FINAL TECHNICAL REPORT FROM HEALTHBRIDGE TO HARVEST PLUS

Re: HarvestPlus Challenge Program – Phase II Agreement #8213

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We especially thank Erick Boy of HarvestPlus who provided managerial and technical guidance and support throughout this work. His efforts and encouragement helped the project surmount all hurdles.

Rwanda is a poor and food insecure country. To date, there has been relative little research done on the food and nutrition situation in Rwanda. We trust that this report will help to fill in some of the knowledge gaps and it is our hope that it will be useful in improving food security, nutrition and health in Rwanda.

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List of Acronyms

DHS: Demographic and Health Surveys

SES: Socioeconomic Status

WRA: Women of Reproductive Age

NPNL: Non-pregnant non-lactating

FGD: Focus Group Discussions

SF: Serum Ferritin

TfR: Transferritin Receptor

CRP: C Reactive Protein

AGP: a-1-acid glycoprotein

RBP: Retinol Building Protein

Hb: Haemoglobin

BMR: Basal Metabolic Rate

PHC: Project Healthy Children

1. SUMMARY

HarvestPlus and its partners are planning a study of the efficacy of biofortified beans in improving iron status among Rwandan women and children. The study reported here provides a detailed description of the diet, especially bean intake, and iron deficiency and anaemia in women and children in the Northern and Southern provinces of Rwanda.

Representative random samples of households were drawn from 34 villages in each of the Northern and Southern Provinces, 12 households per village. Seven hundred and eight households provided demographic, SES and bean cultivation and use data. Dietary data were collected from 743 women and 674 children and analysed for nutrient intake and adequacy, food sources and quantity of beans in the diet. Blood samples were taken from 672 women and 577 children and analysed for iron status indicators.

Average energy intakes in children 3 to 5 years of age were 1073 ± 492 kcal; average iron intakes were 10 ± 5.0 mg. Average energy intakes in women were 1705 ± 477 kcal; average iron intakes were 16.5 ± 6.3 mg. For both energy and iron, in both women and children, intakes in the Northern Province were higher than that in the Southern Province, by approximately 30%. Approximately 23% of dietary energy and 40% of dietary iron came from beans, with little difference between provinces. These low intakes led to high prevalences of inadequacy of dietary iron, of more than 60% in children and more than 90% in women. However, biochemical measures of iron status indicate that only ~30% of children and ~11% of women are anaemic, and only approximately 5% of women and children are iron deficient.

The high discordance between the dietary and biochemical indicators of iron status is unexpected and unexplainable. There were probably errors in estimation of intake of bioavailable iron, but unlikely that these errors were large enough to explain the discordance. Other hypotheses to explain the discordance include high intakes of iron from ground water, under estimation of iron levels in the food composition tables, and errors in measurement of biochemical indicators.

In conclusion, the study indicates that beans would be a suitable crop for iron biofortification in Rwanda, but it is unclear whether such an intervention is necessary. Further research, including re-surveying the study populations, is required to determine the reason for the discordance in the dietary and blood data, and to provide unequivocal estimates of iron deficiency. Nonetheless, the presented data help to fill the information gap regarding food and nutrition in Rwanda and point towards a number of pragmatic interventions to improve the health, nutrition and food security of Rwandan women and children.

2. BACKGROUND

Introduction

HarvestPlus and its partners are planning a study of the efficacy of biofortified beans in improving iron status among Rwandan women and children. There have been only a few studies on food consumption in Rwanda, most of which are limited in focus to preschool age children, or to cursory dietary descriptions (described further below), and few studies on nutritional status. The study reported here provides a more detailed understanding of anaemia and the diet,especially bean intake, in women and children in two provinces in Rwanda.

The objectives of the study are: (1) to describe the mean usual iron intake for women and children; (2) to assess the proportion of women and children at risk of inadequate iron intakes; (3) to determine the micronutrient status of the women and children, specifically anaemia and iron status; (4) and to assess the mean intake of common beans by women and children.

Rwanda

Rwanda is landlocked, situated in central Africa, with a total area of 26,338 square kilometers. It is bordered by Uganda to the north, Tanzania to the east, Democratic Republic of Congo to the west, and Burundi to the south (see **Figure 1**). Rwanda is the most densely populated country in continental Africa (population density of ~380 inhabitants per km^2) with an average population growth of 2.7% (2005-2010) and a population of about 10 million. In 2009, it was estimated that 19% of the population lived in urban areas and 81% lived in rural areas [1]. Much of the Rwandan population practices subsistence agriculture, with farming operations of less than one hectare, traditional practices, and a low rate of investment[2]. Rural households make up 81% of the population with very small land area available per person (4.9 persons per ha arable and permanent crop land) [1]. As is common in populations practicing traditional subsistence agriculture, food insecurity is widespread especially in the rural areas[3]. Rwanda was reorganized in January 2006 and is now administratively divided into Kigali city and four provinces: the Northern province (former provinces of Ruhengeri and Byumba), the Southern province (former provinces of Butare, Gitarama and Gikongoro), the Eastern province (former provinces of Kigali Ngali, Umutara and Kibungo), and the Western province (former provinces of Gisenyi, Kibuye and Cyangugu). Provinces are further divided into a total of 30 districts, and these are divided in sectors and cells.

Rwanda's economy is based largely on rain-fed agricultural production. There is a bi-modal rainfall pattern with two main growing seasons, called locally "Season A" (September to January) and "Season B" (March to August). Droughts in the 1980s and the genocide in 1994 (when 1 million people were killed, 2 million became refugees, and much of the country's infrastructure was destroyed) disrupted the food supply and resulted in widespread food deficits. Since the genocide, Rwanda has made steady progress in economic and social development (as reflected in child mortality rates and per capita GDP shown in **Figure 2**), although child mortality remains unacceptably high with more than 10% of Rwandan children not living to their 5th birthday. The economic recovery has been attributed to foreign aid and governmental reforms [4].

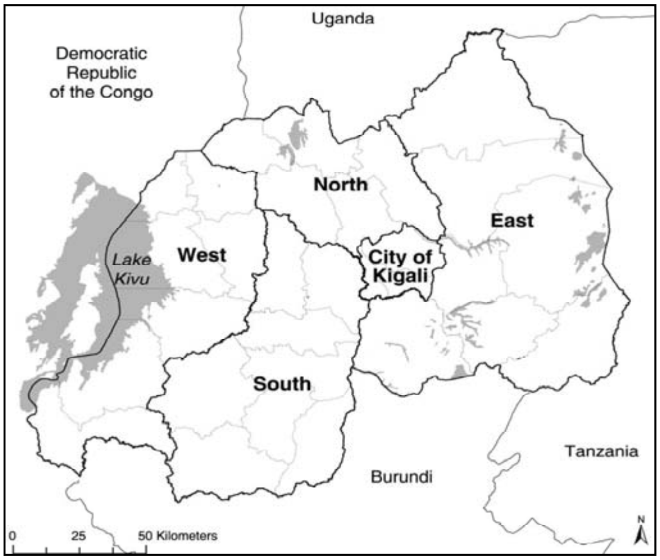

Figure 1: Map of Rwanda

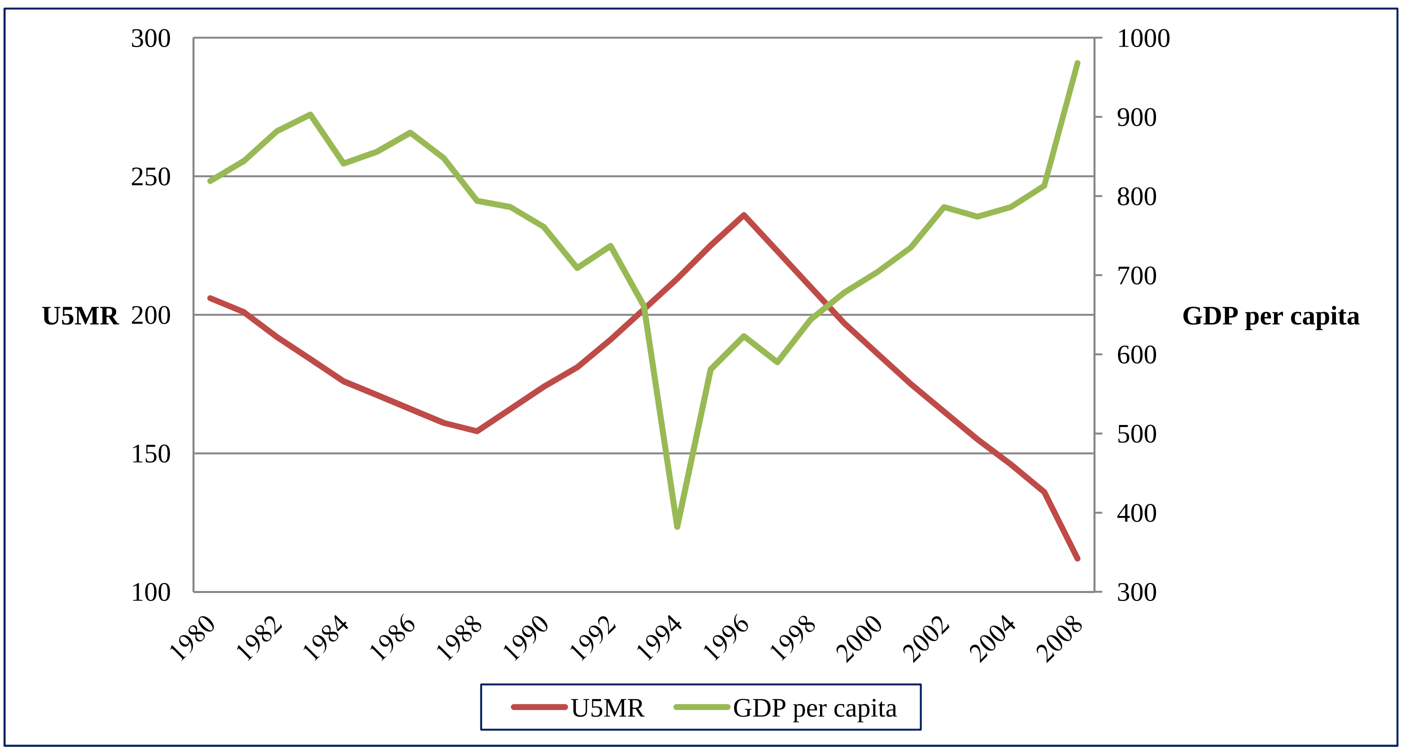

Figure 2: Under 5 mortality rate (U5MR, per 1000) and GDP per capita by year
Source: www.gapminder.org

Nutritional and anaemia status of women and children in Rwanda

For the last two decades, protein-energy malnutrition and micronutrient deficiencies have remained significant public health problems in Rwanda, contributing to the high infant, child and maternal mortality. This is partly due to the cyclical food crises (seasonal food shortages typical of marginal subsistence agriculture) and chronic food deficits (a result of long term factors such as systemic poverty) at the household level[5]. Child growth, a general indicator of child health and malnutrition has not improved over the past four Demographic and Health Surveys in 1992, 2000, 2005, and 2007-8 (see **Table 1**)[6-9]. There is little regional variation, although underweight is somewhat less common in Kigali (see **Figure 3**). In addition, maternal malnutrition has also not shown much improvement during this period (**Table 2**). Similar to children, there is little regional variation in the maternal health indicators (see **Figure 4**).

Table 1: National trends in growth and health status in children 6-59 months (1992-2008)

	1992		**2000**		**2005**		**2007-2008**	
	%	n	%	n	%	n	%	n
Stunting	48.3	4363	42.6	6231	45.3	3859		
Wasting	3.8	4363	6.8	6231	3.9	3859		
Underweight	29.2	4363	24.3	6231	22.5	3859		
Anaemia(Hb<11.0g/dL)					56.3	3537	47.5	4752
Malaria							2.6	4662

Table 2: National trends in maternal nutritional status and anaemia (2000-2008)

	2000		**2005**		**2007-2008**	
	%	n	%	n	%	n
Maternal BMI<18.5kg/m²	*9*	*10421*	*9.8*	*5100*		
Anaemia(Hb<12.0g/dL)			*32.8*	*5657*	*27.1*	*7137*
Malaria					1.4	6768

Approximately one-third of the world's population is anemic and ~50% of all anaemias can be attributed to iron deficiency[10]. According to recent DHS data, anaemia is similarly widespread in Rwanda affecting about half (47.5%) of the children under 5 years of age and 27% of women of reproductive age in the 2007-08 DHS[9]. The Rwandese diet is based on cereals, legumes and tubers that are poor sources of readily absorbed iron and there appears to be very little iron supplementation[5]. Therefore, iron deficiency may account for a significant portion of the anaemia. Infectious disease may account for a large proportion of the anaemia as well. While malaria is not highly prevalent among children (2.6%) or women (1.4%)[2], *Ascaris,* a gastrointestinal parasite which promotes iron loss, was widespread among primary school children affecting as few as 3% in the Eastern Province and 6.6% in Kigali, and up to 31.1 % in the Western Province and 38% in the Northern Province[11].

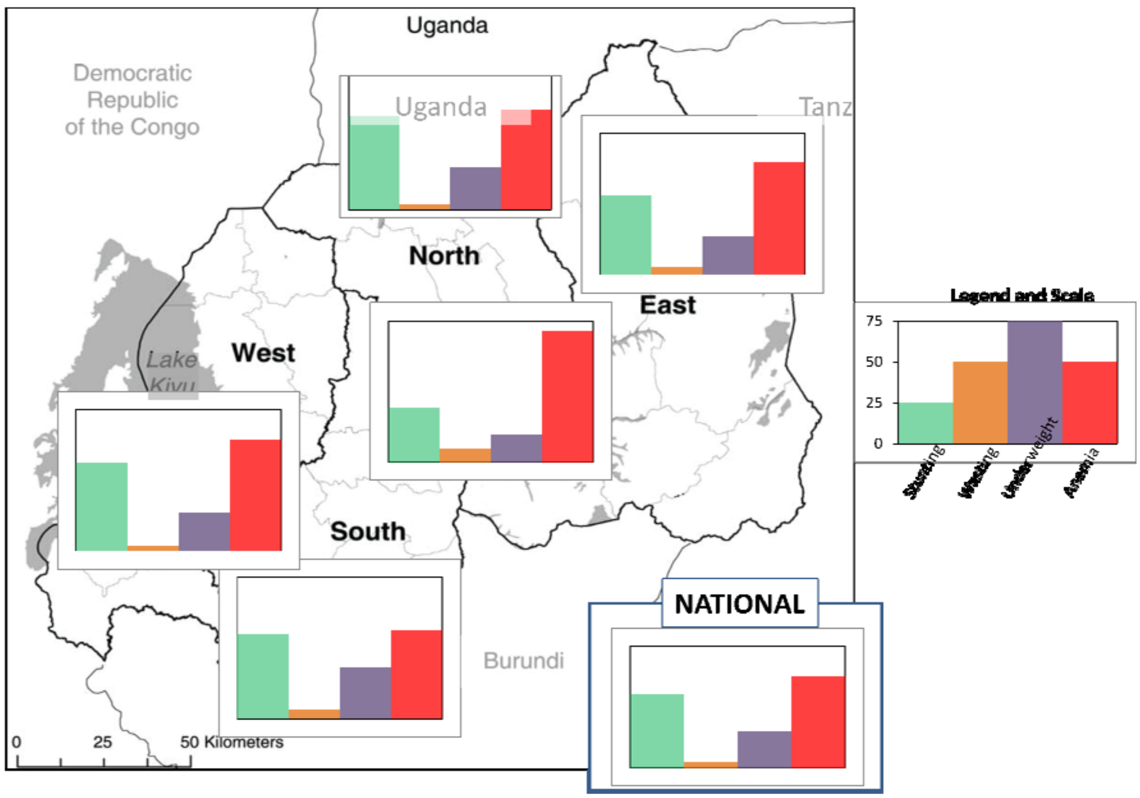

Figure 3: Regional differences in growth and anaemia (Hb<11.0g/dL) in children 6-59 months (2005).

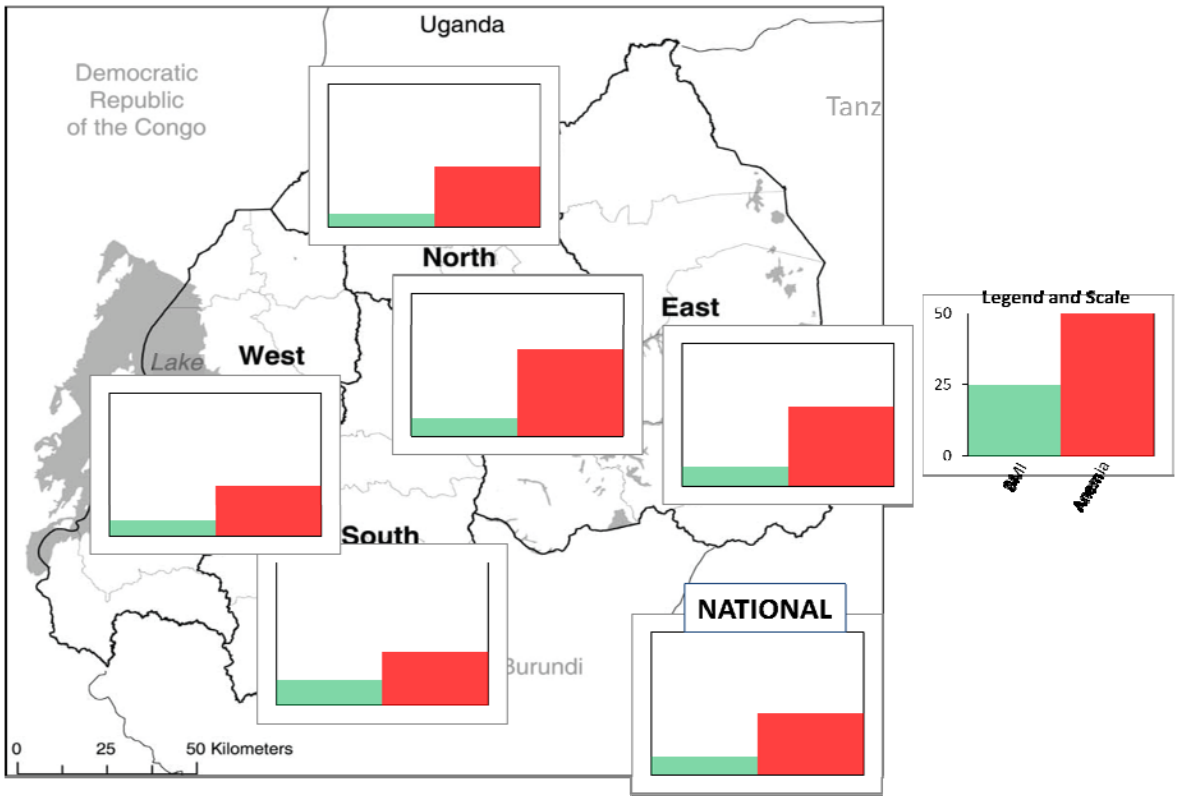

Figure 4: Regional differences in maternal BMI and anaemia (Hb<12.0g/dL) (2005).

The Rwandan diet

National Food Supply Data

Figure 5 shows that energy availability in Rwanda between 1980-2005 ranges from a low of 1629 kcal per capita per day in 1997 to a high of 2259 kcal per capita per day in 1982[12]. The low in 1997 was likely a result of the disruption in the food system following the genocide in 1994[13]. In general, per capita energy supply has declined from both animal and vegetable sources. The share of dietary energy supplied by vegetable products has remained relatively stable over time, representing an average of about 97% of dietary energy supply (animal products supply the remaining 3%). Also, since 1985, the total per capita energy supply has remained below the recommended minimum intake of 2200 Kcal/day, i.e. the per capita food supply has been insufficient to meet the recommended energy demand. Beans have contributed an average of 12% of dietary national energy supply.

The national protein supply in Rwanda for 1980-2005, like energy, has been consistently below the recommended minimum protein intake of 55g/day. On average, 91.5% of the protein supply is of vegetable origin – one-third of this is from beans. Animal products contribute only 8.5% of the protein supply or an average of 3.9g/capita/day [12].

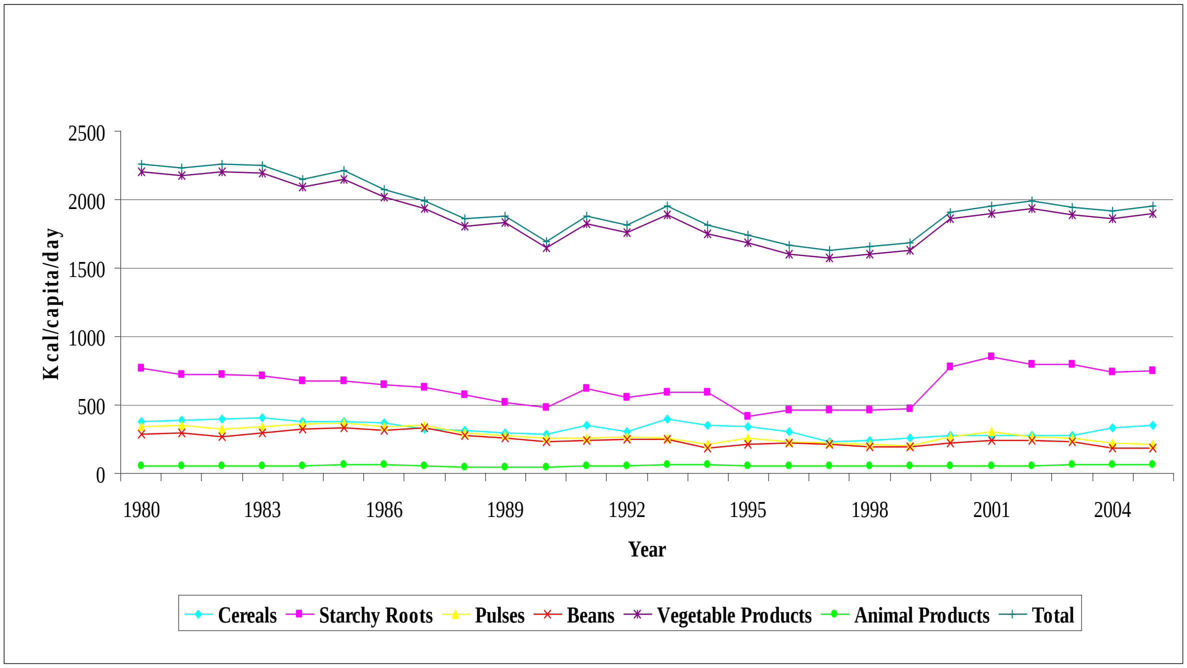

Figure 5: National Food Supply in Rwanda 1980-2005 (Kcal/capita/day).

Cereals = Wheat + Rice + Maize + Millet + Sorghum; **Starchy Roots** = Cassava + Potatoes + Sweet potatoes + Yams; **Pulses** = Beans + Peas; **Vegetable products** = Cereals + Starchy Roots + Pulses; **Total** = Vegetable products + Animal products

Consumption studies

There have not been many studies on food consumption in Rwanda. In a 1982 nutritional study in Eastern Rwanda, a short dietary history was taken and the high incidence of stunting (33%) was attributed in part to under- nutrition. Stunting was significantly lower in children who received specially prepared weaning supplements than in children whose weaning diet came from the family pot and was of lower nutritional value[14].

In a consumption survey of 1985/86 [15], 41% of households consumed less than 80% of the recommended level of calories and 60% of the households were continuously in energy deficit over the survey period. Twenty one and a half percent of all children below seven years of age were stunted and 12.3% were underweight. Poor nutritional status was attributed to scarcity of subsistence food, cash, and time. Also, competing interests such as traditional beer (consumed mainly by men) have been shown to divert scarce resources from staple foods[16].

The Kigali Survey of 1991 collected data on feeding customs during weaning. The deterioration in nutritional status during the weaning period of 8-24 month old children was attributed to two factors: inadequate quantity of complementary food, combined with unhygienic preparation and storage, and poor hygiene of the household after the child began crawling and walking and was able to move to objects to put into the mouth[17].

More recently, two surveys have been conducted. Nationally representative data on the consumption patterns of women 16-45 years and children under 59 months of age were collected for six staple food items identified as potential fortification vehicles (oil, sugar, salt, rice, maize and cassava), with results leading to the recommendation that salt, oil, sugar and maize flour be considered for fortification. Salt was consumed by approximately 99% of women and children every day throughout the year; oil was consumed on average 4.5 times per week throughout the year by approximately 75% of women and 90% of children; sugar was consumed throughout the year by approximately 45% of women and children outside of Kigali and approximately 75% of women and children within Kigali; and maize flour was consumed on average four times per week by approximately 45% of women and children throughout the year. Only 20% of women and children outside Kigali reported consuming rice (this figure was much higher, 50% of women and children, within Kigali). While cassava was consumed by approximately 30% of women and children, it was not frequently processed centrally, but instead grown and prepared in the home[18].

Secondly, the Comprehensive Food Security and Vulnerability Analysis and Nutrition Survey was conducted in 5400 households across four provinces excluding Kigali city [19]. This survey found that the most commonly eaten items were tubers and pulses, which were consumed at least once a week by 98% and 97% of the households, respectively. Over 80% of the households ate tubers and pulses five times a week or more, and they were consumed on average six times a week. Vegetables and oil were also consumed frequently (an average of four times a week) with 86% of the households eating vegetables at least once a week and 40% eating them five times a week or more. Seventy six percent of the households used oil at least once a week and 46% used it five times or more. Sugar (32%), fruits (29%), animal source foods (22%) and milk (17%) were less frequently consumed at least once a week.

Processing and consumption of beans

Traditional processing and preparation practices such as thermal processing, mechanical processing, soaking, fermentation, and germination/malting have been shown to enhance bioavailability of micronutrients in plant based diets[20] . In Rwanda, these processing and preparation practices are carried out at household level (Hilda Vasanthakaalam, personal communication). At an industrial scale, Enterprise Kubumwe, a food Processing industry in Huye, Southern Province processes beans in a variety of ways such as fermentation; drying to increase shelf life; packaging of green beans and storage in cool places; and making bean powder for soups and food mixtures [21].

Despite the low per capita supply of calories from beans in the period 1980-2005 (250Kcal/capita/day ~62.5g of beans/capita/day), it has been observed that rural populations willingly consume high quantities of beans if price and availability permit. National statistics typically suggest per capita consumption of 40-55g/day, but both anecdotal accounts and reports of surveys estimate that levels can be twice as high in rural areas[22]. A recent survey employing food frequency questionnaire and 24 hour recall showed that approximately 80% of the population consumes beans daily (daily average 200 g/per capita) (Martha Nyagaya, unpublished data), which would make Rwanda one of highest bean consumers in the world.

3. METHODS

Study design and Sampling

For the study, representative random samples of households from the Northern and Southern Provinces were drawn. Thirty-four villages were selected from each of the provinces (out of a total of 2,748 in the Northern and 3,517 in the Southern province) using random sampling, and based on probability proportional to sample size. Within each village, 12 households which met the inclusion criteria were randomly selected. The inclusion criteria were having at least one woman of reproductive age (15 to 44 years), or one child (6 - 59 months old), who were usual residents of the household. Random selection of households was by systematic sampling. A route through the village, in which every household was passed was predetermined. Then at the starting point of that route, a random household was selected from the 1st through kth household, and every kth household after that, where

k=(n households in village) ÷12 (rounded down).

Note: All analyses of household/SES data, dietary data and blood data were weighted according to the probability of the household/individual being selected and thus all results presented in this report are representative of the Northern or Southern Provinces, or the two provinces combined.

Sample size justification

Based on our experience in other similar surveys, and on the relatively low level of clustering in the planned design, we estimate that the design effect of this sampling method will be a modest 1.5. We estimated that 67% of households would have a child between 6 and 59 months of age, and 80% of households would have a woman of reproductive age (WRA).

Objective 1: Describing the mean usual iron intake for the study group

The number of subjects was selected to provide estimates of dietary iron intake within ± 1.2 mg/day at the province level, assuming variation of the iron intake in children and women was be similar to previous studies in East and South Africa using the 24-hour recall method (see **Table 3**).

Table 3: Variation in iron intake in 24-hour recall studies

Country and reference	Subjects	Mean iron intake per day(mg) ± SD/ Median(1st and 3rd quartiles)
Nigeria, 1985 [23]	Lactating women (n=232)	29.0 ± 5.8
Malawi, 1995[24]	Pregnant rural women (n=60)	14.8 (11.2, 17.4)
Kenya, 1997 [25]	Preschool children (n=41)	Period 1 (lean) 11.4 ± 5.0 Period 2 (harvest) 11.9 ± 5.2 Period 3 (lean) 12.9 ± 5.0
Kenya, 1997 [25]	Elderly subjects (n=41)	Period 1 (lean) 19.2 ± 11.3 Period 2 (harvest) 23.3 ± 14.6 Period 3 (lean) 24.2 ± 15.2
Morocco, 2005 [26]	Children 6-10years (n=63)	10.8 ± 2.3
Kenya, 2007 [27]	Children 7-9years (n=78)	15.8 ± 3.4
Kenya, 2007 [28]	School children (n=603, lean season ; n=245, harvest season)	Lean season 18.0 ± 9.0 Harvest season 16.0 ± 8.0
Kenya, 2007 [16][29]	Pregnant women (n=716)	16.1 ± 5.4
South Africa, 2008 [30]	Women (n=1726)	8.8 ± 5.8

The observed mean ± SD of iron intake in Kenyan children with a diet broadly similar to the Rwandese diet was 15.8±3.4mg/day[1] [27], and other estimates of SD for children were 2.3 to 9.0 mg per day (Table 3). We used a conservative estimate of 7.5 mg/day. The 95 percent confidence interval for iron intake is calculated as $Z_{0.95}$ × standard deviation of iron intake/ (square root of sample size). Therefore to estimate the iron intake to be within +/- 1.2 mg (95%CI), would require a sample size of:

1.2 = 1.96 x SD/(n^.5)

$n = [(1.96)^2 \times (7.5)^2] / (1.2)^2$

= 151

Considering the design effect of 1.5 and a non-response rate of 10%, a sample of 253 children is required.

For women, we used a conservative estimate of SD of iron intake from several dietary intake studies in Africa of 7 mg/day. To estimate the iron intake to be within +/- 1.2 mg (95%CI), would require a sample size of:

1.2 = 1.96 x SD/(n^.5)

$n = [(1.96)^2 \times (7)^2] / (1.2)^2$

= 131

We estimated that ~10.6% of the women will be pregnant[2] [31] and ~22.1% of the women will be lactating [3][19]. To account for the pregnant and lactating women (a total of ~33%) and non-response or refusals (10%), and a design effect of 1.5, we estimate that a sample of 327 women is required.

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[1] The main sources of iron for children (median age 7 yrs) were white maize (42% of total iron intake) and kidney beans (36% of total iron intake).

[2] The 2009 birthrate for Rwanda is 38.06 births/1,000 population, and the Rwandese population was 10,746,311 thus there were ~409,004 births in 2009 (1120 births/day and 313,756 in 280days, the average gestation period) so that ~313,756 women are pregnant at any given time, which is 10.60% of the ~2,961,300 women 15-64 years.

[3] At least 80% of the children under 24 months are breastfed. If there were 1120 births/day, then there were ~817600 children born in 24 months. At any given time, ~22.1% of the ~2,961,300 women 15-64 years breastfed their children.

Objective 2: Assessing the proportion of the study group at risk of inadequate iron intakes

To fulfill Objective 2, replicate 24 hour recalls on non-consecutive days on a representative subsample of 30 to 40 subjects were required [32]. A sample of 40 will allow for 10% refusals on the replicate days while meeting the suggested sample size.

Objective 3: Determining the micronutrient status of women and children

The estimated prevalence of anaemia among children was 48% [20]. With the level of confidence, E, set at 10%, the required sample size was calculated as follows:

$$n = \frac{Z_{0.95}^2 (1-P)P}{E^2}$$

$$n = \frac{1.96^2 (0.52)(0.48)}{(0.10)^2}$$

$$= 96$$

With a design effect of 1.5 and non-response rate of 10%, a sample of 160 children was required.

Similarly for women, for whom the prevalence of anaemia among women was estimated to be 27.1% [20], and the level of confidence of 10%;

$$n = \frac{Z_{0.95}^2 (1-P)P}{E^2}$$

$$n = \frac{1.96^2 (0.73)(0.27)}{(0.10)^2}$$

$$= 76$$

To account for ~33% pregnant and lactating women, a non-response rate of 10%, and a design effect of 1.5, we estimated that a sample of 190 women was required.

Objective 4: Assessing the mean intake of common beans by women and children

National statistics suggest per capita consumption of 40-55g/day, but both anecdotal accounts and reports of surveys estimate that levels can be twice as high in rural areas. Since we did not have accurate estimates of variation in intake of common beans, we let the other objectives drive the sample size.

Therefore, we proposed sampling 408 households per province (i.e., the highest number from the above calculations (327) divided by 0.80 (as WRA were expected in only 80% of households) and thus sufficiently powered for both the 24-hour recall and anaemia estimates. See **Table 4** below).

Table 4. Summary of sample size calculations, showing required sample in each province

	a	b	c	d	e	F	g
	Required n (from above calculations)	n accounting for DE, 10% refusals, 33% pregnant or lactating	n hh to reach n in column b (67% hh with child, 80% with WRA)	Planned n hh (max from column c)	Expected n for children and NPNL WRA	Resulting Precision using expected n (column e)	Target precision
Child anaemia	96	160	239	408	248	7.6%	10%
WRA anaemia	76	190	237	408	198	7.6%	10%
Child iron intake	151	253	377	408	248	1.1 mg	1.2 mg
WRA iron intake	131	327	408	408	198	1.2 mg	1.2 mg

Child=age 6 to 59 months; WRA= women 15-44 years; n=sample size; hh=households; NPNL=non-pregnant non-lactating)

The appropriate 24-hour recall schedule

One day of dietary recall from a group of individuals is sufficient to calculate the mean group intake. However, to estimate the proportion of the study group at risk of inadequate intakes, the population distribution of usual intakes must be described and to develop this distribution more than one day of recall data is required from at least a sub-group of the study population [32]. We therefore planned to collect one 24-hour recall on the entire sample, and a second 24- hour recall on a subsample of 40 households. A statistical method could then be employed which effectively removed the intra-individual variation from the total variation (in any dietary intake parameter), leaving the inter-individual variation of usual intakes [32]. The software PC-SIDE (V1.0, Iowa State University, 2003) was used to carry out this adjustment.

The dietary recalls were collected in November and December 2010.

Preparations for 24 hour recall interviews

Focus Group Discussion

Focus group discussions (FGD) were held in communities similar to the surveyed communities (i.e., in the same provinces, but neighboring districts) with women who were responsible for food preparation in their households, through which information was collected on foods consumed, standard recipes and household unique recipes. This information was used to generate conversion factors (explained below) and a nutrient composition table of local foods.

Conversion factors*:* Several procedures can be used to convert recalled food portion sizes (from the 24 hour recalls) to weights, and these procedures may differ between foods, according to whatever is most understandable to or preferred by the local participants. The procedures include:

a) direct weighing - recording the weight in grams of actual foods (or salted replicas) of the size the respondent reported consuming directly using dietary scales;

b) volume equivalent - recording the volume of water that is equivalent to the recalled volume of the food or beverage item consumed and then converting the volume to grams by multiplying volume (in mLs) by the specific gravity (density) for the food or beverage item consumed;

c) household measures - recording the recalled portion sizes of food or beverage in household measures and converting to weight equivalents;

d) clay or play dough models - measuring and recording the volume of a clay or play dough model identical in size and shape to the recalled size and shape of the food item consumed, and then converting the volume into weight equivalents of the actual food;

e) linear dimensions - measuring the linear dimensions (length, width, and thickness) of a food item of the recalled size as the consumed food with a non-stretch tape measure and then converting into weight equivalents of the actual food;

f) monetary value - converting the monetary value of a purchased food item into weight equivalents.

For each food that the FGD report eating at least one conversion factor was generated, and all these conversion factors were recorded in a database.

Compiling a local food composition table and retention factors

A local food nutrient composition table was developed based on the list of food and recipes generated during the FGD. The USDA Nutrient Database 22 was used as the main source in calculating nutrients in foods from the study [33]. The USDA Retention Factor for cooked foods was applied to cooked foods and ingredients. This approach of using cooked food allowed for any nutrient value changes (losses or gains per gram consumed) during cooking to be taken into account. When nutrient values and foods are not available in the USDA Database 22, published data and other food composition tables were used. In addition, HarvestPlus completed a dietary study in Uganda in 2009 where they developed a local food composition table. Given that similarities in the local foods in Rwanda and Uganda were anticipated, the Uganda Food Composition Tables was used as a starting point.

Training Interviewers

A total of 24 interviewers with a university level education and fluent in the local language (Kinyarwanda) and French were recruited and trained to conduct the study. They were paired in teams of two to make twelve teams that each visited both provinces.

Training activities for the interviewer followed the guidelines in the manual [34].

Pilot testing the interactive 24-hour recall

The dietary recall was pilot tested in mid November with a population comparable to the actual study setting and participants. Each of the 24 interviewers conducted at least two 24-hour recalls, and one was video-taped and reviewed by the training team.

Interactive 24-hour recall procedure

The procedure followed the guidelines in the manual [34], and took place in three phases: Preparing the respondents for the recall, Conducting the multiple pass 24-hour recall, and Data entry and analysis.

Preparing the respondents for the recall

The respondents were informed about the study and their informed consent was sought. Then the interviewers visited their homes, two days before the day of the interview. When preparing the respondents for the recall, some training of portion size estimation, as well as instructions on how to complete the "picture charts", was given. Picture charts with sketches of the foods most often eaten in the study area were given to the respondents to make note of everything they eat on the recalled day by placing a checkmark beside the appropriate picture. This chart was then used by the interviewer to compare with the recall as a double check on capturing all consumed foods during Pass 1 (see below)[34]. The preparation visit was also used to give the reference woman and child the utensils from which they would eat on the recall day. On the day of the recall, the respondents gathered in a pre-determined central location (such as a school or health clinic) to facilitate the interviewing.

Multiple pass 24-hour recall

Pass 1: Generating a list of foods and drinks consumed - For the first pass of the recall interview, a list of all the foods and drinks (including drinking water) consumed during the preceding 24-hour period was obtained. After completing this list, the interviewer checked the respondent's responses against the picture chart they filled in. If there is any discrepancy, they were probe for more information to see whether the food was forgotten in the interview.

Pass 2: Description of foods and drinks consumed - The interviewer went over, in chronological order, each of the responses made by the respondent in Pass 1, probing for more specific descriptions of all the foods and drinks consumed, including cooking methods and (where possible or relevant) recipe names. In addition, the interviewers asked for any additional items that were consumed but which were forgotten in the first pass.

Pass 3: Estimating portion size consumed - To increase accuracy of their estimates of portion sizes the tools described in the *Conversion Factor* section were used. The final step in the third pass is to record details of recipes on a separate recipe form.

Pass 4: Reviewing the recall interview data - In this the final stage of the interview, the interviewer will review the recall to ensure that all the items have been recorded correctly.

Data entry and analysis

Data were double entered using the CSDietary system (developed using the CSPro software by Serpro S.A. and HarvestPlus) which calculates the nutrients consumed by the observed persons based on their reported food consumption and the data bases prepared before the data collection: conversion factors, food composition, food groups, recipes and retention factors. Analysis of nutrient intake and adequacy, contribution of food groups to nutrient intake, bean intake and additional analyses were conducted. Analyses were done by provinces separately and combined, and for children aged < 1year, 1-<3 years, and 3-5 years.

Biochemical indicators of iron status

A venous blood sample of at least 3mL was drawn by venipuncture and stored in a collection tube. The blood was allowed to settle and plasma pipetted out and aliquoted into 0.2mL tubes. Frozen samples were transported in a Styrofoam box with dry ice to Dr. Juergen Erhardt, in Germany where the sandwich ELISA technique was used to determine Serum Ferritin (SF), Transferritin Receptor (TfR), C Reactive Protein (CRP), a-1-acid glycoprotein (AGP) and Retinol Binding Protein (RBP) [35].

Blood data analysis

All villages were located at an altitude higher than 1000 metres and therefore haemoglobin (Hb) concentrations were adjusted using the CDC method[36], which corresponds to the method used in the Rwanda DHS 2008-09 report. The Nestel method [37]of altitude adjustment was also used for comparison purposes but the results were very similar. Anaemia was defined based on WHO guidelines[10], consistent with DHS reported results (race-specific criterion not used). For children, an Hb cutoff of <110 g/L was defined as anaemia, Hb 100-109 g/L as mild anaemia, Hb 70-99 g/L as moderate anaemia and Hb <70 g/L as severe anaemia. For non-pregnant women, anaemia was defined as Hb <120 g/L; for pregnant women, the cutoff is Hb <110 g/L.

Serum ferritin concentration distributions were skewed to the right; therefore, analysis was done on both raw values and log-transformed values. As a result, the geometric mean is reported for ferritin. Since ferritin is an acute phase protein, levels are raised during infection. Therefore the individual's inflammation status, based on CRP and AGP measures, was taken into account during the analysis[38]. Both recommended approaches– excluding individuals with evidence of infection or adjusting ferritin concentrations to remove the effects of inflammation (see below for more details) – were used and results presented for comparison purposes.

Serum transferrin receptor concentration distributions were only slightly skewed to the right and transformation was not deemed to be necessary. Two children had TfR concentration >20 μg/mL, which were considered extreme values (>IQR*1.5+75th percentile). Analysis of mean TfR concentration with and without these cases showed little meaningful difference and therefore the cases were included in the final analysis.

Recent guidelines for adjusting serum ferritin [39]and RBP [40] concentrations to remove the effects of subclinical inflammation recommend using a combination of elevated acute phase proteins (i.e. CRP and AGP) to categorize apparently healthy individuals by their inflammatory state. Individuals were classified as having a normal CRP if the serum concentration was ≤5 mg/L[41][4] and a normal AGP if the concentration was ≤ 1 g/L. The inflammatory state of each individual was classified as "healthy" if neither CRP nor AGP were raised; "incubating" if only CRP was raised; "early convalescence" if both CRP and AGP were raised; and "late convalescence" if only AGP was raised. (**Table 31** in the results provides a summary of the distribution of subclinical inflammation for each target group.) Nearly 30% of the sample of children and about 15% of women had some form of inflammation.[5]

Based on an individual's inflammation status, a corresponding correction factor was used for both serum RBP and serum ferritin as follows:

Group	Stage of subclinical inflammation	Raised acute-phase proteins	Plasma retinol correction factor	Ferritin correction factor
I	Healthy	None	None	None
II	Incubating/preclinical	CRP only	1.13	0.77
III	Early convalescence	CRP & AGP	1.24	0.53
IV	Late convalescence	AGP only	1.11	0.75

adapted from [39-41]

[4] Justification for this cutoff per Thurnham et al. 2005: "…An appropriate threshold should be used to evaluate the effects of CRP concentrations on plasma biomarkers. Clinicians use a cut-off of 10 mg/l, as this value relates better to the clinical relevance of the data. However, healthy subjects tend to display plasma CRP concentrations <5 mg/l, thus CRP values between 5 and 10 mg/l probably indicate mild inflammation and such subjects could be assigned to either groups II (incubating or preclinical) or III (early convalescence), which show a correspondingly low plasma retinol concentration."

[5] Note that a child's reported sickness status was not associated with high CRP or AGP; however, in women, her reported sickness status was associated with having high CRP (p=0.0004) and a tendency (p=0.09) to be associated with high AGP.

Interpretation of the iron status of populations is best done using a combination of measurements of serum ferritin and transferrin receptor so as to enable distinguishing between iron deficiency and inflammation [42]. For the purposes of this study, iron deficiency was defined in several ways.

1) Low ferritin concentration using standard cutoffs with inflammation-adjusted estimates (<12 μg/L for children or <15 μg/L for women) or high TfR concentration (>8.3 μg/mL (equivalent to Ramco assay; Juergen Erhardt, personal communication)) or both.
2) Low ferritin concentration using higher cutoff (<30 μg/L for children;[42] recommended in the presence of infection – either applied only to cases with inflammation or to all cases regardless of inflammation status (assuming widespread chronic infections in this context).

Participants

Confidentiality

Each household selected by the sampling procedure was given a Household Identification number was used to label the blood samples and 24-hour recall forms. During study, the identification numbers were used to identify households and revisit them if the need arises. The data sheets have been kept in a locked room and the databases are password protected.

Compensation

Participants were compensated for their participation with for their time at the rate 1000RFW. In addition, all households that provided beans and food samples were compensated for the cost of the food items they provided.

Informed Consent Process

A statement of the research purpose in the local language was communicated to eligible adult participants and eligible children's guardian. They were given a chance to ask questions about the study and to review the informed consent form (Appendix 4). Participation was voluntary. As a sign of acceptance, the women who could write signed the form and those who could not write gave verbal consent documented by signature of a literate witness and thumb print. In addition, informed consent was also obtained from the mothers or from the guardians of all children who participate

Ethics reviews

Approval for the research was granted by the National Ethics Committee of Rwanda, the research commission of National University of Rwanda Faculty of Medicine and the HealthBridge Research Ethics Board.

4. RESULTS

Sample Characteristics

The villages selected and the village coordinates are shown in **Appendix 1**. In total, 708 households participated in at least part of the survey. The sample for each type of data is shown in **Table 5.**

Table 5. Sample sizes for dietary, blood, and household level data, by province and total.

	Number of Households			**Number of Women**			**Number of Children**		
	Northern	**Southern**	**Total**	**Northern**	**Southern**	**Total**	**Northern**	**Southern**	**Total**
Dietary data									
24-hour recall				389	354	743	343	331	674
repeat 24 hr recall				34	32	66	30	21	51
SES, demographic & bean data	362	346	708	357	322	679	311	307	618
Blood data									
Hemoglobin				354	318	672	290	287	577
Blood proteins				354	318	672	290	287	577

Because households with young children were targeted, we had a sample made up of more lactating women (60% of the women in the sample) (see **Table 6**) then would be found in the general population. Ten percent of the women reported being pregnant. As women themselves would probably not know they were pregnant until the second or third month, and given the cultural aversion to acknowledging one's pregnancy, it is likely that more than 10% of the women were pregnant, and that of those who reported being pregnant they would disproportionately be visibly pregnant and in the third trimester when pregnancy can not be easily hidden.

Table 6. Characteristics of the adult women (>15 yr) in the study

	Northern		Southern		Total	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	30.9	6.3	30.9	6.9	30.9	6.6
	n	**%**	**n**	**%**	**n**	**%**
Pregnant	38	10.6	31	9.6	69	10.2
Breastfeeding	200	56.0	204	63.4	404	59.5
Pregnant and Breastfeeding	3	0.8	4	1.2	7	1.0
Not Pregnant Not BF	116	32.5	82	25.5	198	29.2
TOTAL	357		322 (1 missing)		679 (1 missing)	

The characteristics of the children in the sample are summarized in **Table 7**. While most children breastfed, it was not as high as expected (and required for infant health), and it continued for longer than necessary for health in a number of children (see **Figure 6**).

Table 7. Characteristics of the children (0-6 years) in the study

	Northern		Southern		Total	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (months)	35.0	15.4	33.5	14.7	34.3	15.1
Was child breastfed yesterday	**n**	**%**	**n**	**%**	**n**	**%**
No	46	14.8	48	15.6	94	15.2
Yes	122	39.2	144	46.9	266	43.0
Missing	3	1.0	2	0.7	5	0.8
N/A (child off breastmilk)	140	45.0	113	36.8	253	40.9
	n	**%**	**n**	**%**	**n**	**%**
Boys	148	48.2	157	45.8	320	47.5
Girls	159	51.8	186	54.2	354	52.5
TOTAL	307		343		674	

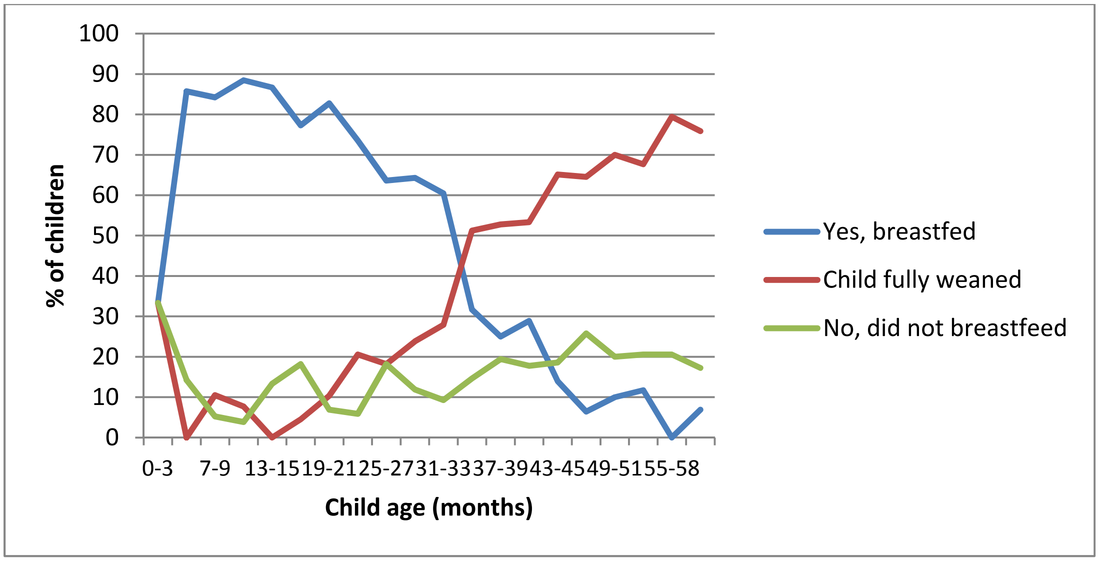


Figure 6. The proportion of children who breastfed the day prior to the survey.

Illness, Supplements, Meds and ITN use

Illness was not uncommonly reported in both women and children, with 11%, 4% and 5% of the children reporting cough, diarrhoea and fever the day prior to the survey (see **Table 8**). The adult women report about half as much illness as the children.

Table 8. Illness on day prior to survey in children and women (% responding "yes").

Yesterday, was this individual suffering from:	REFERENCE CHILD				REFERENCE WOMAN			
			95% CI				95% CI	
	n	Percent	lower	upper	n	Percent	lower	upper
COUGH?								
Northern Province	64	9.0	6.4	11.7	45	6.6	4.6	8.5
Southern Province	95	12.7	9.3	16.2	50	6.6	4.7	8.6
DIARRHOEA								
Northern Province	17	2.4	1.0	3.8	8	1.1	0.3	2.0
Southern Province	32	4.6	2.6	6.5	14	1.9	0.9	2.8
FEVER?								
Northern Province	34	4.7	2.8	6.7	21	2.9	1.6	4.2
Southern Province	44	6.2	4.2	8.1	29	3.9	2.6	5.3

Micronutrient supplement use was uncommon, with only vitamin A supplementation in Northern Province children occurring with any regularity (16%) (see **Table 9**).

The use of medicines was more common than the use of micronutrient supplements, with 30% of Northern children and 15% of Southern children having taken a deworming drug in the past 6 months (see **Table 10**). Antimalarials were much less common. Approximately 40% of women and children reported sleeping under a mosquito net the previous night (see **Table 11**).

Table 9. Supplement use in children and women (% responding "yes").

In the past 6 months, has this individual taken any of the following supplements:	REFERENCE CHILD				REFERENCE WOMAN			
			95% CI				95% CI	
	n	Percent	lower	upper	n	Percent	lower	upper
Iron?								
Northern	2	0.3	0.0	0.6	8	1.2	0.3	2.0
Southern Province	6	0.7	0.0	1.6	6	0.7	0.2	1.3
Vitamin A?								
Northern	114	16.4	11.9	20.9	11	1.6	0.7	2.5
Southern Province	46	5.9	2.7	9.0	7	0.9	0.1	1.6
Zinc?								
Northern	1	0.2	0.0	0.7				
Southern Province	1	0.2	0.0	0.6				
Any								
Northern	2	0.3	0.0	0.6	5	0.7	0.1	1.4
Southern Province	9	1.1	0.1	2.2	8	1.0	0.3	1.7

Table 10. Medical drug use in children and women (% responding "yes")

In the past 6 months, has this individual taken any of the following:	REFERENCE CHILD				REFERENCE WOMAN			
			95% CI				95% CI	
	n	Percent	lower	upper	n	Percent	lower	upper
Anti-malarials?								
Northern	25	3.5	1.4	5.6	36	5.1	3.5	6.7
Southern Province	50	6.7	4.0	9.4	29	3.9	2.0	5.7
Deworming								
Northern	205	30.0	25.9	34.1	57	8.4	6.6	10.2
Southern Province	112	15.4	11.6	19.1	22	2.8	1.6	4.1

Table 11. Insecticide treated bednet use in children and women (% responding "yes")

Last night did this individual sleep under an ITN:	REFERENCE CHILD				REFERENCE WOMAN			
			95% CI				95% CI	
	n	Percent	lower	upper	n	Percent	lower	upper
Northern	284	41.5	38.6	44.3	326	47.5	45.5	49.4
Southern	278	38.3	35.6	41.1	292	39.7	37.2	42.1

Socioeconomic Status

The households were largely agricultural-based in both the northern and southern provinces, and agriculture was the primary source of income for 67% of the households. A further 26% reported "casual labour" as their primary income source, with less than 4% reporting salaried employment, formal business, selling natural products, petty trading or other.

Source of water and toilet facilities

There was little difference between provinces in the water sources and type of toilets. The average household reported taking almost 30 minutes to get water and bring it to the house. Piped water was the most common source at 34%, open wells and covered wells were each the main source of water for 25% of households and surface water (springs, rivers, streams or ponds) was the main sources for 14%. One household reported their water came from tanker truck.

Almost all households used traditional pit latrines (96%). A few (4%) used flush toilets and less than 1% used improved pit latrines.

Cooking Fuel

Ninety four percent of the households use firewood, with 5% using charcoal and 1% electricity, with no difference between Northern and Southern Provinces.

Flooring

Most floors are earth (83%) or cement (10%). Mud mixed with dung is used in 5% of the households and less than 1% of the households use each of wood planks, parquet or polished floors, ceramic tiles, carpet or other.

Household services and goods

The level of ownership of basic goods is low in both provinces (see **Table 12**), with, for example, less than 4% of the households having electricity.

Table 12. Household services and ownership of goods, by province (% with service or good).

Does your household have:	Northern (%)	Southern (%)
Electricity?	3.3	2.2
Radio?	37.5	27.3
Television?	1.8	1.6
Landline Telephone?	0.3	0.7
Refrigerator?	0.6	1.5
Does anyone in household own:		
a Bicycle	8.0	5.8
a Car or truck	1.1	1.2
a Motorcycle	1.4	1.1
a Mobile phone	18.6	11.1

Beans

Many of the questions focused on beans – the production, preparation, and consumption of beans and the different varieties. Most of the households have land or access to land, and use that land to cultivate a couple varieties of beans (see **Table 13**). Seeds generally come from the farmer saving the previous years seeds, or buying from the local market (see **Table 14**).

Table 13. Household access to land for cultivating beans, and number of bean varieties grown.

	Northern	Southern	Northern & Southern
	% answering yes (95% CI)		
Does household have access to land?	93.1(87.6-98.6)	89.2(83.4-95.1)	91.3(87.1-95.5)
Does household cultivate crops on this land?	92.9(87.4-98.5)	88.5(82.6-94.4)	90.8(86.4-95.2)
Are beans one of crops cultivated on this land?*	89.9(83.9-95.9)	85.9(79.6-92.1)	88(83.3-92.6)
	mean ± SD		
number of varieties of beans cultivated**	1.9 ± 0.5	1.8 ± 0.3	1.9 ± 0.4

*These are the percentage who answered "yes, every year". Less than 2% answered "Yes, some years".
** 83% answered either 1 or 2 varieties, 4% said 3, 3% said between 4 and 11, and 1 household answered each of 14, 19,23, 30 and 32.

Table 14. Households' source of bean seeds (% and 95% CI)

Main source of bean seeds	First Answer (%)	Second Answer (%)
Northern		
Saved seed from previous year harvest	34.4 (27.9-40.8)	5 (0-10.7)
Purchased seed from local market	56.5 (48.7-64.4)	12.7 (7.9-17.4)
Purchased or received from government inst	1.5 (0-3.4)	0.2 (0-0.7)
Missing	7.3	82.1)
Purchased seed from seed company; Received as gift	< 1%	<1%
Southern		
Saved seed from previous year harvest	30.2 (21.4-39)	4.7 (0-9.4)
Purchased seed from local market	61.3 (53-69.7)	8.7 (3.8-13.7)
Missing	7.2 (3.9-10.5)	86 (78.7-93.3)
Purchased seed from seed company; Received as gift; Received seed from a food security program; Purchased or received from government	< 1%	<1%
Northern and Southern		
Saved seed from previous year harvest	32.4 (27.4-37.4)	4.9 (1.3-8.4)
Purchased seed from local market	58.8 (54.4-63.2)	10.8 (7.6-14.1)
Missing	7.3 (4.1-10.5)	83.9 (78.4-89.5)
Purchased seed from seed company; Received as gift; Purchased or received from government	< 1%	<1%

Bean Harvest and Sales

Most households did not harvest enough beans to meet their needs (see **Table 15**), with half of households running out within a few months of harvest (see **Table 16**). Some households answered more than 12 months, but it is not clear how this should be interpreted, as after 12 months the next year's harvest would meet their needs. Sixteen percent of households sold some of their beans (see **Table 17**); presumable this was from the 23% which said they grew enough beans for their needs.

Table 15. Answering "No" to "Do you harvest enough beans to meet your family's needs?

	% No (95% CI)
Northern	74.9(68.2-81.6)
Southern	79.9(73.9-86)
Northern and Southern	77.3(73.1-81.5)

Table 16. Distribution of responses (number of months) to questions "If harvest is not enough for family needs, how soon (months) do you often run out of bean after harvest?"

Number of months	Northern	Southern	Northern and Southern
0	0.6	0.5	0.6
1	8.8	18.5	13.4
2	22.2	18.3	20.3
3	23.3	17.0	20.3
4	9.6	9.4	9.5
5	3.7	7.1	5.3
6	4.2	3.5	3.9
7	0.9	0.2	0.6
8	0.5	2.3	1.3
9	0.5	.	0.3
10	.	1.3	0.6
15	.	0.5	0.3
20	0.3	0.5	0.4
30	0.3	0.8	0.5
Do not know		0.7	0.3
Harvest was enough	25.3	19.4	22.5

Table 17. The percentage of households that sold beans from their harvest, and the amount sold.

	% (95% CI) answering Yes to "Last season, did you sell any beans you cultivated?"	Of those who sold, average±SD (max), kg
Northern	20.3 (14.2-26.5)	53±8 (200)
Southern	11.1 (6.4-15.9)	62±31 (1000)
Northern and Southern	16 (11.4-20.5)	56±18 (1000)

A small number of farmers reported selling specific varieties. The most common were Types 1 and 3, sold by 16 farmers.

There were 15 different varieties of bean reported cultivated in the study households (see **Table 18**), with the most common being Types 1 and 3. For most of the varieties an average of ~10kg of seed were planted yielding harvests of around 60 kg, but there was marked variation in yields.

Table 18. The number of farmers growing each bean variety, they amount they planted and harvest last sesaon (kg) and the number of years they have been growing that variety.   Average ± SD (Maximum)

Variety name	n	Amount planted last season	Total harvested last season	Years cultivated
Kidney (Type 1)	286	9.9±10.9(80)	63±81(1000)	8.1±10.2(40)
Kidney (Type 2)	25	9.8±6.5(25)	69±68(300)	7±8.1(40)
Kidney (Type 3)	329	10±8.7(60)	66±84(1000)	9±8.3(40)
Cranberry (Type 4)	41	10±8.2(30)	47±36(160)	4.8±4.5(24)
Black (Type 5)	45	8.7±7.8(30)	45±37(150)	10.1±11.7(40)
Small Brown (Type 6)	42	10.2±9.6(35)	67±54(250)	6±8.9(40)
Kidney (Type 7)	14	9.1±6.8(26)	55±42(130)	8.5±10.2(40)
Cranberry (Type 8)	21	10.9±7.6(30)	68±75(330)	16.9±16.4(40)
Kidney (Type 9)	3	22.7±2.5(25)	71±26(100)	7±5.2(10)
Kidney (Type 10)	8	14.5±13.7(45)	90±93(300)	8±7.4(23)
Kidney (Type 11)	4	9.3±1.5(10)	61±37(115)	7.3±3.2(12)
Pinto Type 12)	4	12.8±5.3(17)	68±27(100)	5.5±4.4(12)
Kidney (Type 13)	2	12.5±6.4(17)	75±7(80)	6±4.2(9)
(Type 14)	2	7±4.2(10)	80±28(100)	3±0(3)
(Type 15)	57	6.4±4.7(22)	30±24(100)	11.8±13.9(40)

While 77% of households reported not growing enough beans for their needs, only 58% reported purchasing or receiving beans (see **Table 19**). Furthermore, while more than 50% ran out beans within a few months of harvest, households which purchased beans did so for only ~4 months. Combined this suggests that for many households they did not have (whether through growing, purchasing or receiving) sufficient beans to meet their needs. Almost all of the beans (95%) that were purchased or received were from the local market. A few came from friends, relatives, and a food security program.

Table 19. Household report on purchase or receipt of beans for own consumption. The responses to the two questions: "Has anyone in household purchased or received beans for own consumption since last season?" and "If beans purchased or received for consumption, for how many months in last farming season did you purchase or receive beans?"

	Purchased? Average (95% CI)	How many months? mean±SD (max)
Northern	56.7(48.2-65.2)	4.3±0.6(30)
Southern	59.6(50.2-69)	3.9±0.5(32)
Northern and Southern	58.1(51.4-64.7)	4.2±3.5(32)

The majority of households do no preparation to beans before cooking them (see **Table 20**). Given that cooking fuel is surely expensive for the households, and soaking beans can greatly reduce cooking time, it seems strange that only 16% of households report soaking beans prior to cooking.

Table 20. Bean preparation questions.

	Northern	Southern	Northern and Southern
Before cooking, do you process beans by:			
DEHULLING?	2.2 (0-4.4)	4.9 (1.5-8.3)	3.5 (1.5-5.4)
SOAKING?	12.2 (3.9-20.5)	20.6 (12.5-28.7)	16.2 (11.1-21.3)
GERMINATION?	0.5 (0-1.5)	0.8 (0-1.7)	0.6 (0-1.3)
FERMENTATION?	0 (0-0)	0.5 (0-1.2)	0.2 (0-0.6)
MILLING INTO FLOUR?	0.4 (0-1.3)	0.3 (0-0.8)	0.3 (0-0.9)
NO PROCESSING at all	89.4 (82.5-96.4)	76.9 (68.5-85.3)	83.5 (78.6-88.3)
Do you often cook:			
FRESH beans?	90.7 (85.2-96.1)	78.1 (70.1-86)	84.7 (79.5-89.9)
DRY beans?	96.9 (94.8-99.1)	95.2 (91.1-99.3)	96.1 (93.8-98.4)
the LEAVES of beans?	87 (80.6-93.3)	67 (59-75.1)	77.5 (72.6-82.4)
the PODS of beans?	75.3 (68.5-82.1)	60.4 (50.6-70.3)	68.3 (61.9-74.6)
the GRAIN of beans?	97.4 (95.7-99.1)	98 (96.7-99.3)	97.7 (96.5-98.9)
Do you often cook beans by			
BOILING?	82 (75.3-88.7)	63.3 (54.1-72.6)	73.2 (67.6-78.7)
BOILING AND FRYING?	80.1 (73.6-86.5)	77.9 (69.2-86.6)	79 (73.7-84.4)
Does everybody in your household eat beans?	96.4 (93.8-99)	99.1 (98-100)	97.7 (96.2-99.1)

Dietary Data

Dietary data quality check

The dietary data collection method that we employed [34] has been widely used and validated in a number of settings. While it is expected to perform well, all dietary recall methods are prone to various types of error and require careful checking. This study did not include a validation component, and so quality checks are limited to *post hoc* evaluation of the data. A series of checks were performed and the results presented below.

The number of meals per day in the dietary data can serve as a quick indicator of dietary quality. The "meals" in this sense are defined as "Morning" (daybreak-12.00pm), "Afternoon" (12.00-5.00 pm), "Evening" (5.00pm-Sunset), and "Night" (7pm-daybreak). While this lumps eating episodes together, so that, for example, a mid-morning snack is lumped with "breakfast", in practice, snacking is not common in these areas (with the exception of breastfeeding children) and for the most part, each "meal" is in fact a discrete meal. Around 80 to 90% of the population has two to three meals per day, as expected (see **Table 21**).

Table 21. The number of "meals" per person per observed day.

Province	Number of meals	Agegroup							
		0-1 yrs		>1-2 yrs		>2-5 yrs		> 15 yrs	
		n	%	n	%	n	%	n	%
Northern	1	2	9.5%	0	0.0%	3	1.3%	8	2.3%
	2	8	38.1%	16	29.1%	60	25.5%	127	36.1%
	3	9	42.9%	34	61.8%	158	67.2%	198	56.3%
	4	2	9.5%	5	9.1%	14	6.0%	19	5.4%
Southern	1	3	14.3%	4	7.3%	4	1.7%	12	3.4%
	2	5	23.8%	15	27.3%	57	24.3%	146	41.5%
	3	12	57.1%	31	56.4%	158	67.2%	152	43.2%
	4	0	0.0%	5	9.1%	10	4.3%	8	2.3%

We hypothesize that in most cases mothers will have the same as, or fewer, meals than the child, and this is indeed the case (see **Table 22**). In only 6% of the cases did the mother have more meals than the child. While there is no specific number of cases that would suggest the data are of poor quality, 6% seems within reason to the team.

Table 22. The number of meals eaten by mother-child pairs.

		N meals by mothers				
		1	**2**	**3**	**4**	**Total**
N meals by children 2 to 5 years	**1**	0.9	0.7	0.0	0.0	1.6
	2	1.6	20.1	3.7	0.2	25.6
	3	0.5	21.9	44.0	1.6	68.0
	4	0.0	0.7	3.2	0.9	4.8
	Total	3.0	43.3	50.9	2.8	100.0

When the n meals mother > n meals child the cell is shaded - a total of 6.2% of households.
The analyses were repeated for each of the 25 interviewers, and there were no interviewers who were markedly different from the average.

We also hypothesized that as the data collection progressed the quality of the data may change, as the interviewers gain proficiency, or, conversely, as they become fatigued. This could be reflected in the number of meals observed per subject over the course of the data collection. In **Figure 7** the average meals observed each day is plotted against the date. There are differences between days and a downward trend in the latter half of the study, but not so severe a trend as to suggest the data were of deteriorating quality. Similar analyses were done on "foods" per day (that is, the number of items in the 24-hour recall (**Figure 8**) and on energy intake per day (**Figure 9**).

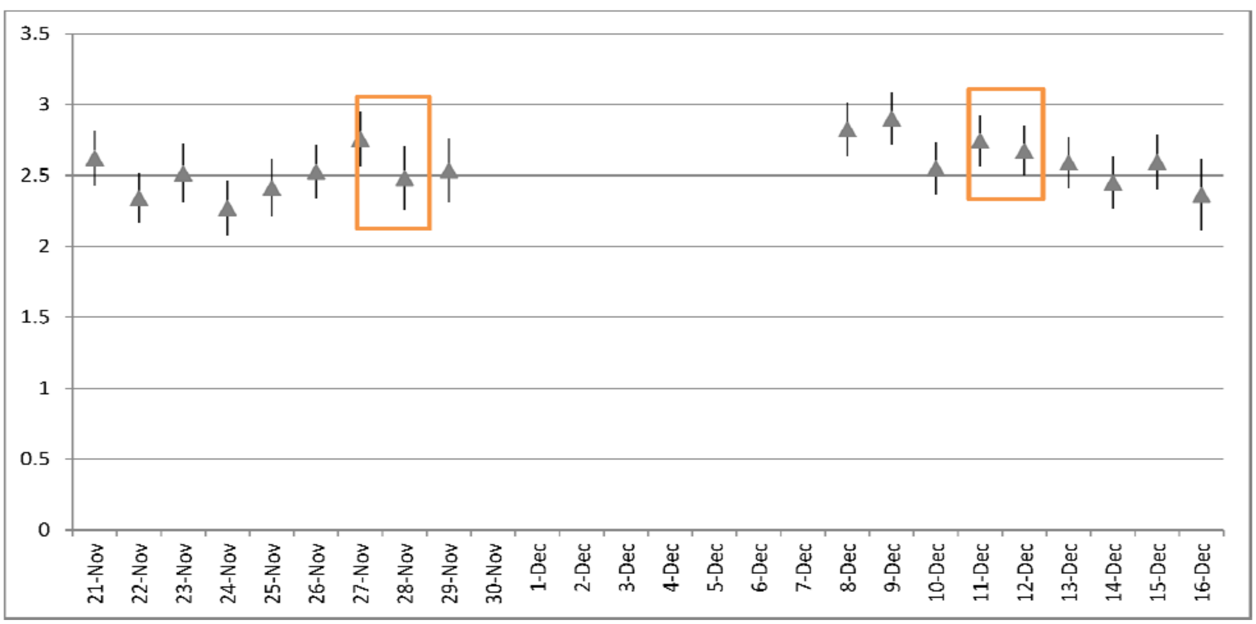


Figure 7. The number of meals (LS Means and 95% CI) observed each day during data collection in adult women. *The bars represent the 95% CI. The orange boxes are around Saturdays and Sundays. The Southern Province data were collected from 21 – 29 November and the Northern Province from 8 to 16 December.

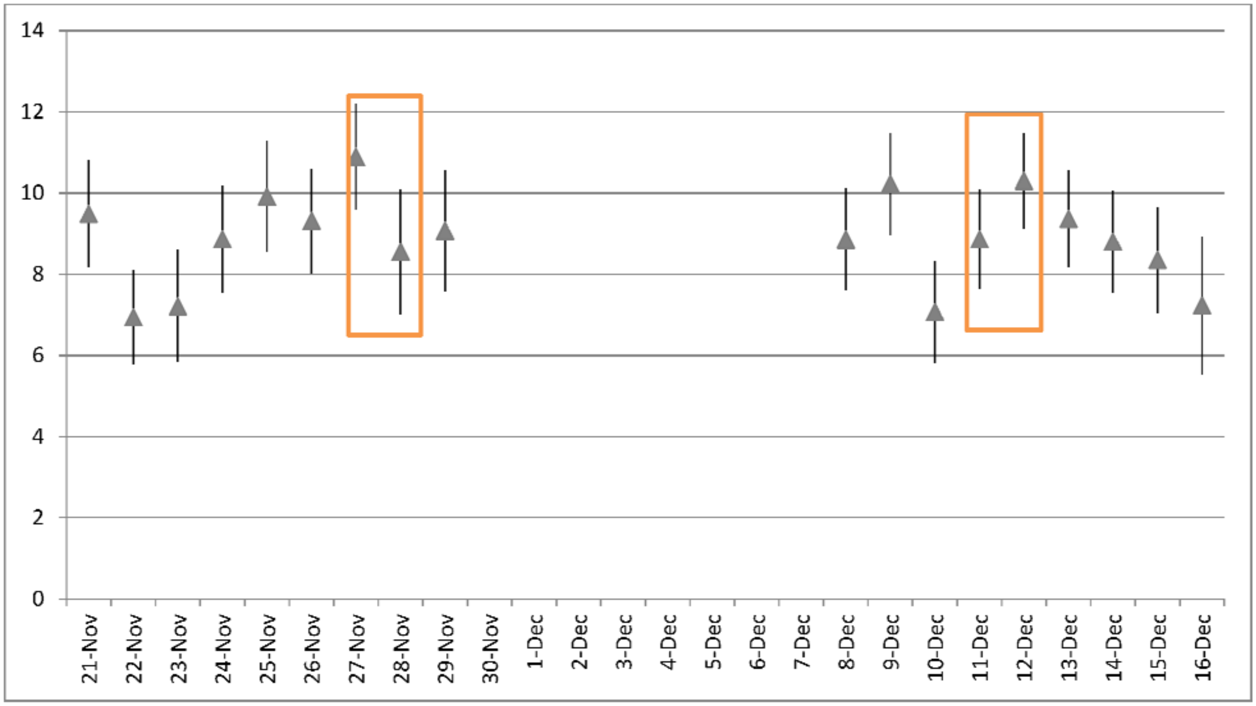


Figure 8. The number of foods (LS Means and 95% CI) reported in each adult women's dietary recall during data collection. *The bars represent the 95% CI. The orange boxes are around Saturdays and Sundays. The Southern Province data were collected from 21–29 November and the Northern Province from 8-16 December.

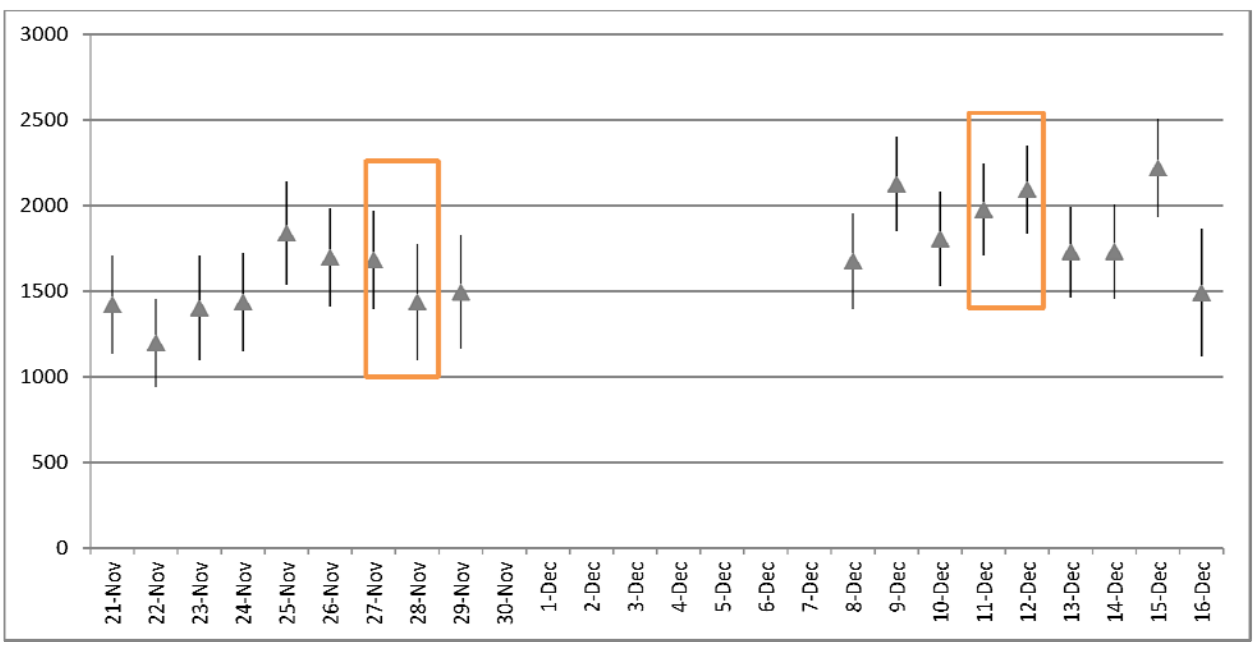


Figure 9. The energy intake ((LS Means and 95% CI, kcal) each day during data collection in adult women. *The bars represent the 95% CI. The orange boxes are around Saturdays and Sundays. The Southern Province data were collected from 21 – 29 November and the Northern Province from 8 to 16 December.

While there was a tendency to decreasing meals and number of foods, there was no similar tendency for energy intakes. Similar figures were created for number of foods per day each interviewer. No interviewers were found to have patterns that suggested they became fatigued or less careful as the survey progressed. As an additional check on the interviewers, the energy intakes of adult women as estimated with the data collected by each interviewer were calculated. There was variation between the means of each interviewer, as shown in **Figure 10**. While the two lowest are noticeably lower than the rest, they are not so low as to justify removing them from the data set. (1) They may well be accurately reporting what they observed; (2) removing them has only a small impact on the estimated intakes (it would increase the average in adult women by ~30 kcals); (3) removing them would disrupt the statistical representativeness and weighting of the sample.

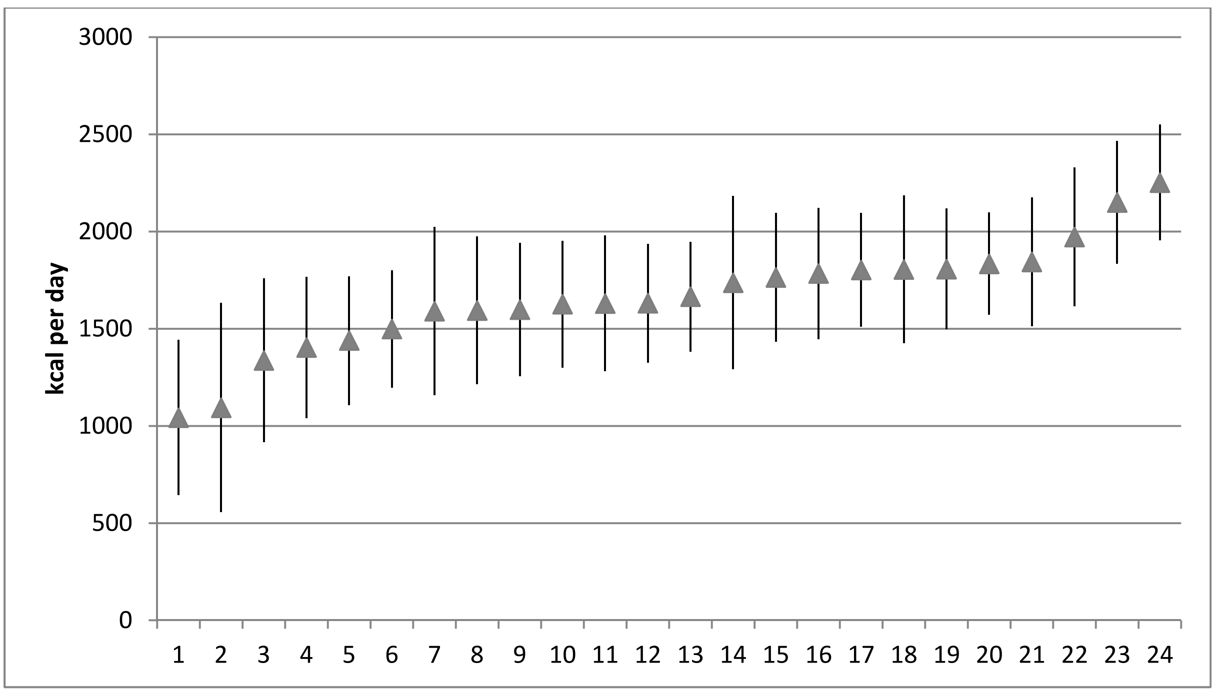


Figure 10. The energy intakes (LS means and 95% CI) in kcal as reported by each study interviewer, ordered from lowest to highest.

Nutrient Intakes

The average nutrient intakes of children and women are shown in **Tables 23 to 25.** These are calculated using PC-SIDE, as described in the methods. The means will be approximately equal to the means if simply calculated arithmetically. However, the SDs are from the estimated distribution of usual intakes, and are not expected to be the same as the SD calculated directly from the data without manipulation.

In the tables, "n individuals" refers to the number of individuals in each grouping and "n repeats" is the number of those individuals who had a second, repeat, day of data.

Table 23. Energy and nutrient intakes (mean±SD) in children 1 to <3 years of age.

	Northern Province	**Southern Province**	**Total**
n individuals	**132**	**148**	**280**
n repeats	**10**	**6**	**16**
Nutrient	**mean±SD**	**mean±SD**	**mean±SD**
Energy (kcal)	732 ± 324	670 ± 434	700 ± 370
Protein (g)	25.9 ± 12.3	20.7 ± 5.3	23.3 ± 10.8
Lipids (g)	12.5 ± 3.8	13.8 ± 14.5	12.9 ± 9.2
Carbohydrates (g)	135.5 ± 61.2	120.9 ± 61.1	128 ± 58.4
Iron (mg)	7.3 ± 3.5	5.5 ± 3.4	6.4 ± 3.4
Zinc (mg)	3.7 ± 1.7	3.1 ± 1.2	3.4 ± 1.4
Fiber (g)	22.9 ± 12.1	17.5 ± 10.7	20.1 ± 11.3

Table 24. Energy and nutrient intakes (mean±SD) in children 3 to 5 years of age.

	Northern Province	Southern Province	Total
n individuals	**161**	**140**	**301**
n repeats	**15**	**14**	**29**
Nutrient	**mean±SD**	**mean±SD**	**mean±SD**
Energy (kcal)	1169 ± 535	951.4 ± 482	1073 ± 492
Protein (g)	40.1 ± 17.6	32.4 ±	35.2 ± 14.4
Lipids (g)	17.7 ± 20.9	25.8 ± 17.4	21.0 ± 20.0
Carbohydrates (g)	220.8 ± 102.6	161.1 ± 76.7	193.7 ± 88.2
Iron (mg)	11.8 ± 6.2	7.8 ± 3.3	10.0 ± 5.0
Zinc (mg)	5.6 ± 2.1	4.6 ± 1.7	5.1 ± 1.9
Fiber (g)	35.7 ± 16.1	25.1 ± 11.8	31 ± 12.7

Table 25. Energy and nutrient intakes (mean±SD) in adult women.

	Northern Province	Southern Province	Total
n individuals	**355**	**322**	**677**
n repeats	**34**	**32**	**66**
Nutrient	**mean±SD**	**mean±SD**	**mean±SD**
Energy (kcal)	1884 ± 469	1493 ± 390	1705 ± 477
Protein (g)	63.6 ± 10.4	43.9 ± 19.3	54.7 ± 19.6
Lipids (g)	22.8 ± 17.8	26.3 ± 9.8	24.1 ± 14.3
Carbohydrates (g)	365.5 ± 96.0	277.9 ± 72.8	325.9 ± 97.3
Iron (mg)	19.5 ± 3.9	13.0 ± 6.1	16.5 ± 6.3
Zinc (mg)	9.5 ± 0.4	6.9 ± 2.3	8.2 ± 1.8
Fiber (g)	60.6 ± 9.9	43.6 ± 13.8	52.7 ± 15.5

The children's iron intakes were also analysed by child's sex (no important differences) and SES (the second lowest quintile had lower intakes than other quintiles). There were age dependent differences in intake as expected. Women's intakes did not differ appreciably with age (younger women vs older women) and similar to children, the 2nd lowest SES quintile had the lowest intakes. Intake by other factors is shown in **Table 26**. The most notable result is that children and women who were sick the previous day had lower intakes than those who did not.

Table 26. Usual iron intakes in children and women by demographic and individual characteristics (Northern and Southern Provinces combined), as determined using PC-SIDE. "na"indicates sample size was too small for PC-SIDE to calculate usual intakes.

	Children		Women	
	n ID, n repeats	**mean±SD**	**n obs, n repeats**	**mean±SD**
Breastfeeding				
Yes (Yesterday)	266, 22	6 ± 3.5		
No (Not Yesterday)	94, 5	9.1 ± 3.8		
No (Child Weaned)	260, 22	9.7 ± 6.1		
Stage of life of index woman				
Pregnant			75, 7	17.3 ± 11.5
Breastfeeding			410, 41	16.3 ± 4.1
Neither pregnant nor breastfeeding			216, 18	16.5 ± 9.5
Morbidity state of index child				
Sick yesterday	205, 19	6.7 ± 4.8	132, 14	14.7 ± 6.3
Not sick yesterday	420, 30	8.4 ± 4.4	545, 42	17.0 ± 6.0
Supplementation of index child				
Iron	9, 1	na	14, 2	na
Vitamin A	163, 15	8.7 ± 4.4	18, 2	na
Multi-micronutrient	11, 2	na	13, 4	na
Zinc	2, 0	na	0	na
Anti-malaria drug	75, 10	8.9 ± 6.4	65, 7	17.2 ± 10.5
Deworming medication	323, 25	8.4 ± 4.3	79, 9	19.4 ± 5.2
Mosquito net use by index child				
Yes	568, 44	8 ± 4.8	682, 65	16.5 ± 6.1
No	51, 4	6.5	61, 6	16.0 ± 12.4

Intake of foods, by food groups

A snapshot of the diet can be captured through summarizing each age group's diet according to the weight of foods consumed, classified into 14 distinct food groups. The results are shown in **Table 27a (women) ,b (boys) and c (girls)**. The means and standard deviation are shown both for consumers only, which gives an idea of the normal serving sizes when consumed, and for consumer + non-consumers (that is, counting non-consumers as 0), which estimates the population daily average intakes.

The proportion of individuals that consumed foods from each food group is shown in the "%" column. Most of the 24 hour recalls (>80%) had items from "beans, nuts, and seeds", "grains and grain products", and "roots and tubers". There were few consumers (<5%) of eggs or meat. Roots and tubers, and beans, nuts, and seeds form the majority of the diet by weight.

Table 27. Intake of food groups, for consumers only (the mean in grams ± SD) of only those who ate foods in the food group, and for consumers + non-consumers counting those who did not eat from the food group as 0. *% is the percent of the group who consumed foods from the group on the observed day. N, S and N+S refer to the Northern and Southern provinces, and the provinces combined.

a) Adult women

	%	CONSUMERS ONLY				CONSUMERS + NON		
Food Group		**N**	**S**	**N+S**		**N**	**S**	**N+S**
Unclassified	1.1%	74 ± 12	42 ± 3	58 ± 10		1 ± 2	0 ± 1	0 ± 1
BEANS, NUTS, AND SEEDS	93.2%	360 ± 51	246 ± 34	309 ± 45		331 ± 52	209 ± 35	274 ± 46
BEVERAGES	12.2%	633 ± 58	666 ± 45	642 ± 55		77 ± 41	33 ± 26	57 ± 35
BIOFORTIFIED CROP	11.4%	535 ± 76	436 ± 52	499 ± 69		62 ± 39	32 ± 23	48 ± 32
EGGS	1.1%	93 ± 11	64 ± 0	85 ± 9		1 ± 2	0 ± 1	0 ± 1
FATS AND OILS	53.4%	16 ± 2	17 ± 2	16 ± 2		7 ± 2	9 ± 2	8 ± 2
FISH AND SEAFOODS	9.1%	20 ± 4	14 ± 3	16 ± 3		2 ± 2	3 ± 2	2 ± 2
FRUITS AND JUICES	18.2%	455 ± 55	578 ± 273	513 ± 186		72 ± 36	91 ± 115	81 ± 83
GRAINS, GRAIN PRODUCTS	59.1%	139 ± 30	127 ± 28	134 ± 29		78 ± 26	69 ± 23	74 ± 25
MEATS, POULTRY, INSECTS	1.7%	123 ± 17	113 ± 14	119 ± 15		2 ± 3	1 ± 3	2 ± 3
MILK AND DAIRY	6.3%	413 ± 36	474 ± 33	442 ± 34		22 ± 18	26 ± 19	23 ± 19
ROOTS AND TUBERS	91.2%	783 ± 86	535 ± 66	670 ± 80		712 ± 91	469 ± 69	599 ± 83
SUGARS AND SWEETS	7.4%	42 ± 7	29 ± 6	38 ± 6		3 ± 3	1 ± 1	2 ± 2
VEGETABLES	84.1%	141 ± 31	154 ± 28	147 ± 30		114 ± 30	130 ± 27	121 ± 29

b) Boys	%	CONSUMERS ONLY				CONSUMERS + NON		
Food Group		**N**	**S**	**N+S**		**N**	**S**	**N+S**
	Boys 0 -1							
BEANS, NUTS, AND SEEDS	60.0%	91 ± 14	51 ± 9	69 ± 11		52 ± 13	44 ± 9	48 ± 11
BEVERAGES	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
BIOFORTIFIED CROP	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
EGGS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
FATS AND OILS	20.0%	1 ± 0	4 ± 0	3 ± 0		0 ± 0	2 ± 0	1 ± 0
FISH AND SEAFOODS	0.0%	0 ± 0	9 ± 0	9 ± 0		0 ± 0	1 ± 0	0 ± 0
FRUITS AND JUICES	30.0%	81 ± 16	48 ± 5	65 ± 12		22 ± 10	16 ± 5	19 ± 8
GRAINS, GRAIN PRODUCTS	90.0%	34 ± 5	91 ± 18	60 ± 13		30 ± 5	85 ± 17	54 ± 13
MEATS, POULTRY, INSECTS	0.0%	0 ± 0	15 ± 0	15 ± 0		0 ± 0	3 ± 1	1 ± 1
MILK AND DAIRY	0.0%	0 ± 0	113 ± 0	113 ± 0		0 ± 0	8 ± 5	4 ± 4
ROOTS AND TUBERS	80.0%	186 ± 20	40 ± 4	156 ± 21		149 ± 22	11 ± 4	89 ± 20
SUGARS AND SWEETS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
VEGETABLES	60.0%	86 ± 25	46 ± 10	63 ± 18		42 ± 20	40 ± 9	41 ± 16
		Boys >1-2						
BEANS, NUTS, AND SEEDS	100.0%	120 ± 10	118 ± 23	119 ± 18		120 ± 10	94 ± 22	105 ±
BEVERAGES	8.0%	116 ± 2	19 ± 0	93 ± 8		10 ± 5	0 ± 0	5 ± 4
BIOFORTIFIED CROP	12.0%	265 ± 25	213 ± 1	241 ± 19		30 ± 16	15 ± 9	21 ± 12
EGGS	8.0%	50 ± 0	0 ± 0	50 ± 0		4 ± 2	0 ± 0	2 ± 1
FATS AND OILS	68.0%	6 ± 1	8 ± 1	7 ± 1		4 ± 1	4 ± 1	4 ± 1
FISH AND SEAFOODS	8.0%	3 ± 0	5 ± 0	4 ± 0		0 ± 0	1 ± 0	1 ± 0
FRUITS AND JUICES	44.0%	226 ± 45	151 ± 14	195 ± 36		92 ± 34	31 ± 12	57 ± 25
GRAINS, GRAIN PRODUCTS	68.0%	55 ± 13	42 ± 13	47 ± 13		34 ± 11	28 ± 11	30 ± 11
MEATS, POULTRY, INSECTS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
MILK AND DAIRY	16.0%	202 ± 17	319 ± 40	253 ± 30		38 ± 14	32 ± 21	35 ± 18
ROOTS AND TUBERS	84.0%	163 ± 24	168 ± 24	166 ± 24		135 ±24	139 ±	137 ±
SUGARS AND SWEETS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
VEGETABLES	88.0%	49 ± 11	54 ± 12	52 ± 11		43 ± 10	48 ± 11	46 ± 11
		Boys >2-6						
BEANS, NUTS, AND SEEDS	92.8%	187 ± 23	135 ± 19	163 ± 22		170 ± 24	115 ±	145 ±
BEVERAGES	0.0%	0 ± 0	203 ± 10	203 ± 10		0 ± 0	7 ± 6	3 ± 4
BIOFORTIFIED CROP	10.8%	166 ± 21	112 ± 10	149 ± 18		18 ± 11	6 ± 5	12 ± 8
EGGS	1.8%	41 ± 2	21 ± 0	29 ± 2		0 ± 1	0 ± 0	0 ± 1
FATS AND OILS	45.9%	9 ± 1	9 ± 1	9 ± 1		3 ± 1	6 ± 1	4 ± 1
FISH AND SEAFOODS	9.0%	16 ± 3	11 ± 4	12 ± 3		1 ± 1	3 ± 2	2 ± 2
FRUITS AND JUICES	23.4%	238 ± 41	168 ± 21	205 ± 33		50 ± 26	37 ± 15	44 ± 21
GRAINS, GRAIN PRODUCTS	54.1%	82 ± 19	72 ± 15	77 ± 17		40 ± 16	45 ± 13	42 ± 14
MEATS, POULTRY, INSECTS	0.0%	0 ± 0	33 ± 0	33 ± 0		0 ± 0	0 ± 1	0 ± 0
MILK AND DAIRY	9.0%	292 ± 35	394 ± 45	344 ± 40		24 ± 17	38 ± 23	30 ± 20
ROOTS AND TUBERS	91.0%	441 ± 62	294 ± 40	374 ± 54		394 ± 64	250 ±	327 ±
SUGARS AND SWEETS	5.4%	17 ± 2	28 ± 3	22 ± 2		1 ± 1	1 ± 1	1 ± 1
VEGETABLES	83.8%	77 ± 16	113 ± 27	94 ± 22		63 ± 15	98 ± 26	80 ± 21

c) Girls		CONSUMERS ONLY				CONSUMERS + NON		
Food Group	**%**	**N**	**S**	**N+S**		**N**	**S**	**N+S**
		Girls 0-1						
BEANS, NUTS, AND SEEDS	72.7%	48 ± 7	73 ± 16	60 ± 12		35 ± 7	48 ± 14	41 ± 11
BEVERAGES	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
BIOFORTIFIED CROP	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
EGGS	0.0%	0 ± 0	50 ± 0	50 ± 0		0 ± 0	4 ± 2	2 ± 2
FATS AND OILS	45.5%	3 ± 1	4 ± 0	4 ± 0		2 ± 0	2 ± 0	2 ± 0
FISH AND SEAFOODS	27.3%	50 ± 13	1 ± 0	30 ± 10		11 ± 7	0 ± 0	6 ± 5
FRUITS AND JUICES	9.1%	71 ± 0	62 ± 15	63 ± 13		5 ± 3	27 ± 10	16 ± 8
GRAINS, GRAIN PRODUCTS	54.5%	22 ± 2	29 ± 7	25 ± 5		13 ± 2	19 ± 6	16 ± 5
MEATS, POULTRY, INSECTS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
MILK AND DAIRY	0.0%	0 ± 0	202 ± 7	202 ± 7		0 ± 0	33 ± 13	17 ± 9
ROOTS AND TUBERS	81.8%	253 ± 76	159 ±	219 ±		203 ± 70	76 ± 21	140 ±
SUGARS AND SWEETS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
VEGETABLES	81.8%	102 ± 17	61 ± 11	86 ± 15		84 ± 17	33 ± 10	58 ± 14
		Girls >1 -2						
BEANS, NUTS, AND SEEDS	93.3%	122 ± 15	172 ±	142 ±		108 ± 16	122 ±	114 ±
BEVERAGES	3.3%	323 ± 0	0 ± 0	323 ± 0		8 ± 8	0 ± 0	5 ± 6
BIOFORTIFIED CROP	6.7%	111 ± 13	72 ± 0	92 ± 10		7 ± 5	5 ± 3	6 ± 4
EGGS	3.3%	101 ± 0	0 ± 0	101 ± 0		2 ± 2	0 ± 0	1 ± 2
FATS AND OILS	63.3%	4 ± 1	8 ± 1	6 ± 1		3 ± 1	4 ± 1	3 ± 1
FISH AND SEAFOODS	26.7%	9 ± 2	6 ± 1	8 ± 1		2 ± 1	2 ± 1	2 ± 1
FRUITS AND JUICES	33.3%	218 ± 56	113 ± 9	168 ±		65 ± 35	38 ± 10	53 ± 27
GRAINS, GRAIN PRODUCTS	70.0%	58 ± 7	73 ± 15	65 ± 11		39 ± 7	46 ± 13	42 ± 10
MEATS, POULTRY, INSECTS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
MILK AND DAIRY	23.3%	319 ± 29	186 ± 9	252 ±		71 ± 25	52 ± 14	62 ± 21
ROOTS AND TUBERS	76.7%	183 ± 29	175 ±	180 ±		143 ± 28	122 ±	133 ±
SUGARS AND SWEETS	16.7%	11 ± 1	30 ± 4	17 ± 2		2 ± 1	3 ± 2	2 ± 1
VEGETABLES	86.7%	60 ± 12	74 ± 11	66 ± 12		52 ± 12	60 ± 11	56 ± 11
		Girls >2-6						
BEANS, NUTS, AND SEEDS	95.2%	185 ± 25	129 ±	159 ±		177 ± 26	112 ±	145 ±
BEVERAGES	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
BIOFORTIFIED CROP	8.1%	268 ± 18	283 ±	272 ±		27 ± 15	9 ± 11	18 ± 13
EGGS	0.0%	0 ± 0	0 ± 0	0 ± 0		0 ± 0	0 ± 0	0 ± 0
FATS AND OILS	54.0%	8 ± 1	9 ± 2	9 ± 2		4 ± 1	5 ± 2	4 ± 1
FISH AND SEAFOODS	11.3%	15 ± 3	12 ± 3	13 ± 3		2 ± 1	1 ± 1	1 ± 1
FRUITS AND JUICES	14.5%	202 ± 32	318 ±	277 ±		27 ± 17	81 ± 41	53 ± 32
GRAINS, GRAIN PRODUCTS	55.6%	122 ± 54	62 ± 12	90 ± 37		67 ± 41	39 ± 11	53 ± 30
MEATS, POULTRY, INSECTS	2.4%	128 ± 25	0 ± 0	128 ±		4 ± 5	0 ± 0	2 ± 3
MILK AND DAIRY	8.1%	342 ± 28	295 ±	309 ±		19 ± 15	39 ± 19	29 ± 17
ROOTS AND TUBERS	91.9%	409 ± 47	222 ±	322 ±		375 ± 49	186 ±	282 ±
SUGARS AND SWEETS	7.3%	10 ± 1	9 ± 1	10 ± 1		1 ± 0	0 ± 0	0 ± 0
VEGETABLES	81.5%	81 ± 20	76 ± 16	79 ± 18		64 ± 19	59 ± 15	62 ± 17

The contribution of beans to the diet is of particular interest and the amount of each type of bean consumed is shown in **Table 28.** Beans are an important source of energy, iron and zinc (see **Table 29**). There are small differences between the provinces, and kidney beans are by far the most important bean in both provinces.

Table 28. Bean consumption by province and agegroup, expressed as "dry bean equivalents". (If recall weight data were for fresh or boiled beans, it was converted to dry weight). "%" represents the proportion of the group that consumed beans. Figures are means ± SD. Consumers and non-consumers as defined previously.

	Northern Province			Southern Province			Northern + Southern Province		
	%	mean±SD, Consumers only	mean±SD, Consumers + Non	%	mean±SD, Consumers only	mean±SD, Consumers + Non	%	mean±SD, Consumers only	mean±SD, Consumers + Non
	WOMEN								
n		352			318			670	
Black	3%	255.8 ± 23.8	7.4 ± 8.3	1%	64.2 ± 4.7	0.9 ± 1.3	2%	200.8 ± 25.1	4.4 ± 6.1
Cranberry	5%	143.8 ± 12.9	5.1 ± 5.2	2%	46.8 ± 4	1 ± 1.3	3%	109.2 ± 13.1	3.2 ± 3.9
Kidney	77%	167.2 ± 27.2	128.1 ± 26.7	77%	120.2 ± 19.6	92.3 ± 19.3	77%	145.4 ± 24.2	111.4 ± 23.6
Pinto	2%	98.4 ± 11.1	2.3 ± 3	0%	105.8 ± 0	0.4 ± 1	1%	99.2 ± 10.4	1.4 ± 2.3
Sm. Brown	5%	140.3 ± 13.3	7.1 ± 6	0%	0 ± 0	0 ± 0	3%	140.3 ± 13.3	3.8 ± 4.4
TOTAL	89%	170.2 ± 26.2	147.4 ± 149	80%	118.6 ± 19.4	95.2 ± 120.6	85%	147.4 ± 23.8	122.6 ± 138.6
	> 1 to 2 Years								
n		55			55			110	
Black	4%	47.6 ± 6.2	1.9 ± 1.7	0%	0 ± 0	0 ± 0	2%	47.6 ± 6.2	0.9 ± 1.2
Cranberry	4%	28.6 ± 5.1	0.9 ± 1.1	0%	0 ± 0	0 ± 0	2%	28.6 ± 5.1	0.4 ± 0.7
Kidney	82%	59.7 ± 7.5	48.1 ± 7.8	67%	67.3 ± 12	46.2 ± 11.1	75%	63.3 ± 9.8	47.1 ± 9.6
Pinto	2%	11.6 ± 0	0.3 ± 0.3	0%	0 ± 0	0 ± 0	1%	11.6 ± 0	0.1 ± 0.2
Sm. Brown	4%	72.1 ± 0.2	2.6 ± 2.2	0%	0 ± 0	0 ± 0	2%	72.1 ± 0.2	1.3 ± 1.6
TOTAL	93%	58.9 ± 7.2	54.3 ± 45.8	67%	67.3 ± 12	39.3 ± 60.5		76.6 ± 13.9	46.8 ± 53.9
	>2 - 5 Years								
n		235			229			464	
Black	3%	97.6 ± 8.5	3 ± 3.2	1%	42.2 ± 3.4	0.6 ± 0.9	2%	81.7 ± 8.4	1.8 ± 2.4
Cranberry	4%	56.8 ± 6	1.8 ± 2.1	1%	33.2 ± 2.4	0.4 ± 0.6	3%	51.3 ± 5.5	1.1 ± 1.5
Kidney	78%	90.2 ± 17.4	70.9 ± 16.6	80%	62 ± 10	49.4 ± 9.9	79%	76.6 ± 14.4	60.6 ± 13.8
Pinto	3%	42.3 ± 7	1.1 ± 1.5	0%	0 ± 0	0 ± 0	1%	42.3 ± 7	0.6 ± 1.1
Sm. Brown	5%	78.7 ± 10.9	4.1 ± 3.8	0%	0 ± 0	0 ± 0	3%	78.7 ± 10.9	2.1 ± 2.7
TOTAL	91%	89.1 ± 16.4	77.4 ± 87.9	82%	61.5 ± 9.9	51.6 ± 61.8	87%	76.6 ± 13.9	64.7 ± 77.2

Table 29. The contribution of beans to the energy, iron and zinc intake. The figures represent the percentage of the total provided by the stated bean variety.

	Northern			Southern			Northern and Southern		
	energy	**iron**	**zinc**	**energy**	**iron**	**zinc**	**energy**	**iron**	**zinc**
Age 0 to 1 years		**n=21**			**n=20**			**n=41**	
Black Beans	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cranberry Beans	0%	0%	0%	1%	5%	0%	0%	3%	0%
Kidney	12%	21%	18%	11%	24%	19%	12%	22%	18%
Pinto	0%	0%	0%	0%	0%	0%	0%	0%	0%
Small Brown	1%	3%	2%	0%	0%	0%	1%	2%	1%
All Beans	13%	24%	20%	12%	29%	19%	13%	27%	20%
Age 1 to 2 years		**n=55**			**n=55**			**n=110**	
Black Beans	2%	2%	2%	0%	0%	0%	1%	1%	1%
Cranberry Beans	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kidney	24%	43%	36%	20%	36%	28%	22%	40%	32%
Pinto	0%	0%	0%	0%	0%	0%	0%	0%	0%
Small Brown	1%	2%	2%	0%	0%	0%	1%	1%	1%
All Beans	28%	48%	41%	20%	36%	28%	23%	42%	34%
Age 2 to 5 years		**n=235**			**n=229**			**n=464**	
Black Beans	1%	2%	2%	0%	1%	1%	1%	1%	1%
Cranberry Beans	0%	1%	1%	0%	0%	0%	0%	1%	1%
Kidney	22%	37%	32%	20%	38%	30%	21%	37%	31%
Pinto	1%	1%	1%	0%	0%	0%	0%	0%	0%
Small Brown	1%	2%	2%	0%	0%	0%	1%	1%	1%
All Beans	25%	42%	37%	20%	38%	31%	23%	40%	34%
Adult women		**n=355**			**n=322**			**n=677**	
Black Beans	1%	2%	2%	0%	0%	0%	1%	1%	1%
Cranberry Beans	0%	1%	1%	0%	1%	1%	0%	1%	1%
Kidney	21%	35%	32%	19%	36%	30%	20%	36%	31%
Pinto	0%	1%	1%	0%	0%	0%	0%	0%	0%
Small Brown	1%	2%	2%	0%	0%	0%	1%	1%	1%
All Beans	24%	40%	37%	19%	37%	30%	22%	39%	34%

Dietary Adequacy

The adequacy of the diet was assessed for iron and zinc (see **Table 30**, see Appendix 2 for iron and zinc requirements). The levels of inadequacy for iron are very high with over 80% of children and 90% of women with inadequate intakes. Zinc inadequacy is very high in young children and pregnant and breastfeeding women, and moderately high in older children and non-pregnant, non breastfeeding women.

Table 30. The prevalence of iron and zinc dietary inadequacy.

	Northern			**Southern**			**North+South**		
Children	**n, R**	**Iron**	**Zinc**	**n, R**	**Iron**	**Zinc**	**n, R**	**Iron**	**Zinc**
< 1yr	22, 3	96.0[1]	86.7	22, 1	98.3	92.3	44, 4	97.2[2]	92.0
1-<3 yr	132, 12	74.1	14.0	148, 6	87.6	14.7	280, 18	82.2	15.0
3-5 yr	161, 15	46.0	22.5	140, 14	79.8	40	301. 29	59.6	30.7
Women									
Pregnant	40, 3	Na	79.9	35, 4	na	84.2	75, 7	na	82.2
Breastfeeding	201, 21	75.4[3]	57.3[4]	209, 20	96.4	91.7	410, 41	92.2	86.7[5]
NPNL	116, 10	88.8	32.6	82, 8	94.4	57.6	198, 18	90.9	42.4

*n represents the number of individuals in the group, and R is the number of individuals for whom there were repeat observations.
**the Iron and Zinc columns represent the proportion of the group with estimated usual intakes less than the EAR.
***NPNL - non-pregnant, non-lactating women
[1,2] These figures are calculated using the dietary data from the 1 to <3 yr group, and the EAR for <1 yr. This was done because the <1 yr data would not solve in PC-SIDE. If done using the <1 yr data it would likely be close to 100% inadequacy.
[3,4] Model would not solve for breastfeeding women, despite trimming extreme variables, all possible parameter variations and using NPNL variance components). Thus these estimates were generated using NPNL data and the BF cut off.
[5] NPNL variance components were used to calculate for this group.

Biochemical indicators of iron status

The following section presents the results of analyses of biochemical indicators of iron status and anaemia, first for children and then for women. As stated in the methods, adjustment for inflammation was done where recommended (see Table 40 for a summary of inflammation status for children and women included in the following analysis).

Children

Anaemia

Results for child anaemia prevalence are reported in **Table 31**. Among children 6-59 mo (N=577), the overall prevalence of anaemia (Hb<110 g/L) was 30.9% with the majority being mild anaemia (Hb 100-109 g/L), and only 0.5% having severe anaemia (Hb<70 g/L). Mean Hb was 114.6 g/L (SD 12.5; 95% CI 113.3, 115.9). Children from the Southern Province were more likely to have moderate or severe anaemia and the mean Hb level of children in the Northern Province was higher than that of children living in the Southern Province (difference in mean 4.3 g/L; 95% CI 1.7, 6.8; p=0.001).

Table 31: Prevalence of anaemia among children under five†

Characteristic	**Anaemia severity**			**Total anaemia (Hb<110)**	**Sample size**
	Mild Hb 100-109	**Moderate Hb 70-99**	**Severe Hb <70**		
Age group, months					
6-8	48.0	23.9	-	71.9	16
9-11	31.2	10.1	-	41.3	17
12-17	37.8	10.5	-	48.3	51
18-23	31.7	12.5	-	44.2	55
24-35	19.1	8.1	-	27.3	157
36-47	19.4	6.3	1.1	26.9	151
48-59	14.6	5.0	0.8	20.4	130
Province					
Northern	22.0 (16.8, 27.1)	4.5 (1.3, 7.7)	0	26.5 (20.2, 32.8)	354
Southern	22.7 (16.1, 29.2)	12.1 (8.2, 16.1)	1.0 (-0.1, 2.1)	35.8 (28.8, 42.8)	318
HH wealth quintile					
Most poor	20.7	5.3	0.5	26.6	151
Second	25.0	6.6	0	31.6	119
Middle	22.2	12.6	0.9	35.7	124
Fourth	21.2	9.7	0	30.9	78
Least poor	22.5	7.4	0.8	30.7	105
Overall	**22.3 (18.2, 26.4)**	**8.1 (5.6, 10.6)**	**0.5 (-0.05, 1.0)**	**30.9 (26.2, 35.6)**	**577**

† Prevalence is adjusted for altitude using CDC formulas [36].

Iron Deficiency

Results for mean serum ferritin and serum transferrin receptor concentrations in children by province and overall are presented in **Table 32**.

Table 32. Mean serum ferritin and transferrin receptor concentrations in children by province and overall

Indicator	Northern Province		Southern Province		Total	
	N	mean ± SD (95% CI)	N	mean ± SD (95% CI)	N	mean ± SD (95% CI)
SF, µg/L	290	43.38 ± 1.89 (38.87, 48.41)	287	35.18 ± 2.22 (31.51, 39.29)	577	39.29 ± 2.06 (36.37, 42.45)
excluding cases with inflammation	209	46.89 ± 1.87 (41.78, 52.61)	200	33.22 ± 2.05 (29.02, 38.02)	409	39.94 ± 1.99 (36.55, 43.63)
TfR, µg/mL (cutoff >8.3)*	290	4.31 ± 1.52 (3.94, 4.68)	287	4.26 ± 2.29 (3.98, 4.53)	577	4.28 ± 1.91 (4.05, 4.52)

* Geometric mean based on log-transformed values that were corrected for inflammation status [39].

Table 33 presents results comparing the prevalence of iron deficiency using different thresholds for serum ferritin and transferrin receptor levels. The lowest estimated prevalence of iron deficiency using serum ferritin data (5.7% overall) is obtained when excluding all children with inflammation (high CRP or high AGP or both) and using the standard cutoff of <12 µg/L. The highest prevalence of iron deficiency (25.2% overall) is obtained when using a cutoff for serum ferritin of <30 µg/L for all children.

No matter what definition is used, there is a tendency for a higher proportion of children to be deficient in the Southern Province compared to the Northern Province, although the confidence intervals slightly overlap for all except the higher cutoff for serum ferritin (<30 µg/L).

Table 33: Proportion of children below serum ferritin thresholds or above serum transferrin receptor thresholds by province and overall.

Indicator	Northern Province		Southern Province		Total	
	N	% below cut-off (95% CI)	N	% below cut-off (95% CI)	N	% below cut-off (95% CI)
Low SF (<12 µg/L, all children)[1]	290	3.1% (1.1, 5.1)	287	8.9% (5.0, 12.9)	577	5.9% (3.7, 8.0)
Low SF (<12 µg/L, *inflammation cases excluded*)	209	3.2% (0.7, 5.7)	200	8.7% (4.0, 13.3)	409	5.7% (3.2, 8.3)
Low SF (<12 µg/L if no inflammation; <30 µg/L if inflammation present)[2]	290	6.6% (3.6, 9.7)	287	11.2% (6.7, 15.7)	577	8.8% (6.1, 11.5)
Low SF (<30 µg/L)	290	17.6% (12.2, 23.1)	287	33.7% (27.7, 39.7)	577	25.2% (21.2, 29.3)
High TfR, (>8.3 µg/mL)[3]	290	2.9% (0.3, 5.4)	287	3.3% (1.4, 5.2)	577	3.1% (1.5, 4.7)

[1] Based on values that were corrected for inflammation status[39]; cut-off used is 12 ug/L (WHO 2001)[10]
[2] Cut-off of 30 µg/L recommended when inflammation is present [42]
[3] Cut-off used is 8.3 based on equivalency to Ramco assay (Ehrhardt, personal communication)

Guidelines on the interpretation of serum ferritin and transferrin receptor concentrations in population surveys suggest that if the proportion of serum ferritin values below threshold is <20% and the proportion with transferrin receptor values above threshold is <10%, then iron deficiency is not prevalent [42]. In this population, the prevalence of low serum ferritin values was <20% for three of the four methods. Using the standard classification of iron deficiency as low serum ferritin (< 12 µg/L) and/or high serum transferrin receptor (> 8.3 µg/mL) concentrations, 7.5% (95% CI 5.1, 10.0) of children overall met these criteria, as shown in **Table 34**.

Iron deficiency was more common among children in the Southern Province. When adjusted for age, a child from the Southern Province was over 2.5 times more likely to be iron deficient compared to a child from the Northern Province (OR 2.55; 95% CI 1.15, 5.67).

Table 34: Summary of iron deficiency (using WHO 2001 cutoffs) with and without anaemia for children.

Indicator	**Northern Province**		**Southern Province**		**Total**	
	N	**% (n) [95% CI]**[1]	**N**	**% (n) [95% CI]**	**N**	**% (n) [95% CI]**
Children						
Iron deficiency (SF<12 or TfR>8.3)	290	4.4 (12) [1.6, 7.1]	287	11.1 (31) [7.0, 15.1]	577	7.5 (43) [5.1, 10.0]
Iron deficiency with anaemia	290	2.2 (6) [0.5, 3.9]	287	7.6 (23) [3.9, 11.3]	577	4.8 (29) [2.8, 6.8]
Iron deficiency without anemia	290	2.0 (6) [0.3, 3.8]	287	2.7 (8) [0.8, 4.6]	577	2.3 (14) [1.1, 3.6]
Anaemia with no iron deficiency	290	25.2 [19.0, 31.5]	287	30.9 [23.9, 37.8]	577	27.8 [53.7, 84.1]

[1] All 95% CI estimated using svy command in Stata to take the cluster design into account.

Women

Anaemia

Based on DHS 07-08 results, the prevalence of anaemia among women of reproductive age in Rwanda was 27.1%. Anaemia results for women surveyed in our study are presented in **Table 35.** Overall, 11.5% of women had low Hb levels (<110 if pregnant; <120 if not pregnant). Mean Hb was 124.8 g/L (SD 15.6) for pregnant women (N=76) and 134.4 g/L (SD 13.7) for non-pregnant women (N=595).

Women living in the Southern province were nearly two times more likely to be anaemic compared to those living in the Northern province (OR 1.95; 95% CI 1.05, 3.62; p=0.03). This is in contrast to the DHS results where anaemia prevalence was higher among women from the North Province (30.1%) compared to the South Province (18.8%).

Table 35: Prevalence of anaemia in women†

Characteristic	Anaemia severity			Total anaemia	Sample size
	Mild	Moderate	Severe		
Age group, months					
15-19	0	0	0	0	8
20-29	10.4	1.3	1.0	12.7	292
30-39	7.1	1.3	2.7	8.6	282
40-49	11.1	6.4	0	17.5	90
Current status					
Non-pregnant	9.1	1.5	0.6	11.2	595
Pregnant	8.1	6.3	0	14.5	76
Unknown	0	0	0	0	1
Province					
Northern	7.3 (3.9, 10.8)	0.9 (-0.1, 1.9)	0.3 (-0.3, 0.8)	8.5 (4.8, 12.2)	354
Southern	11.0 (6.6, 15.5)	3.4 (1.5, 5.3)	0.9 (-0.1, 1.9)	15.3 (10.2, 20.4)	318
HH wealth quintile					
Most poor	2.8	1.0	1.0	4.8	168
Second	16.0	1.4	0.8	18.2	133
Middle	5.7	2.1	0	7.7	135
Fourth	10.8	3.3	0.9	15.0	105
Least poor	11.6	2.7	0	14.4	131
Overall	**9.0 (6.2, 11.7)**	**2.0 (1.0, 3.0)**	**0.5 (0.01, 1.1)**	**11.5 (8.5, 14.6)**	**672**

† Prevalence is adjusted for altitude using CDC formulas[36]. Women with Hb <70 g/L have severe anaemia, women with Hb 70-99 g/L have moderate anaemia and pregnant women with Hb 100-109 and non-pregnant women with Hb 100-119 have mild anaemia.

The risk of anaemia in women was associated with province of residence, household wealth quintile, deworming status and ITN use, as shown in **Table 36**. In most cases, the direction of association was counter-intuitive. Women in the poorest households were at the lowest risk of anaemia. Women who reported having taken deworming pills in the last 6 months or having slept under an ITN the previous night were at higher risk of anaemia compared to women who had not.

Table 36: Risk factors for anaemia in women†
(Based on univariate and multiple logistic regression models)

Characteristic	Prevalence	Crude OR	95% CI	Adjusted OR	95% CI
Province Southern (Ref=Northern)	44.6	**1.95***	1.05, 3.62	**2.40***	1.33, 4.36
Age group 30-49 y (Ref=15-29 y)	55.5	0.87	0.55, 1.36	–	
Wealth quintile (Ref=1 poorest)	24.7				
2	19.3	**4.45***	1.66, 11.94	**4.23***	1.57, 11.41
3 middle	19.5	1.68	0.64, 4.39	1.64	0.62, 4.34
4	16.2	**3.53***	1.48, 8.42	**3.83***	1.62, 9.04
5 least poor	20.3	**3.35***	1.33, 8.49	**3.45***	1.35, 8.84
Sick (fever, diarrhea or cough)	19.3	1.30	0.75, 2.22	–	
Iron supplement in last 6 m	2.0	1.16	0.27, 5.02	–	
VAC in last 6 m	2.6	0.99	0.21, 4.58	–	
Antimalarial taken in last 6 m	9.4	1.24	0.58, 2.64	–	
Deworming pills taken in last 6 m	11.9	**2.01***	1.06, 3.82	**2.62***	1.29, 5.29
Slept under ITN last night	91.1	**2.01***	1.02, 3.96	**2.17***	1.12, 4.19

† Based on logistic regression model; final model svy: logistic anaemia_cdc province i.ses5 itn deworm if pid==1. * p<0.05

Iron Deficiency

Results for mean serum ferritin and serum transferrin receptor concentrations in women (combined and by reported pregnancy status) by province and overall are presented in **Table 37**.

Table 37: Mean serum ferritin and transferrin receptor concentrations in women by province and overall

Indicator	Northern Province		Southern Province		Total	
	N	mean ± SD (95% CI)	N	mean ± SD (95% CI)	N	mean ± SD (95% CI)
ALL WOMEN						
Serum Ferritin, µg/L[1]	354	64.7 ± 2.0 (57.8, 72.4)	318	46.7 ± 2.1 (42.01, 51.9)	672	55.9 ± 2.1 (51.7, 60.5)
SF, excluding cases with inflammation	297	68.1 ± 1.9 (61.7, 75.2)	268	47.6 ± 2.1 (42.6, 53.2)	565	58.0 ± 2.0 (53.8, 62.5)
TfR, µg/mL (cutoff >8.3)	354	4.2 ± 1.5 (3.9, 4.5)	318	4.0 ± 1.8 (3.7, 4.3)	672	4.1 ± 1.6 (3.9, 4.3)
NON-PREGNANT WOMEN						
Serum Ferritin, µg/L[1]	313	66.8 ± 1.9 (59.4, 75.2)	282	49.3 ± 2.1 (44.0, 55.1)	595	58.3 ± 2.1 (53.7, 63.3)
SF, excluding cases with inflammation	266	71.0 ± 1.9 (64.2, 78.6)	237	50.3 ± 2.1 (44.9, 56.3)	503	60.9 ± 2.0 (56.3, 65.7)
TfR, µg/mL (cutoff >8.3)	313	4.2 ± 1.5 (3.9, 4.5)	282	3.9 ± 1.7 (3.6, 4.2)	595	4.1 ± 1.6 (3.9, 4.3)
PREGNANT WOMEN						
Serum Ferritin, µg/L[1]	41	50.6 ± 2.0 (39.2, 65.2)	35	30.8 ± 2.1 (24.2, 39.0)	76	40.8 ± 2.1 (34.1, 48.6)
SF, excluding cases with inflammation	31	47.6 ± 2.1 (35.1, 64.4)	30	31.2 ± 2.1 (23.9, 40.7)	61	39.2 ± 2.1 (32.0, 47.9)
TfR, µg/mL (cutoff >8.3)	41	4.2 ± 1.3 (3.7, 4.7)	35	4.4 ± 2.3 (3.6, 5.2)	76	4.3 ± 1.8 (3.9, 4.7)

[1] Geometric mean based on log-transformed values that were corrected for inflammation status [39].

Women in the Southern Province have significantly lower serum ferritin levels than women in the Northern Province, even when women with inflammation are excluded from the analysis. A similar relationship was evident among both pregnant and non-pregnant women.

Table 38 presents the results for the proportion of women with evidence of iron deficiency, based on different thresholds for serum ferritin and transferrin receptor levels.

Table 38: Proportion of women below serum ferritin thresholds or above serum transferrin receptor thresholds by province and overall

Indicator	Northern Province		Southern Province		Total	
	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)
Low SF (<15 µg/L, all women)[1]	354	3.7% (1.3, 6.1)	318	7.7% (4.4, 11.0)	672	5.5% (3.5, 7.5)
Low SF (<15 µg/L, *inflammation cases excluded*)	297	2.9% (0.8, 4.9)	268	7.1% (3.4, 10.7)	565	4.7% (2.7, 6.8)
Low SF (<15 µg/L if no inflammation; <30 µg/L if inflammation present)[2]	354	5.0% (1.8, 8.1)	318	6.3% (3.7, 8.8)	672	5.5% (3.4, 7.6)
Low SF (<30 µg/L)	354	12.9% (7.0, 18.7)	318	21.1% (16.1, 26.0)	672	16.5% (12.6, 20.4)
High TfR, (>8.3 µg/mL)[3]	354	2.9% (1.2, 4.6)	318	3.0% (1.0, 5.0)	672	2.9% (1.6, 4.2)
NON-PREGNANT WOMEN						
Low SF (<15 µg/L, all women)[1]	313	3.3% (0.7, 5.9)	282	6.8% (3.7, 9.8)	595	4.8% (2.9, 6.8)
Low SF (<15 µg/L, *inflammation cases excluded*)	266	2.2% (0.3, 4.0)	237	6.2% (2.9, 9.5)	503	4.0% (2.2, 5.8)
High TfR, (>8.3 µg/mL)[3]	313	3.0% (1.1, 4.9)	282	3.0% (0.9, 5.1)	595	3.0% (1.6, 4.4)
PREGNANT WOMEN						
Low SF (<15 µg/L, all women)[1]	41	6.7% (-3.2, 16.5)	35	15.1% (2.8, 27.4)	76	10.4% (2.6, 18.1)
Low SF (<15 µg/L, *inflammation cases excluded*)	31	8.9% (-4.0, 21.8)	30	14.2% (1.0, 27.5)	61	11.4% (2.1, 20.6)
High TfR, (>8.3 µg/mL)[3]	41	2.2% (-2.3, 6.6)	35	3.2% (-3.1, 9.5)	76	2.6% (-1.1, 6.3)

[1] Based on values that were corrected for inflammation status [39]; cut-off used is 15 ug/L [10]
[2] Cut-off of 30 µg/L recommended when inflammation is present [42]
[3] Cut-off used is 8.3 based on equivalency to Ramco assay (Ehrhardt, personal communication)

Iron deficiency prevalence for women was similar to children, with 7.6% of women overall having low SF (<15 µg/L) and/or high sTfR (> 8.3 µg/mL) concentrations (see **Table 39**). Iron deficiency prevalence was similar between Northern and Southern Provinces.

Table 39: Summary of iron deficiency with and without anaemia for women

Indicator	Northern Province		Southern Province		Total	
	N	% (n) [95% CI][1]	N	% (n) [95% CI]	N	% (n) [95% CI]
Iron deficiency (low SF or high TfR)	354	5.8 (19) [3.3, 8.3]	318	9.9 (31) [6.1, 13.7]	672	7.6 (50) [5.5, 9.8]
Iron deficiency with anaemia	354	1.8 (6) [0.4, 3.1]	318	4.0 (13) [2.1, 6.0]	672	2.8 (19) [1.6, 3.9]
Iron deficiency without anaemia	354	4.0 (13) [2.2, 5.9]	318	5.8 (18) [2.6, 9.0]	672	4.8 (31) [3.1, 6.6]

[1] All 95% CI estimated using svy command in Stata to take the cluster design into account.

Table 40: Inflammation status by target group [40, 41]*

Groups	N	Healthy Reference (no APP raised)	Incubation (raised CRP only)	Early convalescence (raised CRP & AGP)	Late convalescence (raised AGP only)
		n (%)	n (%)	n (%)	n (%)
Children	577	409 (70.9)	11 (1.9)	68 (11.8)	89 (15.4)
All women	672	565 (84.1)	27 (4.0)	30 (4.5)	50 (7.4)
Pregnant women	76	61 (80.3)	8 (10.5)	5 (6.6)	2 (2.6)
Non-pregnant women	595	503 (84.5)	19 (3.2)	25 (4.2)	48 (8.1)

Results of analysis using corrected values were compared with analysis of only those individuals with no sign of inflammation (i.e. excluding all individuals with any raised APP). No meaningful differences in results were observed.

5. Discussion

Sample population characteristics

Some national level data, such as that presented in Figure 2, suggest that the quality of life is improving in Rwanda, with under five mortality rates dropping from about 200 in 1980 to about 100 in 2008. However for the visiting field team, who are experienced working in poor communities, the study populations were strikingly poor in appearance and this poverty is reflected in many of the indicators. Based on the data presented in Figures 3 and 4 regarding child growth, maternal BMI and child and maternal anaemia from 2005, there is no reason to expect that the regions that the Northern and Southern Provinces were markedly different from the rest of the country – child stunting and underweight and child and maternal anaemia were high everywhere. There are inter-provincial differences - for example, the Northern Province is considered the "bread-basket" of Rwanda, and the Southern Province is less productive, but the range of experiences surrounding food and nutrition, in broad terms, throughout Rwanda are likely captured in the data presented here from the two provinces sampled.

Breastfeeding

The practices of breastfeeding in the observed children seem to follow common African practice of duration of breastfeeding, with only 50% of children being weaned by three years of age, and 20% still being breastfed at five years of age. Furthermore, while almost all children are breastfeed in their first months, it may often not be exclusive breastfeeding, or at least very infrequent breastfeeding, with ~10% of children not breastfeeding on the day before the survey (see Figure 6). While breastfeeding until five years seems unlikely, these data may be more close to the reality than the DHS survey data[6] that report 5.7 months median age of exclusive breastfeeding (breastfeeding is often accompanied with drinks or porridges and is not truly exclusive [43])

While striking, these data are thought to be reliable by the authors and suggest an avenue for health intervention separate from the primary bean focus of this research.

Supplements and Medicines

There is low reported incidence of any sort of supplement or medicine use (Tables 9 and 10), with the most common being 30% of children taking deworming medication. There are no directly comparable DHS data: 42% of women took at least some iron tablets during pregnancy (2007-08 DHS) and 34% received postpartum VAC (2005 DHS), suggesting that the low coverage rates observed for other micronutrients is not unexpected. The number of individuals sleeping under ITNs (Table 11) was similar to DHS 2007-08, with ~40% of children (vs 57% in DHS) and 44% of women (vs 45% in DHS) sleeping under ITNs the previous night.

[6] All DHS data in the discussion is from http://www.statcompiler.com/, accessed between 27 and 30 Sept 2011.

Household Services and Goods

The household services as found in Table 12 were similar to DHS 2007-08. Even when different (e.g., electricity at ~3% in Table 12 vs 6% in DHS) it is still clear that it is a poor population, with few durable goods of any kind. However almost all (>90%) of the households do have access to land for cultivation, and most grow beans on this land. Interestingly, access to land was lowest in the highest SES quintile (at 85% and second lowest in the second poorest quintile at 87%. All other quintiles were at over 95% land access. The lower access in the most wealthy may be because they are more often urban or employed rather than farmers, but the anomaly of the second lowest quintile (which, incidentally occurs with other indicators as well) suggest that the SES classification guide may be malfunctioning.

Beans

Beans are a central feature of the farm in both Northern and Southern Provinces, with 88% of households (97% of those with access to farm land) growing beans in the previous season (Table 13). The source of bean seeds is revealing. While saving beans for seeds is not technically difficult for farmers, only about 30% do so, with over 50% purchasing seeds from the market (Table 14). There is a tendency for poorer households to save seeds less often (25% in the lowest SES quintile) than wealthiest households (42% in the wealthiest SES quintile). In other settings, this has been observed to be done out of desperate hunger – the poorer farmers eat their bean seeds or sell the beans at the low, post harvest prices, only to have to purchase seeds at higher, planting-season prices [44]. The wealthier households more often are able to save their own seeds for planting. This presents both an opportunity and a threat to attempts to introduce new bean varieties – there is already a ready market for selling beans for seed during the planting season, but there will be a tendency to not keep the bean seed from year to year.

This is reflected in the responses to "Do you harvest enough beans to meet your family's needs?" (Table 15) , where 77% did not. The results are presented by SES quintile in **Table 41.** In **Figure 11** the number of months until the household runs out of beans is shown as a cumulative distribution plot. Only the wealthiest SES quintile differs noticeable from the other quintiles, in that their bean supplies generally last longer, or year round.

Most households prepare their beans by simply boiling or boiling and frying the beans. There appears to be very little germination or fermentation of beans and only 12% of households soak the beans prior to cooking. These practices do not vary across SES groups (data not shown). It suggests an avenue of intervention to improve the absorption of iron and zinc in the diet. While germination and fermentation would be more efficacious, even simple soaking of beans would likely improve iron and zinc absorption [45], while having the added benefit of decreasing cooking time and fuel use.

Table 41. Answering "No" to "Do you harvest enough beans to meet your family's needs? ", by SES quintile (%).

	Northern	Southern
Lowest SES quintile	79.3	83.5
2nd quintile	81.7	86.5
3rd quintile	83.8	89.2
4th quintile	82.0	70.9
Wealthiest quintile	54.0	63.5

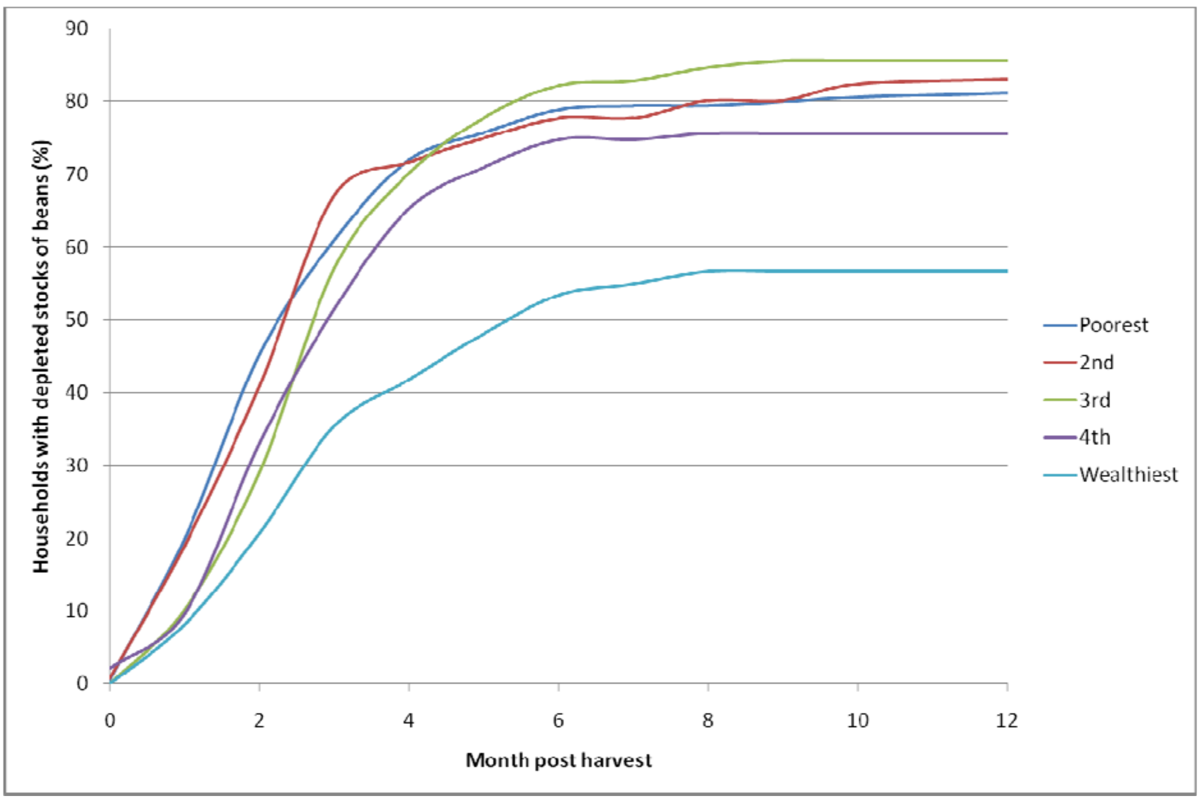


Figure 11. The number of months post-harvest until households have depleted their own grown bean stocks, by SES quintile.

Diet

The likelihood and nature of under-reporting

Discussing the quality of the data and likelihood of under-reporting goes hand in hand with a consideration of the estimated energy intakes, and so these two topics are discussed together.

An accurate estimation of energy intake is required for an accurate evaluation of the diet. Especially in a setting like Rwanda where supplement intake is almost nil, all nutrients must be provided by the food consumed to meet energy needs [46]. If total energy intake is underestimated, then the intakes of nutrients correlated with energy are also likely to be underestimated [46]. In this study, the intake of energy in adult women is strongly positively correlated with most nutrients (see **Table 42**). We may expect that on average, under-reporting of energy will be strongly matched by under estimation of iron and zinc intakes, and therefore an overestimate of the prevalences of iron and zinc intake inadequacy.

Table 42. The correlation between energy intake and nutrient intakes in adult Rwandan women.

Nutrient class	Nutrient	r^2
Macronutrients	Protein	0.71
	Lipid	0.24
	Carbohydrates	0.92
Minerals	Calcium	0.32
	Iron	0.62
	Zinc	0.76
Vitamins	A	0.07
	Niacin	0.65
	Thiamin	0.64
	Riboflavin	0.01
	B 6	0.57
	Folate	0.50
	B 12	0.02
	C	0.12

While accurate estimation of energy intakes is essential in dietary assessment, it is well established that under-reporting of energy intakes is almost universal in dietary studies [46, 47]. We were of course aware of this tendency and the multipass 24-hour recall which was used for this study was developed as a method to improve dietary data collection[34]. However, Dr. Gibson, the developer of the method, is no longer confident in its ability to accurately collect dietary data and would recommend using weighed dietary records instead (R.S. Gibson, personal communication, April 2011); however she feels the multipass method may be suitable to collect information on nutrient densities (nutrients per unit energy intake) for most nutrients, as was observed recently in Ethiopia [48].

Acknowledging that the reported intakes are likely under estimates, it would be useful if we could quantify, or at least estimate, the magnitude of the underestimation. In **Figure 12** the cumulative distribution curve for adult women's energy intakes (observed, and usual as estimated with PC-SIDE) are shown, along with key BMR multiples (BMR, the basal metabolic rate, is estimated to be approximately 1290 kcal). Two times the BMR would support a high activity level (such as a peasant farmer), and 1.55 times the BMR would support a sedentary lifestyle levels. While it is possible for single day observations to be low, even zero, it is unlikely that a large percentage of adult women would have intakes lower than their estimated BMR, and it would be impossible for them to have usual intakes lower than BMR. Furthermore, it is highly unlikely that many would have usual intakes less than 1.55 x BMR, except during times of severe food shortage. Although the survey was done during a "hungry season", anecdotal reports from Rwandan colleagues indicate that seasonality is not marked in Rwanda (there are two harvests per year), and people are food insecure year round. Only 25% of the population were estimated to have intakes above 1.55 x BMR. The fifth centile of usual intake is 1015 kcal, 1000 kcals below 1.55 x BMR. The data to estimate the nature of the underestimation are not available, but it seems likely that low reporters would underestimate more than high reporters. In **Figure 13** a transformation of the usual intake graph is shown which increases low reporters more than high reporters, namely "(usual + 1500) x 0.75", but this is conjecture, seems rather extreme[7] and the true relationship is unknown.

[7] Previous research observes under reporting in the range of 10 to 30%, not >100%48. Alemayehu, A.A., Y. Abebe, and R.S. Gibson, *A 24-h recall does not provide a valid estimate of absolute nutrient intakes for rural women in southern Ethiopia.* Nutrition, 2011. **27**(9): p. 919-24.)

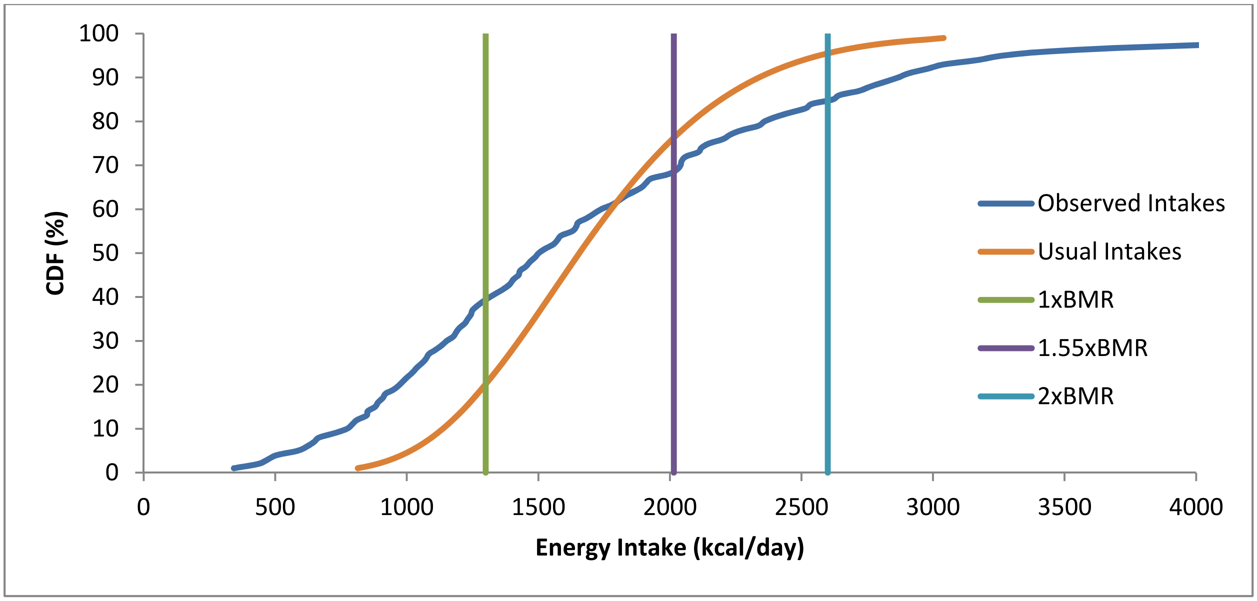


Figure 12. Cumulative distribution function of women's observed energy intakes and usual intakes (as estimated using PC-SIDE). Markers for estimated BMR, and 155% and 200% of BMR are shown.

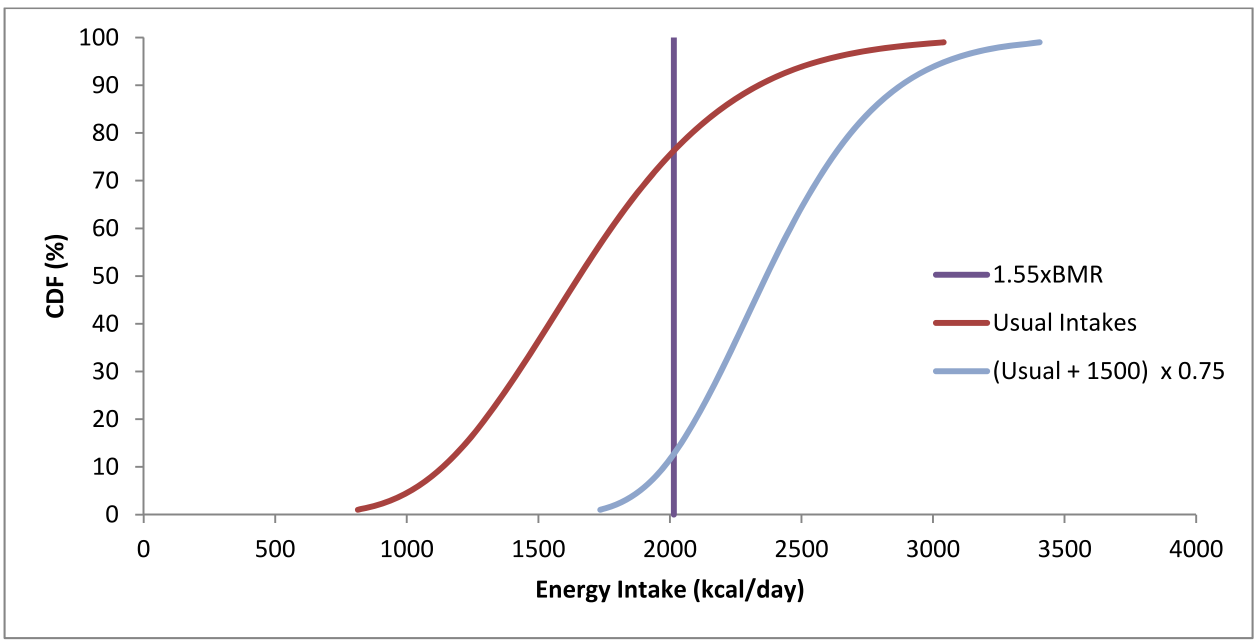


Figure 13. Cumulative distribution function of women's usual energy intakes and "(usual intake + 1000 kcal) x 0.80". Marker for target minimum of BMR x 1.55 is shown.

Thus we are limited in our conclusions to knowing that, yes there is serious under reporting and the nature of the under reporting is unknown and unpredictable. However, there is some reassurance in the work of Gibson [48] and others that suggests that, even when energy intakes are underestimated, the data are reasonably good estimates of nutrient density (nutrients per kcal). Given (1) this evidence in the literature that nutrient density is accurate, (2) the rigor of the method used, (3) the assurance of the field coordinators that the methods were stuck to scrupulously, (4) the lack of rationale for excluding any particular interviewer or date of interviews (see Figures 7 to 10) and (4) our inability to do any valid transformation with the data, the discussion of results will proceed assuming that there is under reporting, but the general patterns (relative intakes of energy from different food groups, relative energy intakes between different age groups) are accurate. In the final section of the discussion, an integration of the dietary and blood data will be carried out.

Dietary patterns

As reviewed in the background section of this report, there has been very little nutrition research carried out in Rwanda, and not a great deal of data to which these findings can be compared. The study carried out by Project Healthy Children (PHC) [18] provides a useful comparison point. The PHC study was designed to identify and evaluate a few potential food fortification vehicles, namely oil, sugar, salt, rice, maize and cassava. It was carried out in April-June 2008, so there is potential for seasonal differences (although anecdotal reports suggest they should be minimal), and because the PHC survey asked about only a few specific foods, it would likely get higher estimates of the frequency of consumption of these foods then would a full 24 hour recall. In **Figure 14** the proportion of women who ate the target foods on the day prior to the survey are shown. The PHC food category “oil” is compared to the current study’s “fats and oils”, and the PHC’s “sugar” is compared to “sugar and sweets”. Rice, maize and cassava are the same in both surveys, although the current study groups all the different preparations of rice, of maize and of cassava together. The proportions are quite similar in both provinces, with the exception of sugar, which was reported consumed much more often in the PHC study. In **Figure 15** the average quantity of rice, maize and cassava consumed by adult women in the PHC and current surveys are compared. Because PHC recorded “raw” weights and the current study reports ingredient weights (as it appears in the 24 hour recall, which may include in cooked form), from which dry weight equivalents can be calculated. Neither Reported nor DWE is directly comparable to PHC’s “raw”, however for rice, raw is similar to DWE (raw rice has very little water), and the average amounts reported in the two surveys are similar.

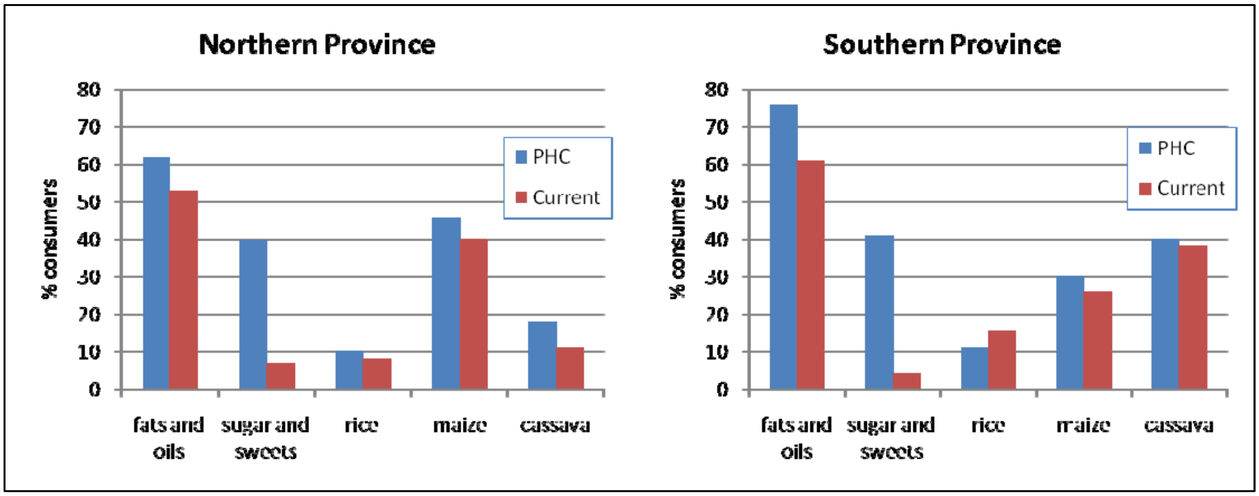


Figure 14. The proportion of adult women who consumed different food groups on the previous day in a PHC survey, compared to the current study.

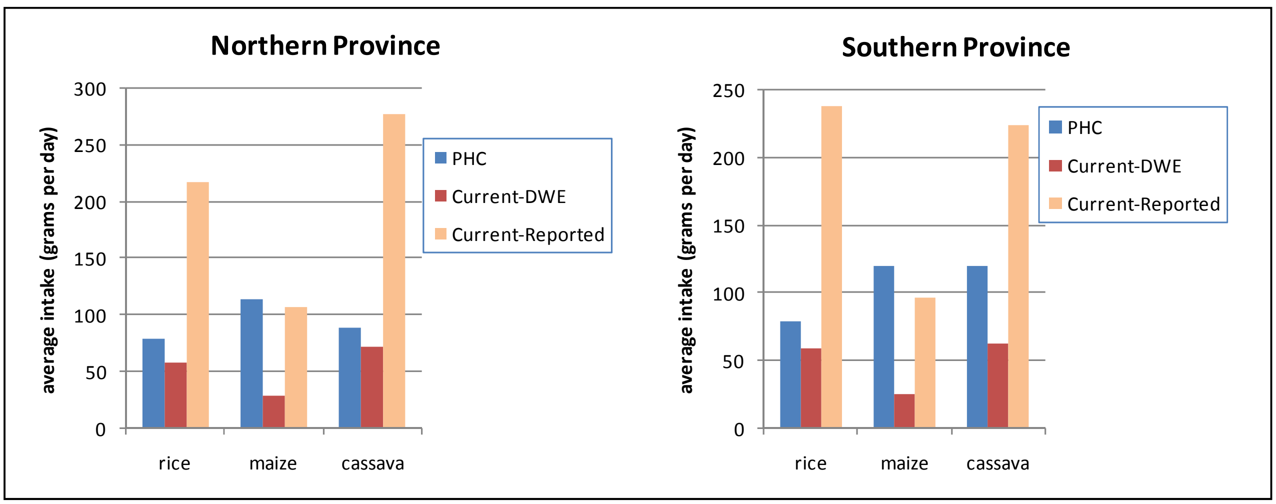


Figure 15. The average quantity of rice, maize and cassava consumed by adult women in the day prior to the survey in a PHC survey, compared to the current study. PHC reports "raw" weights; the current study reports "Reported" (as it appears in the 24 hour recall, which may include in cooked form), and "DWE", dry weight equivalents.

The quantity of food consumed differs between the different age groups of course (see Table 27), but the food types consumed are broadly similar. In **Figure 16**, the proportion of foods appearing in the 24-hour recall of the different age groups is shown as a pattern profile. While there are small differences, there are no important differences between groups, with all individuals having a plant-dominated data, with very few animal source foods. Low animal food intake is consistent with national level production data (Figure 5), with anecdotal observation, and with studies elsewhere in east Africa [49]. Even with the under-reporting likely in this survey, it is unlikely that there was much more animal source food consumed then reported. Diets with very low animal source foods are often deficient in numerous micronutrients, including iron and zinc [50], discussed in the next section. On the other hand, beans were consumed by most people in all age groups in large amounts and contributed significantly to total dietary energy, iron and zinc intakes (breast milk not included), and this is shown graphically in **Figure 17**. Data on anti-nutrient content of the bean varieties chosen are not currently available, but given the low frequency of germination, fermentation or soaking of beans (which could improve bioavailability), it is likely that the iron and zinc from beans are not highly bioavailable [51].

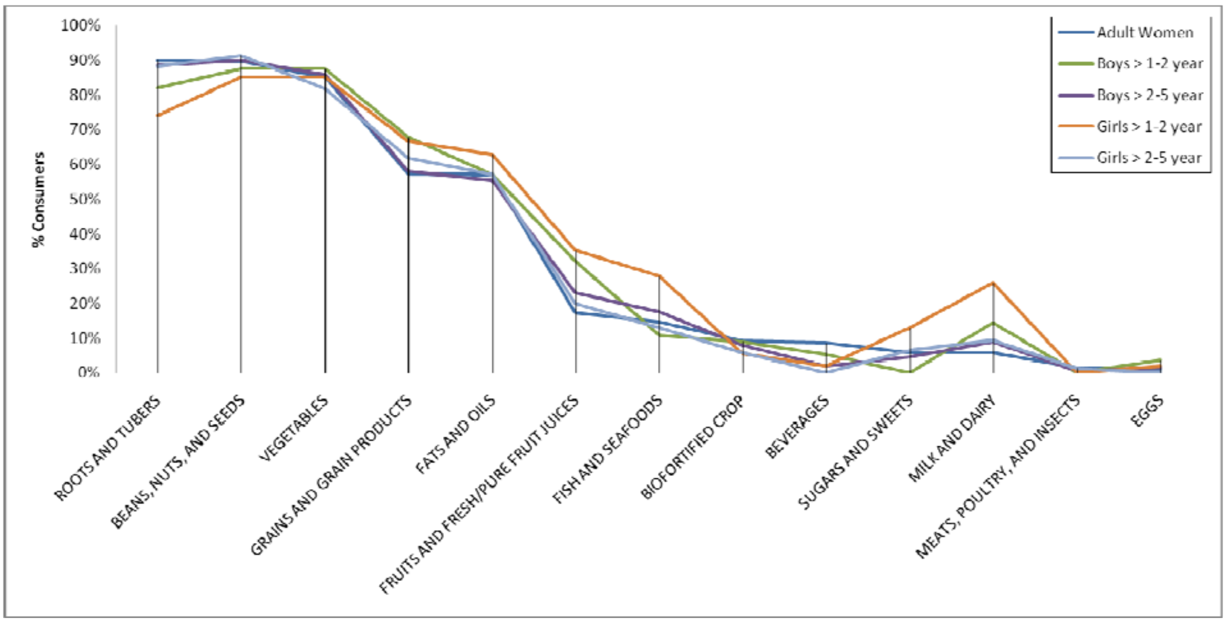


Figure 16. Pattern profile of proportion of age groups that consumed each of 13 different food groups, sorted from adult women's highest to lowest, left to right.

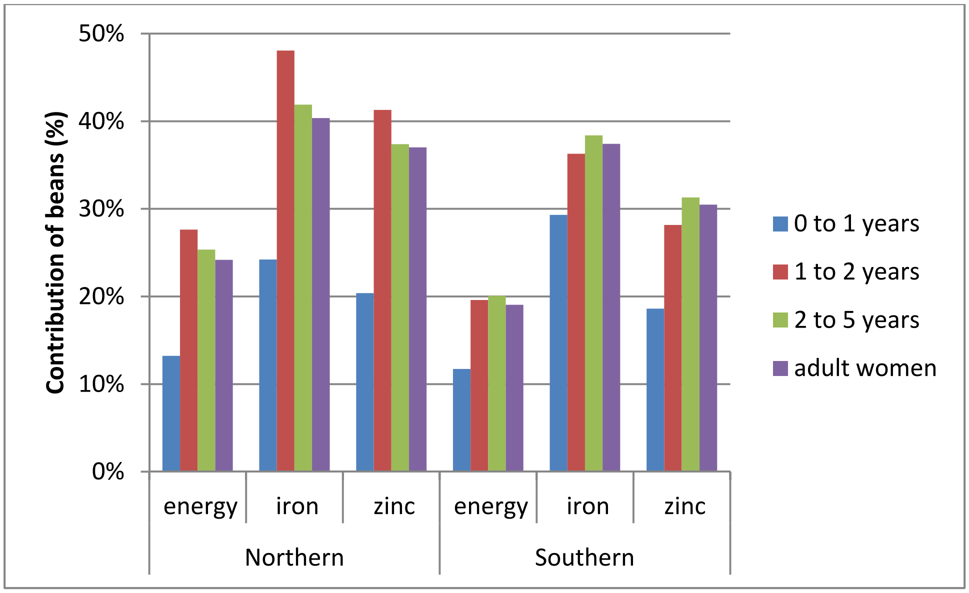


Figure 17. The contribution of beans to dietary energy, iron and zinc of children and adult women, expressed as a percentage of the total.

Iron and zinc dietary adequacy

Consistent with the low reported energy intakes, and the very low intakes of animal source foods, the diet of the women and children is generally inadequate (see Table 30). This assessment is made without considering breastmilk contributions to the children's diet, and there is breastfeeding to advanced ages. While breastmilk does not contain large quantities of iron or zinc, it is highly bioavailable and including it in the assessment could change the conclusions.

There are few studies to compare these results to – there are no surveys from Rwanda, or anywhere else in Sub-Saharan Africa, that have used the SIDE method to estimate usual intakes, and from which prevalences of inadequacy can be calculated. There are very few studies in Sub-Saharan Africa that have done dietary assessments of women and children and estimated the prevalence of dietary inadequacy. The few studies located are summarized in **Table 43.**

Table 43. The prevalence of dietary inadequacy in the current study, and other studies from Sub-Saharan Africa. A) Iron B) Zinc.

A) Iron

	Current, North+South	Nigeria[52]	Kenya[52]	Malawi[53]	Malawi[24]	Rwanda[54]
Children						
< 1yr	97.2					> 50%[1]
1-<3 yr	82.2	43%	78%			
3-5 yr	59.6			20%		
Women						
Pregnant	na				95	
Breastfeeding	92.2					
NPNL	90.9					

[1] Imputed from results, where mean household intake << household requirements.

B) Zinc

	Current, North+South	Nigeria[52]	Kenya[52]	Malawi[53]	Malawi[24]	Rwanda[54]
Children						
< 1yr	92.0					~50%[2]
1-<3 yr	15.0	59%	69%			
3-5 yr	30.7			26%/44% [1]		
Women						
Pregnant	82.2				98	
Breastfeeding	86.7[5]					
NPNL	42.4					

[1] Intervention and control communities
[2] Imputed from results, where mean household intake << household requirements.

Predictors of Energy and Iron Intake

Univariate and multivariate analyses were conducted on energy and iron intake in women and children, in Northern and Southern provinces. Most univariate predictors of energy intake are also predictors of iron intake in children, including province, if the mother is breastfeeding, if the mother is sick, if the child is sick, household SES, number of children in house and adults age (see **Table 44**). Multivariate models including all variables with p<.15 in the univariate analyses were developed for children (1 to <3 years, 3 to 5 years), and adult women, for both Northern and

Southern Provinces, for both iron and energy. Only the model for iron for 3 to 5 year old children, in the Northern Province, had any predictive value. The key independent variable was the health of the mother. Children whose mother's were not sick had iron intakes 6.6 mg higher than children whose mother's were sick (p=.0001). If this relationship were more broadly held, it would suggest a novel approach – caring for day-to-day maternal health - for addressing childhood iron deficiency.

Table 44. Univariate predictors of energy and iron intake in children.

	Energy		**Iron**	
Anova	Difference (kcal)	*p*	Difference (mg)	*p*
Province (Ref: South)	**177**	**p<.0001**	**3.1**	**p<.0001**
Mother Pregnant (Ref: preg)	-133	p=0.15	-1.5	p=.11
Mother Breastfeeding (Ref: BF)	**289**	**p<.0001**	**3.4**	**p<.0001**
Sex	nd	p>0.15	nd	p>0.15
Mother sick (Ref: sick)	**226**	**p=.001**	**1.1**	**p=.112**
Child sick (Ref: sick)	**90**	**p=.127**	**1.7**	**p=.004**
SES quintile (Ref: 1st)		**p=.001**		**p=.015**
2nd	**-100**	**<.05**	**-2.1**	**<.05**
3rd	17	>.05	0.5	>.05
4th	**297**	**<.05**	0.9	>.05
5th	**193**	**<.05**	0.0	>.05
Regression	Slope	*p*	Slope	*p*
n children in house	**61 kcal/adult**	**p=.005**	**1.0 mg/adult**	**p=.006**
n adults in house	44 kcal/adult	p=.085	**0.6 mg/adult**	**p=.006**
mother's age	8 kcal/yr	p=.07	**0.1 mg/yr**	**p=.001**
child's age	**165 kcal/yr**	**p<.0001**	**1.8 mg/yr**	**p<.0001**

Biochemical Indicators

Children

The prevalence of anaemia was high in the study population's children at 31%, somewhat higher in the Northern Province and lower in the Southern Province. This is lower than reported in the DHS survey of 2007-08 at 47.5%, is and at the low end of the prevalence of anaemia observed in other Sub-Saharan countries (see **Figure 18**). Given the very low iron intakes observed in this study, the high rate of *Ascaris* in the Northern Province[11], and the presence of malaria in at least some of the study villages [2], it is unexpected that Rwandan children would have lower rates of anaemia than other countries. However, in this study, similar to the DHS 2007-2008, anaemia prevalence varied widely by age group, decreasing from 72% among the youngest group (6-8 months) to 20% among the oldest children (48-59 months), and did not vary widely by household wealth quintiles. Perhaps the low overall rate of anaemia in children is in part due to the imbalance of the sample towards older children, with only 6% of the sample being <1 year old. If the sampling was balanced across ages, then the overall prevalence of anaemia would be ~ 36%, and if it were imbalanced towards the younger group as much as the actual sample is towards the oldest group, then the overall prevalence of anaemia could be as high as 50%,.

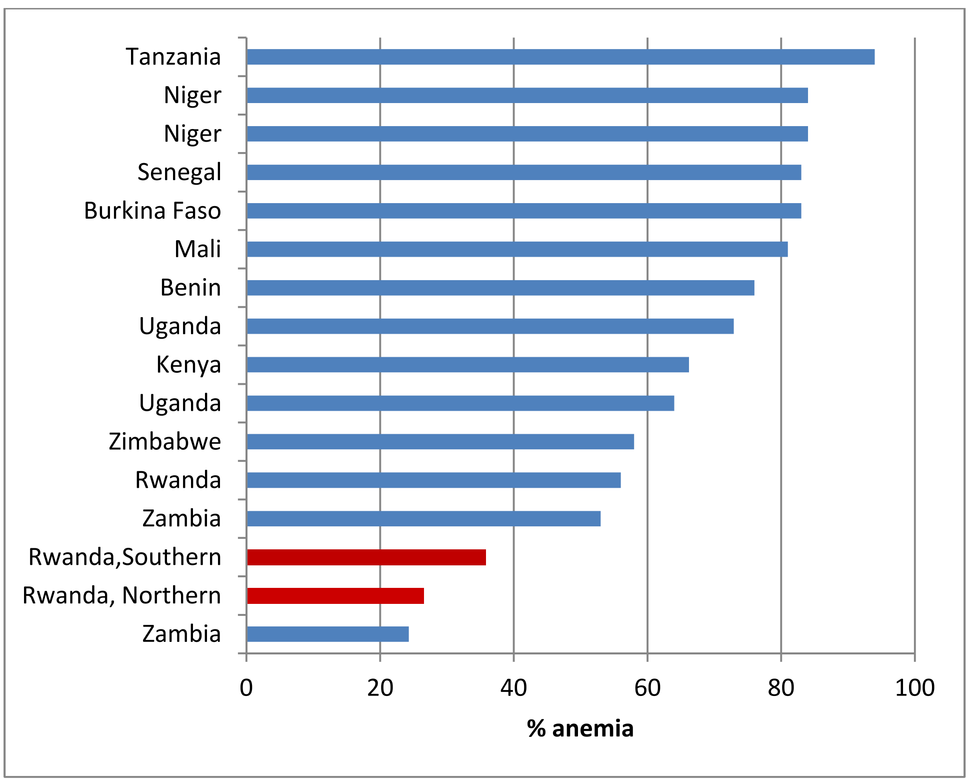


Figure 18. Prevalence of anaemia in children from various Sub-Saharan African countries as reported in the literature and in the current study (in red). Data drawn from reviews of food aid effectiveness[55], general populations[56], and other sources[57, 58].

In **Figure 19** the prevalence of anaemia is shown according to the child's health status (according to levels of acute phase proteins), and it is compared to results from children in Zanzibar[38]. Children without any evidence of inflammation (CRP and AGP levels in normal range) had the lowest prevalence of anaemia (25.9%), while children in the incubation stage (high CRP) or early convalescence stage (high CRP and high AGP) had levels over 50%.

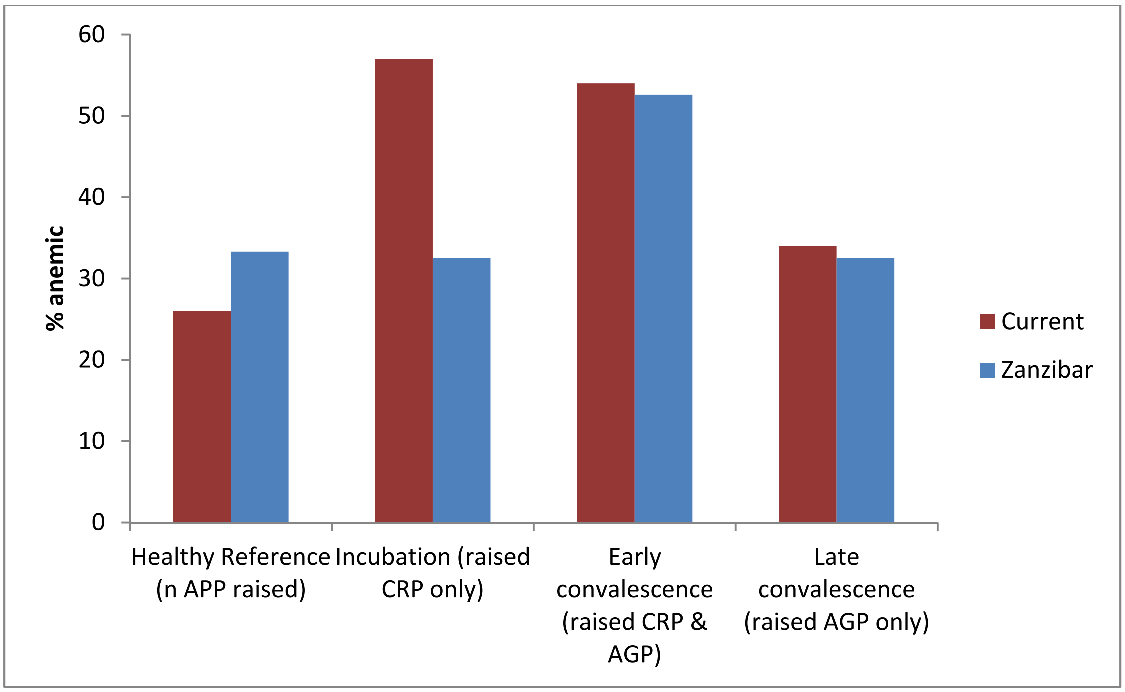


Figure 19. The prevalence of anaemia in children according to child's incubation phase in current study and in children from Zanzibar, where there are high levels of malaria and helminth infection[38].
(In Zanzibar study, children with raised CRP only and raised AGP only were grouped together. For this graph they are assumed to be equivalent).

Figure 20 shows a comparison of iron deficiency prevalence (determined by low serum ferritin) in children with and without concurrent anaemia (low hemoglobin). Children in the Northern Province were equally likely to have iron deficiency with or without anaemia, while children from the Southern Province were more likely to have iron deficiency with concurrent anaemia. This suggests that the aetiology of anaemia may be different between provinces, given the different prevalences of malaria (probably higher in the Southern Province) and helminth infection (probably higher in the Northern Province). Whatever the aetiology, the prevalence of iron deficiency is remarkably low.

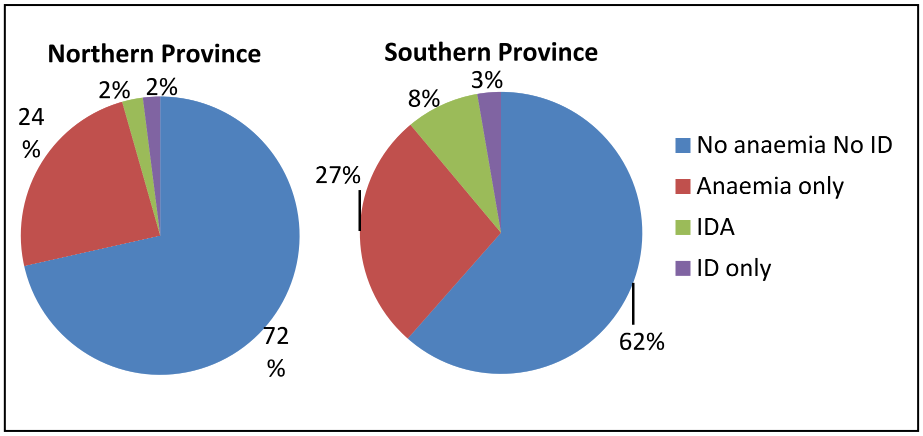


Figure 20: Iron deficiency and anaemia status among children by province.

Women

As in the case of the children, the anaemia levels in the surveyed pregnant (**Figure 21**) and non-pregnant (**Figure 22**) women are at the low end of what has been observed elsewhere in Sub-Saharan Africa. As with the children, this result is unexpected. The results of the risk factor analysis (Table 36) do not point to any likely explanation for this result.

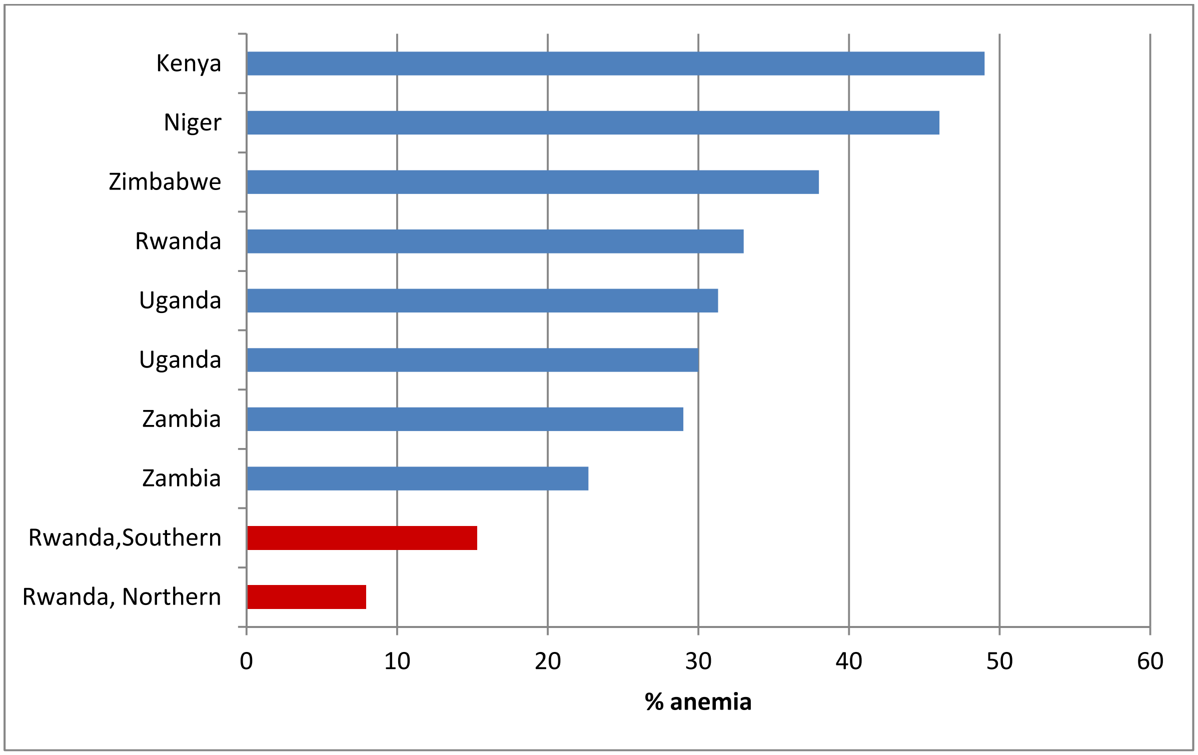


Figure 21. Prevalence of anaemia in pregnant women from various Sub-Saharan African countries as reported in the literature and in the current study (in red). Data drawn from reviews of hookworm and deworming[59], food aid effectiveness[55], general populations[56], and other sources[57, 58].

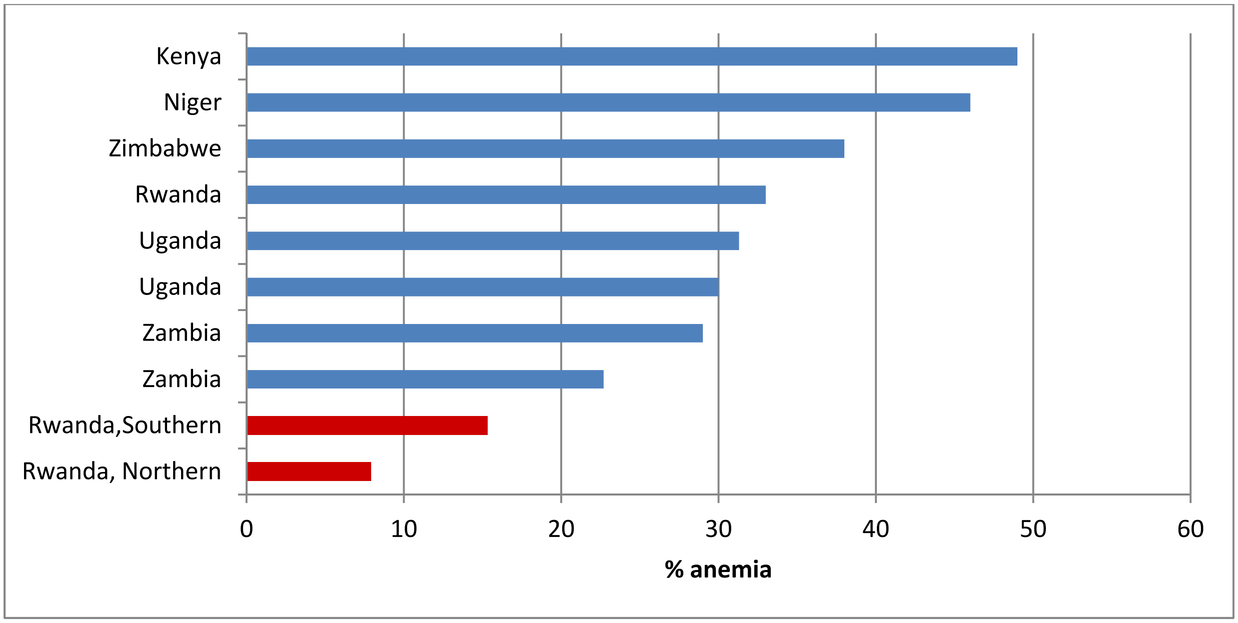


Figure 22. Prevalence of anaemia in non-pregnant women from various Sub-Saharan African countries as reported in the literature and in the current study (in red). Data drawn from reviews of food aid effectiveness[55], general populations[56], and other sources[57, 58].

Again, as in the case of the children, the levels of anaemia and iron deficiency are low, with only 2% of the women in the Northern Province and 4% of the women in the Southern Province having iron deficiency anaemia (see **Figure 24**) . Data on the individual's malaria, hookworm and HIV infection status were not collected in this study, but these have been shown to have a marked effect on both anaemia and iron status. In a recent cross-sectional study in Rwanda, the prevalence of anaemia was much higher among HIV-positive than HIV-negative women (29% vs. 8%)[60]). The prevalence of HIV in Rwandan adults is 2.9%, which is about half the rate throughout Sub-Saharan Africa, and about one-quarter the rate of some countries (e.g., Malawi at 11%, Zimbabwe at 15.3%)[61] . The lower prevalence of HIV in Rwanda may account for some of the between country differences in anaemia levels.

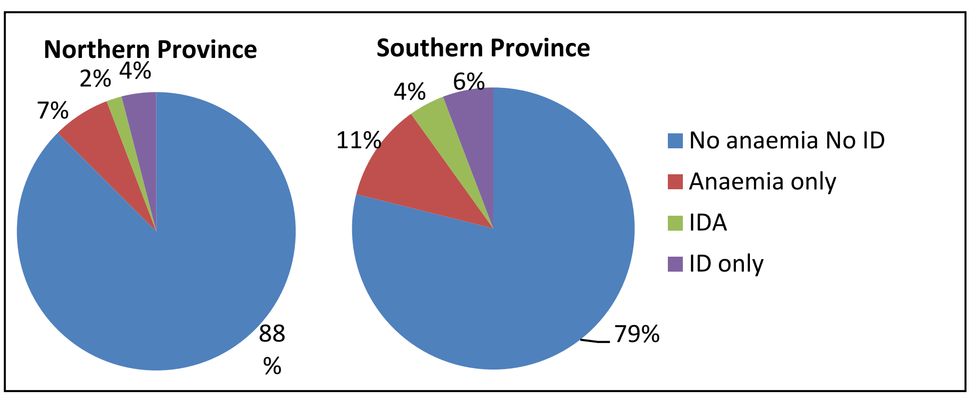


Figure 23. Iron deficiency and anaemia status of women, by province

Discussion of discordance between dietary and biochemical data

While we do not necessarily expect perfect concordance between the different indicators of iron status, the discordance between the dietary data and biochemical data is most unexpected. We do not know of other research from Sub-Saharan Africa which has estimated both the prevalence of dietary iron inadequacy and prevalence of iron deficiency, but some degree of concordance is expected. After all, the estimated dietary iron requirements are set at levels intended to prevent anaemia, and if not met will contribute to anaemia and iron deficiency. Over 60% of children and over 90% of women have insufficient dietary iron to meet their needs yet only ~5% of the individuals are iron deficient. We can consider various possible sources for this discordance, as presented in **Table 45**.

Table 45. Consideration of various possible sources of discordance between dietary and biochemical indicators of iron status. The possible sources are ranked on the scale: Not plausible – Plausible (but not likely) – Likely – Highly Likely.

Possible source of discordance	**Plausibility that it is a source of discordance in this study.**
Dietary iron intakes higher than estimated	
Iron supplement intake is high	*Plausible.* Our data indicates that only ~1% took iron tablets. In DHS 2007-08 42% of women took at least some iron tablets during pregnancy. It is possible that tablet use was higher in women than reported – perhaps that question was not well understood. However, high compliance with iron tablet supplementation is uncommon and it is not likely that this was a major source of discordance.
Individuals practice geophagia	*Not plausible.* While geophagy is practiced in at least some Sub-Saharan countries, including at least some levels in Rwanda, and can be a source of iron,geophagy more often causes anaemia[62-64] and thus, if common, would raise anaemia levels.
Water source is rich in iron	*Plausible.* Groundwater has been observed to be a significant source of iron and positively associated with iron status in Bangladesh [62]
Food sources have higher iron levels than used in analyses	*Plausible*. While there is certainly error in food composition table, and it is possible there are some food varieties with higher iron levels than what was used in the food table, it is unlikely that there are errors large enough in the foods that are consumed often enough to make an important difference.
Diet has higher level of bioavailability than presumed	*Plausible.* Given the largely plant based diet and probable high phytate intakes, the assumption was made that iron bioavailability was 5%. However, without detailed meal-level analysis, this cannot be verified and it is plausible that the bioavailability is actually 6 to 10%.
Food intake underestimated	*Highly likely.*Given the arguments presented earlier, under-reporting of food energy intake is almost certain, and iron intake is strongly correlated with energy intake. However, typical under-reporting is around 10 to 30%[48]. To bring concordance between dietary and biochemical data would require under-reporting of ~100%, which does not seem likely.
Iron deficiency levels are higher than measured	
Errors in measurement of serum ferritin and transferritin receptor	*Plausible.* The samples thawed for a short time in transit, but the proteins have been shown to be stable and should have been unaffected. The method used was valid and accurate and the analyst is a highly qualified expert. However, it is plausible that an error in drawing the blood, drawing off the serum, labelling, shipping or measuring the samples led to systematic bias.
Errors in measurement of hemoglobin	*Plausible.* While not a direct indicator of iron deficiency, hemoglobin levels were higher than would often be found in Sub-Saharan African populations, suggesting that iron deficiency is lower than other populations. However it is unlikely that hemoglobin, measured with hemocue at the time of blood-taking, and the blood proteins, measured much later in an overseas laboratory, would both have large errors in the same direction.

To further consider the discordance, the prevalence of dietary iron inadequacy for non-pregnant women was estimated using PC-SIDE with the observed iron intakes, and with iron intakes one and a half-times, two-times and three-times what was actually observed, with iron bioavailability assumed to range from 5 through 20%. The estimated level of iron inadequacy was plotted in **Figure 24**. The levels of iron deficiency observed in the non-pregnant non-lactating women (~5%) would be expected only in situations where the bioavailability of the iron, or the iron intakes, or both, were much higher than estimated (e.g., at 1.5 times the iron intake and 18% bioavailability, 2 times the iron intake and 12% bioavailability, or 3 times the iron intake and 7% bioavailability). None of these scenario seems plausible. Logic and argument will not determine the cause of the discordance; further study is necessary.

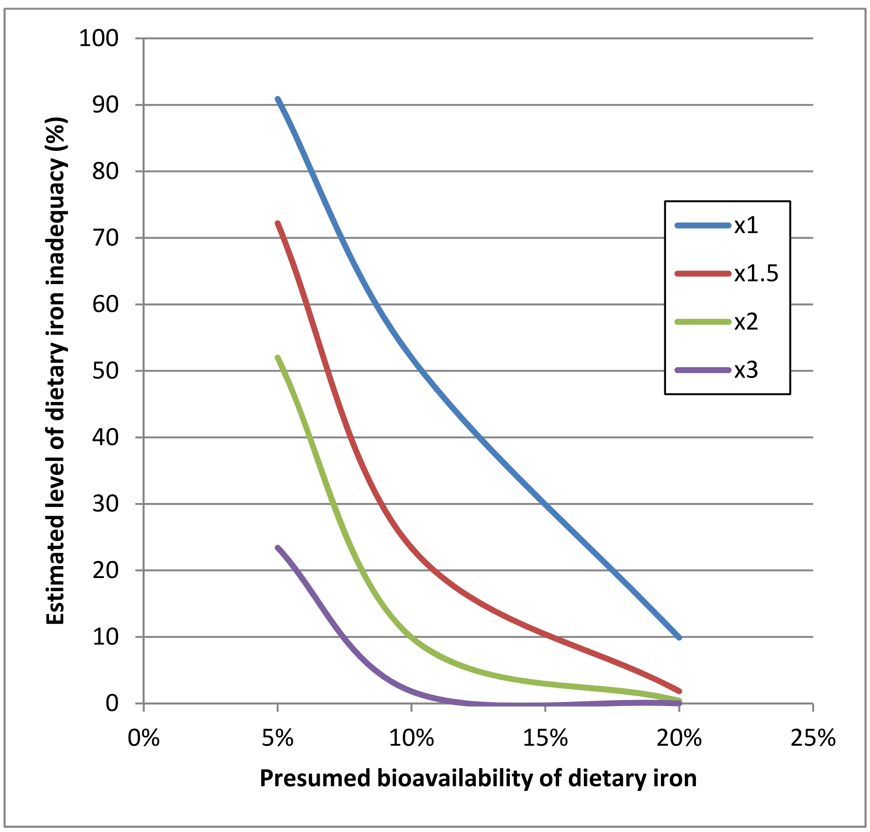


Figure 24. Estimated prevalence of dietary iron inadequacy at observed levels of iron intake, and at 1.5, 2 and 3 times observed intakes, versus bioavailability of dietary iron.

Further research needs.

The primary objective of this research was to serve as a background nutrition study for the planned roll out of biofortified beans and an effectiveness study by HarvestPlus. Rwanda is relatively unstudied, in terms of nutrition, with little biochemical data and very little dietary data. This study helps fill the gap by providing detailed information about the diet and nutritional status of women and children in the Northern and Southern Provinces. However, it does leave some questions unanswered. The biggest question is clearly regarding the large discordance between the dietary data and the biochemical data regarding iron deficiency. While a number of possible explanations have been advanced, there is no clear explanation – or even a "most likely explanation" – for why the discordance exists. Thus, this points to the single greatest research need – to further evaluate the diet and the biochemical status of Rwandan populations to better understand iron status in Rwanda. All other pressing research needs flow from this. If indeed iron deficiency is as low as 5%, then there is no need for interventions to improve iron status, including iron biofortified beans. With more than 80% of the sample eating beans every day, and beans providing in excess of 20% of dietary energy in the provinces, beans are a suitable vehicle to consider for biofortification – the question remains whether there is a need for it.

6. CONCLUSION

This data for this representative survey of two Rwandan provinces was carried out in November and December 2010, preceded by approximately one year of preparation and followed by nearly one year of data and blood analysis, statistical analysis, and result interpretation. The work of many skilled and dedicated people has gone into this work, and in normal circumstances great confidence should be placed in the results generated by such a team. However, this study has documented very low levels of iron deficiency in Rwanda despite very high levels of dietary iron inadequacy. This result is so paradoxical as to be unbelievable and the research team is almost certain that there were errors in data collection or analysis. If the data were accurate (or even in error by ~30%, as is common) it would indicate that the Rwandan population were somehow unique in their ability to maintain relatively good health, specifically good iron status, despite apparently woefully inadequate diets. The research team considers this unlikely, if not impossible, and not to be considered further until all other avenues are explored. Plans are currently in place to conduct another, smaller. round of data collection in November 2011 to corroborate, refine or overturn the data and results presented in this report.

Nonetheless, a number of conclusions can be made with confidence. The people of the Northern and Southern Provinces live in poverty with few modern conveniences or durable goods, and with little access to mechanical or technical aids to their, predominantly agricultural, livelihoods. Their diets are simple and limited in quantity and variety, based almost entirely on plant-based foods, with very little animal-source foods. In other populations, such diets are almost always associated with moderate to high levels of deficiency of iron, zinc, copper and vitamin B12. In this survey only iron status was assessed through blood measures and, contrary to expectations iron deficiency was found to be very low (~5%).

Through this work a very rich data set has been collected. Some aspects of the data have been analysed in detail and presented here. Other aspects of the data set have been analysed only briefly - for example, the mean and SD of intake of some, but not all nutrients is presented in Tables 23-25, and the prevalence of inadequacy is estimated only for iron and zinc (Table 30). Other data (e.g., Retinol Binding Protein) have not been presented at all and other analyses remain to be done (e.g., calculating the dietary diversity scores to assess children's diets). Further analyses of the data set would be useful for continuing to plug remaining holes in the nutrition community's understanding of food and nutrition in Rwanda.

The Rwandan government intends to eliminate malnutrition in Rwanda by mapping and identifying malnourished children, ensuring all households have nutritional support (promoting kitchen gardens and distributing ready to use therapeutic foods), sensitizing the population on nutrition activities (use of social media), monitoring and evaluation of nutrition activities, and nutrition support in schools [65]. Additionally, formal adoption of Rwanda-specific fortification standards by the Bureau of Standards for maize and wheat flour, edible oils, sugar, and salt took place on 22

September 2011 and the roll out of food fortification should improve Rwandan's nutritional status. The data presented in this report will be useful in planning these activities through the identification of the populations most at risk (actually, nearly all women and children) and the nature of some of those risks (food insecurity, food insufficiency, low dietary diversity), while pointing towards potential interventions in addition to bean biofortification, including promotion of bean soaking to improve mineral bioavailability, improved breastfeeding practices, increasing attention given to children of ill mothers and, perhaps, improved micronutrient supplementation coverage.

7. Appendices

Appendix 1. The selected villages and their characteristics.

Appendix 2. The nutrient requirements for zinc and iron used in the assessment of nutrient adequacy of the diet

Appendix 3. Distribution of malaria endemicity, from MARA

Appendix 4: Informed Consent form for women and children participating in a consumption survey in Rwanda

Appendix 1 The selected villages and their characteristics.

DISTRICT			VILLAGE			
Name	**Altitude**	**Latitude + Longitude**	**Name**	**Altitude (m)**	**Latitude + Longitude**	**Population**
NORTHERN PROVINCE						
Burera	**2326**	**S 1° 28' 26'' E 29° 50' 4''**	Butaro	2248	S 1° 24' 28'' E 29° 49' 52''	648
			Kajerijeri	2310	S 1° 30' 45'' E 29° 56' 59''	484
			Kamonyi	1953	S 1° 33' 14'' E 29° 46' 31''	633
			Karambi	1866	S 1° 30' 21''E 30° 5' 50''	352
			Kibumbiro	1891	S 1° 35' 6'' E 29° 36' 27''	460
			Kigina	1814	S 1° 26' 27'' E 29° 44' 40''	653
			Remya	1785	S 1° 36' 34'' E 29° 43' 45''	693
			Sunzu	2162	S 1° 26' 36'' E 29° 44' 8''	564
			Terimbere	1809	S 1° 33' 46'' E 29° 43' 42''	564
Gakenke	**1882**	**S 1° 41' 53'' E 29° 47' 7''**	Kabutwa	2261	S 1° 27' 15'' E 29° 33' 12''	554
			Kajereri	2106	S 1° 39' 6'' E 29° 44' 18''	643
			Kara	1902	S 1° 40' 35'' E 29° 49' 37''	496
			Karuhunge	1724	S 1° 38' 39'' E 29° 39' 9''	746
			Muhororo	1882	S 1° 39' 52'' E 29° 39' 56''	624
			Rugamba	1813	S 1° 36' 59'' E 29° 39' 46''	804
			Ruganda	1996	S 1° 34' 13'' E 29° 36' 29''	565
			Rutaraga	1393	S 1° 43' 31'' E 29° 39' 38''	596
			Wimfizi	1805	S 1° 37' 0'' E 29° 41' 57''	530
Gicumbi	**1782**	**S 1° 36' 59'' E 30° 7' 15''**	Burambira	1997	S 1° 40' 44'' E 29° 54' 24''	549
			Kabaya	1658	S 1° 38' 2'' E 29° 46' 40'	505
			Kintaganirwa	1778	S 1° 33' 32'' E 29° 39' 37''	867
			Nyankokoma	2094	S 1° 38' 52'' E 30° 8' 24''	369
			Nyirantarengwa	2168	S01.59707 E030.02895 30''	448
			Remera	1789	S 1° 32' 20'' E 29° 43' 34''	617
			Rugerero	1692	S 1° 35' 24'' E 30° 9' 53''	528
Musanze	**1872**	**S 1° 30' 27'' E 29° 36' 23''**	Bwuzuri	1882	S 1° 30' 18'' E 29° 39' 5''	1044
			Karuriza	2422	S 1° 33' 25'' E 29° 33' 30''	456
			Murora	1814	S 1° 29' 1'' E 30° 1' 27''	998
			Nyamagumba	1845	S 1° 29' 15'' E 30° 6' 52''	2730
Rulindo	**2087**	**S 1° 44' 17'' E 29° 59' 52''**	Buliza	1927	S 1° 47' 11'' E 30° 2' 53''	676
			Kabanda	2281	S 2° 4' 0'' E 29° 42' 0''	632
			Kadendegeri	2102	S 1° 42' 37'' E 29° 58' 58''	415
			Rwanzu	1789	S 1° 42' 27'' E 29° 55' 32''	729
			Wamahoro	2254	S:01°37.077'E:030°01.600'	536

DISTRICT			VILLAGE			
Name	**Altitude**	**Latitude + Longitude**	**Name**	**Altitude (m)**	**Latitude + Longitude**	**Population**
SOUTHERN PROVINCE						
Gisagara	**1715**	**S 2° 37' 5'' E 29° 51' 0''**	Akarangabo	1450	S 2° 43' 58'' E 29° 49' 4''	647
			Impinga	1706	S 2° 34' 15'' E 29° 44' 27''	524
			Kibumba	1717	S 2° 21' 0'' E 29° 34' 12''	672
			Kigarama	1736	S 2° 31'49. 0'' E 29° 45' 38.3''	577
			Musekera	1607	S 2° 33' 48''E 29° 48' 24''	672
			Nyakagezi	1622	S 2° 41' 2'' E 29° 52' 46''	583
			Nyarure	1833	S 2° 45' 33'' E 29° 33' 47''	619
Huye	**1639**	**S 2° 31' 1'' E 29° 41' 45''**	Bumbogo	1786	S 2° 32' 53'' E 29° 45' 36''	477
			Gitwa	1585	S 2° 10' 19'' E 29° 49' 55''	675
			Icyiri	1747	S 2° 37' 22.6'' E 29° 44' 32.9''	501
			Karuhimbana	1742	S 2° 24' 03.2'' E 29° 46' 35.3''	493
			Rwamambariro	1750	S 2° 33' 02.0'' E 29° 45' 49.9''	920
			Taba	1650	S 2° 22' 49''E 29° 44' 9''	1015
Kamonyi	**1606**	**S 2° 0' 18''E 29° 53' 53''**	Nkoto	1595	S 1° 58' 52'' E 29° 56' 1''	663
			Rugaragara	1613	S 1° 53' 40''E 29° 49' 55''	1155
Muhanga	**1684**	**S 1° 56' 20''E 29° 43' 5''**	Gitima	1881	S:02°04.26.6'E:029°45'57.5'	1126
			Kabuga	1928	2° 28' 28'' E 29° 34' 26''	1119
			Mucyamo	1598	S01.6497 E029.75690	783
			Nyamirambo	1720	S01.87849 E029.75127	737
Nyamagabe	**2219**	**S 2° 24' 29''E 29° 28' 4''**	Bireka	2214	S 2° 31' 37'' E 29° 29' 5''	557
			Gishwati	2403	S 2° 28' 24'' E 29° 24' 59''	886
			Ndogondwe	2238	S:02°24.381'E:029°28.967'	371
Nyanza	**1553**	**S 2° 20' 12''E 29° 47' 40''**	Gisika	1624	S 2° 38' 57'' E 29° 46' 49''	688
			Karwiru	1586	S 2° 23' 25'' E 29° 42' 9''	481
Nyaruguru	**2006**	**S 2° 41' 54''E 29° 31' 25''**	Agatovu	1681	S:2°44'56.6" E:29°42'38.6"	545
			Gituramigina	1678	S:2°44'49.6" E:29°42'19.7"	591
			Kinteko	1661	S 2° 42' 12''E 29° 44' 12''	1107
			Musebeya	2077	S:2°43'21.5"E:29°28'56.5"	637
			Ruganza	2085	S 2° 38' 7''E 29° 27' 52''	587
			Rusuzumiro	1944	S 2° 37' 21'' E 29° 29' 5''	851
Ruhango	**1796**	**S 2° 11' 58''E 29° 46' 11''**	Kabacuzi	1880	S 2° 15' 0''E 29° 37' 41''	588
			Kamonyi	1775	S 2° 0' 8''E 29° 54' 14''	639
			Kirambo	1733	S 2° 20' 31''E 29° 44' 45''	313
			Rugarama	1836	S 2° 10' 153''E 29° 4614.0''	595

Appendix 2.

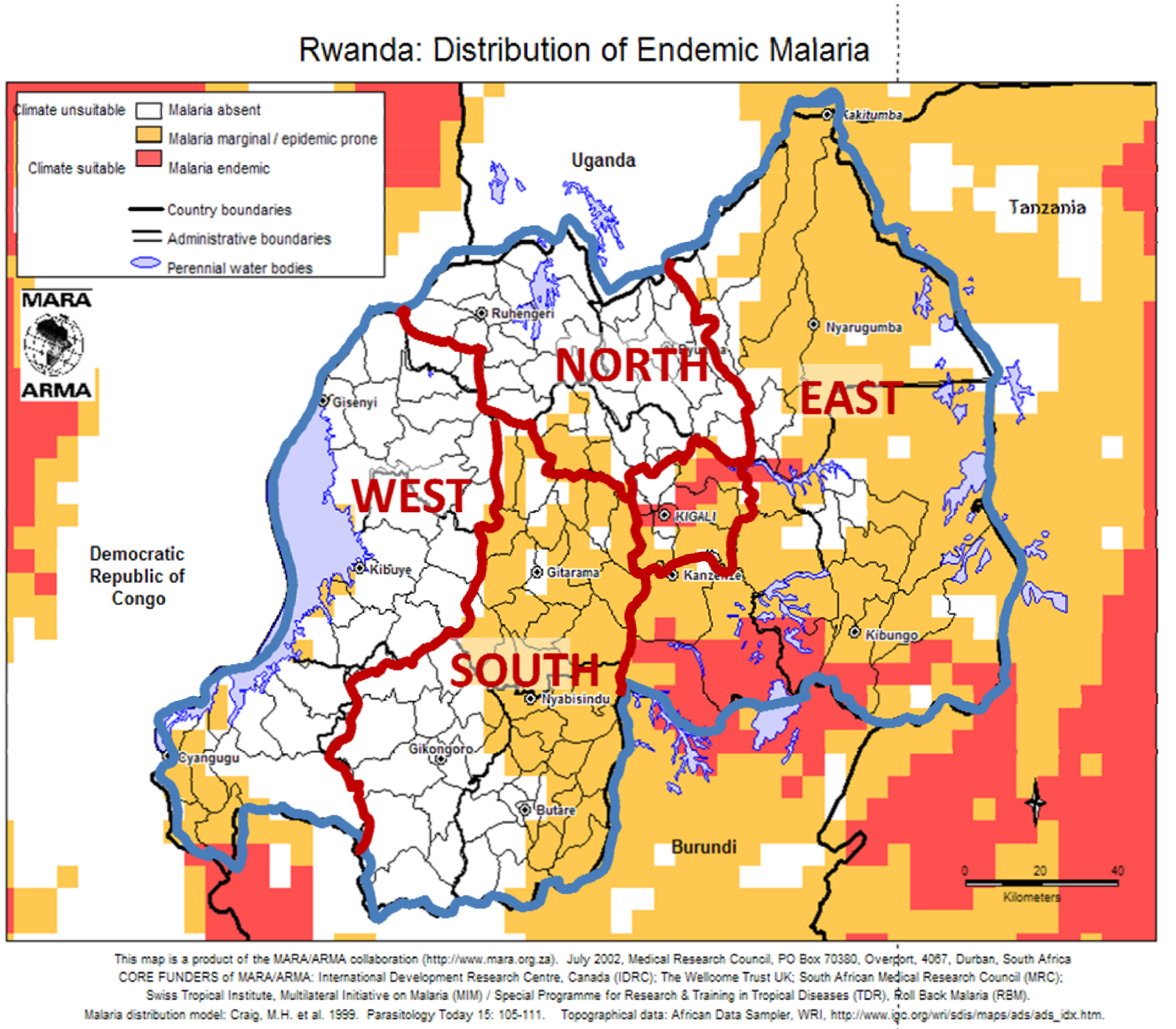
The nutrient requirements for zinc and iron used in the assessment of nutrient adequacy of the diet

ZINC Requirements		
From: http://www.izincg.org/publications/files/English_brief3.pdf		
Study Agegroups	Guideline agegroups	IZINCG EAR (mg/d) (unrefined plant based diet)
< 1yr	6-12 m	4
1-3 yr	1-3 years	2
3-5 yr	4-8 years	4
Pregnant	Pregnant	12
Breastfeeding	Lactation	9
Neither pregnant nor breastfeeding	>19 years	7

IRON Requirements[66]					
Study Agegroups	Guideline agegroups	Total Absolute Median Requirements (mg/day)	Total Absolute RNI (mg/day)	RNI at low bioavailability	Back Calculation of EAR
< 1yr	0.5-1 yr	0.72	0.93	18.6	14.4
1-3 yr	1-3 yr	0.46	0.58	11.6	9.2
3-5 yr	4-6 yr	0.5	0.63	12.6	10
Pregnant				NA (suppl required)	
Breastfeeding	Lactating	1.15	1.5	30	23
Neither pregnant nor breastfeeding	18+	1.46	2.94	58.8	29.2

Appendix 3.

Distribution of malaria endemicity, from MARA (http://www.mara.org.za/mapsdownltab_bmp.htm)



Appendix 4: Informed Consent form for women and children participating in a consumption survey in Rwanda

(To be read to each individual who attends the participant preparation meeting and/or at each household)

I am ______________________ a field supervisor working for the National University of Rwanda. We are doing research on the foods that you eat and how these affect your nutritional status and your children's nutrition status. I am going to give you information and invite you to be part of this research. Before you decide, you can talk to anyone you feel comfortable with about the research. If there is anything you do not understand, please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask them of me, the field supervisor or the staff.

Previous researchers have found that the foods that we eat in Rwanda and elsewhere in Africa are not nutritious enough to ensure good health. As such, we are doing a study on the local foods that you eat and how they affect your health. Specifically we would like to (1) describe the average iron intake of the group that we study, (2) we will also be able to state what proportion of the group has insufficient iron intake, (3) we will be able to determine the levels of some vitamins and minerals in your bodies, (4) we will assess the mean intake of common beans by women and children, (5) and we will establish the (baseline) iron , zinc, phytic acid and polyphenol concentrations of popular bean varieties consumed at the households included in the dietary survey and in the local markets used by these households.

If you accept to participate in this study, we will provide you with utensils that you will use and a chart to record the foods you eat. We will then visit your household two days after this for the research where we will ask you questions about the foods you ate the previous day. For a few households, we will visit a second time and ask the same questions. If by any chance we need to clarify the information we have collected, we may visit your household again. Also as part of the study, we will request you to provide us with a blood sample of one child and the mother. We will take blood from the arm using a sterile needle. About 3mL of blood will be taken once. Hemoglobin concentration will be determined in the nearest health facility and any individual found with severe anemia will be recommended for immediate treatment. The rest of the blood sample will be processed into plasma or serum and some of it will be stored in the National University of Rwanda – School of Medicine and a portion of it will be shipped to Germany for additional measurements of iron and vitamin A content. At the end of the research, any leftover blood sample will be stored for 12 months or until the bean efficacy study is completed and then will be destroyed. Each visit will take about one hour.

This information is important as it will help with deciding whether to introduce iron-rich beans to your area, which could help improve your diet. There are minimal risks in participating in this study. The main one is that getting blood from you may cause a bit of swelling.

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may change your mind later and stop participating even if you agree now. The information that we collect from this research will be kept confidential. Information about you or other members of your household that will be collected during the research will be put away and no one but the researchers will be able to see it. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except our sponsors.

The knowledge that we get from doing this research will be shared with you through community meetings before it is made widely available to the public. Individual information will not be shared. There will be small meetings in the community and these will be announced. After these meetings, we will publish the results in order that other interested people may learn from our research. When biofortified foods are successfully implemented, there can be widespread, immediate increases in intake of targeted micronutrients. If biofortified beans are successfully implemented in Rwanda, there could be a 10% reduction in the burden of iron deficiency.

Name of Principal Investigators – Dr. Jacqueline K. Kung'u and Peter R. Berti

Name of Organizations – National University of Rwanda faculty of Medicine and HealthBridge Canada

Name of Sponsors – HarvestPlus and HealthBridge Canada

This proposal has been reviewed and approved by the National Ethics Committee of Rwanda, the research commission of National University of Rwanda faculty of Medicine and HealthBridge Canada research ethics committees, which are committees whose task it is to make sure that research participants are protected from harm. For any ethical issue please contact Dr Justin Wane: +250 7885 00499, Dr Emmanuel Nkeramihigo: +250 7885 57273 and Ismael Téta: +1 613 782 6832

Certificate of Consent

(Please check the boxes)

☐ I have read the foregoing information or the foregoing information has been read to me.

☐ I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction.

☐ I consent voluntarily to participate as a participant in this research.

Print Name of Participant________________________

Signature of Participant ________________________

(Participant signs if she can write. If not see section below)

Date ________________________

Day/month/year

If illiterate

A literate witness must sign (if possible, this person should be selected by the participant and should have no connection to the research team). Participants who are illiterate should include their thumb-print as well.

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness ___________________ AND Thumb print of participant

Signature of witness ____________________

Date ______________________

Day/month/year

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1. We will visit the household and ask questions about foods consumed by the household, the mother and an index child

2. If we review the information and if we need to clarify, we will revisit the household

3. We will request for a blood sample from the mother and the index child

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily. A copy of this informed consent form has been provided to the participant.

Print Name of Researcher/person taking the consent ________________________

Signature of Researcher /person taking the consent ________________________

Date ________________________

Day/month/year

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