Economic and Nutrition Impacts of Irrigated fodder and crossbred cows on households in Lemo woreda, SNNP region of Ethiopia

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Abstract

The livestock sector is one of the main pillars of Ethiopia's economy for its contribution to agriculture and national gross domestic product (GDP). In smallholder mixed farming systems, livestock products provide nutritious food, additional emergency and cash income. Despite its importance, several constraints related to livestock production such as low livestock productivity, remain a major barrier to the development of the livestock sector in Ethiopia. Improving animal feed resources and breeds can have impacts on both household income and nutrition through the production, consumption and sale of animals and animal products. In this study small scale irrigation (SSI) technologies along with fertilizer were used to grow and improve yields of fodder (oats & vetch) with the purpose to feed native and crossbred cows and generate income. Supplementing feeding of crossbred cows with fodder is expected to increase milk production and animal weight which in turn will improve family nutrition and generate income.

A farm level economic and nutrition simulation model (FARMSIM) is used to evaluate the potential nutrition and economic impacts of the SSI technologies and crossbred cows on households in Lemo woreda, Upper Gana kebele of Ethiopia. The model simulates and forecasts for five years the current (baseline) crop and livestock farming system and an alternative system simultaneously. Annual net cash income (profit) and the benefit cost ratio are the economic key output variables while nutrition variables comprise average available daily intake of calories, protein, fat, calcium, iron, and vitamin A for an adult equivalent. In the baseline scenario, fodder is grown on limited land with minimal irrigation and fertilizer while in alternative scenarios, more land and fertilizers are allocated to fodder during the dry season due to irrigation.

Results showed that the annual average profit under alternative scenarios was between 2 and 4 times that of the Baseline scenario. However, the distribution results highlighted the risk associated with high production and water lifting tools (e.g. solar pump) costs from SSI technologies investment. The nutrition results showed that the quantities of crops and livestock products consumed by families in both the baseline and alternative scenarios met the minimum daily requirements for calories, proteins, iron, and vitamin A but were insufficient for calcium and fat. However, the increase in quantity of animal products consumption led to the increase in available proteins by 12%, fat by 24%, calcium by 73%, iron by 5% and vitamin A by 17% under the alternative scenarios with improved livestock production technologies and purchase option.

Introduction

The livestock sector is one of the main pillars of the Ethiopia's economy in terms of its contributions to agriculture and national gross domestic product (GDP) ((Negassa et al. 2013; (FAO 2017). Currently, the livestock sector contributes about 45% to the agricultural GDP and this share is likely to increase in the coming decades as the sector goes through significant transformation to become a major contributor to national agricultural production. At the household level, beside the critical economic and social roles that livestock plays in the livelihoods of pastoralists, agro-pastoralists, and smallholder farm households, they help people cope with shocks and accumulate wealth, specifically as a store of value where regular financial institutions are not present. In smallholder mixed farming systems, livestock products provide nutritious food, additional emergency and cash income as well as input for agricultural farming.

A livestock sector analysis (LSA) conducted in 2013 indicated that about 11.4 million households produce livestock in Ethiopia with predominance of households raising cattle between 70 and 90 percent and thus dominating smallholder source of income and meat-milk production (Shapiro et al. 2015). In addition, the study showed that cattle accounted respectively for about 72 and 78 percent of the meat and milk production annually, playing an important role in smallholder income generation and meeting meat and milk nutritional needs. Beyond these positive economic and nutritional impacts on rural population, the livestock sector transformation in Ethiopia has the potential to impact urban dwellers in terms of employment, access to low price animal products and the overall success in achieving the food and nutritional security.

With high population projected to increase from 99 to 150 million by 2050 in Ethiopia, especially in urban areas, alongside the increase in income from a GDP per capita of 700 to 5,500 USD, an exponential growth in demand for livestock products should be expected (FAO, 2017). Although this is a daunting task, the growing demand for livestock products will provide an incentive for livestock keeping households to expand their assets and productivity to meet the new demand. It was as well observed that national consumption absorbs a large share of the already overall low net commercial off-take rates or market supply from smallholder farmers and pastoralists leaving a small share for live animal sale and meat export activities (Negassa and Jabbar 2008).

Despite the importance of livestock in the Ethiopian economy, several constraints related to livestock production (e.g. low livestock productivity) remain a major barrier to the development of the livestock sector in Ethiopia (Negassa et al., 2013; Shapiro et al., 2015). Based on a livestock sector analysis (LSA) study from 2013, there are three areas of concern with regard to dairy cow productivity improvement, which include the improvement of genetic breed, feed and veterinary care (Shapiro et al., 2015). For instance, the main challenge to increase dairy cow productivity, in terms of feed, include mainly the limited access to land for forage production and quality forage planting materials. One way of increasing land access to forage would be to use small-scale irrigation to grow forage and fodder during the dry season.

The LSA study indicates that if no investment is made in raising livestock productivity, the projections for the year 2028 show a deficit of 53 percent for all meat (1.332 million tons) and 24 percent for cow milk (1987 million liters) due to exponential increase in demand as a result of rapid population growth and rising per capita income (Shapiro et al., 2015). Moreover, based on potential returns per Ethiopian birr invested (internal rate of return, IRR) in available technologies (genetic, feed, and health), the LSA results show a high return on investment in cattle productivity in terms of poverty reduction, income growth, meeting future domestic consumption as well as the increase in meat and milk exports and foreign exchange earnings. Although much of the research is geared towards breeding to increase high yielding cow breeds and improve local breeds, feed shortages in both quality and quantity is a major constraint affecting animal production in the highland and lowland areas (Shapiro et al., 2015). Research on forage seed production needs to be strengthened to develop crop management technologies that contribute to improved forage seed availability and by enhancing research capacity in the area of forage and forage seed production. At the household level, priority needs to be given to improved forage production by using available forage technologies as well as the use of improved forage varieties with better management techniques. Irrigation can be used to expand forage production on irrigated land and a factor of attraction to private investment into seed and feed production that will ensure sufficient feed supply for the emerging market-oriented livestock operations.

The introduction of small-scale irrigation (SSI) technologies by the Feed the Future Innovation Laboratory for Small-Scale Irrigation (ILSSI) project came at the right time and led to field trials with local farmers beginning in 2015 in Ethiopia. Biophysical and socio-economic data were collected since 2015 on different irrigated crops that include onions, cabbage, carrots for human nutrition but also napier grass, oats and vetch for animal nutrition. The use of SSI technologies to grow forage and irrigated fodder can help increase the feed availability and also help livestock keepers and pastoralists with feed to smooth out difficult times such as drought.

Normally in non-drought times, pastoralists are not in hurry to sell their livestock and have the flexibility to negotiate better prices (Sara 2010). However, in times of drought with low feed availability, pastoralists sell at lower prices to get emergency cash. Thus, the use of SSI to produce irrigated fodder can help smooth that period out by feeding livestock and increasing chance to sell at good price (as in normal times). Also, the migration of livestock in search of pasture during drought reduce the family access to animal products (e.g. milk) that they normally access when their flock are around, increasing malnutrition and food insecurity (p.13). The use of SSI technology to produce irrigated fodder can as well reduce the possibility of milk shortages for households and better nutrition.

Poor breeds genetics is cited also as one of the main barriers to high livestock productivity in terms of milk and meat in Ethiopia (Negassa et al., 2013). Currently in Ethiopia, the livestock population is in majority from local breeds with a very negligible number of crossbreds of about 1 percent of total population in the country (Shapiro et al., 2015). In Ethiopia, early genetic improvement efforts carried out under the Ethiopia Institute of Agricultural Research (EIAR) and focused on improving milk production potential of local breed through selection, did not produce expected results (Shapiro et al., 2015). This led the government to redirect the dairy cattle breed improvement toward crossbreeding with a high potential to increase milk production from local breeds cattle. For example, results from a study conducted in Western Oromia revealed that the total daily milk yield improved five-fold for crossbred cows as compared to local breeds (Abera 2012). A value chain study in Lemo district, SNNP region shows that about 2% of the dairy cows are cross-bred cows kept mainly in urban and peri-urban areas to produce fresh milk consumed by urban consumers and diary businesses (Dubale et al. 2015). Despite the low proportion of crossbreed cattle (less than 2%) compared to the total cattle population in Ethiopia, the potential in milk production increase due to crossbreeding is expected to expand the milk marketable surplus and the milk sales share (Shapiro et al., 2015).

Although there are many barriers to livestock sector development and improvement in Ethiopia that include production (breeds, feeds, veterinary), financial and institutional barriers, this research will focus on the production challenges related to feeds production improvement.

To fill some of the research gaps and evaluate the impacts of feed production increase in Ethiopia, a farm level economic and nutrition simulation model (FARMSIM) is used to evaluate the potential nutrition and economic impacts of irrigated fodder on farming households in Lemo woreda, Upper Gana kebele, SNNP region of Ethiopia. The Upper Gana kebele was selected in 2013 by the ILSSI project as one the study sites to assess the impact of small-scale irrigation technologies on the households' livelihoods. This research study will focus on the use of crossbred cows and the increase in animal feed production, in addition to vegetable production and their impacts on consumption and nutrition of households in Lemo woreda.

Data and study site

Input data for the farm simulation model (FARMSIM) comprise information on farm assets, liabilities, production costs, yields, output prices, and use of crops and livestock products for human consumption and livestock feed. For each input data the user must provide information for the current (baseline) and the alternative farming systems (scenarios).
In Lemo woreda (district) located in Hadiya zone, SNNP region of Ethiopia, crop and animal production are the major economic activities (Berhanu, 2010).

The input information on crops and livestock for the baseline scenario was acquired from a household survey conducted in Lemo ILSSI sites of Upper Gana by the International Food Policy Research Institute (IFPRI) in 2017. This survey was a follow-up survey, from a previous baseline household survey conducted by IFPRI in 2015, to study the impacts of small-scale irrigation technology adoption and helped update the crop and livestock baseline information. The surveys show that the major crops grown in the wet season, by area, in Upper Gana are wheat (440 Ha), teff (360 Ha), maize (161 Ha), potatoes (182 ha), haricot bean (162 ha) and peas (43 ha) on an estimated total cropland of 1500 Ha (rain-fed and irrigated). The main irrigated crops are cabbage, carrot, tomatoes and pepper. Only 3% of the surveyed household indicated to have irrigated plots and 50% among them mentioned ground water to be their water source. About 50% said to obtain water using hand bucket and hose while 4% use hand/foot pump.

Data input for the alternative scenarios were collected during field trials conducted from 2015-2017 with local farmers in Upper Gana and Jawe kebeles and led by the Africa Research in Sustainable Intensification for the Next Generation (Africa Rising), the International Water Management Institute (IWMI) and the International Livestock Research Institute (ILRI) (Schmitter et al. 2016). About 45 farmers participated in the field trials that comprised several water and farm management practices ranging from the use of fertilizers (DAP and Urea) and pesticide, water lifting and water management technologies. These included the use of rope & washer and solar pumps, drip irrigation kits as well as the use of wetting front detector (WFD) to supply optimal water to irrigated crops during the dry season. In this study, carrots, cabbage and oats & vetch are considered for irrigated crops in Upper Gana kebele to evaluate their impacts on income and livestock production. However, carrots were excluded from the simulation study but acquired by the farm families through purchase to focus on livestock production technologies.

Information on crossbred cows was collected both from field trials and farmers in Lemo (SNNP region) and Robit kebele (Amhara). A crossbred cow can produce about 5 liters per day with supplemental forage nutrition or about 1500 liters assuming 305 lactating days in year as opposed to 1.2 liter for local or native cows (Adie Aberra and Bezabih, M. Derseh/ILRI, personal communication 2019). This information aligns and is comparable to the numbers reported in the Ethiopian livestock master plan (ELMP) for the period from 2014/15-2019/2020 where crossbred dairy cows would produce 6 liters/day compared to 1.9 liters for local or native cows (Shapiro et al., 2015).

Lemo woreda, located in Hadiya zone, SNNPR region, is comprised of 35 peasant associations (PA/Kebele) that include Uppder Gana and has a total population of 118,594 according to the 2007 Ethiopian census (Figure 1). It was selected to study the impact of irrigated fodder due to its high production potential of oats and vetch as indicated in figure 1. Most of the Lemo woreda falls into the agro-ecological zone (AEZ) moist “Woinadega” (Dubale et al. 2015). The rainfall in the woreda varies between 950–1200mm annually and most of the area is between 2100 and 2500 m.a.s.l. The average temperature in most of the district varies between 12–24 Celsius degree. The Upper Gana kebele has a total population of 6,195 living in about 796 households (Ethiopian Census, 2007). In addition to being a high livestock production area, Lemo was also selected as a case study site due to its high potential to produce fodder biomass.

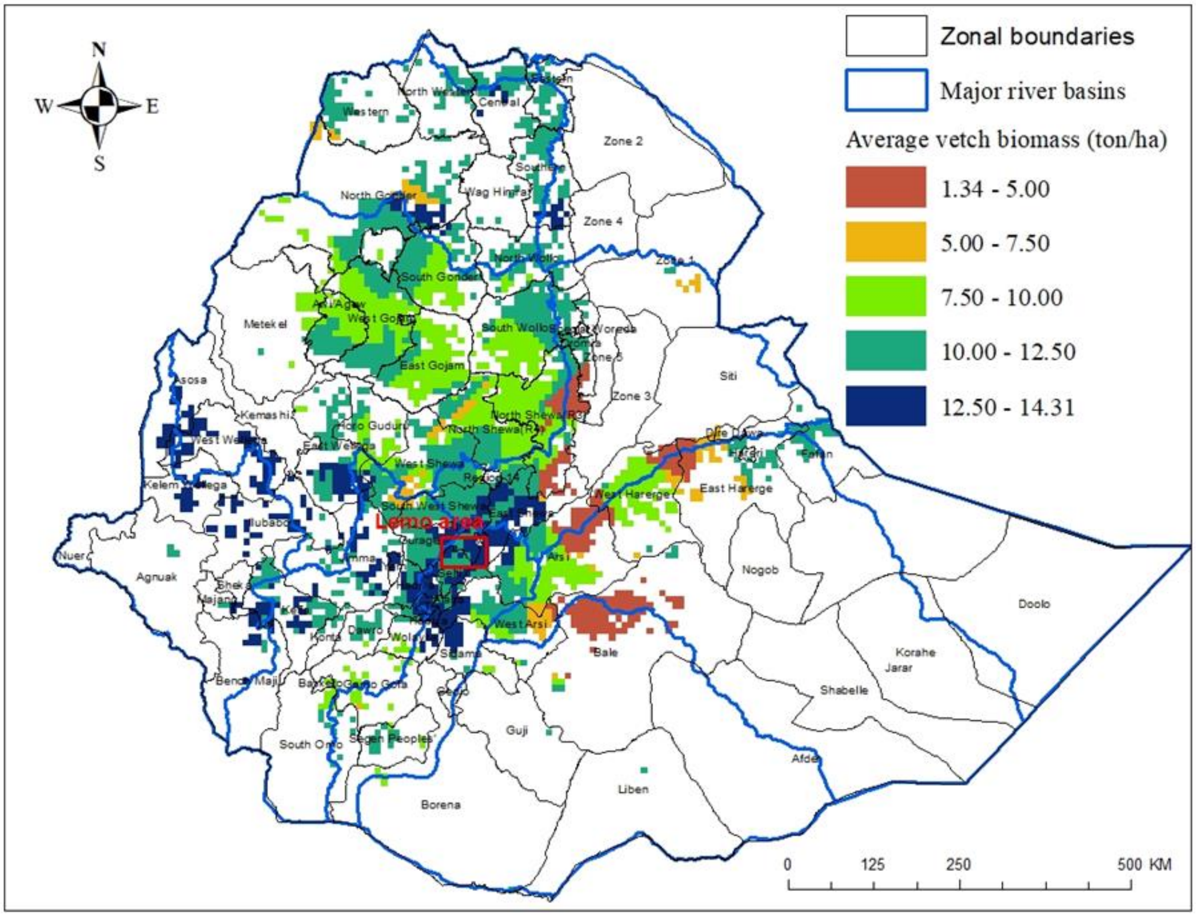

Figure 1. Location of Lemo woreda and average vetch biomass production, Ethiopia

Methods and scenario analysis

A farm level simulation model (FARMSIM) was used to conduct an ex-post study on the profitability and nutrition outcomes of the SSI technologies at the household level. FARMSIM is a Monte Carlo simulation model for quantitatively analyzing the economic and nutritional impacts of alternative farming technologies on small farms(Bizimana and Richardson 2019). The model simulates and forecasts for five years the current crop and livestock farming systems and an alternative farming system simultaneously. Risk for crop yields, livestock production (birth rates, death rates, weight gain, and milk production), and market prices is explicitly included in the model so the results can be presented in terms of probabilities. Stochastic annual crop yields are simulated from a simple distribution using the GRKS function. The key output variables are probability of positive annual net cash income (profit) and probability of a benefit cost ratio greater than one. For the nutrition analysis, the model presents the probability of consumption exceeding average daily minimum requirements for calories, protein, fat, calcium, iron, and vitamin A for an adult equivalent at the household level (FAO, 2001a&b; FAO, 2010; Institute of Medicine 2006). The evaluation of nutrition in FARMSIM reflects more the concept of food

security in terms of accessibility and availability of the six nutrients described above at the household level.
Irrigated fodder (oats and vetch) and crossbred cows are targeted in this study to assess their economic and nutritional impacts on household wellbeing. Improving animal feed resources and breed can have tremendous impacts on both household income and nutrition through the production, consumption and sale of live animals and animal products such as milk, butter, eggs and meat. In this study small scale irrigation (SSI) technologies along with fertilizer application were used to grow and improve yields of fodder (oats & vetch) with the purpose of feeding animals and generating income. Supplementing animal feeding with fodder to both native and crossbred cows 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 (feeding fodder from a mix of oats & vetch; cow breed) were aligned with water lifting irrigation technologies (rope & washer and solar pumps). In the baseline scenario, fodder crops (oats & vetch) are grown on limited land with minimal irrigation and fertilizer applications. Due to limited production, all the fodder produced is sold at the market for revenue generation. However, in the alternative scenarios, more land (3-7 times the Baseline scenario land) is allocated to fodder especially during the dry season due to irrigation in addition to raising crossbred cows. Higher fertilizer rates and improved seeds are also utilized in the alternative scenarios compared to the baseline. A portion of the total production of fodder is fed to cows, bulls and sheep to increase the production of milk and meat while the remainder is sold to generate income (See Appendix C). Following are the four scenarios analyzed: a baseline and three alternative scenarios (Alt.1.; Alt.2. and Alt.3).

Baseline: No or minimal irrigation; no supplemental fodder feeding; local or native cows
Alt.1--R&W-P_N: Rope & Washer pump used in optimally irrigated systems + Supplemental fodder feeding on native cows
Alt.2--Solar-P_N: Solar pump used in optimally irrigated systems + Supplemental fodder feeding on native cows
Alt.3--Solar-P_CB: Solar pump used in optimally irrigated systems + Supplemental fodder feeding on crossbred cows

In this study, we consider four scenarios comprising a baseline with current farming conditions (non-intervention farmers) and three alternative scenarios implementing the SSI technologies (with intervention farmers). Six crops that include three grains (maize, teff and wheat), one vegetable (cabbage) and one fodder (oats and vetch) were analyzed at the farm household. In all three alternative scenarios, the grain cropping area, input cost and yield were kept constant; only the crops under irrigation (cabbage and oats & vetch) had different input costs, yields, and cropping areas associated with the different SSI technologies (Appendix B). Additionally, the fodder (oats & vetch) was fed to cattle and sheep as a supplement to increase the milk and meat production. On average supplemental feeding quantity was estimated to be between 2000 and 3000 Kgs and 750 Kgs of fresh fodder for one cow (native and crossbred) and one sheep respectively during a year. Expected additional milk and weight gain were estimated to be between 400-1000 liters and 52.4 Kgs respectively for one cow and 26 Kgs per sheep (Adie Aberra and Bezabih M. Derseh/ILRI, personal communication, 2019). Two water lifting technologies (WLT) associated with the alternative scenarios and SSI technologies were analyzed: the rope and washer pump and the solar pump systems.

The baseline scenario considers no or minimal irrigation based on the household survey information while the alternative scenarios considers irrigation of vegetables (cabbage) and fodder during the dry season using the rope & washer and solar pump tools. Alternative scenarios one, two and three (Alt. 1 and Alt. 2, Alt. 3) consider, respectively, the use of the two WLT technologies under adequate irrigation conditions that supply 500 mm of irrigation water for optimal growth of cabbage and fodder. All the alternative scenarios take into account the full input labor costs to carry out the farming and irrigation activities at the household level. Irrigated cabbage and fodder were adequately fertilized with urea and DAP for alternative scenarios Alt.1&2 and only fodder was considered for Alt.3 to increase its production area.

In addition to evaluating the profitability of SSI technologies, a utility-based approach is used to rank the different alternative scenarios. There are several methods that can be used to rank risky scenarios (mean, standard deviations etc.) but utility-based ranking methods are a better approach to help decision make select among scenario since they take into consideration risk preferences. In this study, the Stochastic Efficiency with Respect to a Function (SERF) was used to rank the risky alternatives given its many advantages over the others. Hardaker, Richardson, Lien and Schuman (Hardaker et al. 2004) merged the use of certainty equivalent (CE) and Meyer's range of risk aversion coefficients to create the stochastic efficiency with respect to a function (SERF) method for ranking risky alternatives. SERF assumes a utility function with a risk aversion range of U (r_1 (z), r_2 (z)) and evaluates the CEs over a range of risk aversion coefficients (RAC) between a LRAC (lower RAC) and an URAC (upper RAC). The range can go from an LRAC = 0 (risk neutral) to URAC = 1/wealth (normal risk aversion). In ranking the risky alternatives, the SERF approach compares the CE of all risky alternative scenarios for all RACs over the range and chooses the scenario with the highest CE at the decision maker's RAC as the most preferred (identifying the efficient set) and summarizes the CE results in a chart. Any key output variable (NPV, NCFI, EC…) distribution can be selected to rank alternative farming systems (irrigation technologies).

Assumptions

In FARMSIM model, to show the full potential of adopting new technologies, the alternative crop farming technologies are assumed to be fully adopted (100%) as demonstrated in the field trials by the intervention farmers. The baseline household survey shows that all the sampled households used fertilizers but around 46% of them used improved seeds. As for livestock technology, although we assume in the model at least one crossbred cow per household in Lemo, the high cost of purchasing a crossbred cow and its adoption is still low in Lemo (3%). We assumed and incorporated a loan scheme for each family in Lemo to purchase one crossbred cow, payable in four years at 10 percent interest level. A lower and progressive adoption rate was considered for the livestock technologies in the course of the five-year forecasting period based on household survey information which shows that about 25% of the sampled households made expenses toward animal care. For this reason, the adoption rate in the alternative scenario was assumed to be 60% and 80% respectively in the first and second year and 100% in the following three years. Note that the adoption rate in FARMSIM refers to the percentage of acreage or animal under new farming or livestock technology adopted by a household or village. Second, the markets were assumed to be accessible and competitive with no distortion where the supply and demand determine the market prices. However, in the five-year economic forecast, market selling price in each of the five years was assumed to equal the average selling price of year one for each crop sold. Last, based on preliminary simulation runs on profitability, we assume in the alternative scenario that each household will allocate up to 40 percent of their net profit (if available) to purchase supplemental foodstuff of animal source especially eggs and butter to improve nutrition except milk due to the increase in milk production at the household (Fig. 2). The focus on animal products purchase to supplement nutrition is motivated by the low consumption of animal products at the household level as shown by the surveys (See Appendices A & B on model input).

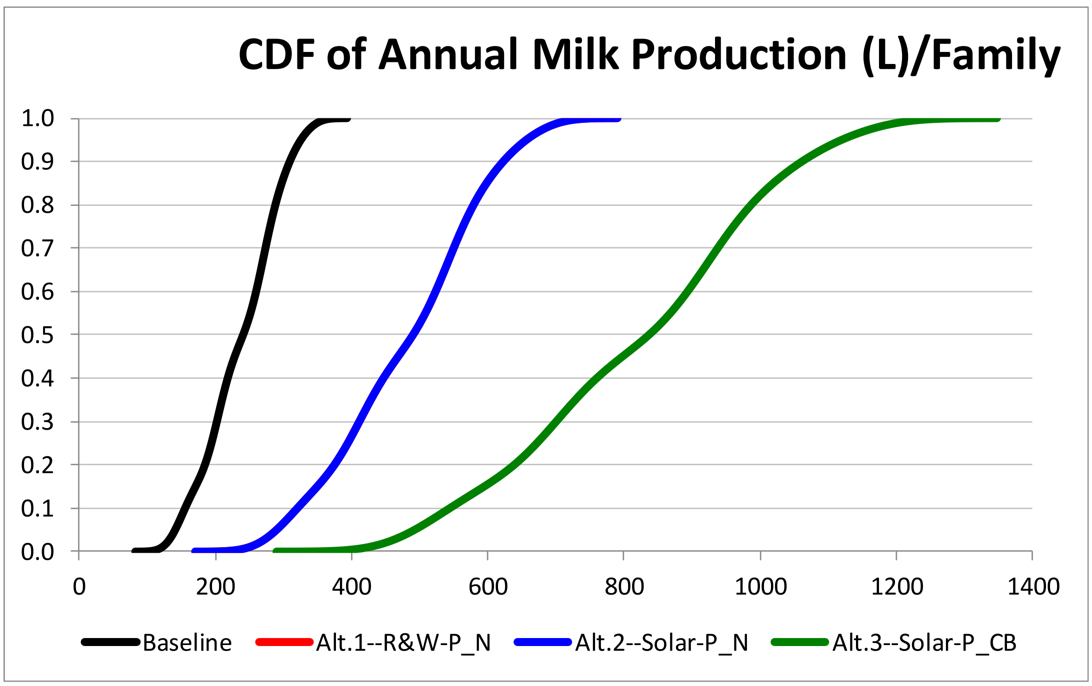

Figure 2. Cumulative distribution of annual milk production per family in Lemo

Simulation results and discussion

Economic impacts

The simulation results for net present value (NPV), which assesses the long-term feasibility of an investment, show a positive NPV value for all the scenarios in Lemo woreda. Although we do not see a very significant difference, both the NPV values under the rope & washer and solar pumps scenario (Alt. 1 and Alt. 2) show higher NPV value compared to the baseline scenarios. Lower NPV values under the crossbred alternative scenario (Alt.3) compared to Alt. 1&2 is mainly due to higher investment costs incurred for solar pump and crossbred cow purchases.

The annual net cash farm income (NCFI) which represents the economic profitability at the household level, shows in year five, that the average profit under alternative scenarios (Alt. 1, Alt. 2, and Alt.3), is two to three times higher than that of the Baseline scenario, with a percentage change in profit from the baseline to the alternative scenarios standing at 90%, 99% and 263% increase respectively (Table 1).

The net profit distribution (CDF) shows however, between 4 and 6% probability of having a profit (NCFI) equal or less than zero (loss) for Alt. 1 and Alt. 2 and 0.2% probability for Alt.3 (Crossbred scenario) to fall below zero (Fig. 3). The CDF indicates as well a 12% probability of having a net profit for Alt. 1 and Alt. 2 equal or less than that of the Baseline scenario at the mark of 2,185 Birr of the distribution. Although the profit under alternative farming technologies show higher gains compared to the baseline, the distribution results highlight the risk associated with high production and water lifting tool (such as solar pump) costs involved in the SSI technologies investment. The net cash income or profit for Alt.3 associated with the crossbred cow clearly shows higher profit compared to other scenarios as its CDF curve stands farther to the right of all other scenarios, mainly due to increase in fodder sale.

Table 1. Economic impacts of livestock technologies in Lemo woreda

	Baseline	Alt. 1--R&W-P_N	Alt. 2--Solar-P_N	Alt. 3--Solar-P_CB
Economics:	Averages values in Birr /family in year 5			
Net present value (5yrs)	119,429	160,237	152,340	140,750
Tot avg. net profit	4,139	7,863	8,233	15,009
% change profit: Alt./Baseline		**90%**	**99%**	**263%**
Benefit-Cost Ratio: Alt/Base		**1.9**	**1**	**1.2**
IRR		0.5	0.1	0.2
Prob BCR> 1 (%)		97	50	88
Prob IRR> 0.1 (%)		97.5	50.8	88
Avg. Livestock net profit	3,134	2,833	2,833	3,089

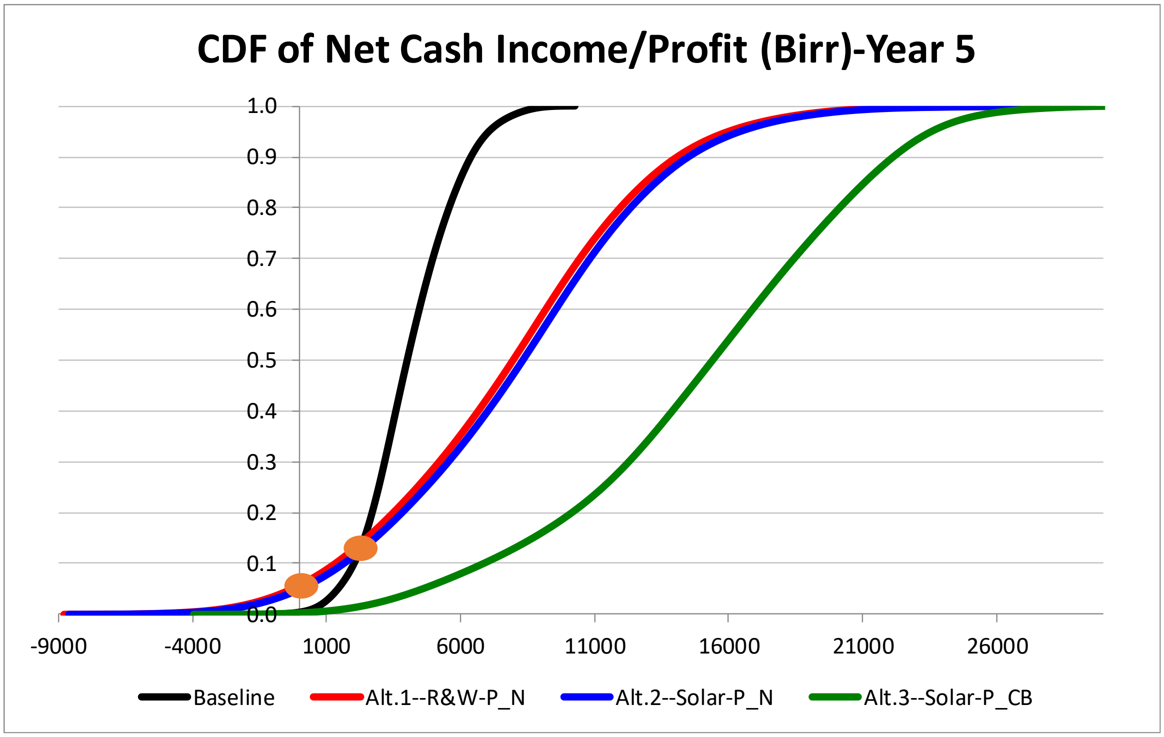

Figure 3. Cumulative distribution of net cash income per family in Lemo

To assess whether the benefits are worth the investment cost, a cost benefit analysis (CBA) is conducted using two NPV-related metrics illustrated by the benefit cost ratio (BCR) and the internal rate of return (IRR). The two metrics inform on the profitability and return on investment of new business or enterprise, in this case, the investment in small-scale irrigation technologies (SSI) such as irrigation tools and fertilizers and crossbred cows. Moreover, the cost benefit analysis presents the probability distributions of the BCR and IRR from 500 iterations (simulations) in FARMSIM (Fig. 4). The results indicate on average BCR values for all alternative scenarios equal or greater than 1.0 and IRR values equal or greater than the discount rate of 0.1 (threshold values) which is an indication of the profitability (or break-even) of the investment under alternative scenarios compared to the baseline (Table 1).
For the Alt.2 scenario under the solar pump system and native cows, the results show on average a BCR ratio of 1 and an IRR of 0.1 values on the border line (break-even) as they equal their respective threshold values. Also, the distribution indicates that the BCR and IRR simulated values have respectively about 50% and 49.2% probability of falling below their threshold values meaning a 50% chance of negative return on investment for the solar pump scenario (Figure 4). This is partially due to high investment costs in labor and solar pump costs compared to receipts. For the Alt.3 scenario under the solar pump system and crossbred cows, the results show on average a BCR ratio of 1.2 and an IRR of 0.2 both greater than their threshold values. Also, the distribution indicates that the BCR and IRR simulated values have both about 12% probability of falling below their threshold values meaning a 12% chance of negative return on investment for the solar pump and crossbred scenario (Fig. 4). Although high investment costs (operational and

capital) are recorded under Alt. 3, its high receipts due to the fodder and animal sale increased its overall profitability.

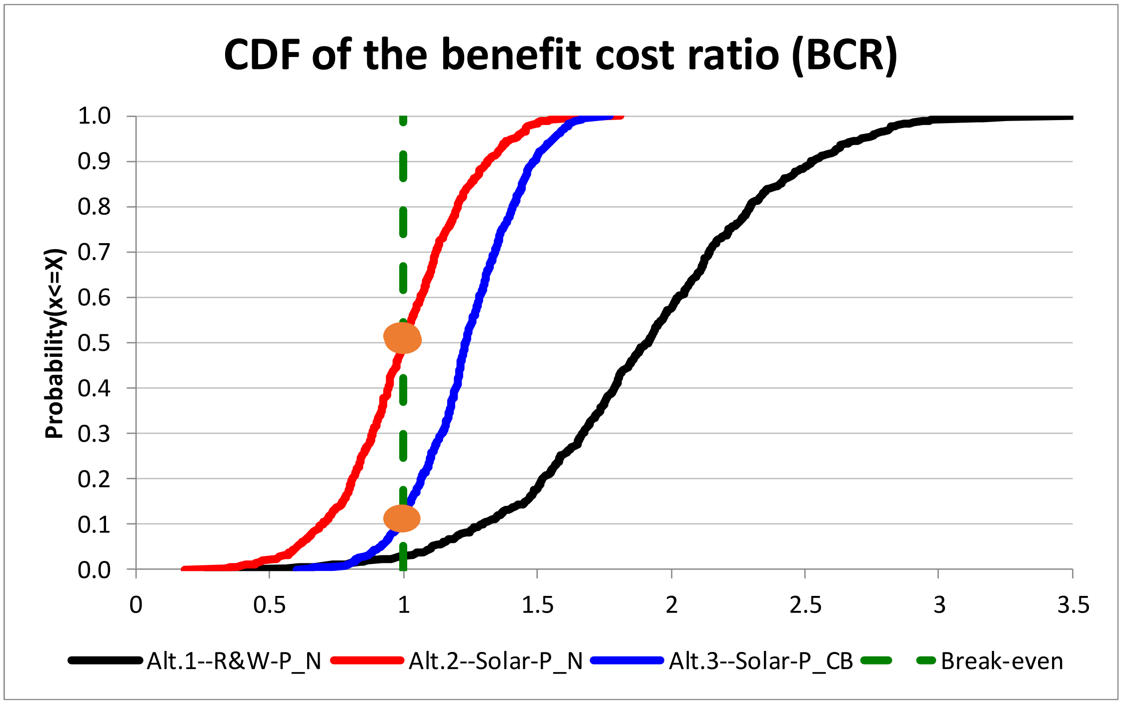

Figure 4. Cumulative distribution of the benefit cost ratio for alternative scenarios

In this study, the four scenarios (the baseline and three alternative scenarios) were ranked based on year 5 simulation results of net cash farm income (NCFI) or profit. Results in figure 5 show that the crossbred/solar pump scenario (Alt. 3) is distinctively the most preferred scenario across all levels of risk aversion, ranging from risk neutral (0) to moderately risk averse (0.0003). Alternative 3 is the preferred scenario because the certainty equivalence values at every RAC level are greater than the other scenarios. The next most preferred scenarios are the native cows alternative scenarios 2 and 1 that are respectively associated with solar and Rope & washer pumps, all of which are ranked higher than the baseline scenario. In figure 5 the CEs for all scenario functions decrease as we assume an increasingly risk-averse decision maker.

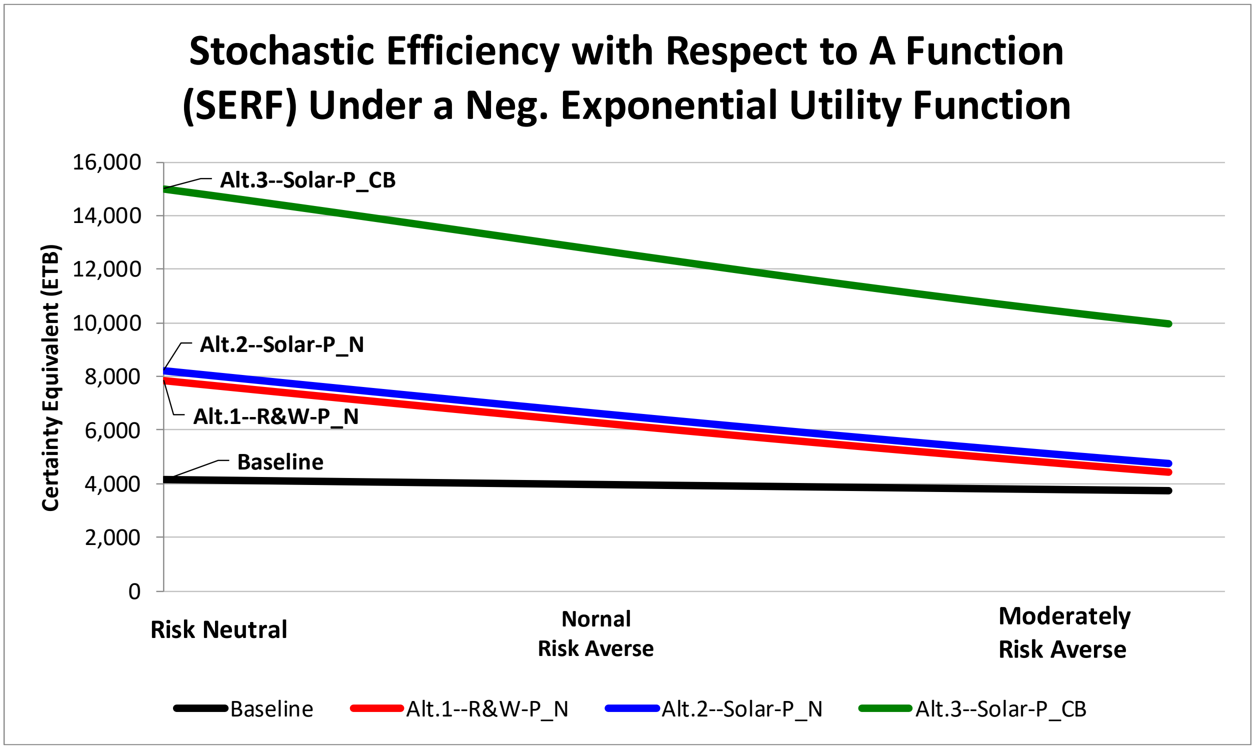

Figure 5. SERF ranking of alternative farming systems in Lemo woreda

Nutrition variables simulation

Generally, the adoption and proper use of agricultural technologies (crop & livestock) contribute to an increase in the quantity and variety of crops and products produced. The implications for family nutrition vary according to the types of crops grown and products consumed at the household. Note also that surplus crops can be sold to generate revenues used to buy food items needed to complement nutrition requirements.

We evaluate nutrition variables and compare them to daily minimum requirements per adult equivalent (AE), to determine adequacy in calories, proteins, fat, calcium, iron, and vitamin A intake, available to the household. In this analysis, farm families consume food grown on the farm and/or purchased at the market for their nutrition. A preliminary analysis of food items consumed by the household in Lemo woreda, Upper Gana kebele using household surveys indicate a predominance of a cereal-based diet with substantial shortage of animal-source products consumption such as meat, eggs, milk and fish (see Appendix E). Based on the amount of profit available and nutrition needs, only households in alternative scenarios were allowed in the model to use up to 40% of their profit to purchase food for nutrition improvement with a priority for food of animal origin. However, the level of profit only permitted mainly the purchase of eggs and butter from markets by the households. Families filled the gap for other animal products such as milk and meat through the consumption of on-farm production that increased its output due to improved livestock production technologies based on fodder feeding and dairy crossbred cows.

The types of crops grown and consumed by the family in Lemo woreda, Upper Gana kebele comprised mainly wheat, maize, teff, cabbage, carrots, banana and haricot beans to which were added moderate purchases of teff and maize as indicated by household surveys. Under Alt. 3 (crossbred cow scenario), significant amount of vegetables (carrot and cabbage) were purchased to compensate the on-farm production whose land was allocated to fodder production. Animal products such as milk, butter, eggs, chicken, sheep, and beef produced and consumed on farm by the household were as well included in the analysis for all scenarios.

Simulated levels of nutrition variables (calories, proteins, fat, calcium, iron and vitamin A) available to farm families increased substantially in the alternative scenarios because of production increases in the alternative scenarios due to farming technology (fertilizer, irrigation and breed) and purchase. For instance, simulation results show that the amount of milk consumed by families in Upper Gana kebele increased by 77% in Alt.1 and Alt.2 alternative scenarios associated with native cow compared to the baseline scenario while the amount of eggs consumed increased four times. Under Alt.3 associated with crossbred cows, milk consumption by families increased 3 folds (304%) while the consumption of eggs increased 28 folds due to purchase. The amount of butter consumed by families increased by 62% from the baseline to alternative scenarios for Alt.1 & 2 while it increased 20 times for Alt.3. associated with crossbred cows due to purchase. The expansion of irrigated fodder cropping area under Alt.3. associated with crossbred cow scenario, by shifting the irrigated land for vegetables, led not only to the increase in feeds but also fodder sales which saw the surge in receipts and profit by 5 times in comparison to the baseline. The increase in live weight for cattle and sheep led to the increase in consumption of beef by 31% and mutton by 54 percent.
Simulation results for each of the nutrition variables in this study are discussed below in details. Note that the fraction of crop consumed by the family and reported in the household survey, was kept constant for the baseline and alternative scenarios for all crops except the irrigated vegetables (Alt.1&2) for which the fraction was adjusted to provide the needed amount and sell the rest at the market. Therefore, the increase in crop and livestock production due to improved farming technologies (fertilizer, irrigation, breed) and supplemental food purchase in alternative scenarios led to an increase in available nutrients.

Calorie intake
The calories intake simulation results for a representative household in Lemo woreda, Upper Gana kebele, indicate an average daily calories intake available of 2,437 and 2,646 calories (Table 2), respectively for the baseline and alternative scenarios, which are higher than the daily minimum requirement of 2,353 calories per adult equivalent (AE) for global average (FAO, 2001a). Although farm families show adequacy in available calorie intake, the simulation results indicate that households under the baseline scenario have a 25% chance of having their calories intake available less than the required minimum of 2,353 Kcal/AE/day while alternative scenarios have on average between 1% and 3% probability of falling below the minimum calorie required (Appendix D).

Proteins intake

The protein intake simulation results show that on average a representative household in the baseline and alternative scenarios has 69 and 78 grams/AE respectively of protein intake available which meet and exceed the daily minimum requirement of 41 gr/AE (Table 2 and

Appendix D). The simulation results show as well that there is zero chance for the baseline and alternative scenarios to fall below the minimum proteins required per adult (AE) per day.

Fat intake

Simulation results for available fat intake show a deficit in fat intake for both the baseline and alternative scenarios (Table 2 and Appendix D). Although there is an improvement of fat intake available between the baseline and the alternative scenarios, their respective averages 23 and 37 grams, are still below the daily minimum fat requirement average of 39 grams for an adult. Major improvement in available fat intake is noticed under the crossbred/solar pump alternative scenario which was 30% above the minimum requirement. However, the full distribution of the fat intake simulation results shows about 2% chance for the c alternative scenario 3 under crossbred cows to fall below the minimum proteins required per adult (AE) per day while that probability stands between 99% and 100% for all other scenarios (Fig. 6).

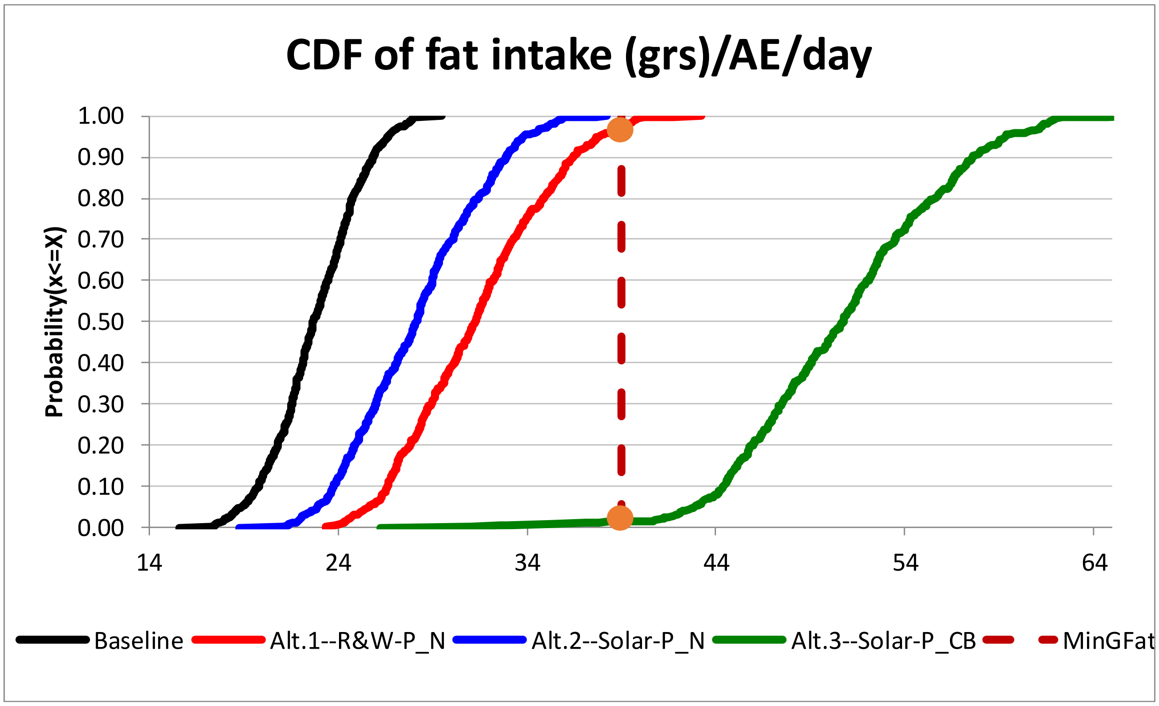

Figure 6. Cumulative distribution of fat intake (grs) per AE per day in Lemo

Calcium intake

The simulation results show large deficits in calcium intake for both the baseline and alternative scenarios (Table 2). The average calcium intake per AE per day is 0.38 and 0.68 grams, respectively, for the baseline and the three alternative scenarios (ALT1, 2 and 3), falling short of the daily minimum requirements of 1 gram per AE. The full distribution of calcium intake shows that the best performing scenario (Alt.3) under the crossbred/solar pump is the only alternative scenario that has a very slim 1% chance of being above the minimum calcium requirement of 1g per AE per day (Fig.7). 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, 2001b). Moreover, due to a mismatch between the calcium intake data and the relatively high intake requirements, a revised US/Canada Dietary Reference Intakes (DRIs) recommends replacing the Recommended Daily Allowance (RDA) with the Acceptable Intake (AI) calcium. An additional concern related to calcium requirements, is the wide difference between gender and age, making it difficult to find an acceptable average requirement.

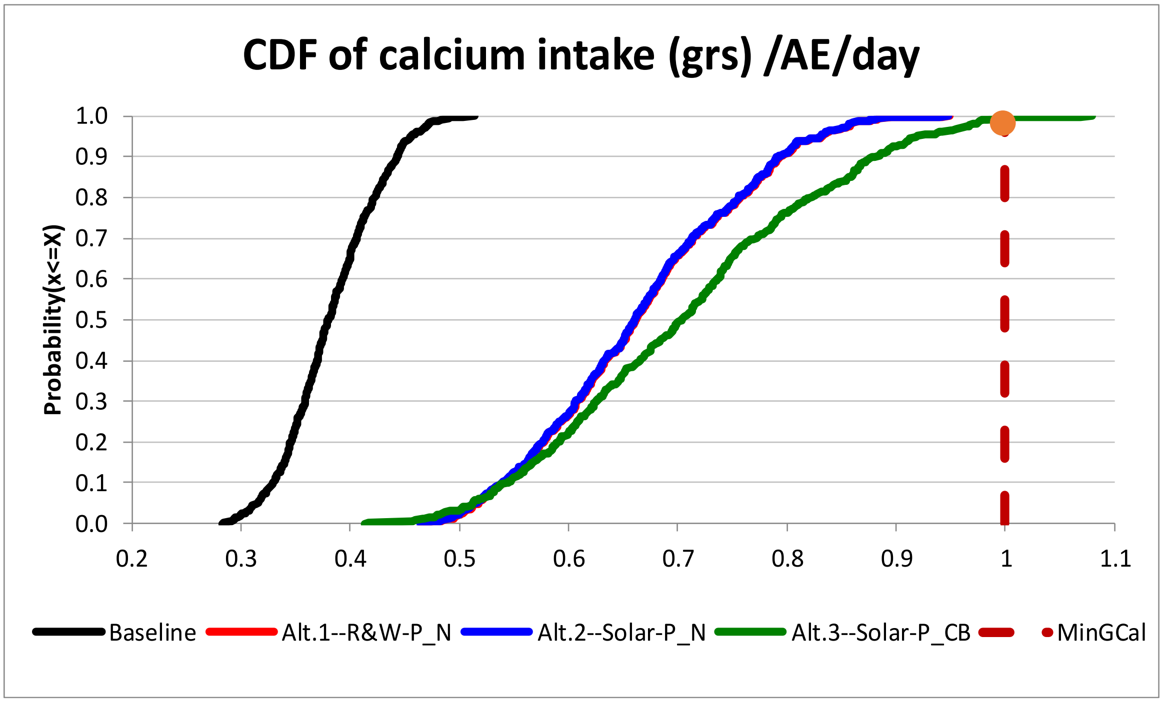

Figure 7. Cumulative distribution of calcium intake (grs) per AE per day in Lemo

Iron intake

Simulation results indicate that households in Lemo get more than the required minimum levels of iron. The average iron intake available per AE per day for all scenarios, estimated at 0.017 grams was almost twice that of the daily minimum requirement of 0.009 grams per AE (Table 2). Moreover, there was a very slight improvement between the baseline and the alternative scenarios in terms of iron available, which averaged 0.16 and 0.17 grams respectively. The detailed simulation results show as well that there is zero chance for the baseline and alternative scenarios to fall below the minimum iron intake required per adult (AE) per day (Appendix D).

Vitamin A intake

In this study, the simulation results for vitamin A, expressed in terms of retinol activity equivalent (RAE), indicate adequate to surplus vitamin A intake levels in both the baseline and alternative scenarios. The average levels of vitamin A intake for the baseline and alternative scenarios are 825 µg RAE and 1000 µg RAE respectively, and 37% to 67% higher than the daily minimum requirement for an adult equivalent of 600 µg RAE (Table 2). The full distribution of available vitamin A intake shows that there is almost zero chance for all the scenarios to fall below the minimum requirement vitamin A intake per day and adult equivalent (Appendix D).

Table 2. Nutritional impacts of livestock technologies in Lemo woreda

		Baseline	Alt. 1-- R&W-P_N	Alt. 2-- Solar-P_N	Alt. 3-- Solar-P_CB	% Change in Nutrient: Base/Alt	
Nutrition:	Min req.	Average daily nutrients in year 5				Base/Alt2	Base/Alt3
Energy (calories/AE)	2,353	2,437	2,608	2,576	2,752	***6***	***13***
Proteins (grs/AE)	41.2	69	78	77	80	***12***	***16***
Fat (grs/AE)	39	23	31	28	**51**	***24***	***122***
Calcium (grs/AE)	1	0.38	0.67	0.66	0.71	***73***	***84***
Iron (grs/AE)	0.009	0.016	0.017	0.017	0.016	***5***	***0***
Vitamin A (µg/AE)	600	1,000	1,000	1,000	1,000	***17***	***31***

Note: AE = Adult equivalent; grs=grams; Unit for vitamin A = µg RAE/ AE; Min req. = Minimum requirements; Base/Alt = increase from the baseline to the alternative scenario (Alt.2 and Alt.3)

Overall, the nutrition simulation results show that the food products consumed by families in the baseline and alternative scenarios met the minimum daily requirements for calories, proteins, iron, and vitamin A but were insufficient for calcium and fat especially for the baseline (Table 2). Large deficits are associated with calcium whose averages range from 0.38 – 0.71 grams per day per adult equivalent (AE) and are below the 1gram daily minimum required per AE. A close look at calcium intake probability distribution from simulated values indicates a slim probability (1%) for the available calcium to be greater than the minimum required. Several previous nutrition studies for Ethiopia using FARMSIM have as well shown persistent deficiency in calcium.

The large deficiencies in calcium may be due to two main reasons. First, there is an issue of low consumption of animal products rich in calcium in developing countries (vs. developed countries) (FAO, 2001b; Agueh et al., 2015). Second, there is still discussion on the appropriate level of minimum required calcium intake to consider for nutrition analysis as the current threshold of 1 gram appears to be relatively higher than what a human body normally requires. Another reason could be related to the wide range of calcium requirements between gender and age making it difficult to find an acceptable average requirement. Slight deficits are observed for fat in Baseline and Alt.1&2 scenarios associated with native cows whose averages range from 23 – 31 grams per day and AE and are below the minimum required quantity of 39 grams/day/AE. However, Alt.3 associated with crossbred cows is well above the minimum requirement (51g).

The nutrition outcome indicated an improvement in quantity intake available from the baseline to the alternative scenarios for all nutrition variables (calories, proteins, fat, calcium, and iron). It is worth mentioning that wheat and maize contributed a great deal to the provision of most of the nutrients ranging from calories to proteins, fat and iron, an indication of low consumption of animal-source products at the household level.

The consumption of milk however alleviated some of the deficits in calcium increasing its intake by 73% under Alt.1 & 2 and 84% under Alt.3 associated with dairy crossbred cows. Deficits in fat were completely addressed due to the increase in consumption of butter through purchase under Alt.3 scenario associated with crossbred cows. Specifically, the improvement in calcium intake under Alt.3 related to crossbred cow scenario was due to the increase in milk consumption which contributed about 54% to the total available calcium while that contribution stands at 28% in the baseline scenario. The purchase of additional butter to supplement nutrition at the household level increased, in comparison to the baseline, its intake by 24% under Alt.1 & 2 and 122% under Alt.3 associated with crossbred cows (Table 2). The improvement in fat intake under Alt.3 related to crossbred cow scenario was due to the increase in butter consumption which contributed about 35% to the total available fat while that contribution stands at 3% in the baseline scenario. It is worth mentioning that wheat and maize contributed a great deal to the provision of most of the nutrients ranging from calories to proteins, fat and iron, an indication of low consumption of animal-source products at the household.

The nutritional impacts from increased animal products consumption consistently led to the increase in available nutrients under alternative scenarios with improved livestock production technologies and purchase option specifically under Alt.3 associated with crossbred cows (Table 2). For instance, the percentage change and increase in nutrients intake ranges from 12% to 16% for proteins, 24% to 122% for fat, 73% to 84% for calcium and 17% to 31% for vitamin A for Alt.2 and Alt.3 respectively. Several studies assessing the impact of adopting dairy technology in Kenya and Rwanda showed that children from households with improved dairy cattle were taller than those from households without improved breeds (FAO, 2012). The contribution of cabbage consumption was as well important. Also, the increase in milk and beef consumption, in alternative scenarios, contributed to the tune of 30% to the total fat intake available at the household level compared to 34% contribution in the baseline scenario. Note that the consumption of carrots (from purchase) improved the vitamin A availability, contributing to about 86% of the household intake. However, the fact that a low number of crop and livestock products were considered in the nutrition simulations in comparison to the detailed family diet as shown in the dietary diversity table (Appendix E) may have slightly under-estimated the actual available nutrient intake figures.
Although the economic impacts of irrigated fodder may seem small, its nutritional impacts are significant provided that the households adopt and apply improved livestock production technologies as shown in the simulation results. The distribution of livestock net income shows that the baseline outperformed at some levels the alternative scenario with improved livestock technologies. This can be explained by the fact that most of the animal products output were consumed on the farm by farm families to improve their nutritional standards. So, there was a trade-off between selling the animal products to increase total net profit or consume a portion of the products to improve nutrition and forgo some extra income. Note however that the extra income made could have been used as well to purchase the necessary food items to improve nutrition.

Conclusions and recommendations

The objective of this study was to evaluate the impacts of adopting agricultural technologies (increased fertilizers and irrigation) to grow irrigated fodder and the use of crossbred cows on household nutrition and farm profitability in Lemo woreda, SNNP region of Ethiopia. A baseline scenario with native cows, current fertilizer application rates and no or minimal irrigation was compared to three alternative scenarios where recommended fertilizers rates and irrigation were applied to crops in association with raising crossbred cows.

Household under alternative and improved small-scale irrigation technologies scenarios associated native and crossbred cows generated more income than their counterparts in the baseline scenario which produced vegetables and fodder using current farming technologies. Also, the use improved livestock production technologies through the production and feeding livestock with irrigated fodder (oats & vetch) increased livestock production in terms of milk and meat at the household level. The increase in consumption of animal products at the household increased the nutrient intake especially calcium and fat which were deficient at the household, improving thus the overall nutrition status.

Improving feed resources and breed for high milk production and yield can address some of the livestock production and productivity challenges in Ethiopia. In this study, the production and use of irrigated fodder through improved small-scale irrigation technologies increased feeds production for livestock nutrition and the surplus was sold for income generation. This is coupled with the introduction of dairy crossbred cows with a potential milk production three times that of local or native cows. The simulation results show not only feasibility of these enterprises but also decent profit under the alternative scenarios (irrigation technologies and crossbred cows) compared to the baseline or current practices. Deficits in fat intake at the household level are addressed while those in calcium are partially alleviated through the increase in milk consumption. Therefore, adopting improved livestock technologies (feeds and breed) has a high potential to improve economic and nutritional wellbeing particularly in Lemo woreda and generally in Ethiopia and could be an opportunity for the country to meet its goals of economic development and reduce food insecurity.

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Appendices

Appendix A. Food of animal origin consumed per year at village and household level--Lemo

	Baseline scenario		Alternative scenarios	
Food items (in Kgs)	Raised	purchased	Raised	purchased
Village level (1503 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; HH = household.

Appendix B. Mean crop yields (Kg/ha), land are (ha) and input costs (Birr/ha) for scenarios in Lemo woreda

	Baseline scenario						Alternative scenarios					
Crops	Mean yield (Kgs/ha)	Crop area /hh (ha)	Cost fert. (Birr/ha)	Cost seed (Birr/ha)	Cost irrig labor (Birr/ha)	Other labor cost (Birr/ha)	Mean yield (Kgs/ha)	Crop area /hh (ha)	Cost fert. (Birr/ha)	Cost seed (Birr/ha)	Cost irrig labor (Birr/ha)	Other labor cost (Birr/ha)
Teff	657	0.23	2364	230	0	78	657	0.23	2364	230	0	78
Maize	1634	0.10	284	201	0	66	1634	0.10	284	201	0	66
Wheat	1320	0.30	2450	495	250	0	1320	0.30	2450	495	250	0
Cabbage	14291	0.01	700	224	0	278	31523	0.05	3987	3132	40613	5000
Fodder (O & V)	12654	0.01	0	0	0	70	34168	0.07	2050	3300	17487	3500

Notes: 1) fert. = fertilizer; irrig. = irrigation; hh = household; O & V = Oats & Vetch;
2) Increase in "Other labor cost" in alternative scenarios are due to increased labor costs of breaking down the hardpan soil

Appendix C. Input variables and livestock technologies scenarios, Lemo woreda

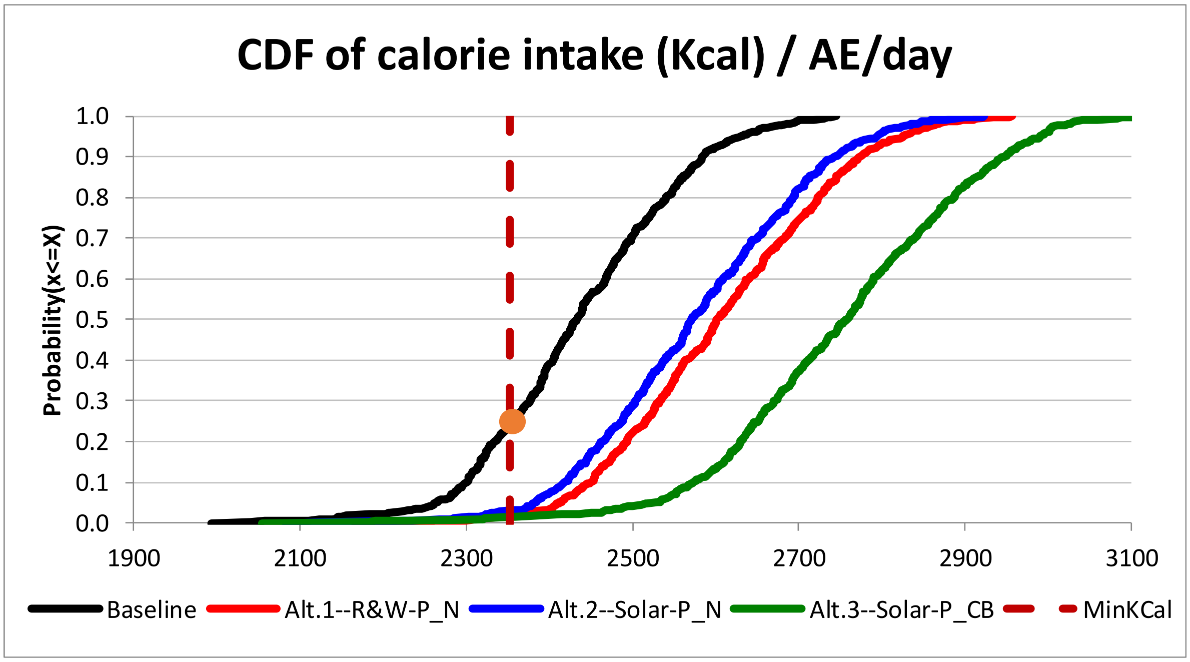
	Baseline	Alt. 1--R&W-P_N	Alt. 2--Solar-P_N	Alt. 2--Solar-P_CB
Irrigated fodder				
Crop area (ha/household)	0.03	0.13	0.13	**0.23**
Yield (t/ha)	12.6	34.1	34.1	34.1
Cows / village or kebele				
Native	1102	1102	1102	**0**
Improved	37	37	37	**796**
Milk per cow				
Liters/cow/year	237	640 [a]	640	**1200**[b]
Live Weight gain (Kgs)/year	0	52.4	52.4	52.4
Live weight /bull	160	212.4	212.4	212.4
Consumption/family		Percent (%)		
Milk by family	70	70	70	70
Milk by employees	0	0	0	0
Milk made into butter	30	30	30	30
Butter consumed	44	34	34	34
Butter sold	56	66	66	66
Sheep (ewes)/ village or kebele	240	240	240	240
Live Weight gain (Kgs)/year	0	26	26	26
Live weight /sheep	34	60	60	60
Fraction consumed/family	0.09	0.09	0.09	0.09

Note [a]: quantity of milk produced under alternative livestock production technologies are based on feeding native cows of about 2kgs/day of fodder with extra milk yield of 2liters/day for about 200 days (milking) (Personal communication, Adie Aberra-ILRI, 2016)

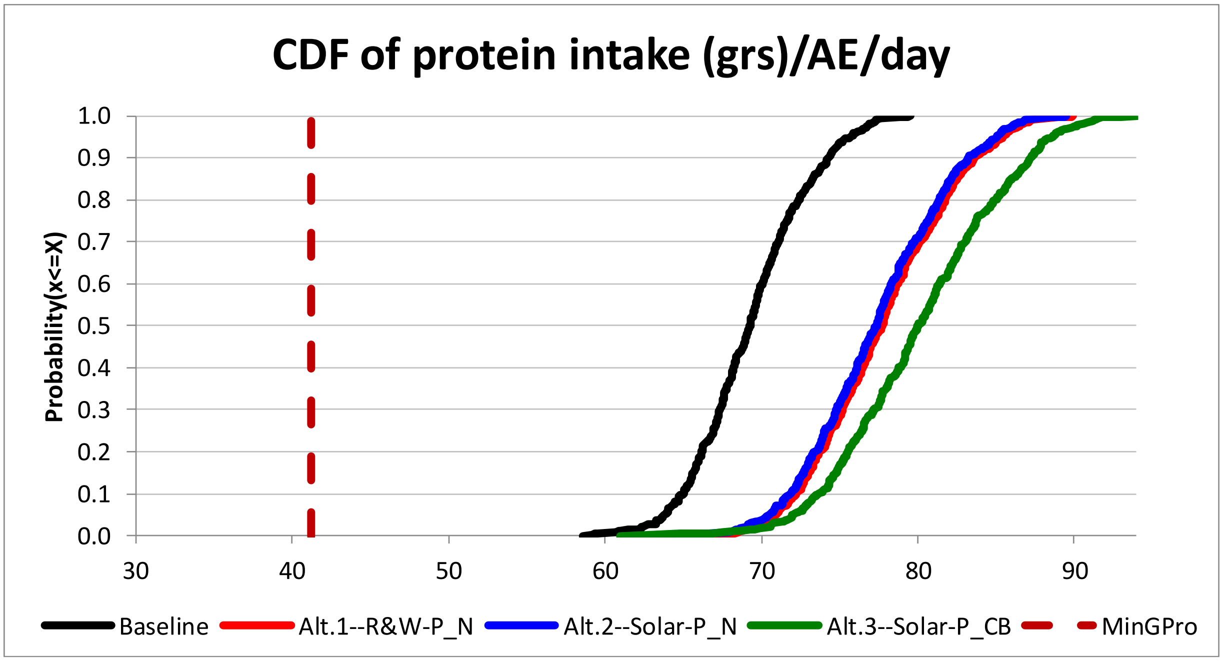
[b]: quantity of milk produced under alternative scenario based on fodder feeding for dairy crossbred cows with milk production of 5liters/da for 305 lactating days

Appendix D. Cumulative distribution function of nutritional variables

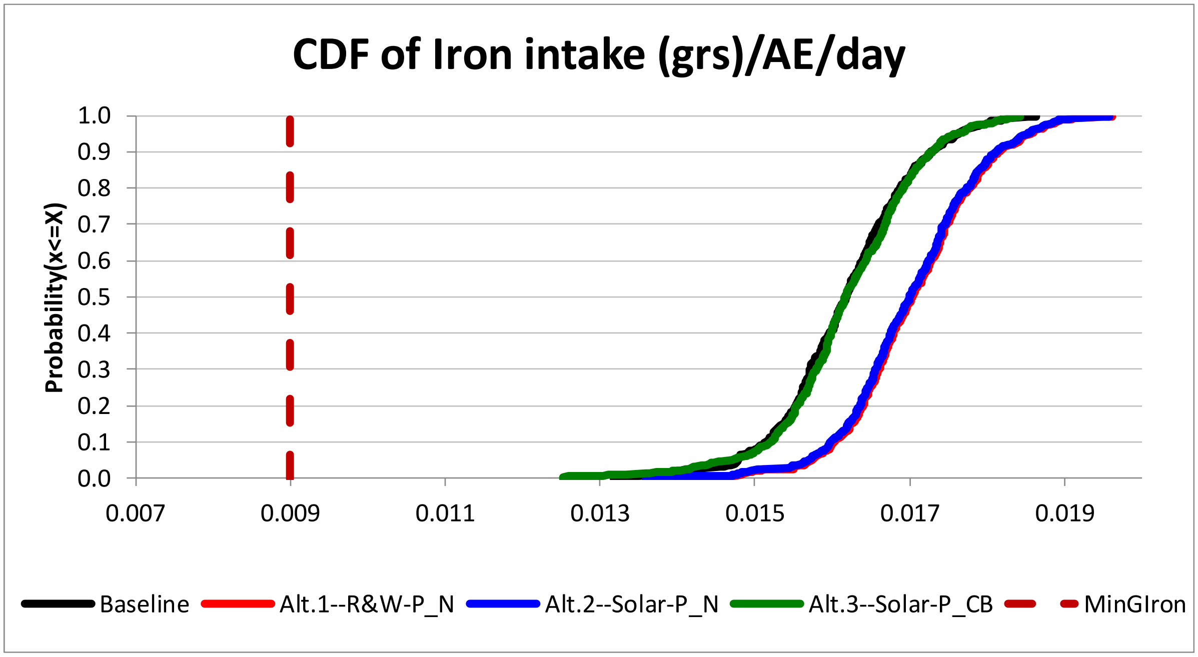
Calories (or energy) intake



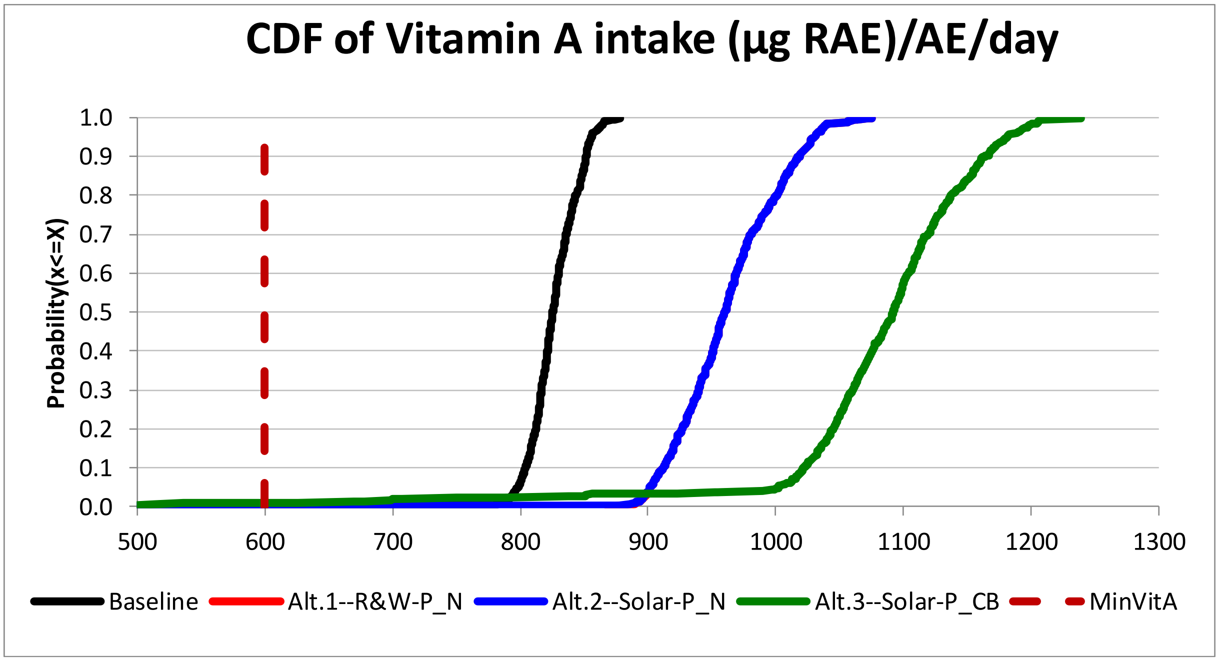
Proteins intake distribution



Iron intake distribution



Vitamin A intake distribution



Appendix E. Household dietary diversity score (HDDS) for Lemo woreda

Food groups	Examples	**Food group consumption score (Yes=1 or No=0)**					
		Baseline survey (2015)		**Score**	Endline survey (2017)		**Score**
		Yes (%)	No (%)		Yes (%)	No (%)	
1.Cereals/Grains	Maize, rice sorghum, millet	98	2	**1**	100	0	**1**
2.White roots and tubers	Potatoes, yam,	35	65	**0**	25	75	**0**
3.Vitamin A rich vegetables and tubers	Pumpkin, carrot, pepper, sweet pot	25	75	**0**	34	66	**0**
4.Dark green leafy vegetables	Spinach, kale, amaranth	42	58	**0**	26	74	**0**
5.Other vegetables	Tomatoes, onions, eggplants	75	25	**1**	80	20	**1**
6.Vitamin A rich fruits	Mango, apricot, papaya, peach	15	85	**0**	14	86	**0**
7.Other fruits	Apple, orange, grape	10	90	**0**	2	98	**0**
8.Organ meat	Liver, kidney, heart	0	100	**0**	0	100	**0**
9.Flesh meat	Beef, pork, lamb, goat	0	100	**0**	0	100	**0**
10.Eggs	Eggs from chicken, duck	6	94	**0**	8	92	**0**
11.Fish and seafood	Fresh or dried fish	2	98	**0**	8	92	**0**
12.Legumes, nuts and seeds	Beans, peas, lentils, nuts	85	15	**1**	91	9	**1**
13.Milk and milk products	Milk, cheese, butter	51	49	**1**	20	80	**0**
14.Oils ad fat	Oils, fat or butter	57	43	**1**	75	23	**1**
15.Sweets	Sugar, honey, candies	23	76	**0**	38	61	**0**
16.Spices, condiments, beverages	Pepper, salt, condiments	96	4	**1**	95	5	**1**
	Total HDD score			**6**			**5**

Note: number of households sampled = 65