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Household Level Food Security and Nutrition Analysis Using A Farm Simulation Model (FARMSIM): Case Study of Ethiopia

Texas A&M University Integrated Decision Support System Team
USAID Feed the Future Innovation Laboratory for Small-Scale Irrigation

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Table of Contents

Tables

Figures

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Abstract

The rural population in developing countries depends on agriculture. However, in many of these countries, agricultural productivity remains low with episodes of famines in drought-prone areas, making the issue of food security and nutrition critical for their survival. The vast majority of the world's undernourished people are located in developing countries, especially in the Sub-Saharan Africa region. Other aspects of hunger and malnourishment that are often overlooked, relate to micronutrient deficiency, which can have long-term health consequences. Among other options to combat malnutrition and hunger is to increase the food production and promote the consumption of balanced diets specifically in regions and zones of food deficits. However to achieve this goal there is a need to increase the agricultural productivity through the adoption and use of agricultural technologies such as irrigation and fertilizers. This study focused on the use of small-scale irrigation technologies to assess the impact of food production and consumption on food security and nutrition in Robit kebele (village), Amhara region of Ethiopia. The farm level economic and nutrition simulation model (FARMSIM) was used to carry out the analysis. It is complemented by a qualitative analysis of the food diversity consumed at the household level using a household dietary diversity score (HDDS). A baseline scenario with minimal irrigation capacity and current food consumption is compared to four alternative scenarios that benefited from irrigation and production of vegetable and fodder that are aligned with four different consumption patterns. Current food consumption and nutrient intake by an average household in Robit indicates a satisfactory consumption and intake of calories from a cereal-based diet dominated by teff and maize but is limited in consumption of fruits, vegetables and pulses most importantly a lack in the diet of food of animal source. The alternative scenario where vegetables and fodder are produced through irrigation shows the highest nutritional and economic benefits. Beside providing a variety of vegetables consumed at home in addition to consuming potatoes and chickpeas, revenues from vegetable sales at the markets allowed the household to purchase supplemental food items such as milk, meat, and eggs. Simulation results show that both scenarios meet the daily minimum required intake quantities per adult for calories, proteins, iron and vitamin A, but fall short in meeting those minimums for fat and calcium intakes. However, the results show a significant increase from the Baseline to the alternative scenario. Other alternative scenarios except the one that removes the irrigated vegetable in the food and crop mix, performed fairly well in terms of nutrition and income generation. The introduction of small-scale irrigation technologies allowed farmers to grow more crops, which not only increased the cash income at the household level but also the food diversity. The income from vegetable sales was instrumental in allowing the household to access and purchase supplemental foods items, mainly of animal source improving significantly the diet quality and diversity. Broad-base agricultural growth in staple food, vegetables, fruit and livestock production is key to reducing poverty and increase food security and nutrition in developing countries.

Key words: food security, simulation, irrigation, risk, nutrition

Introduction:

Global food security remains an important topic for the political and development agenda of many governments especially those in the developing world where the vast majority of the world's undernourished people are located (FAO, 2010). The 2016 Global Hunger Index (GHI) report shows that progress has been made since 2000 to reduce the proportion of hungry people where the level of hunger was cut by 29 percent in developing countries (von Grebmer et al., 2016). However, its levels are still alarming especially in African countries south of the Sahara as reported in the 2014 Global Hunger Index report. A widely accepted definition of food security describes it as a state "when all people at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life" (Leroy et al., 2015, p.169).

In addition to hunger and undernourishment that are characterized by a lack of minimum required caloric intake (1800 calories/day/person), the other aspects of hunger and food security that are often overlooked and ignored relate to micronutrient deficiency, known as "hidden hunger" (von Grebmer et al., 2014). While hunger globally affects around 805 million people, hidden hunger is estimated to reach two billion people around the world (IFPRI, 2015). A chronic lack and deficiency in minerals and vitamins can have long term and serious health consequences that include child and maternal death, physical disabilities, weakened immune systems, and intellectual deficits (Muthayya et al., 2013; Shetty, 2010). In developing countries a combination of deficiency for several micronutrients occur together and account for about 7% of global disease each year (Muthayya et al., 2013). Most notable deficiencies are in zinc and vitamin A, which were responsible for about one million child deaths according to the 2008 Lancet series on Maternal and Child Undernutrition. Several factors can lead to the "hidden hunger" such as unbalanced diet, diseases, impaired absorption, and increased micronutrient needs during certain life stages that include but are not limited to pregnancy, lactation, and infancy (von Grebmer et al., 2014, p.5). In developing countries, the micronutrients deficiency or hidden hunger is partly due to continuous consumption of cereal-based diets that lack diversity. The issue of hidden hunger can be mitigated and lead to better nutritional outcomes especially for children by increasing the food diversity (Kennedy et al., 2007; Shetty, 2010)

Despite notable progress made to reduce hunger in the last twenty five years that saw a reduction in the GHI score of 39 percent, it is noteworthy mentioning that global hunger reduction statistics tend to hide the disparities existing between countries and regions around the globe (von Grebmer et al., 2014). Compared to 1990 GHI scores, the 2014 GHI scores in Sub-Saharan Africa, South Asia, and Near East and North Africa are respectively 28 percent, 41 percent, and 40 percent lower. GHI Scores in East and Southeast Asia, Latin America significantly fell by 54 percent and 53 percent, respectively. South Asia and Sub-Saharan Africa still had the highest hunger scores in 2014 compared to the rest of the globe (18.2 and 18.2, respectively). South Asia, and East and Southeast Asia recorded the largest improvements with the deepest decline in GHI scores since 1990 of around 12 points in South Asia. Numbers of children underweight and their malnutrition levels were significantly reduced which contributed to the overall progress. The Sub-Saharan Africa (SSA) region has the highest regional GHI score, followed by South Asia. The SSA region started with lower GHI scores in the 1990 compared to South Asia but recorded less improvement over the years specifically during the period between 1990 and 2000 (FAO, 2010; von Grebmer et al., 2014). Several factors such as civil wars in the 1990s and 2000s, the HIV pandemic and other epidemic diseases such as malaria contributed to the decline and poor records on hunger and malnutrition. However as the wars wound down in the late

2000s, political stability allowed some economic growth, which combined with improvement in care for HIV and malaria prevention reduced significantly the child mortality rates.

In addition to civil wars and disease that continue to negatively affect the SSA region, other types of threats linked to frequent and unpredictable climate-related shocks pose serious risks to the stability and wellbeing of many households in SSA and beyond (IFPRI, 2015; UNOCHA, 2016). For instance, recurrent drought and episodes of famine are plaguing several parts of the Horn of Africa, including Ethiopia. In recent years, the needs for food aid has increased in Ethiopia due to severe drought caused by poor rains (e.g. 2010-2011 and 2015 droughts) and have put at risk around 7.5 million people, worsening the hunger and malnutrition status in households (FEWSNET, 2015; UNOCHA, 2016). Historically Ethiopia has known several droughts that led to famines and hunger but the worst and most memorable remains the one associated with the famine of 1983-1985. Since the early 1980s, several major droughts have hit Ethiopia with the majority of them resulting in famine (Diao & Pratt, 2007).

Ending hunger is one of the United Nations agenda on Sustainable Development Goals set up after the 2015 deadline for achieving the Millennium Development Goals (MDGs). One of the MDG's goal agreed upon by all the United Nations members was to cut by half the proportion of people suffering from hunger by 2015 (FAO, 2010). Although the issue of malnutrition and hunger is multifaceted and needs a multidimensional approach, part of the solution to combat malnutrition and hunger is to increase the food production and promote the consumption of balanced diets specifically in regions of food deficits. A study in Ethiopia by Diao and Pratt (2007, p. 207) identified that more than 50% of the poor people live in food-deficit areas where the staple food availability per household is half the national average level. Several studies conducted in Ethiopia (e.g. Farta woreda and in Addis Ababa) showed that between 58% and

70% of households sampled in 2012 lived below the food security level (Motbainor, Worku, & Kumie, 2015). Given that the majority of Ethiopia population depends on agriculture, broad-base agriculture growth, especially in staple food and livestock production, is key to reducing poverty and increasing food security. However, to achieve this goal, there is a need to reduce the productivity gap between the old and modern agricultural technologies that still exit in the farming community of Ethiopia (Bogale and Shimelis, 2009; Diao & Pratt, 2007).

Generally, the adoption and use of irrigation technologies has shown potential impact on poverty reduction and income generation and can play an important role in food price reduction (Rosegrant, Ringler, & Zhu, 2009; Namara et al., 2010). Moreover, the adoption and proper use of irrigation technologies contribute to an increase in the quantity and variety of crops produced as it allows households to have multiple cropping seasons (dry and wet seasons) and harvests which expands the variety of crops (e.g. vegetables) produced and consumed by the household (Domenech & Ringler, 2013). This is very critical for countries located in Africa South of Sahara where only about 4% of the cultivated area is irrigated, the lowest irrigation percentage compared to other countries. Despite a large irrigation potential, many SSA countries still lag behind in expanding irrigated area and could see a continuous decline in agricultural productivity associated with an increase in net food imports as their population continue to rise (Domenech & Ringler, 2013; Xie et al., 2014). Most of the time crops benefiting from irrigation expansion are vegetables grown during the dry season, their consumption and nutritional benefits are numerous for household families (Domenech & Ringler, 2013). The implications of using the small-scale irrigation (SSI)[1] technologies for family nutrition vary according to the types of crops grown and

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[1] Small-scale irrigation (SSI) technologies can be defined as small community-managed irrigation systems by individual or group of farmers on small plots over which smallholder farmers have control and use a level of technology they can operate and maintain effectively (see Carter and Howsam, 1994)

consumed. In addition, surplus crops can be sold and resulting revenues used to buy food items needed to complement nutritional needs at the household level, such as vegetables, which are rich in micronutrients needed for children nutrition. Irrigation systems improve as well the consumption of food products of animal origin due to potential increase in income and improved livestock productivity from feeds. Food products from animal sources are credited with providing and increasing the intake in vitamim A, iron, riboflavin, calcium, zinc and vitamin B12 (Shetty, 2010). Several studies have shown that a better socio-economic status is key to increasing food diversity and security at the household level (Barrett, 2010; Diao & Pratt, 2007; Kennedy et al., 2013; Per Pinstrup-Andersen, 2002).

In addition to producing enough food for consumption, which ensures availability, the food security concept requires as well accessibility and good utilization of produced food (Barrett, 2010; Domenech and Ringler, 2013; Domenech, 2015). While the accessibility relates to the well-being of the family, the utilization reflects more on the good use of the accessible food by individuals at the household level, and emphasizes the knowledge and practices of good nutrition (von Grebmer et al., 2014).

Combatting hunger and malnutrition, especially the “hidden hunger”, requires very specific and community-based approaches. Improving local food systems and encouraging the consumption of food produced by the household is key to succeeding in nutrition improvement (von Grebmer et al., 2014, p.32). For instance in one district (Mumbwa) of Zambia, reinforcing local food systems that are mainly cereal-based (maize) with homestead gardening and small-scale animal husbandry showed preliminary signs of nutrition improvement at the household. This approach was however, accompanied by several awareness campaigns on good nutrition and health that were facilitated by the government staff and programs.

It is in this line that a farm level economic and nutrition analysis model such as FARMSIM can be used to project changes in the level of food security and accessibility at the household level in Ethiopia that could be observed after adopting modern farming technologies. The model takes into account increased food production and income generated from adoption of improved agricultural technologies and its implication on nutrition through food production and purchase. The objectives of this paper are two-fold:

1) Show how adoption of irrigation technologies improve quantity and variety of food crops produced and consumed at the household level and its impact on nutrition
2) Evaluate how the increase of income and profit at the household level from sale of surplus crop production can improve nutrition at the household through purchase of supplemental food items

The rest of the paper is organized in three sections. First we offer a description of the farm economic and nutrition model (FARMSIM)[2] followed by the presentation of the base and alternative scenarios analyzed in the study. Third, we present the results and discussion, followed by the conclusions and implications on food nutrition.

Data source and study area

This study used both primary and secondary data farming information as input into the FARMSIM model. The primary data source consisted of a household and community survey[3] conducted in 2014 by the ILRI-LIVES project (Gebremedhin et al., 2015). The primary data

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[2] Detailed information on methods and results presented in this paper are from a research report for the Robit kebele, Amhara region of Ethiopia that was carried out under the Feed the Future Innovation Laboratory for Small Scale Irrigation (ILSSI: http://ilssi.tamu.edu/).

[3] For more information on the survey, see: https://lives-ethiopia.org/2014/06/06/baseline-surveys/

were supplemented by secondary data that included expert opinion, research articles, and reports from government and non-government agencies. The information from the survey and other sources were summarized according to the FARMSIM model input datasheet which requires information on crops, livestock, assets, liabilities and fixed and variable costs for a representative farm. The input data for a representative farm in Robit was drawn from a sample of 24 households.

The Robit village (kebele) is located in Bahir Dar Zuria district (woreda), West Gojam zone in Amhara region of Ethiopia approximately 20 Kms from Bahir Dar town (fig. 1). The village area has an average elevation of 1848 masl. According to the 2007 Ethiopia Census results a total of 8,900 people were living in the village (Population Census Commission, 2007).

A mixed crop-livestock production is the predominant farming system in the area where the main crops grown include maize, finger millet, teff, rice, and chickpeas. Crops are grown using both rain and irrigation water. Two major cropping seasons are identified in Ethiopia: *Kiremt* and *Bega*. *Kiremt* is the main rainy season (June-September) during which major field crops (mainly grains) are grown and harvested in *Meher* season. Irrigated crops such as tomatoes, grass peas, chickpeas, cabbage and onions are grown during the *Bega* season (dry from October to January). The main source of irrigation water is from shallow wells. Most of the households keep cattle, small ruminants, poultry, and bees (apiculture). Cattle are mainly raised to meet draught power requirements while milk, meat, manure, dung cake, breeding replacement stock are income sources, but are of secondary importance. The majority of the milk produced is retained for home consumption. However, some milk is processed into butter for sale and family consumption.

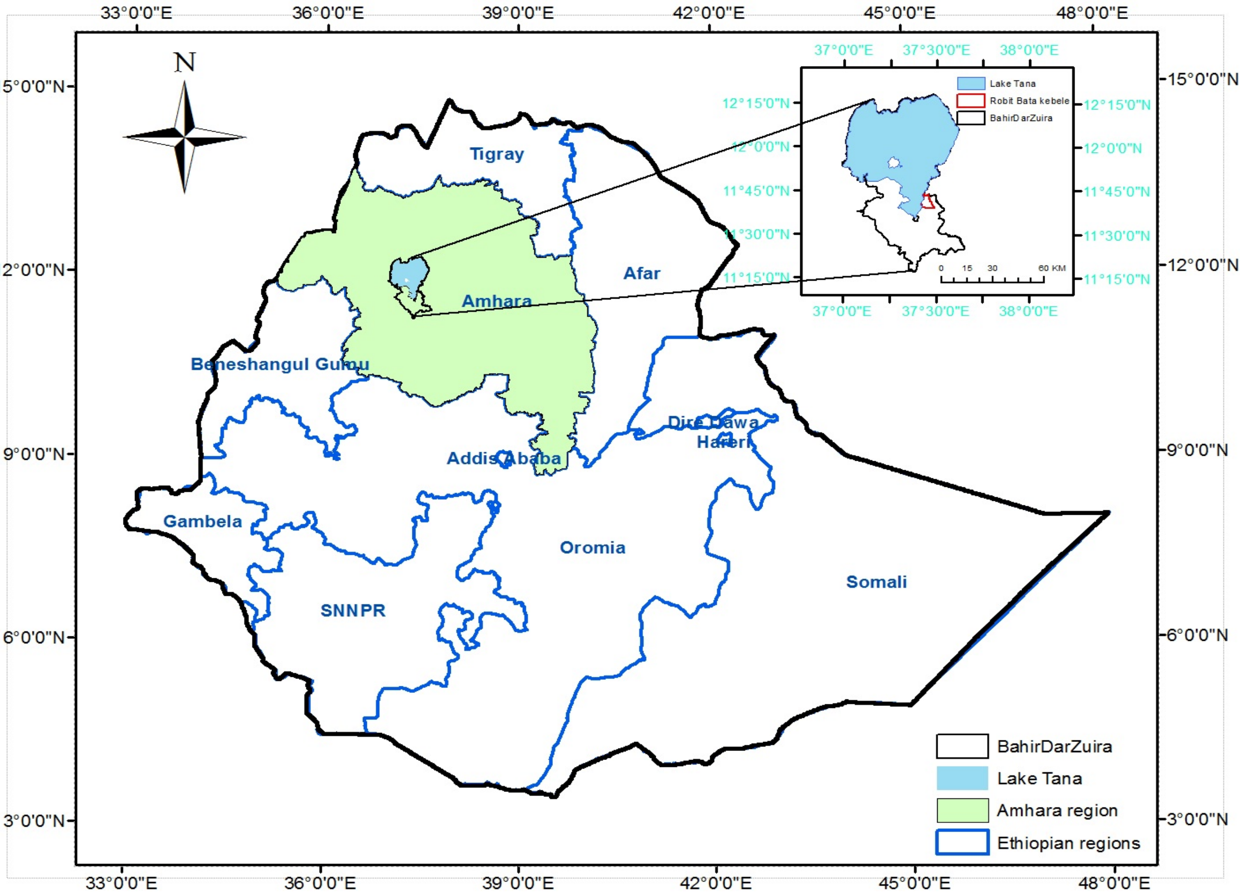

Figure 1. Location of Robit kebele in Bahir Dar Zuria woreda, Amhara region

Methods

1. Farm economic and nutrition simulation model (FARMSIM)

The farm simulation model "FARMSIM" is a Monte Carlo simulation model that simultaneously evaluates a baseline and alternative technologies for a farm. The model is programmed in Microsoft ® Excel and utilizes the Simetar© add-in to estimate parameters for price and yield distributions, simulate random variables, estimate probability distributions for key output variables (KOVs) and rank technologies (Richardson et al., 2006)[4].

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[4] FARMSIM is a micro-computer, Excel/Simetar driven, and an enhanced version of FLIPSIM designed to simulate smallholder farms in developing countries (Richardson and Nixon, 1985). FLIPSIM has been used extensively for policy analysis and technology assessment for farms in the United States.

FARMSIM is programmed to recursively simulate a five year planning horizon for a diversified crop and livestock farm and repeats the five-year planning horizon for 500 iterations[5]. A new sample of random values is drawn to simulate each iteration. After simulating 500 iterations, the resulting 500 values for each of the key output variables (KOVs) defines the empirical probability distributions to compare the base and alternative farming technologies. By comparing the probability distributions for the base and alternative technologies, decision makers can quantitatively analyze the probable consequences of introducing alternative farming systems (see flowcharts in fig. 2 and Appendix A).

FARMSIM is programmed to simulate 1-15 crops as well as cattle, dairy, sheep, goats, chickens, and swine annually for five years. The farm family is modeled as the first claimant for crop and livestock production with deficit food production met through food purchases using net cash income from selling surplus crops and livestock production. Standard accounting procedures are used to calculate: receipts, expenses, net cash income, and annual cash flows. The KOVs for the model can include all endogenous variables in the model but most attention is focused on the following KOVs: annual net cash income, annual ending cash reserves, net present value, benefit-cost ratio and annual family nutrient consumption of protein, calories, fat, calcium, iron, and vitamin A.

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[5] Extensive testing with the Latin Hypercube sampling procedure in Simetar has shown that a sample size of 500 iterations is more than adequate to estimate a probability distribution for KOVs in a business model with more than 100 random variables.

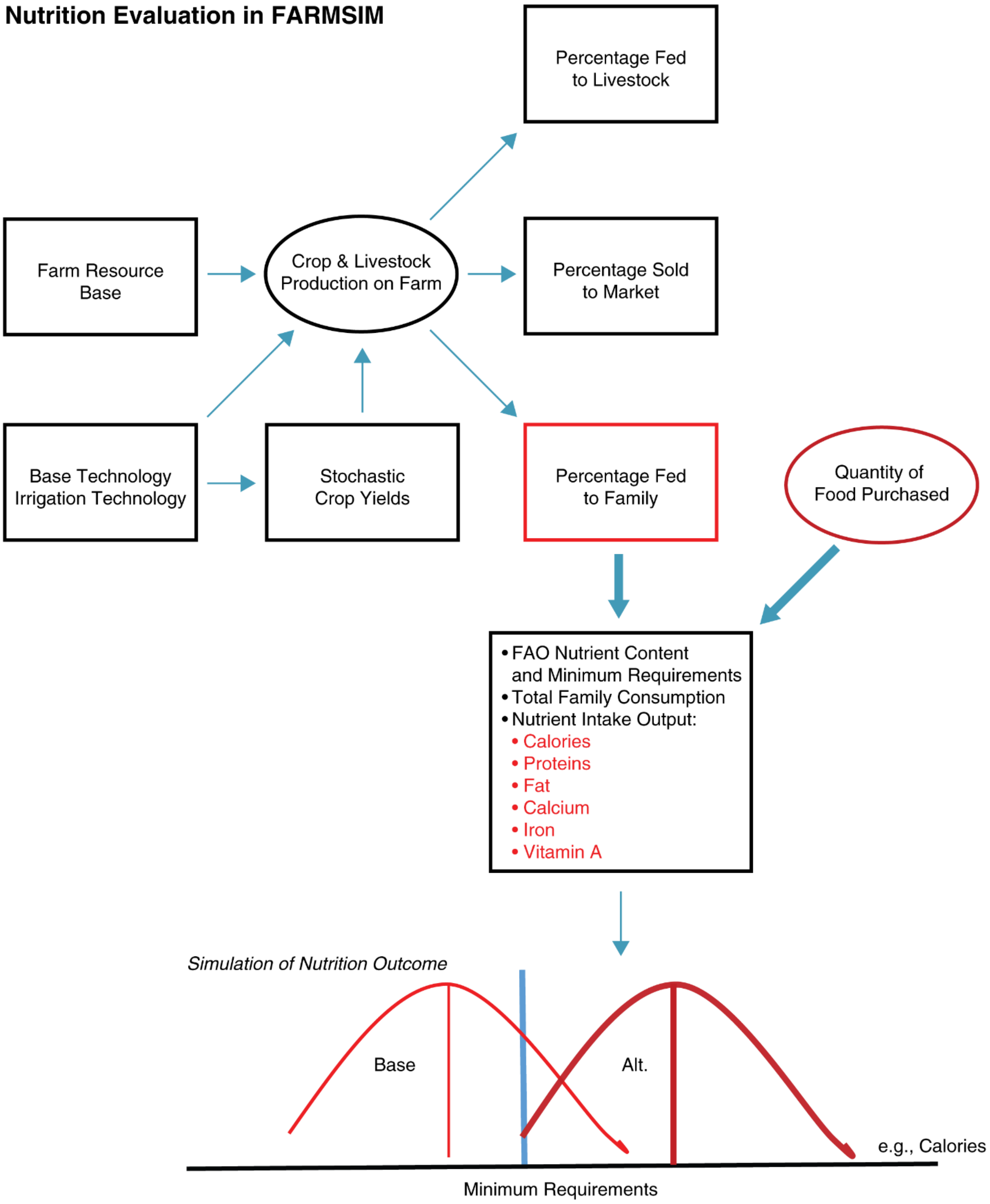

Figure 2. Nutrition simulation process in FARMSIM

Stochastic annual output prices for crops and livestock are simulated using multivariate empirical probability distributions estimated from historical data. Stochastic annual crop yields are simulated from multivariate empirical probability distributions estimated using 32 years of crop yields generated by APEX (Agricultural Policy / Environmental eXtender) (Williams et al., 1998). APEX uses the most recent 32 years of local weather data, soil conditions, and an internationally validated crop growth modeling algorithm to simulate 32 yields for the baseline and alternative cropping/irrigation systems. APEX simulates plant growth from planting through harvest for all crops on the farm using the base technology (seed, fertilizer, soils, etc.) and the alternative technology (improved seed, fertilizer, soils, irrigation, etc.). Both technologies are simulated by APEX using the same historical weather data and plant growth parameters consistent with the assumed technologies so the only difference between the yield distributions is the technology package.

The baseline and alternative technology scenarios are simulated by FARMSIM using the same equations so the only difference in the economic and family nutrition outcomes are due to the technology differences. The random crop yields are simulated using the same stochastic uniform standard deviates to insure that the weather risk for a crop under the base and alternative technology scenarios is identical. The same stochastic prices for crops are used for both scenarios, unless the alternative scenarios call for a different marketing program, which shifts the price distribution to a higher or lower level. Price flexibilities are as well included in the model to handle the price changes due to market demand and supply of agricultural products. Since the base and alternative models use identical equations, the decision maker can be assured that the differences in the KOVs are due to the differences in the two farming systems and their assumed yield distributions. The FARMSIM model has four major components: crop, livestock, nutritional, and financial. Since the focus of the paper is on nutrition and food security, only the nutrition component of the model is described in this study; see details on other model components in Richardson & Bizimana (2017).

In the nutrition simulation section of the FARMSIM model, the total kilograms of each raised crop consumed by the family plus the kilograms of purchased foodstuffs are multiplied by their respective nutrient scores to calculate total calories, protein, fat, calcium, iron and vitamin A from the food stocks. Similar calculations are made to simulate the nutrients derived from consuming cattle, oxen, milk, butter, chickens, eggs, mutton, lamb, nannies, kids, and pig meat. Total nutrients consumed by the family from all sources, including donated food, are summed across plant and animal food stocks and compared with minimum daily recommended amounts for adults based on the FAO minimum requirements standards (FAO & WHO, 2001; FAO, 2010) . The average minimum daily requirements (MDR) per adult equivalent of the six basic nutrients are available in the model and can be adjusted by the user. The default values are:

- MDR calories per adult equivalent are 1,750-2100
- MDR grams of protein per adult equivalent are 41-56
- MDR grams of fat per adult equivalent are 25-30
- MDR grams of calcium per adult equivalent are 0.8-1
- MDR grams of iron per adult equivalent are 0.009
- MDR grams of vitamin A per adult equivalent are 0.0006

FARMSIM is capable of evaluating the nutrition status by comparing the potential for current and alternative scenarios to increase food nutrition after adoption of alternative agricultural technologies. The model can be used for policy analysis as it considers different crops produced and how income can be targeted to purchase specific food items designed to improve nutrition.

The quantity of the crop that can be sold is the residual after subtracting the quantity consumed by the family and livestock. Family consumption and livestock feed requirements are identities that are simulated as:

$$Family\ Consumption_{it} = QF_i * \ No.Adult\ Equivalent$$

QF_i is the minimum quantity of crop i consumed per adult equivalent per year and

No. Adult Equivalent is the number of adult equivalents in the farm family.

Nutrition calculations for the farm family extend FARMSIM beyond traditional farm budget and whole farm simulation models. The nutritional values for all crops and livestock products (meat, milk, and eggs) consumed by the family are simulated using FAO's nutrient values for each crop and livestock product (FAO & WHO, 2001), based on their average content of protein, calories, fat, iron, calcium and vitamin A. The formula to simulate protein intake for the farm family is:

$$\tilde{P}rotein_t = [\textstyle\sum_i \ (Family\ Consumption_{it} + Purchased\ Crop_{it}) *$$

$$Grams\ of\ Protein\ /Unit\ of\ Crop\ i] + [\textstyle\sum_j \ (Family\ Consumption_{jt} + Purchased$$

$$Livestock\ Product_{jt}) * Grams\ of\ Protein\ /Unit\ of\ Livestock\ Product_j]$$

The protein equation is repeated for each of the remaining nutrient categories of: calories, fat, iron, calcium and vitamin A. Probability that the farm family's nutritional intake exceeds the FAO recommended daily requirements is calculated annually over the 500 iterations for each of the six nutrient categories to determine the probability that a particular nutrient is not deficient. The formula for each nutrient is the same as the equation for protein.

$$P(Protein_t) = \textstyle\sum_s \ (1\ if\ Protein_{ts}\ /\ 365 > Daily\ Minimum\ Reg, 0\ else)\ /\ 500$$

2. Baseline and alternative scenarios

Data input in FARMSIM is entered in parallel for the baseline and alternative scenarios. For each input variable the user must provide information for the current (base) and alternative farming system (scenario) (see flowchart in Appendix A). The model is designed so the user can enter complete data sets for the baseline and up to 21 alternative scenarios. Due to recurrent drought episodes observed in Ethiopia, small-scale irrigation technologies were considered in this study to grow vegetables and fodder on a farm in Robit village. Small-scale irrigation technologies enable smallholder farmers to have dry season crops that provide improved nutrition and generate income with less risk, provided a sustainable source of water for the land area to be irrigated; they can as well be used for supplemental irrigation when rain season is delayed or cut short during the cropping season.

The scenario analysis allows the user to evaluate the impact of water lifting technologies on crop irrigation and production in dry season as well as the impact of consuming diversified foods (that includes vegetables and animal products) on nutrition at the household level. Optimal fertilizer applications were assumed for the alternative scenarios while current fertilizer rates were used for the baseline conditions. The water lifting technology contributes to the increase of irrigable land and expansion of the variety of vegetable crops grown on a household farm. Given that most of the water used for irrigation in Amhara is groundwater from wells, four different water lifting technologies ranging from pulley/bucket and tank, to rope and washer pump, to motor and solar pumps were evaluated for their capacity and affordability. Field studies conducted in Robit site by IWMI-ILSSI staff through during field trials (2015-2016) showed that farmers preferred to use a pulley instead of a rope and washer pump (Petra Schmitter, personal communication)[6]. For this reason, only scenarios using the pulley/bucket and tank water lifting technology (referred to as "pulley") were analyzed in the study; see details on analysis of other irrigation systems in Robit in Richardson & Bizimana (2017).

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[6] Petra Schmitter is a researcher at the International Water Management Institute (IWMI) and an ILSSI team member.

Besides evaluating the impact of irrigation tools (WLT) on food production increases, the variety of food crops consumed from production and purchased determine the nutrition value and dietary quality of the food consumed by the family members. The dietary diversity score metric will be introduced as well to measure the changes and improvement of nutrition value between the baseline and alternative scenarios.

Three major cereal crops consistent with the current cropping systems in Robit are studied; they comprise maize, teff and millet grown during the wet season. In addition to cereal crops, chickpeas, potato, cabbage, tomato, fodder (oats and vetch) and napier grass are included in the model (table 1).

Table 1. Crop mix and land allocation (ha) scenarios for Robit kebele

Scenarios	Millet	Teff	Maize	Chickpeas	Potato	Irrigated Cabbage	Irrigated Tomato	Irrigated Fodder	Irrigated Napier	**Total (ha)**	Irrigated land losses
	Wet season					Dry season					
Baseline	708.0	266.0	728.0	57.0	24.0	126.0	102.0	43.0	43.0	2,097.0	
ALT.1 P_All	708.0	266.0	728.0	110.0	50.0	228.0	204.0	145.0	63.0	2,502.0	
ALT.2 P_NoVeg	708.0	266.0	728.0	110.0	50.0	0.0	0.0	148.0	63.0	2,073.0	***-438 ha***
ALT.3 P_NoFod	708.0	266.0	728.0	110.0	50.0	356.0	332.0	0.0	0.0	2,550.0	***-376 ha***
ALT.4 P_NoPC	708.0	266.0	728.0	0.0	0.0	240.0	216.0	157.0	63.0	2,378.0	***-160 ha***

Legend:
Baseline: current fertilizer + no or minimal irrigation;
ALT.1_P_All: irrigate tomato, cabbage & fodder with pulley + Potato & chickpeas + recommended fertilizer
ALT.2_P_NoVeg: irrigate fodder with pulley + No vegetables + Potato & chickpeas + recommended fertilizer
ALT.3_P_NoFod: irrigate tomato, cabbage with pulley+ No fodder + Potato & chickpeas+ recommend fertilizer
ALT.4_P_NoPC: irrigate tomato, cabbage & fodder with pulley + No potato & chickpeas + recommended fertilizer

Several literature sources, including a recent household survey carried out in Robit by the ILRI-LIVES project indicate that a relatively adequate amount of fertilizer (DAP and Urea), close to the recommended rates, is used in household farms in Robit for maize and millet (Minot & Sawyer, 2013; Rashid, 2013). Increased levels of fertilizers were used for teff in the alternative scenario. As for chickpeas and potato, additional fertilizers were applied in alternative scenarios for potato since chickpeas did not show any stress for phosphorus and has the capability of fixing nitrogen (tables 2 and 3). The survey information shows that most of the households used stored seeds from the previous harvest for planting and that the use of chemicals was limited. It was also noted that the level of farm labor hiring for agricultural production was low since family members performed most of the agricultural tasks. It is worth mentioning that, the use of actual crops to feed animals is not common as most of the animal feed comes from crop residues. However, for this study animal feed based on fodder (oats & vetch) were fed to cattle to increase milk and meat production. Napier was mainly produced for market sale whose income and profit are used to purchase any supplemental food items that the family needs for their nutrition enhancement.

The irrigated crops are grown during the dry season and consist mainly of tomato and cabbage in the vegetable category and fodder (vetch/oats) and napier grass in the animal feed category. While the required fertilizer rates for tomato were applied for the alternative scenario (Urea: 200 Kgs/ha and DAP: 50 Kgs/ha), household data from the ILRI-LIVES survey showed only limited application of fertilizer for the baseline scenario (table 2). Only Urea was applied by a few households at a rate of 150 Kgs/ha (average of all 10 households was 56 Kgs/ha) while no farmer applied DAP. In the case of cabbage, the baseline and alternative scenarios differed as to the quantities of applied irrigation water and subsequent water stress levels, which were at 50% for the baseline and 0% for the alternative scenarios. However, similar amounts of fertilizer rates were applied for both scenarios. For fodder and napier grass, additional amounts of fertilizer beyond the current levels were applied. Details for crop yields and associated input costs for the baseline and alternative scenarios are provided in table 3. Following are the five scenarios.

- Baseline: current fertilizer + no or minimal irrigation
- Alt.1 (Pulley-All): irrigate vegetables, fodder and napier with pulley + Optimal fertilizer
- Alt.2 (Pulley_NoVeg): irrigate fodder and napier with pulley + Optimal fertilizer (no vegetables grown)
- Alt.3 (Pulley_NoFod): irrigate vegetables with pulley/tank & hose + Optimal fertilizer (no fodder & napier grown)
- Alt.4 (Pulley_NoPC): irrigate vegetables, fodder and napier with pulley + Optimal fertilizer (no potato & chickpeas grown)

Table 2. Current and recommended annual application rates of Urea and DAP in Robit

	Fertilizers (Kgs/ha)			
Crops	Urea (Kgs/ha)		DAP (Kgs/ha)	
	Current	Recommended	Current	Recommended
Teff	36	100	88	100
Maize	83	100	70	100
Millet	60	0	80	100
Tomato	56	200	0	200
Cabbage	8	100	0	40
Chickpeas	0	-	25.6	-
Potato	13.3	100	90.7	60
Fodder (oats & vetch)	0	100	0	100
Napier grass	0	100	0	100

Table 3. Mean crop yields (Kg/ha) and input costs (Birr/ha) for the baseline and alternative scenarios in Robit

	Baseline scenario				Alternative scenario			
Crops	Mean yield	Cost fert.	Cost seed	Cost irrig.	Mean yield	Cost fert.	Cost seed	Cost irrig.
Teff	838	1614	470	0	1995	4800	470	0
Maize	2127	4284	476	258	2773	4284	476	258
Millet	1640	3110	46	0	2257	3110	46	0
Tomato	14293	783	420	258	21714	642	420	10757
Cabbage	11376	110	880	258	18089	110	880	10757
Chickpeas	1274	358	122	258	1274	358	122	258
Potato	3770	0	0	736	7728	1504	2595	736
Fodder (oats & vetch)	1398	0	300	258	3285	3000	1200	10757
Napier grass	10936	926	234	258	10936	926	234	10757

3. Livestock production technologies

Improving animal feed resources can have a tremendous impact on both household income and nutrition through the production, consumption and sale of live animals and animal products such as milk, butter and meat. In this study small scale irrigation (SSI) technologies along with fertilizer application were used to grow and improve yields of fodder and napier grass with the purpose of feeding animals and generating income. Supplementing animal feeding with fodder and napier grass is expected to increase milk production and animal live weight which in turn will improve the family nutrition through milk and meat consumption and generates income through the sale of live animals and animal products.

Livestock production technologies were aligned with crop production and water lifting irrigation technologies (table 4). In the baseline scenario, fodder crops (oats & vetch) and napier grass are grown on limited land with minimal irrigation and fertilizer applications. However, in the alternative scenarios, more land is allocated to fodder and napier especially during the dry season due to irrigation. Additional land area covered by irrigation for fodder and napier grass varies according to the water lifting technology pumping capacity. Higher fertilizer rates are also utilized in the alternative scenarios compared to the baseline. A portion of the total production of fodder and napier grass is fed to cows and bulls to increase the production of milk and meat while the remainder is sold to generate income. For instance, the input data information for fodder quantity produced from a single cut, based on yield (1400 Kgs/ha) and allocated land per farm (0.02 ha) for the baseline scenario in Robit, shows that the household uses all of the fodder production for feeding. For the alternative scenarios, yields are doubled and allocated land for fodder tripled so the household produces a surplus of fodder for sale after satisfying the animal feeding needs.

Preliminary results on the calculations of meat and milk production from a single cut of fodder (vetch & oats mix) and napier grass were produced by researchers at the International Livestock Research Institute (ILRI) (ILSSI mid-term report, October 2016)[7]. Assuming all forage is used for production and none for maintenance purposes and considering local cattle breeds feeding with fodder (oats & vetch) and napier grass, there is on average a live weight gain of around 52.4 Kgs and an improved milk yield of 312 liters per year per cow. In this study we assumed also an adoption rate of 60% for the livestock technology based on feeding animals fodder and napier and doubling the 30% rate of adoption indicated by the ILRI-LIVES household survey. The

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[7] Find the report at: http://ilssi.tamu.edu/media/1389/final-ilssi-mtr-6-dec-16-3.pdf

number of cattle is held constant for the 5 year planning horizon. Following are the baseline and alternative technology scenarios for livestock:

- Baseline: No or minimal irrigation + current animal feeding (no supplemental feed)
- Scenario 1 (ALT1): Irrigation of fodder & napier w/pulley + supplemental fodder feeding
- Scenario 2 (ALT2): Irrigation of fodder & napier w/pulley + supplemental fodder feeding
- Scenario 3 (ALT3): No fodder & napier irrigation + no supplemental feeding
- Scenario 4 (ALT4): Irrigation of fodder & napier w/pulley + supplemental fodder feeding

Table 4. Input variables and livestock technology scenarios in Robit kebele

	Baseline	ALT1	ALT2	ALT3	ALT4
Cows					
Native	2640	2640	2640	2640	2640
Cross-breds	165	165	165	165	165
Milk per cow					
Liters/cow/year	185	312	312	185	312
Live Weight gain (Kgs)	0	52.4	52.4	0	52.4
Live weight /bull	184	236.4	236.4	184	236.4
Consumption			Percent (%)		
Milk by family	28	38	38	28	38
Milk by employees	0	0	0	0	0
Made into butter	70	50	50	50	50
Butter sold	54	54	54	54	54

Nutrition evaluation in this study requires more than one approach (besides the nutrient simulation through FARMSIM) to assess whether the farm families in Robit kebele are accessing enough food and quality foods with the required nutrients. Part of this process is to have a balanced and diversified nutrition that goes beyond the caloric requirements needed for minimal food security. For this reason, the use of a dietary diversity score approach will help determine the individual foods and food groups that the household families consume and compare among the scenarios which ones provide more diversified foods.

Dietary diversity score (DDS) as a measure of nutrition and food access

Micro-nutrients deficiency or hidden hunger is a growing concern in the fight against hunger that is often overlooked since the common perception of hunger is more related to lack of calories than other nutrients. It is mainly characterized by the lack of essential vitamins and minerals that are key to the human well-being and development and whose consequences can have long-term and irreversible health problems (FAO & WHO, 2001; Kennedy et al., 2011; von Grebmer et al., 2014). Nutritionists and health care professionals recognize that dietary diversity is key to not only provide high quality diets but also combat malnutrition that include the lack of micronutrients (Kennedy et al., 2011; Leroy et al., 2015; Ruel, 2003). The increase in food variety is recommended in most dietary guidelines and recognized by nutritionists as a path to improved nutrition and health. It is worth noting as well that the issue of low dietary diversity affects more poor populations in the developing world than any other parts of the globe as most of their diets are based on cereals with limited consumption of animal products, fruit and vegetables. However, despite the importance of the dietary diversity metric, there is still no unified approach on how to measure the dietary diversity, and develop and validate its indictors. Dietary diversity or dietary variety refers to the number of individual foods or food groups consumed over a given time period (Ruel, 2003). The dietary diversity can be measured at the household or individual level through the use of a questionnaire and is often evaluated by counting the number of food groups instead of food items consumed (Kennedy et al., 2011). At the household level, the dietary diversity generally reflects a measure of access to food; while at individual level it reflects dietary quality, mainly micronutrient adequacy of the diet. The reference period can vary, but it is generally the previous day or week.

As previously stated, nutrition professionals recognize dietary diversity as a key element of diet quality, especially when measured at the individual level, because the consumption of diversified foods ensure the intake of essential nutrients and good health. A direct scoring method has been developed to measure the dietary diversity at the household or individual levels. Dietary diversity scores are built using a simple count of food or food groups consumed over a given period, usually a 24 hours period or a week. Some dietary diversity indicators have as well been developed to measure food security that include the Household Dietary Diversity Score (HDDS), the Infant and Young Child Dietary Diversity Score (IYCDDS), the Women Dietary Diversity Score (WDDS) (Leroy et al., 2015). In line with the FARMSIM nutrition analysis and outcome, the HDDS scoring will be used to define the food availability and access and the overall food security at the household level. The HDDS was originally developed to measure changes in access to adequate quantity and quality of food at the household level and to evaluate the impact of programs (Leroy et al., 2015, p. 184). In general, the HDDS has been shown to be a good indicator of household access to food, one of the components of food security but was not tested for its robustness to determine the quality of food access. Also note that no cut off point was established for the HDDS to categorize households as food secure or food insecure. A standardized tool (questionnaire) was developed to measure the dietary diversity and can be administered either at the household or individual level (Kennedy et al., 2011). The questionnaire uses an open recall method to collect information on all the foods and drinks consumed by the household or individual over the previous 24 hours. The questionnaire has been adapted to facilitate data collection from the FANTA Household Dietary Diversity Score Indicator Guide (see questionnaire in Appendix B). The information on consumption collected from the questionnaire relate to 16 food groups; no cutoff point had been defined to classify household with low or adequate food diversity.

Nutrition and economic simulation results

In general, adoption and proper use of agricultural technologies leads to an increase in the amount and variety of crops produced. With the increase in production per unit area, households enjoy surplus production, which increases the quantity of food crops sold at the market for added income. The implications for family nutrition vary according to the types of crops grown and consumed. However, surplus crops can be sold and resulting revenues can be used to buy food items needed to complement nutrition. This study will consider both avenues of improving nutrition through production and purchase.

1. Current status of food consumption and nutrition in Robit (baseline scenario)

First, an assessment of the current situation (Baseline scenario) of food consumption by a representative household in Robit kebele is summarized from the survey data collected by the ILRI-LIVES project[8] (table 5). The summary results show on average that a typical household in Robit has a cereal-based diet dominated mainly by the consumption of teff and maize which represent about 63% of the total amount (in Kgs) of food items consumed by the family in a week. The consumption of vegetable and fruits represents about 5% of total amount (in Kgs) of all food items while the quantity of pulse (beans and peas) account for 9% of the total amount of food consumed by the farm family. Notice that products of animal origin were not at all

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[8] Given that there were no food consumption data collected on Robit kebele we used data from two other kebeles located near Robit on Lake Tana (Wenijata and Wegelsa kebeles).

consumed (zero percent of total amount consumed). However, conclusions cannot be drawn given that only a small number of households was reported in the survey.

Table 5. Average quantity of food items (Kgs) a household consume per week in Robit kebele

Food items	Hh #1	Hh #2	Hh #3	Hh #4	Hh #5	Hh #6	Hh #7	Avg. Qty. Food /wk/Hh (Kgs)
Teff	4	0	14	18	10	10	4	8.6
Maize	10	10	24	30	24	10	10	16.9
Rice/millet/barley	6	0	0	0	6	0	4	2.3
Beans	4	4	0	0	0	4	4	2.3
Peas/lentil	4	5	0	0	1	0	0	1.4
Fruits	2	4	0	0	0	2	0	1.1
Vegetables	2	4	0	0	0	0	0	0.9
Tubers	4	6	0	0	0	0	0	1.4
Animal products (milk, butter, eggs cheese, meat)	0	0	0	0	0	0	0	0.0
Fish	0	10	0	0	0	0	0	1.4
Spices/pepper/salt	2.5	2.5	3.5	4.5	1.5	2	5.5	3.1
Sugar	0.5	0.5	0	0.3	0	2	0	0.5
Cooking oil	0.5	0.5	0.5	0.5	1	1	1	0.7

Based on principles of good nutrition (discussed above), which are characterized by the consumption of a diverse range of food items, the survey results indicate a lack of variety and diversity of food items consumed and hence a low quality nutrition. Diets predominantly based on starchy staples and cereals but poor in micronutrients are characteristic of food insecure areas and contribute to the malnutrition issue (Arimond and Ruel, 2006; Kennedy et al., 2011). Food based-approaches to combat malnutrition often recommend dietary diversity and the consumption of a wide range of food across different food groups to ensure adequate micronutrient intake. Dietary diversity and nutritional status, which are strongly related, tend also to indicate the household socio-economic status where families with higher income and economic resources are more likely to consume more diverse diets than poor households (Arimond & Ruel, 2004).

Other aspects of food security, besides the quality of diet determined by diversity, relate to food availability, accessibility and stability at the household level. The baseline scenario summary results indicate a good access and availability of calorific diets but does not assure future access and availability of other type of nutrients such of proteins, fat, calcium, iron, vitamin A and other macro and micronutrients. In other words, there is no assurance for families to obtain sufficient quantity and quality food that meet nutritional and health requirements with the ability for households to make choices and consume their preferred foods (Leroy et al., 2015).

To assess the potential of increasing food security through food production and diversification at the household level, small-scale irrigation technologies are evaluated using farm level simulation. Beside the multiple use of irrigation water in various household activities that include sanitation, irrigation in Sub-Saharan Africa is seen as a way to reduce malnutrition incidence by enhancing food security and nutrition (Domenech, 2015). Following is a summary results from simulation of the baseline and alternative technologies showing their impact of using of irrigation to improve nutrition and food security through food diversification.

2. Economic variables simulation and food purchase options

The evaluation of food security and nutrition is based both on the amount of food produced and consumed on the farm by the family and that acquired by purchase at the market, which depends on the cash available. The simulation results of the baseline and alternative scenarios indicate on average the cash availability and nutritional quantities intakes for the calories, proteins, fat, calcium, iron and vitamin A (table 6).

The economic indicators in table 6 show a high NPV average for ALT1 that involves the use of a pulley to irrigate vegetables and fodder in the dry season in addition to growing potatoes and chickpeas. It is followed by ALT4 that uses a pulley for vegetable and fodder irrigation but where potatoes and chickpeas are not grown. Notice that ALT2, which does not consider growing vegetables, has the lowest average NPV value. Similar results are observed for the net cash farm income (NCFI) which represents the cash profit at the household level. ALT1 and ALT4 have the highest average cash profit compared to the other scenarios.

Table 6. Economic and nutritional impacts of SSI and food category consumed in Robit

	Baseline	ALT1_P_All	ALT2_P_NoVeg	ALT3_P_NoFod	ALT4_P_NoPC	
Averages values/family in year 5						
Net present value	129415	175234	120162	171119	172373	
Avg. net cash income	21265	29902	15814	29061	29787	
min net cash income	2375	7188	-5090	8965	7093	
max net cash income	66356	76572	58071	78612	76460	
Averages daily nutrients in year 5						Min. required
Energy (calories/AE)	2364	3167	3083	3150	2995	1750
Proteins (grs/AE)	59	79	75	79	74	41
Fat (grs/AE)	25.0	34.7	32.7	33.6	33.7	39.0
Calcium (grs/AE)	0.22	0.39	0.31	0.37	0.33	1.00
Iron (grs/AE)	0.018	0.026	0.025	0.026	0.024	0.009
Vitamin A (grs/AE)	0.0026	0.0061	0.0054	0.0061	0.0007	0.0006

Note: numbers in red indicate deficits or shortage to meet minimum requirements

Legend:
Baseline: current fertilizer + no or minimal irrigation;
ALT1_P_All: irrigate tomato, cabbage & fodder with pulley + Potato & chickpeas + recommended fertilizer
ALT2_P_NoVeg: irrigate fodder with pulley + No vegetable + Potato & chickpeas + recommended fertilizer
ALT3_P_NoFod: irrigate tomato, cabbage with pulley+ No fodder + Potato & chickpeas+ recommended fertilizer
ALT4_P_NoPC: irrigate tomato, cabbage & fodder with pulley + No potato & chickpeas + recommended fertilizer
AE = Adult Equivalent

It is worth noting that ALT2, which does not consider growing vegetables, has the lowest average cash profit, ranking behind the baseline scenario. The simulation results based on the cumulative distribution function chart (fig. 3) show that the alternative scenarios ALT1, 4 and 3 generated higher net cash farm income (NCFI) than the baseline and ALT2 at all probability levels, so their CDF values lie completely to the right of the other scenarios for all 500 draws of the model. Alternatives 1, 4, and 3 are considered first degree stochastic dominant over the baseline and ALT2 by all decision makers.

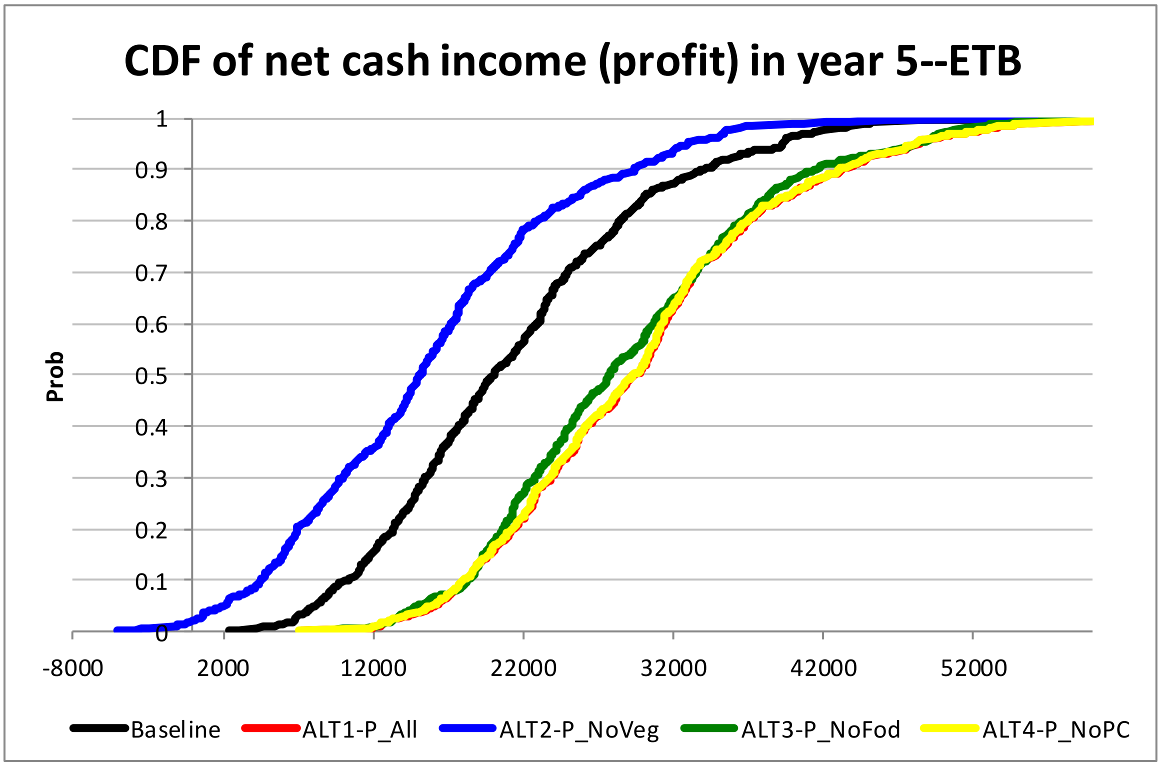

Figure 3. CDF of NCFI in year 5 for Robit kebele, Amhara region

A StopLight chart presents the probabilities of NCFI (profit) being less than 15,000 ETB (Ethiopian Birr) (red), greater than 29,000 ETB (green), and between the two target values (yellow) for the last year of the five-year planning horizon (2016-2020) (fig. 4). The target values are average profit for the lowest performing scenario (ALT2) for the lower bound; and the highest performing alternative scenario (ALT. 1, 4 and 3) for the upper bound. In basic terms, reading from the chart, scenarios with more red section show a low performance while those with more green are the best performing scenarios. Results in figure 4 indicate that, for a representative farm in the baseline scenario with current practices, there is a 28% probability that NCFI will be less than 15,000 ETB and a 19% probability that NCFI will exceed 29,000 ETB in year 5. Notice that a representative farmer in ALT2 where vegetables are not grown has the lowest probability (49%) that cash profit will exceed 15,000 ETB in year 5 and only an 11% probability of cash profit exceeding 29,000 ETB. In contrast, for representative farmers in ALT1, 3 and 4, there is between 46 % and 51% probability that annual cash profit will exceed 29,000 ETB and between 4% and 5% that the profit will be less than 15,000 ETB.

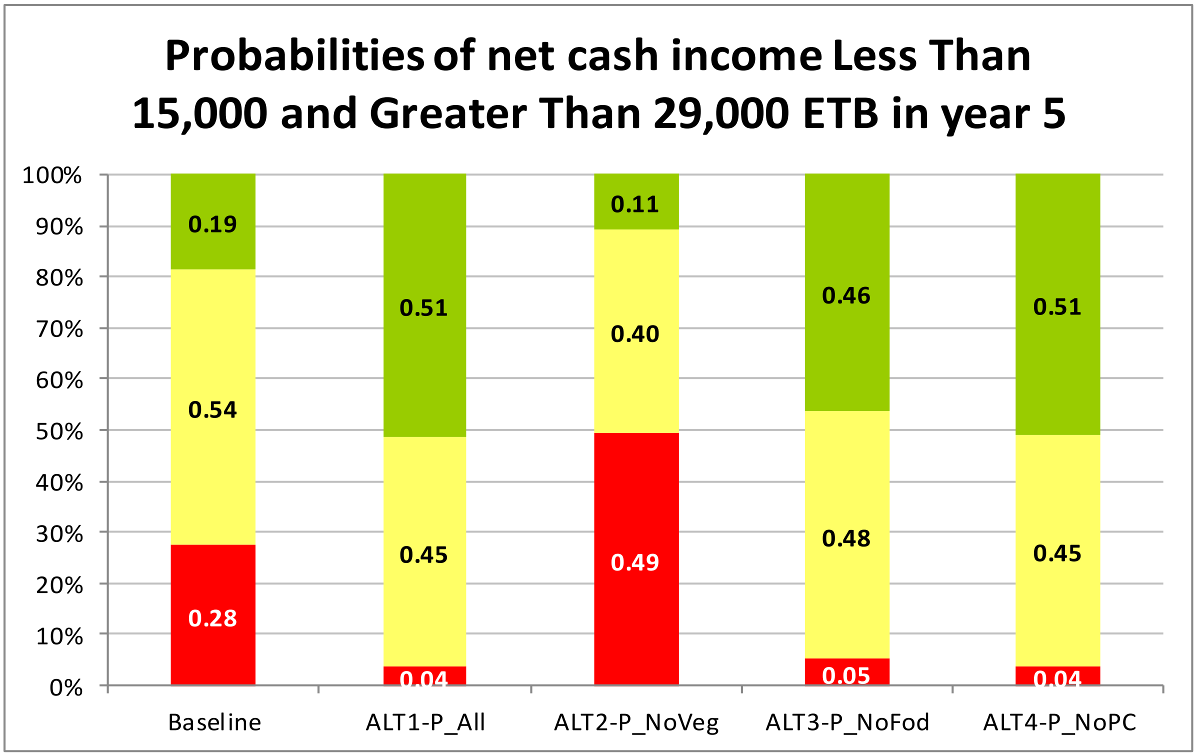

Figure 4. StopLight chart for per-family NCFI in Robit kebele, Amhara region

Overall results show that removing vegetables from the crop mix led to large NCFI losses that farm families could gain by irrigating and producing vegetables (tomato and cabbage) during the dry season and selling them at the market to generate revenues. Notice that the removal of fodder (ALT3-NoFod) or potatoes and chickpeas (ALT4-NoPC) in the crop mix does not show much variation in terms of revenue generated as the cultivated land loss is much smaller, compared to the scenario considering the vegetable cultivation (ALT1). With enough cash profit at hand, farm families adopting alternative scenarios ALT1, 3 and 4 can afford to purchase supplemental food items for nutrition. The main food items purchased by the farm family considered in this study to supplement nutrition consisted of products of animal origin such as meat (beef and chicken), milk and eggs in addition to purchasing other staple food such as rice and horse beans (table 7).

Table 7. Food of animal origin consumed per year at village and household level--Robit

	Baseline scenario		Alternative scenarios	
Food items (in Kgs)	Raised	purchased	Raised	purchased
Village level (1980 HH)				
Milk in KG	49244	0	94368	30000
Eggs in KG	5160	0	5160	5040
Chicken in KG	4075	0	4075	2000
Beef in KG	3478	0	3478	2000
Lamb in KG	1712	0	1712	0
Goat Meat in KG	30	0	27	3
Pig Meat in KG	0	0	0	0
Butter in KG	3432	0	4846	0
Household level (1 HH)				
Milk in KG	25	0	48	15
Eggs in KG	3	0	3	3
Chicken in KG	2	0	2	1
Beef in KG	2	0	2	1
Lamb in KG	1	0	1	0
Goat Meat in KG	0	0	0	0
Pig Meat in KG	0	0	0	0
Butter in KG	2	0	2	0

Note: Information was summarized from a household survey data collected by ILRI-LIVES project.

Only a fraction of the total net cash available (about 10%) was used to purchase supplemental food. It is worth mentioning that additional quantities of foodstuff from animal origin consumed at home were made available as well due to the improvement in animal productivity that targeted the increase in meat and milk production (see description above in section 3 on livestock). For instance with improved animal feeding, milk production doubled and the family consumption fraction increased by 10%. Nutritional impacts due to the increased quantities of proteins, fat, calcium, iron and vitamin A for the alternative scenarios under the purchase option showed significant improvement for nutrient intake (table 8).

Table 8. Change in nutrient intake for alternative scenarios under purchase option

Nutrients	Baseline	Purchase scenarios ALT 1 (Buy: eggs,	 ALT 3 milk, chicken	 ALT 4 & beef)	No purchase scenario ALT 2	% change in nutrient from Baseline to Alt .scenario with purchase
Proteins (gr/AE)	59	79	79	74	75	31%
Fat (gr/AE)	25.0	34.7	33.6	33.7	32.7	36%
Calcium (gr/AE)	0.22	0.39	0.37	0.33	0.31	65%
Iron (gr/AE)	0.018	0.026	0.026	0.024	0.025	40%
Vitamin A (gr/AE)	0.0026	0.0061	0.0061	0.0007	0.0054	65%

3. Nutrition variables simulation

Overall simulation results show that in Robit kebele, the quantities of crops and livestock products consumed by families in both the baseline and alternative scenarios met minimum daily requirements for calories, proteins, iron and vitamin A but were insufficient for calcium and fat (see more detailed information on minimum requirements in FAO & WHO, 2001 and FAO, 2010). Moreover, the ILRI-LIVES survey shows that individual households did not currently purchase large quantities of food or receive any food aid to supplement the food they produce. Simulation results for each of the nutrition variables analyzed in this study are discussed below in details.

Calorie intake

Grain or cereal crops represent the basic staple food and a source of calories (or energy) in many developing countries with agriculture-based economies, including Ethiopia. In this study, the grain crops analyzed are teff and maize. Survey information shows that, on average, 72% of all grains produced by households in Robit kebele are consumed at home. The allocation of large land areas to the grain crops and the use of fertilizer contributed to an increase in grain production and mitigated any deficiency in energy and calories requirement per adult for both the baseline and alternative scenarios. In fact, for a typical household in Robit kebele, the simulation results indicate an average daily calories intake of 2360 and 3100 calories, respectively for the baseline and alternative scenarios, which is significantly higher than the daily minimum requirement of 1750 calories per adult equivalent (AE) (fig. 5a).

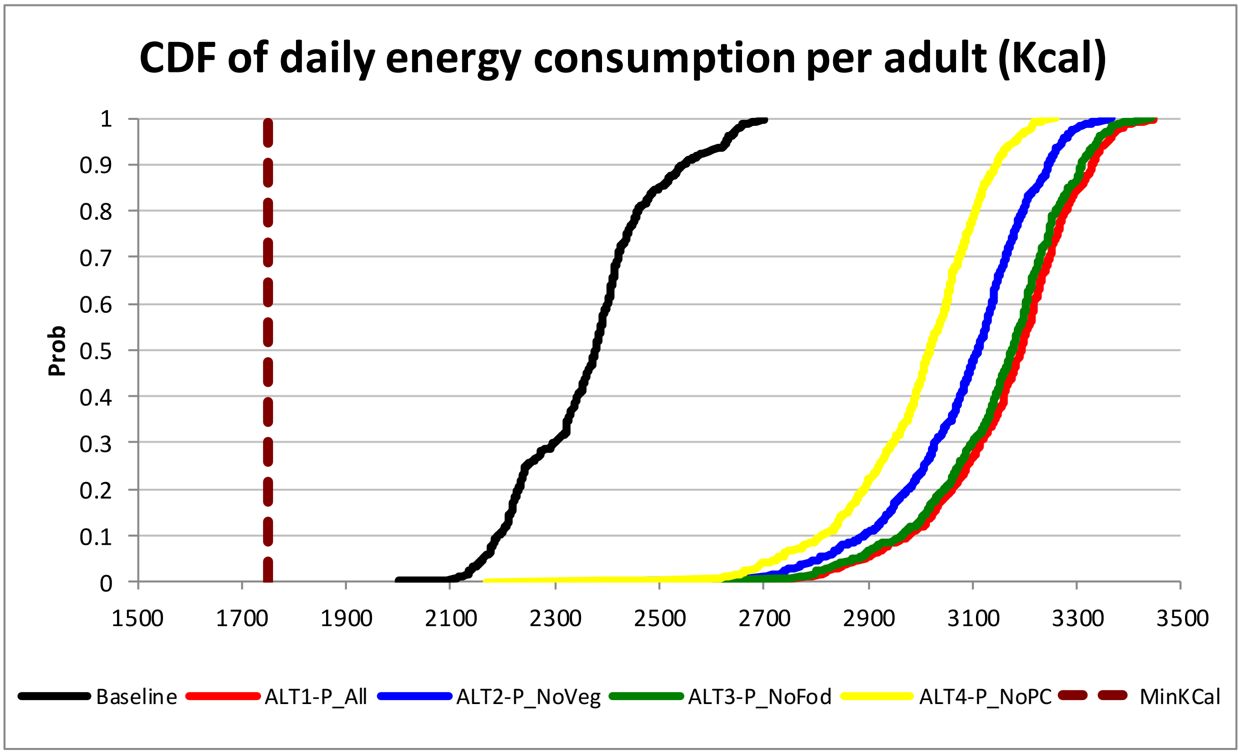

Figure 5a. CDF of daily energy consumption per AE on a farm in Robit kebele

The StopLight chart for daily energy consumption per AE is (fig. 5b) presents the probabilities of household calorific intake based on the lower and upper bound targets at 2,300 and 3,100. In the baseline scenario, there is a 30% chance that daily energy consumption per AE will be less than 2,300 calories and a 70% chance that it will be between 2300 and 3,100 calories. There is between 70% and 73% probability of exceeding the upper target value of 3,100 calories for alternative scenarios ALT1 (all crops/vegetables in crop mix) and ALT3 (exclude fodder from crop mix). Note that the high target value of 3,100 calories represents the average daily calories intake per AE for the four alternative scenarios. Excluding potatoes and chickpeas (ALT4) shows a significant reduction in calorie intake and availability where there is only a 22% chance of having a calorie intake greater than 3,100.

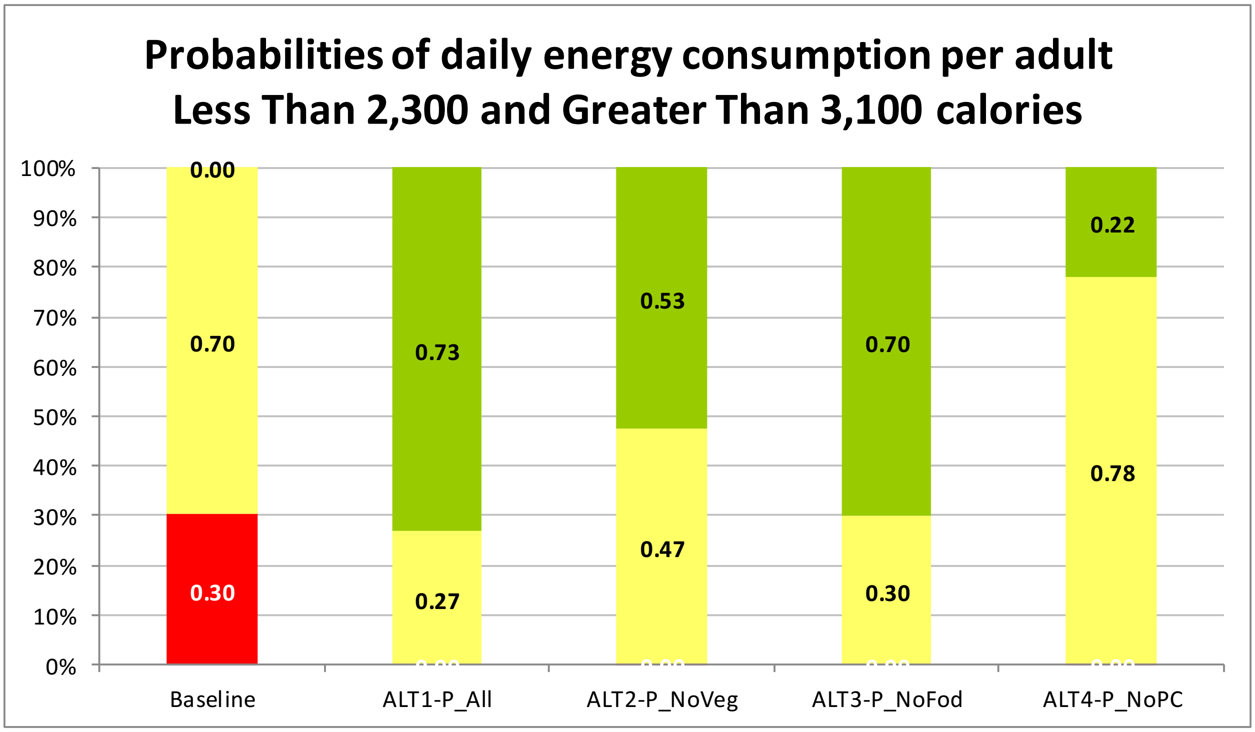

Figure 5b. StopLight Chart for daily energy consumption per AE on a farm in Robit kebele

<u>Protein intake</u>

Animal products are often considered as the main source of proteins at the household level. However, household surveys showed that the majority of the proteins intake in Robit kebele were obtained from grain crops (54%) rather than animal products (3%). Maize and horse bean alone contributed 68% of the total proteins intake for an average family in Robit kebele. This is a general pattern in many developing countries, including Ethiopia where the per capita consumption of livestock products, especially meat, is extremely low (Tafere & Worku, 2004).

Generally, foods of animal origin are richer and contain more absorbable micronutrients than plant foods (Shetty, 2010). Animal foods can provide recommended multiple micronutrients at a higher concentration and lower volume of intake than plant-source foods. For instance, 100 g of beef has zinc content more than twice that of maize and beans and is ten times more absorbable. The simulation results in figure 6a show that on average households in both the baseline and alternative scenarios meet and exceed the daily minimum requirement for proteins intake (59 and 79 grams/AE respectively compared to minimum requirement of 41 gr/AE). There is also a significant improvement in protein intake for the alternative scenarios compared to the baseline scenario due to the use of improved livestock and crop technologies.

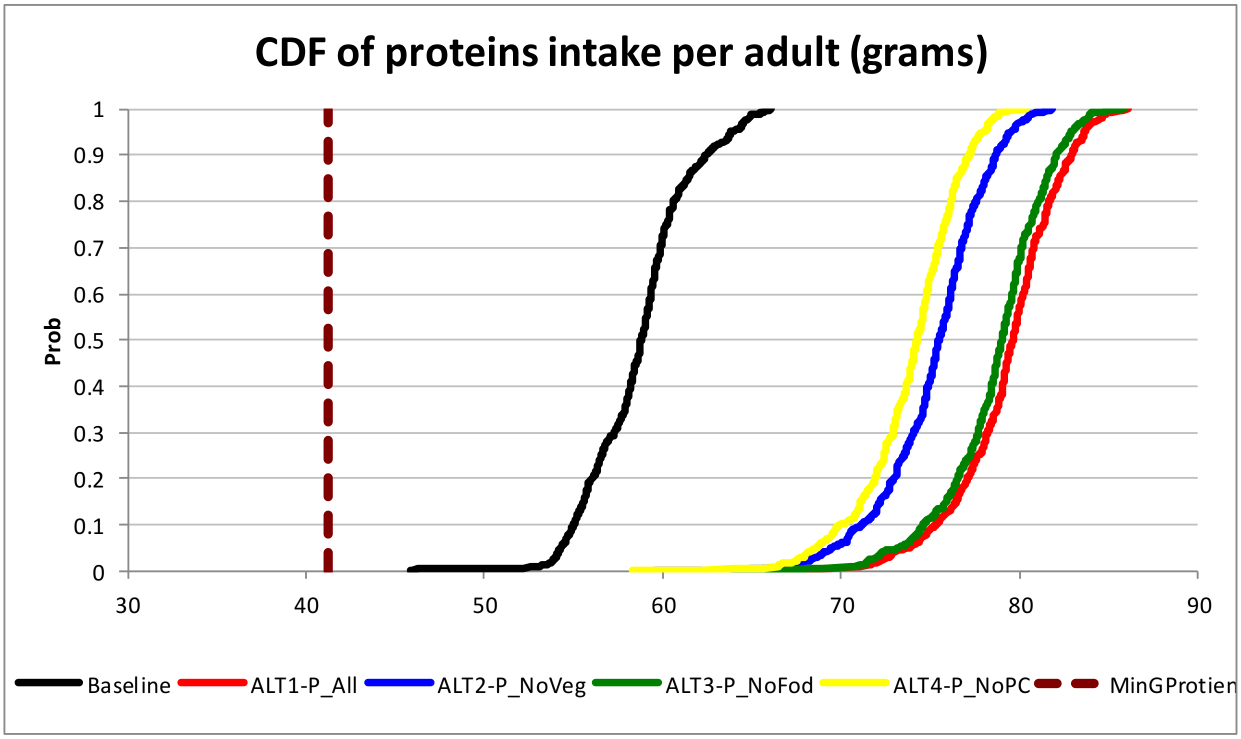

Figure 6a. CDF of daily proteins consumption per AE on a farm in Robit kebele

The StopLight chart for protein consumption indicates that ALT1 and ALT3 scenarios performed significantly better than the baseline scenario and other alternative scenarios in terms of protein intake for the farm family (fig. 6b). The simulation results show that there is a zero probability that the daily protein intake per AE will be less than the minimum daily requirement of 41 grams for both the baseline and alternative scenarios. The chance that daily protein intake per AE will exceed 79 grams is zero in the baseline scenario but between 50% and 62% for ALT3 and ALT1, while the probability of having a daily protein intake less than 59 grams is 53% for the baseline scenario and zero for alternative scenarios. On average, the baseline and alternative scenarios protein intake of 59 and 79 grams respectively (also StopLight chart target values) are significantly higher than the minimum required amount of 41 grams. Notice the sharp drop in protein intake for ALT4 where chickpeas was dropped from the crop mix, which highlights the importance of chickpeas contribution to nutrition. Chickpeas is an important pulse grown and consumed in many developing countries, especially those from Asia and Africa (Jukanti et al., 2012). Chickpeas is considered a good source of carbohydrates and proteins with a better quality of proteins than other types of pulses. Chickpeas nutritional content also includes several vitamins such as riboflavin, niacin, thiamin, foliate and vitamin A.

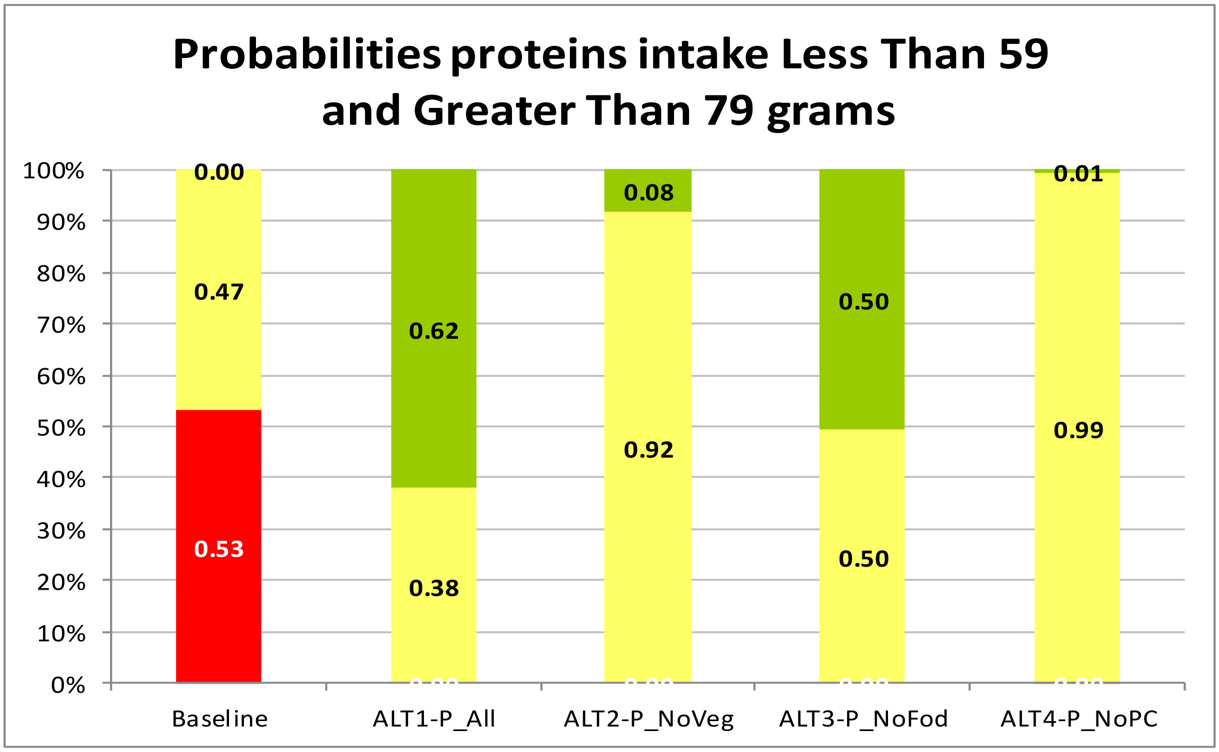

Figure 6b. StopLight Chart for daily protein consumption per AE on a farm in Robit kebele

Fat intake

Fat along with carbohydrates are the main source of energy, providing the essential amount of calories for the human body to function (FAO, 2010). However, beside that role, the body with a balanced dietary fat easily absorbs fat-soluble vitamins such as Vitamin A (von Grebmer et al., 2014).

Simulation results for fat intake presented as a CDF graph in Robit kebele show a deficit in fat intake for both the baseline and alternative scenarios (fig. 7a). Although there is an improvement of fat intake between the baseline and the alternative scenarios, their respective averages, 25 and 33.6 grams, are still below the daily minimum fat requirement average of 39 grams for an adult. The best performing alternative scenario (ALT1) provides on average 34.7 grams of fat per day per adult equivalent.

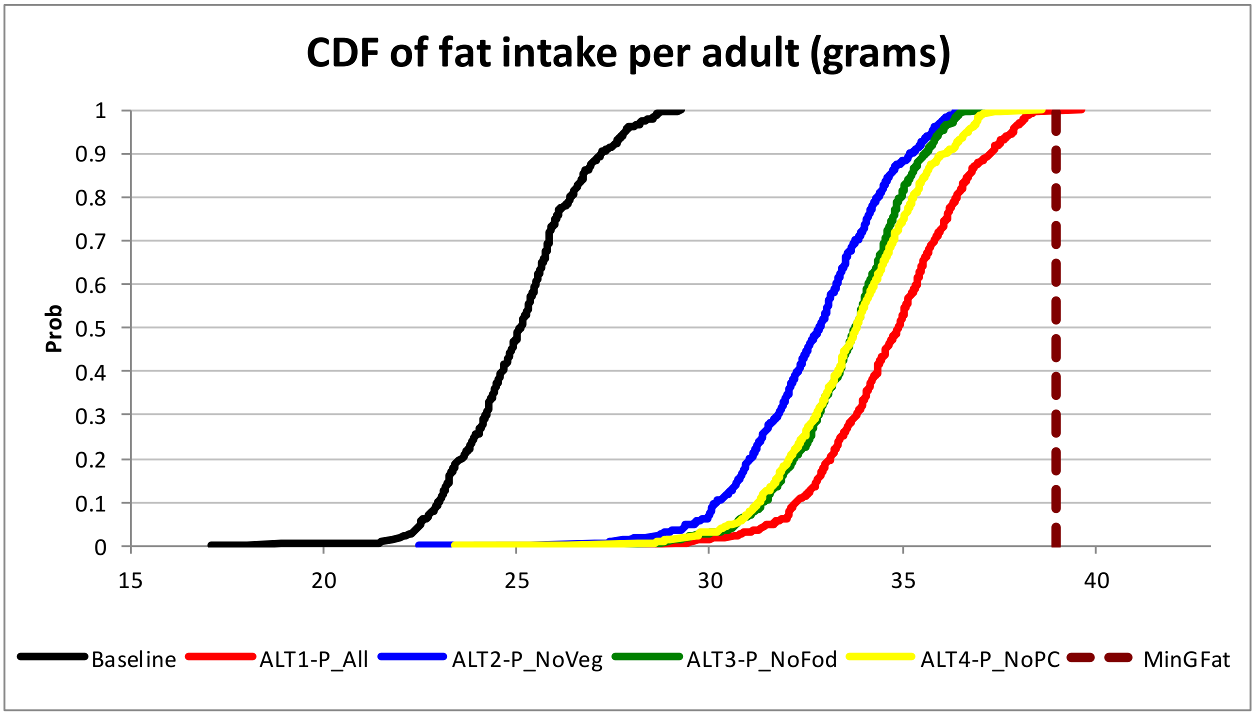

Figure 7a. CDF of daily fat consumption per AE on a farm in Robit kebele

Using the averages values of baseline and best alternative scenario (ALT1) as lower and upper bound target values for the StopLight chart, simulation results for fat indicate a 47% probability that the fat intake per AE will be less than 25 grams and zero probability that it will be greater than 34.7 grams for the baseline scenario (fig. 7b). Alternatively, there is a zero probability that the fat intake per AE will be less than 25 grams and a 53% chance it will be greater than 34.7 grams for the best performing alternative scenario (ALT1). Note that there is a zero probability for all scenarios that the fat intake will be greater than 39 g, the daily minimum requirement for an adult. Deficits in fat intake at the household level in Robit are mainly due to the low consumption of animal source products. Simulation results show that fat intakes in both the baseline and alternative scenarios were provided mainly by maize at the household level, supplying between 64% and 70% of the total fat intake. However, increase in milk and beef consumption in the alternative scenarios through production and purchase show a slight improvement in contribution of fat intake from animal products at the household level from 7% (baseline scenario) to an average of 10% for ALT1, ALT3 and ALT4. Although excessive intake in fat may lead to other health issues such as risk for obesity, moderate increase in consumption of butter and beef in Robit can remedy the fat intake deficit.

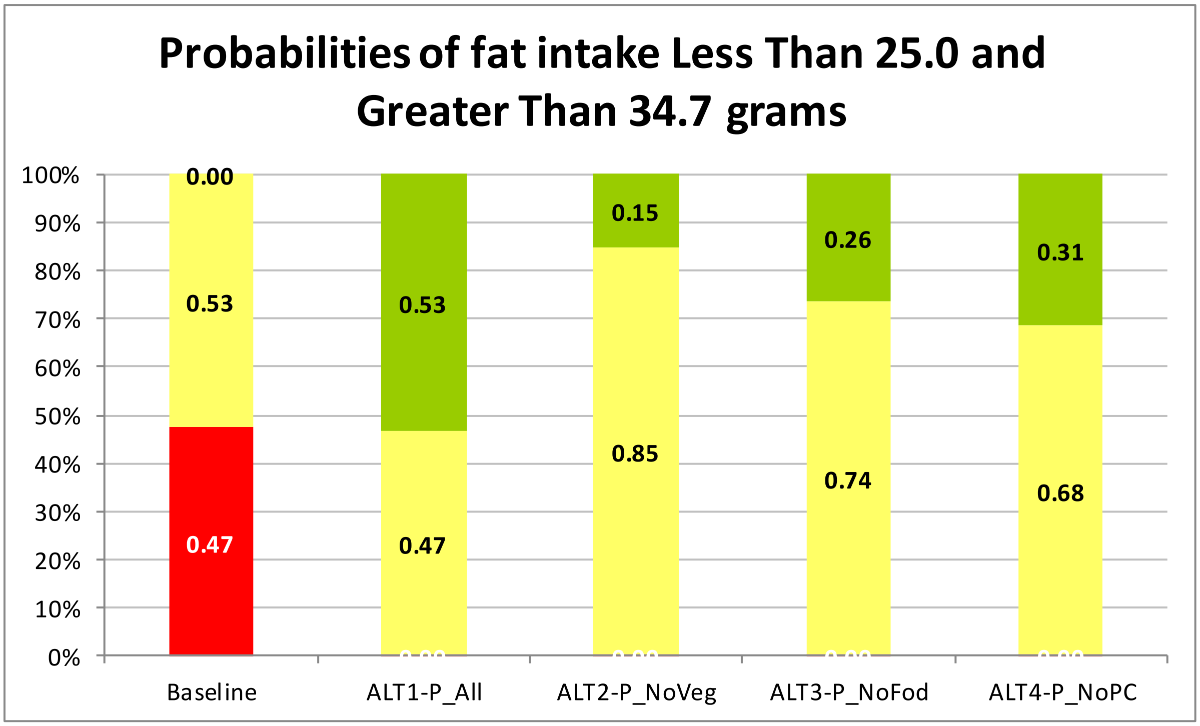

Figure 7b. StopLight Chart for daily fat consumption per AE on a farm in Robit kebele

<u>Calcium intake</u>

Calcium is among the nutrients that are required for a healthy body functioning (for bone formation and maintenance) and may be of concern given the difficulty to meet its recommended nutrients intake (RNI) without the consumption of dairy products (FAO & WHO, 2001).

The simulation results for calcium show large deficits in calcium intake in both the baseline and alternative scenarios (fig. 8a). The average calcium intake per AE is 0.22 and 0.38 grams, respectively, for the baseline and the two best performing alternative scenarios (ALT1 and ALT3), falling short of the daily minimum requirements of 1 gram per AE (fig. 8a). Note however the significant improvement of calcium intake from the baseline to the alternative scenarios which increased on average by 60 percent.

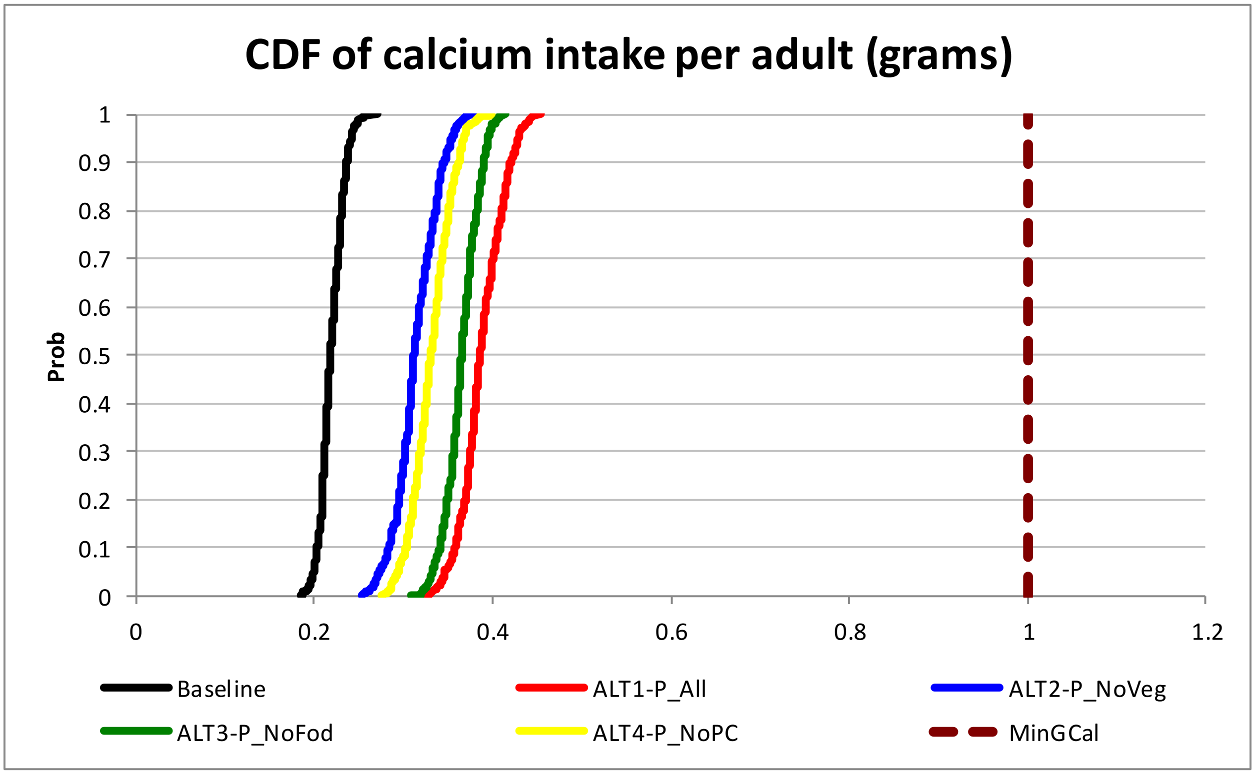

Figure 8a. CDF of daily calcium consumption per AE on a farm in Robit kebele

The StopLight chart in figure 8b shows that there is a 54% probability that the daily calcium intake per AE will be less than 0.22 grams and a zero probability that the intake will exceed 0.38 grams for the baseline. Alternatively, there is a zero probability that the calcium intake amount will be less than 0.22 grams and a 62% probability that the intake will exceed 0.38 grams for the ALT1 that includes all of the crops in the mix (best performing scenario). The second best performing alternative scenario, ALT3, does not include fodder in the crop mix, reducing therefore the potential of increased milk production and consumption at the household level. In

ALT3, there is a 23% chance that the calcium intake will exceed 0.38 grams and a 77% chance that the daily intake will range between 0.22 and 0.38 grams. ALT2 which, does not consider vegetable irrigation and production, has the lowest calcium intake due mainly to the reduction in income and the resulting potential to purchase supplemental foods (including milk). Overall simulation results show significant deficiencies in calcium for all the scenarios.

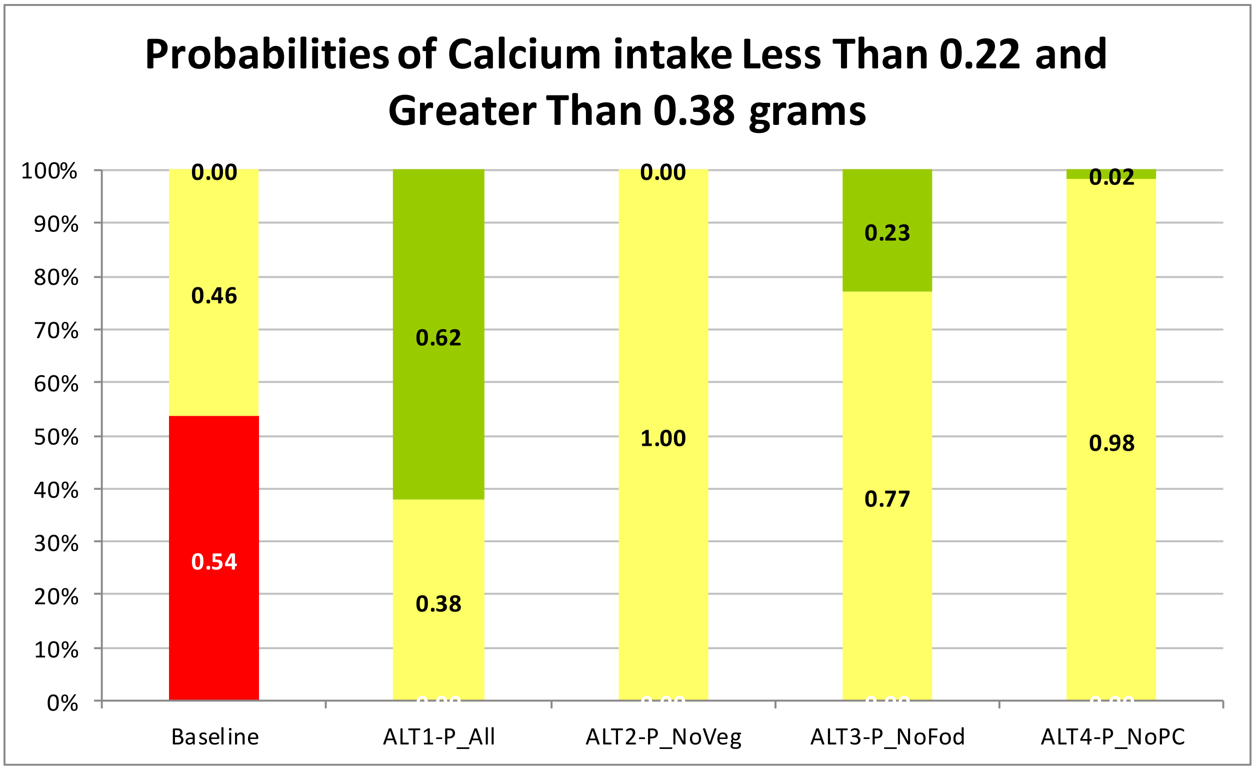

Figure 8b. StopLight Chart for daily calcium consumption per AE on a farm in Robit kebele

Iron intake

The consumption of micronutrients like iron, zinc, vitamin A, and iodine is important for human health and well-being, and help in the absorption of other nutrients, and child development (Golden, 2009; von Grebmer et al., 2014). Iron deficiency, specifically, is a risk factor for maternal mortality and anemia in both mothers and children (Domenech 2015). Iron deficiency is more predominant in developing countries and tend to become a chronic malnutrition issue even in grown children with iron deficiency when iron is supplemented rather than provided in a balanced diet. While supplementation has saved many lives in controlling the three major deficiencies in public health (vitamin A, iron and iodine), it failed to address the root cause of malnutrition which should be based on food approaches for a long-term sustainability (Shetty, 2010). This study analyzes the iron intake at the household level through the consumption of food items produced and purchased.

Simulation results indicated that households in Robit kebele get more than the required minimum levels of iron. The average iron intake per AE of all scenarios, estimated at 0.023 grams (or 23 mg), was more than twice the daily minimum requirement of 0.009 grams (or 9 mg) per AE (fig. 9a). There was also a significant improvement between the baseline and the alternative scenarios in terms of iron intake, which averaged 0.18 and 0.25 grams respectively. However, given that the model simulation does not disaggregate among age and gender groups at the family level, it is difficult to assess the iron intake for children and women for an average family in Robit.

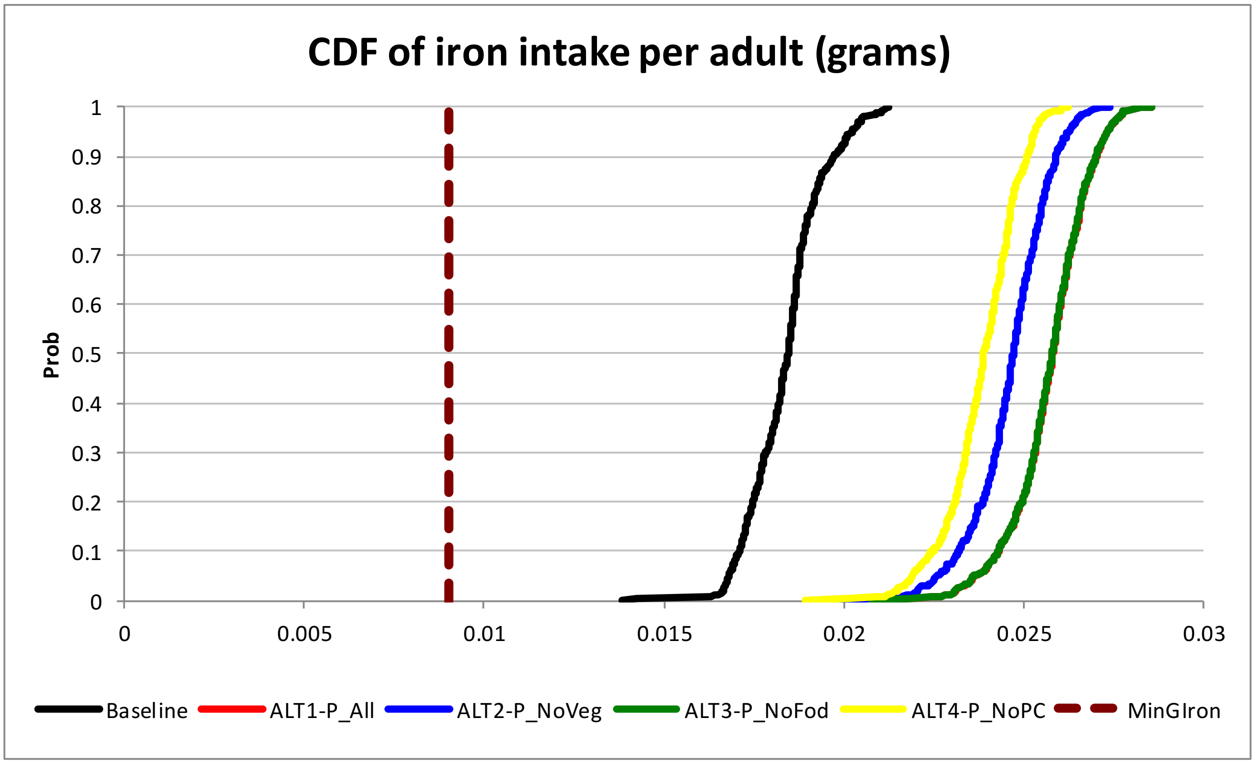

Figure 9a. CDF of daily iron consumption per AE on a farm in Robit kebele

The StopLight chart for iron intake indicates that two alternative scenarios (ALT1 and ALT3) performed significantly better than the baseline scenario, ALT2, and ALT4 in terms of iron availability (fig. 9b). ALT1 and ALT3 consider both irrigation under pulley system but ALT1 takes into account all crops for the study while ALT3 removes fodder from the crop mix. The simulation results from the 500 draws measures the performance of scenarios based on target values of 0.018 and 0.025 grams, which are respectively the averages of the baseline and alternative scenarios. In the baseline scenario, there is a 34% probability that the daily iron intake per AE will be less than 0.018 grams and zero percent chance that the daily iron intake will be greater than 0.025 grams. Alternatively, there is on average a 79% chance that the daily iron intake per AE will exceed 0.025 grams and a zero percent chance that daily iron intake will be less than 0.018 grams for the best performing alternative scenarios, ALT1 and ALT3. The results show as well that ALT2, which removes vegetables from the crop mix, produced higher iron intake to the family than ALT4, which removes potatoes and chickpeas in the crop mix. This indicates a relatively low contribution to iron by cabbage and tomatoes and a higher contribution to iron from potatoes and chickpeas.

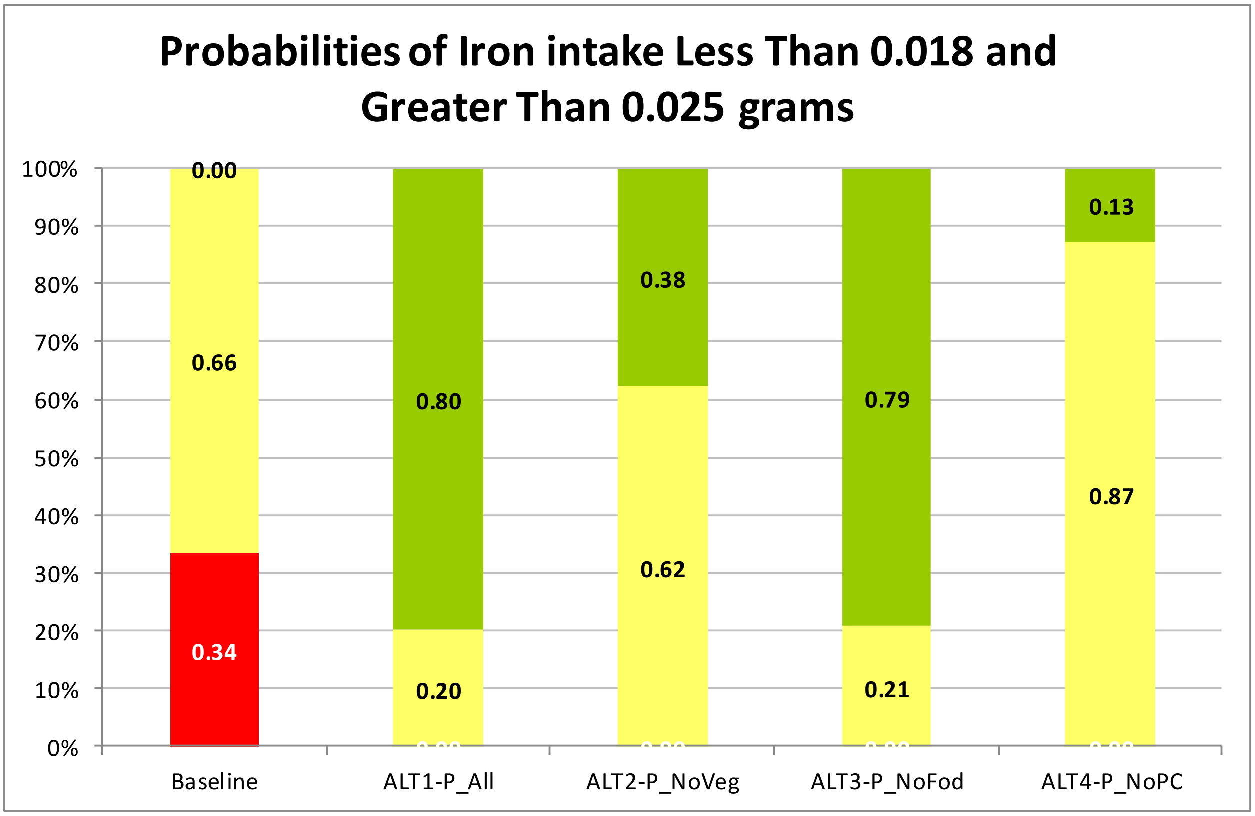

Figure 9b. StopLight Chart for daily iron consumption per AE on a farm in Robit kebele

Vitamin A intake

Like iron, iodine, and zinc, vitamin A is an important micronutrient needed in small amounts for a good functioning human body. Vitamin A is essential for healthy vision and plays a vital role in bone growth, reproduction and a healthy immune system. Generally, cereal-based diets, which contain low concentration of carotenoids compounds, a precursor of vitamin A, are characteristic of a low vitamin A intake and deficiency at the household level (FAO & WHO, 2001; Shetty, 2010). While pro-vitamin A carotenoids from plants present a low absorption rate, preformed vitamin A from animal sources such as milk, liver, glandular meat, eggs, fish liver oils, etc. have around 90 percent of absorption efficiency (FAO & WHO, 2001).

In this study, the simulation results for vitamin A intake indicate adequate to surplus vitamin A intake levels in both the baseline and alternative scenarios (fig. 10a and 10b). The average levels of vitamin A intake for the baseline and alternative scenarios (excluding ALT4) are 0.0026 grams and 0.0057 grams respectively, 4 to 9 times higher than the daily minimum requirement for an adult equivalent of 0.0006 grams (fig. 10a). Notice the low vitamin A intake (close to the minimum required) provided under ALT4 in which potatoes and chickpeas were removed from the crop mix.

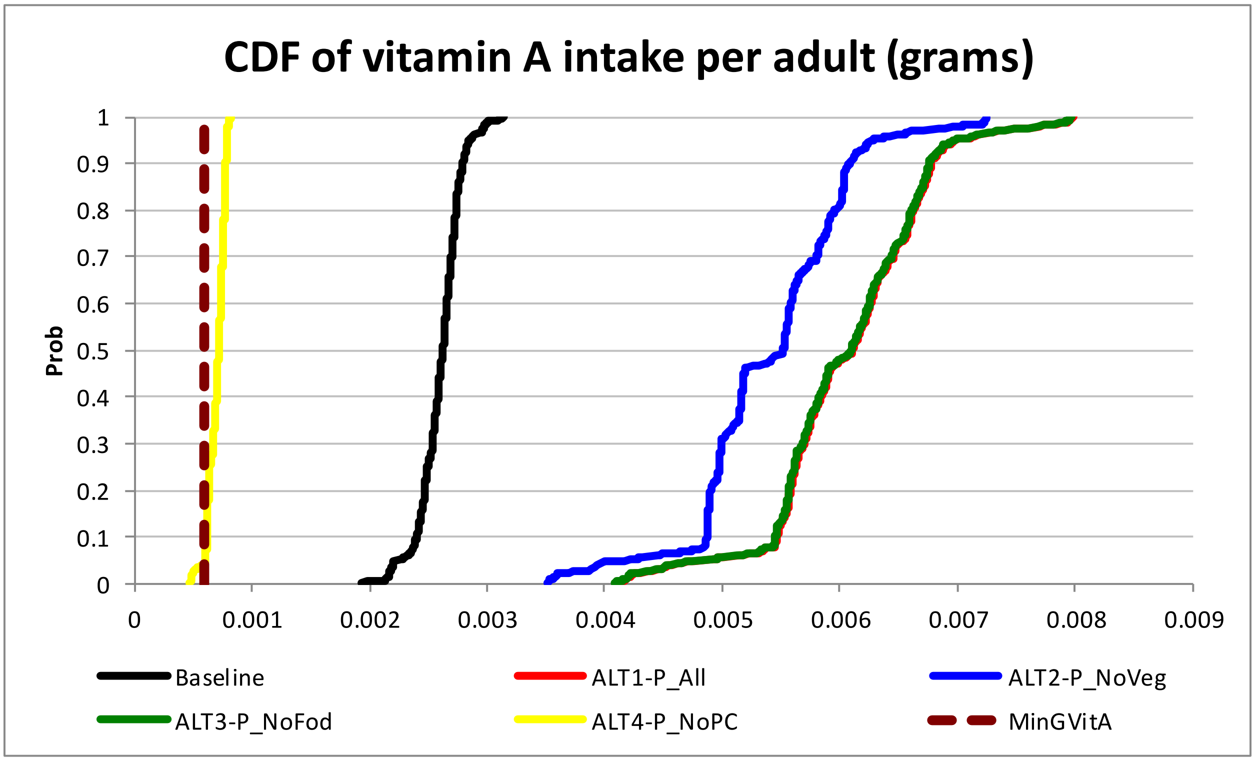

Figure 10a. CDF of daily vitamin A consumption per AE on a farm in Robit kebele

The StopLight chart in figure 10b shows, for the baseline scenario, that there is a 46% probability that the daily vitamin A intake per AE will be less than 0.0026 grams (baseline average), while there is a zero probability that the vitamin A intake will be greater than 0.0057 grams (best alternative scenarios average). Alternatively, for ALT1 and ALT3 (best performing alternative scenarios), there is zero chance that the vitamin A intake will be less than the average baseline vitamin A intake for an adult while there is a 70% chance that vitamin A intake will exceed 0.0057 grams. The least performing scenario, regarding vitamin A intake is ALT4, which assumes a crop mix that removed potatoes and chickpeas, shows a 100% chance that the vitamin A intake will be less than 0.0026 grams. The simulation results show that removal of potatoes in the crop mix for ALT4 is the main cause of the drop in vitamin A intake since potatoes contributed about 88% of the total vitamin A supply for an average household in Robit.

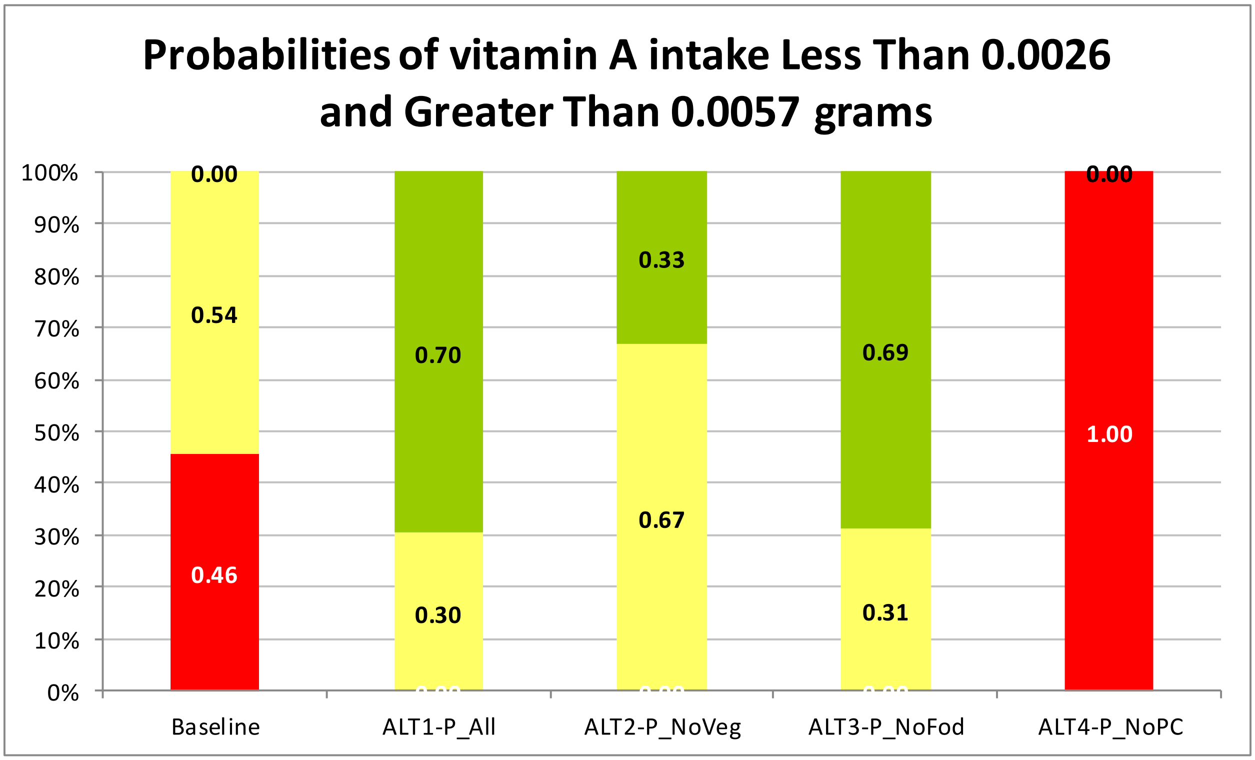

Figure 10b. StopLight Chart for daily vitamin A intake per AE on a farm in Robit kebele

A summary of nutrition simulation results based on the last year of the 5-year planning horizon (2016-2020) is presented in table 9. Specifically, it lists the nutritional variables measured, the probability that the quantity of each nutrient consumed exceeds the minimum daily requirement, and whether the intake amounts made available or consumed in the alternative scenarios (ALT1 and ALT3) show improvement (due to technology) as compared to the baseline scenario[9].

Table 9. Summary results for nutritional and scenarios performance in Robit kebele

	Performance		
Nutrition variables	Surplus or deficit	Probability: nutrient cons > min requirement	Improvement from baseline to alternative
Calories	Surplus	100%	Yes
Proteins	Surplus	100%	Yes
Fat	Deficit	0.0%	Yes
Calcium	Deficit	0.0%	Yes
Iron	Surplus	100%	Yes
Vitamin A	Surplus	100%	Yes

Overall nutrition results show adequate daily access (and surplus) to calories, proteins, iron and vitamin A per adult equivalent at the household level in Robit kebele. However, calcium and fat daily intakes per adult equivalent were deficient. A deficit in availability and access to calcium and fat is mainly due to low consumption of animal source foods, which can effectively close the nutrition gap in fat and calcium intake. There is much easier absorption of many micro and

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[9] Note that in case of a surplus in production households do not necessarily increase their fraction of the crop consumed unless there is a deficit in the baseline scenario that would require them to increase the amount consumed in the alternative scenario. Otherwise, consumption fractions in the alternative scenarios are adjusted to reflect the amount the household needs to consume and the rest is sold at the market.

macronutrients such as iron, zinc, riboflavin, vitamin A, proteins and calcium from products of animal origin than plant-based (FAO & WHO, 2001; Shetty, 2010).

The large and consistent gap in calcium intake in the current study reflects the existing concern regarding low calcium intake observed in developing countries (vs. developed countries) due to low animal products access and consumption (FAO & WHO, 2001). Moreover, there is a mismatch between the calcium intake data and the relatively high intake requirements, which led the US/Canada Dietary Reference Intakes (DRIs) to propose an Acceptable Intake (AI) for calcium, instead of a Recommended Daily Allowance (RDA) for adjustment. Another reason could be related to calcium requirements, which widely vary between gender and age making difficult to find an acceptable average requirement. The possibility to increase the consumption of foods from animal sources, to close the deficit in calcium and fat at the household level, is through the use of improved animal production technologies (feeds and breeds) or purchase of food products like milk, eggs and meat. In the case of purchase however, households need to have extra cash income or profit that mainly comes from sales of crop and animal products at the market. In this study, only about 10% of the profit was used to purchase supplemental foods for family nutrition at the market, which was not enough to fill the nutritional gaps. Also the contribution from improved animal production technology through animal feeding of fodder show a small improvement in productivity of milk and meat. However, the comparison of different alternative technology scenarios, whether it is through improved animal or vegetable production technologies, shows different impacts on nutrition for the farm family. For example, the removal of fodder in the crop mix (ALT3) did not have a major impact on nutrition and income compared to the removal of vegetables (ALT2) due to substantial reduction in income under ALT2. In other words, the contribution to milk and meat production by feeding animals fodder had less of an impact on nutrition than purchasing the animal product items using profit from the production and sale of vegetables.

It is worth mentioning that many nutrition professionals and researchers warn about a quick way or shortcut in addressing food insecurity and malnutrition especially the micronutrients deficiency through nutrients supplementation such as iron (FAO & WHO, 2001; Golden, 2008; Shetty, 2010). Instead, they recommend a food and community-based approach as a sustainable way for combatting hunger and malnutrition in which fruits and vegetables are regularly incorporated in a balanced family diet to provide vitamins and minerals. They argue that supplementation is a short-term measure and cannot provide long-term and sustainable strategy to address the root causes of malnutrition and assist households and communities to produce, feed and nourish themselves. For instance, the home gardening approach that integrates gardening and nutrition education led by community leaders may be more beneficial and sustainable than quick and short-term interventions based on mineral or vitamin supplementation. Food and community-based approach have the merit of teaching households members what crops to grow and how to combine the different food groups to make a balanced diet. The diversity is key in ensuring that households access the appropriate set of nutrients needed for a healthy diet that would include at the same time the calorific-based foods and mineral and vitamin rich foods. We analyze below the food diversity based on the crop mix and scenarios discussed in this study.

4. Household dietary diversity score for the baseline and alternative scenarios

Shifting from a cereal and grain-based diet to one containing a more diverse range of foods has been shown to increase intake of calories as well as micronutrients in developing countries (Kennedy et al., 2007, p.472). Consuming a diverse variety of foods has been a recommendation for achieving adequate nutrient intake and the recommendation appears in the dietary guidelines of many countries. For instance the consumption of a diverse group of food that comprise calories-rich staple foods, legumes, pulses, in addition to milk and other dairy products, calcium-rich diets such as small fish and dark green leafs is most likely to improve nutrition and combat micronutrient deficiency. However, measuring food diversity at the household level reflects more food access rather than dietary quality, which is most of the time captured at the individual level. This study uses a simple count of food groups as specified in the Guidelines for measuring household and individual dietary diversity (Kennedy et al., 2013, p.8) to determine and compare the HDDS between the baseline and four alternative scenarios. The alternative scenarios were built based on the crop mix that reflect a variety of food groups which includes vegetable, tubers, pulse and animal products. The four alternative scenarios based on crop mix are the following:

Baseline: Current food items consumed per week by a household
ALT1_All: Current consumption + All additional food items from irrigation and purchase (vegetables, potatoes & chickpeas, animal products)
ALT2_NoVeg: Current consumption + Potato & chickpeas + No Vegetable & No purchase
ALT3_NoFodder: Current consumption + Potato & chickpeas + No animal products + Purchase
ALT4_NoPotato & Chickpeas: Current consumption + Vegetables + animal products + No Potato & chickpeas + Purchase

The diversity score in table 10 shows that ALT1 has the highest dietary diversity score of 11 compared to the other scenarios, which scored 7 and 9 (Baseline, ALT2 and ALT3, ALT4 respectively). From a simple count of food groups in each scenario, households following ALT1 consume a more diversified group of foods than the remaining scenarios. ALT1 scenario comprises all the crops involved in family farming (cereal, vegetables, potatoes, chickpeas, milk, and meat) in addition to purchasing supplemental food items from the sale of excess vegetables and fodder. ALT3 and ALT4 have the second highest diversity score (9) and involve respectively the removal of irrigated fodder in the crop mix, which has implications on the consumption of animal products, and potatoes, and chickpeas. ALT3 and ALT4 have less impact on revenue reduction and food purchase as well as food diversity than ALT2 given that the bulk of revenue/profit for supplemental food purchase comes from the sale of vegetables. Lastly, the baseline and ALT2 have the lowest diversity score (7)

The baseline, which represents the current farming system, has a lower count of food groups consumed by the family given the low level of technology involved in the farming (reduced fertilizer, minimal irrigation and livestock technologies). For example, the lack of irrigation technology reduces the potential to increase food diversity and income that would come from dry season crops (vegetables and fodder) production and sale. The lack of fodder production can have a negative impact on animal feeding and performance, which can reduce the quantity of milk and meat produced and consumed by the family. The low diversity score for ALT2 comes from the removal of vegetables in the crop production mix, which significantly reduces the profit of the household and food diversity from both the production and purchase. However, the dietary diversity score is a qualitative measure that aims to assess the variety of food consumed by the household and can serve as an indicator of healthy diets but may not in a definite way determine quantitatively the nutrients and health consequences of food items consuming.

Table 10. Household dietary diversity score (HDDS) for Robit kebele

Food groups	Examples	**Food group consumption (Yes=1 or No=0)**				
		Baseline	ALT1: All crops	ALT2: No Vegetable	ALT3: No Fodder	ALT4: No Potato & Chickpeas
1.Cereals/Grains	Maize, rice sorghum, millet	1	1	1	1	1
2.White roots and tubers	Potatoes, yam, cassava	1	1	1	1	0
3.Vitamin A rich vegetables and tubers	Pumpkin, carrot, pepper, Sweet potatoes	0	0	0	0	0
4.Dark green leafy vegetables	Spinach, kale, amaranth	0	0	0	0	0
5.Other vegetables	Tomatoes, onions, eggplants	0	1	0	1	1
6.Vitamin A rich fruits	Mango, apricot, papaya, peach	1	1	1	1	1
7.Other fruits	Apple, orange, grape	0	0	0	0	0
8.Organ meat	Liver, kidney, heart	0	0	0	0	0
9.Flesh meat	Beef, pork, lamb, goat	0	1	0	0	1
10.Eggs	Eggs from chicken, duck	0	1	0	1	1
11.Fish and seafood	Fresh or dried fish	0	0	0	0	0
12.Legumes, nuts and seeds	Beans, peas, lentils, nuts	1	1	1	1	0
13.Milk and milk products	Milk, cheese, butter	0	1	0	0	1
14.Oils ad fat	Oils, fat or butter	1	1	1	1	1
15.Sweets	Sugar, honey, candies	1	1	1	1	1
16.Spices, condiments, beverages	Pepper, salt, condiments, soda, coffee	1	1	1	1	1
	Total DD score	**7**	**11**	**7**	**9**	**9**

Conclusions and recommendations

Food security and nutrition remain a major discussion topic in the global development agenda and specifically for countries in and around the Sub-Saharan Africa region where the majority of people suffering from hunger and malnutrition are located. Other aspects of hunger and malnourishment that are often overlooked, relate to micronutrient deficiency, which can have long-term health consequences that include child and maternal death, physical disabilities and intellectual deficit. One option to combat malnutrition and hunger is to increase the food production and promote the consumption of balanced diets, specifically in regions of food deficits. Broad-base agricultural growth in staple food, vegetables, fruit and livestock production is key to reducing poverty and increasing food security. To achieve this goal there is a need to increase the agricultural productivity through the adoption and use of agricultural technologies such as irrigation and fertilizers. This study focused on the use of small-scale irrigation technologies to assess the impact of food production and consumption on food security and nutrition in Robit kebele (village), Amhara region of Ethiopia. The farm level economic and nutrition simulation model (FARMSIM) was used to carry out the analysis. It is complemented by a qualitative analysis of the food diversity consumed at the household level using a household dietary diversity score (HDDS).

A baseline scenario with minimal irrigation capacity and current food consumption is compared to four alternative scenarios that benefited from irrigation and production of vegetable and fodder that are aligned with four different consumption patterns. Current food consumption and nutrient intake by an average household in Robit indicates a satisfactory consumption and intake of calories from a cereal-based diet dominated by teff and maize but is limited in consumption of fruits, vegetables and pulses. The most characteristic feature of the diet in baseline conditions is the absence of consumption of animal origin food. There is an evident lack of food diversity, which may be an indication of low quality diet.

Scenario one (ALT1) where vegetables and fodder are produced through irrigation in addition to potatoes and chickpeas shows the highest nutritional benefits. Besides providing a variety of vegetables consumed at home (tomatoes and cabbage), revenues from vegetables sale at the markets earned considerable profits to the household that was used forpurchasing supplemental food items, mostly animal products such as milk, meat, and eggs. ALT1 had also the highest diet diversity that comprised cereals, vegetables, pulses, tubers, beef, milk, and eggs. Although simulation results show that both scenarios (Baseline and ALT1) meet the daily minimum required intake quantities per adult for calories, proteins, iron and vitamin A, they both fall short in meeting minimums for fat and calcium. However, the results show a significant increase from the baseline to ALT1 for intake by 31% and 65%, respectively, for fat and calcium.

Among the three remaining alternative scenarios (ALT2, ALT3 and ALT4), ALT2 was the poorest performing scenario, providing the lowest amount of nutrients intake and cash profit. ALT2 assumes the removal of vegetable production in the crop mix, which significantly reduced the household profit, and the potential to purchase supplemental food for family consumption. Moreover, under ALT2, the household access to vegetables consumption dropped as well leaving the family with fewer opportunities to consume vegetables. ALT2 had as well the lowest dietary diversity score, which was equal to the Baseline scenario score, indicating a less diversified diet at the household level. ALT3 and ALT4 scenarios, which assumed respectively the removal in the crop mix of fodder (and subsequent reduction in consumption of animal products) and potatoes and chickpeas, performed fairly well in providing adequate nutrients at the household level. However, the removal of potatoes and chickpeas in the crop and food mix showed a significant reduction in the availability of iron and vitamin A.

The introduction of small-scale irrigation technologies allowed farmers to grow more crops especially vegetables and fodder, which not only increased the cash profit at the household level but also the food diversity consumed. The profit from vegetable sales was instrumental in allowing the household to purchase supplemental foods items, mainly animal source products such as milk, beef and eggs that significantly improved the diet quality and diversity. Food and community-based approach that promote the growth and consumption of diverse types of crops and foods seems to be the best strategy to combat hunger and malnutrition and improve food security at the household level.

Although the farm simulation model can evaluate the nutrients availability and accessibility at the household level, it does not disaggregate among the age groups at the household level to account for specific needs for children and women who have particular nutritional requirements. The number of micronutrients and vitamins analyzed in the model needs to expand and cover more elements given the importance of the issue of micronutrients deficiency that is affecting a large number of people worldwide.

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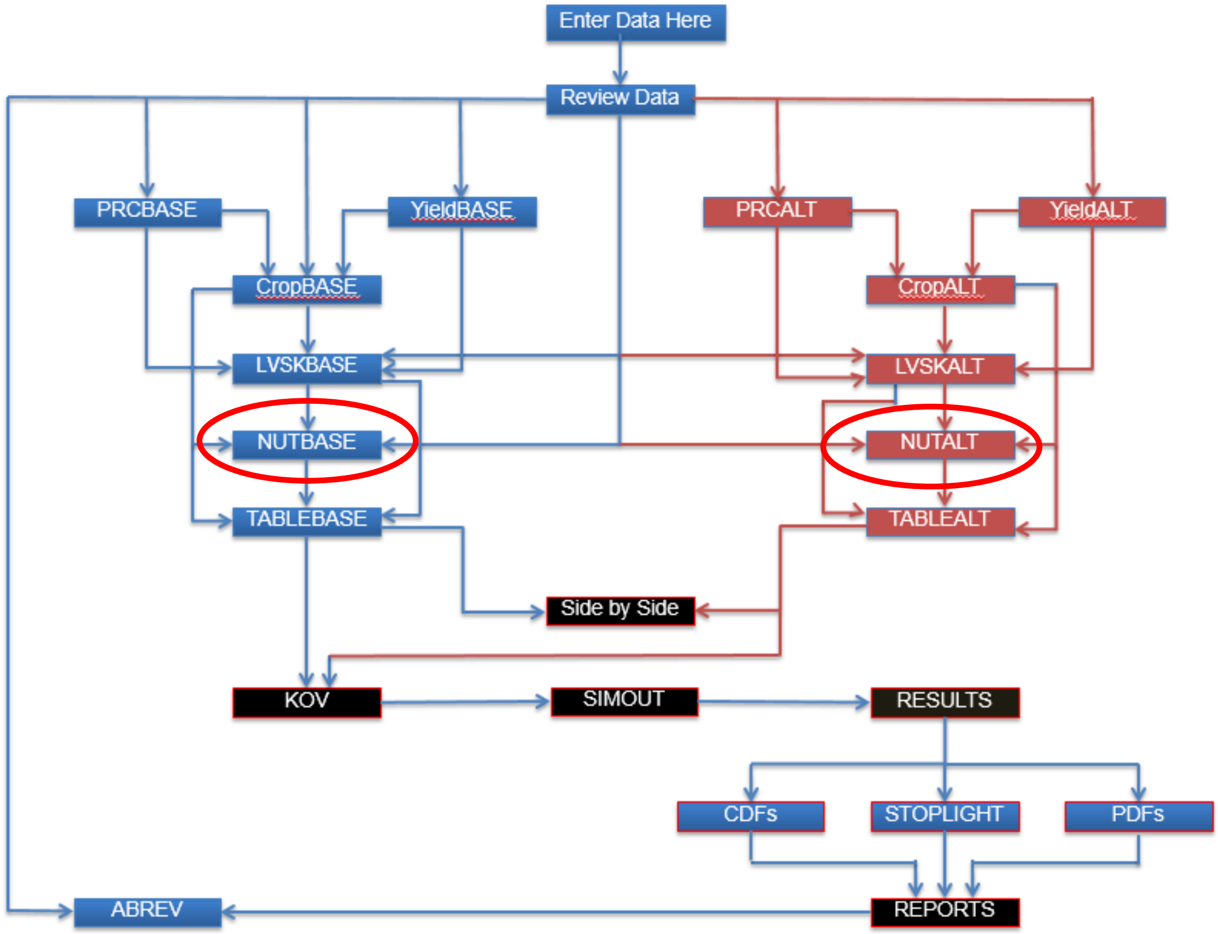
APPENDICES

Appendix A: FARMSIM Flowchart (excel worksheet organization)

Note: the chart shows specific excel sheets (circled in red) where the nutrition variables are simulated and how they relate to other parts of the model.



Appendix B. Dietary diversity score questionnaire

Guidelines for Measuring Household and Individual Dietary Diversity

Questions number	**Food groups**	**Examples**	**Yes= 1** **No=0**
1	Cereals/Grains	Corn/maize, rice, wheat, sorghum, millet or any other grains or foods made from these (e.g. bread, noodles, porridge or other grain products)	
2	White roots and tubers	white potatoes, white yam, white cassava, or other foods made from roots	
3	Vitamin A rich vegetables and tubers	pumpkin, carrot, squash, or sweet potato that are orange inside + *other locally available vitamin A rich vegetables (e.g. red sweet pepper)*	
4	Dark green leafy vegetables	dark green leafy vegetables, including wild forms + *locally available vitamin A rich leaves such as amaranth, cassava leaves, kale, spinach*	
5	Other vegetables	other vegetables (e.g. tomato, onion, eggplant) + *other locally available vegetables*	
6	Vitamin A rich fruits	ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these + *other locally available vitamin A rich fruits*	
7	Other fruits	other fruits, including wild fruits and 100% fruit juice made from these	
8	Organ meat	liver, kidney, heart or other organ meats or blood-based foods	
9	Flesh meat	beef, pork, lamb, goat, rabbit, game, chicken, duck, other birds, insects	
10	Eggs	eggs from chicken, duck, guinea fowl or any other egg	
11	Fish and seafood	fresh or dried fish or shellfish	
12	Legumes, nuts and seeds	dried beans, dried peas, lentils, nuts, seeds or foods made from these (eg. hummus, peanut butter)	
13	Milk and milk products	milk, cheese, yogurt or other milk products	
14	Oils ad fat	oil, fats or butter added to food or used for cooking	
15	Sweets	sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies and cakes	
16	Spices, condiments, beverages	spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages	

Source: G. Kennedy et al., 2013 (p.8)