almadies, Senegal
Tel: +221 33 869 98 00 | Fax: +221 33 869 98 41
Email: ifpri-dakar@cgiar.org | wca.ifpri.info

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