Improving Food Security in the Highlands of Ethiopia through Improved and Sustainable Agricultural Productivity and Human Nutrition
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# Table of Contents

1. Executive Summary .................................................................................................................... 5
2. The Research Problem................................................................................................................ 9
3. Progress towards milestones ..................................................................................................... 10
   3.1 Assessment of Farmers capacity for growing pulse crops and their productivity across target production regions .......................................................... 15
   3.2 Enhanced farm productivity and sustainability through establishment of low-input pulse crops in participatory approach .......................................................... 15
   3.3 Germplasm introduction and testing ................................................................................... 17
   3.4 Soil quality and sustainable agricultural production .......................................................... 17
   3.5 Research opportunities and advanced study for Ethiopian Agricultural and Food Nutrition Scientists and Graduate students .......................................................... 18
   3.6 Improved research facilities at Hawassa University ........................................................... 21
   3.7 Implementation of intervention program of nutrition education ........................................ 21
4. Synthesis of Research Activities and Results ........................................................................... 21
   4.1 Assessment of Farmer capacity for growing pulse crops and their productivity across target areas ........................................................................................... 21
   4.2 Enhanced farm productivity and sustainability through establishment of low-input pulse crops in participatory approach .......................................................... 22
   4.3 Germplasm introduction and testing................................................................................... 25
   4.4 Soil quality and sustainable agricultural production .......................................................... 27
   4.5 Research on nutritional status and food security ............................................................... 32
   4.6 Market and consumer studies ........................................................................................... 32
      4.6.1 Pulse crops production ............................................................................................ 33
      4.6.2 Pulse crops market orientation ................................................................................ 33
5. Synthesis of Results towards AFS Outcomes ........................................................................... 35
   5.1 Generation of new technologies ......................................................................................... 35
   5.2 Dietary diversity and nutrition ............................................................................................ 36
   5.3 Engagement of Canadian researchers with Southern Research Organizations ............... 37
   5.4 Riskmitigation ................................................................................................................... 38
   5.5 Food production .................................................................................................................. 38
   5.6 Policy options ..................................................................................................................... 38
   5.7. Environment ...................................................................................................................... 39
6. Problems and Challenges .......................................................................................................... 39
7. Recommendations .................................................................................................................... 39
List of Tables

Table 1 Achievements of the Milestones ............................................................................................................ 10
Table 2 Farmers participation by activity and sex ........................................................................................... 16
Table 3 Characteristics of the selected sites ...................................................................................................... 22
Table 4 Yield of improved varieties as influenced by inoculation and in comparison with local cultivar in 2011 .................................................................................................................... 23
Table 5 Average yield of wheat with and without N on plots of different varieties of chickpea in chicpea-wheat rotation trial in 2012 ........................................................................................................... 23
Table 6 Days to flowering, Plant height, yield components and straw and grain yields q/ha. .... 27
Table 7 Effect of Rhizobium inoculation and N fertilizer application on grain yield, shoot dry weight, nodule number, and nodule dry weight of lentil varieties at Alaba (field trial)..30
Table 8 Effect of Rhizobium inoculation and N fertilizer application on grain yield, shoot dry weight, nodule number and nodule dry weight of chickpea varieties at Ele Kebele. .... 30

List of Figures

Figure 1 Total and marketable yields (Qt/ha) of eight varieties of snap beans grown with under rain-fed conditions ................................................................................................................................. 24
Figure 2 Total and marketable yields (quintals per hectare) of eight varieties of snap bean grown with 100 kg N/ha, Rhizobium inoculation (strain HB 429) or with no nitrogen application(A) or grown at three different locations (B). ...................................................................................... 24
Figure 3 Chickpea participatory variety selection at Taba kebele of Damot Gale district showing (A) grain and straw yields and (B) farmers’ preference evaluation in 2011. ......................... 26
Figure 4 Chickpea participatory variety selection at Jole Andegna kebele of Meskan district showing (A) grain and straw yields and (B) farmers’ preference evaluation. ............... 26
Figure 5 Symbiotic effectiveness of selected rhizobial strains on lentil biomass production (45 days after seeding). .......................................................................................................................... 28
Figure 6 Symbiotic effectiveness of selected rhizobial strains on chickpea biomass production (45 days after seeding) .................................................................................................................. 29
Figure 7 Interaction effects of land preparation method and sowing date on chickpea biomass weight and grain yield ...................................................................................................................... 31
Figure 8 Producers’ market orientation of haricot bean and chickpea crops .............................................. 34
Figure 9 Major market actors along the market channel ................................................................................. 35
List of Annex

Annex 1. Team Composition ........................................... 41
Annex 2. Monitoring AFS Expected Outcomes ............... 45
1. Executive Summary

Ethiopia covers an area of 1.13 million square km, of which 10.01 percent is arable land used for crop production. Producing sufficient quantities of food is one of the prime goals of food security strategies in the country. This project was initiated with the goal to increase the capacity of Ethiopia to improve food security and human nutrition through research on the breeding, agronomic and nutrient management of pulse crops to enhance the productivity and improve the livelihood of farmers. The lack of adoption of improved production technologies is one of the reasons for low productivity of pulse crops in the southern highlands of Ethiopia. Baseline survey and the inception workshop identified the three pulses (chickpea, lentil and faba bean) as priority crops for the project and four districts for the activities of the project.

One of the most tested means of enhancing productivity with minimized cost is through introduction of adapted high yielding crop varieties. Thus, a participatory variety selection was conducted in 2011 and 2012 with 45 farmers in four districts. The combined evaluation by farmers and researchers showed that the introduced cultivars especially chickpea gave an outstanding performance compared to the local cultivars. For instance, the selected cultivars at Taba and Jole Andegna exceeded the local cultivars under production by 62 and 89%, respectively. Thus, improved cultivars including Habru, Mastewal and Ejere were selected. The research identified early maturing improved chickpea varieties (Habru and Mastewal) with superior yield potential, market acceptability and taste compared to the local variety. These varieties are best fit to the growing conditions of the SNNPR. Farmers in the area have shown great interest in growing these selected varieties. The successful participatory variety selection led to a start of limited pre-scaling up and seed increase activity. All these activities culminated with an agreement to launch a pre-scaling up program on chickpea to be conducted in four districts with the involvement of the Bureau of Agriculture as a major actor.

Overall, results have shown that parts of the southern region are high potential areas for expanding chickpea production in the country. Thousands of farmers have expressed interest and have registered to access seeds of the improved varieties in the 2013 growing season. There are opportunities and urgent need to expand the project partnership in order to pilot a scaling up process for the adoption of chickpea production technologies, targeting 600 seed producers in four districts with the involvement of the Bureau of Agriculture as a major stakeholder.

To assess the impact of pulse crop production on soil quality attributes, the soils of project sites (Butajira, Halaba and Taba) were initially characterized in situ and samples were collected for laboratory analyses. Field descriptions revealed Vertisols at Taba and Butajira (upper and mid-slopes), whereas Halaba and Butajira (lower slopes) are Andosols and Fluvisols, respectively. Although soils of the Butajira region generally had adequate levels of macronutrients, deficiencies existed at other sites, with micronutrient status (Cu, Fe, Mn, Zn) at all sites typically marginal. We concluded that both macro and micronutrient deficiencies may limit crop production potential in these locations. In order to improve the agronomic fortification of the micronutrients, research projects are being conducted on detailed analysis of the soil nutrients, methods and rates of Zn and Fe applications together with intercropping on nutrient uptake and soil quality, and genetic and agronomic approaches for micronutrient enrichment in chickpea under CIFSRF Call 3 project.
The N-fixing efficacy of 104 chickpea and 114 lentil indigenous rhizobial strains isolated from diverse agroecological locations in central and southern Ethiopia were assessed. The isolates were screened for tolerance to environmental stresses (pH, temperature, and salinity) and plant growth promoting attributes under both greenhouse and field conditions and compared to elite national (Cp114 and Lt139) and imported Canadian commercial inoculants (CP113 and Lt137). Several strains were identified as highly effective, outperforming the comparator Ethiopian and Canadian inoculants strains. The tremendous biodiversity of strains isolated indicates that soils in Ethiopia contain a vast reserve of adapted and effective N-fixing rhizobial strains that potentially could be used in the production of effective inoculants for Ethiopian farmers, and are of considerable value in other markets.

The research demonstrated the enormous potential for developing effective N-fixing inoculants for enhanced N fertility in pulse crop production systems. Chickpea and lentil rhizobia isolated from Ethiopian soils were diverse in their capacity to infect respective host plants and to fix atmospheric N. Indigenous rhizobia are uniquely adapted to the environmental conditions encountered in the various regions. The apparent genetic diversity of the Ethiopia isolates was a surprising and encouraging result. It is possible that low input agriculture has maintained a wider genetic diversity than typically is reported for intensive production systems utilizing high chemical/fertilizer inputs. The diversity represents a valuable resource both for Ethiopian farmers, and also for wider markets seeking rhizobial strains that are adapted to the relatively harsh soil conditions (i.e., temperature, pH, salinity) from which these rhizobia were isolated. Not all soils supported indigenous rhizobia compatible. If farmers in these regions want to maximize production of pulse crops, an appropriate rhizobial strain must be introduced via inoculation. Thus developing inoculants for farmers in Ethiopia is an essential component to developing sustainable pulse production systems.

Furthermore, the use of Rhizobium bacteria for chickpea and appropriate seeding date provide sufficient amount of available nitrogen for succeeding wheat crop. These low cost practices will maintain chickpea productivity and sustain chickpea and wheat production in a chickpea-cereal rotation system. The system will reassure chickpea expansion in the area and ensure the sustainability of its production.

The research on snap beans demonstrated that high productivity and sustainable snap bean production under rain-fed conditions can be achieved through the use of improved varieties from the national program and appropriate Rhizobium inoculant. The productivity and quality of the green beans were comparable to those produced under irrigation by the large commercial snap bean producers targeting export markets. These findings provide an opportunity for small scale resource limited snap bean farmers to produce high quality snap beans either for export or local markets or as supplement for family nutrition and cash income.

The benefits of growing a well nodulated N-fixing pulse crop to soil N fertility were revealed by the research results. Nitrogen fixation can contribute N to subsequent crops – but only if sufficient residues are returned to the soil. Traditionally, chickpea is harvested by an uprooting method, removing all residues from the field. Research demonstrated that cutting the plant at the soil surface, and leaving the roots and associated nodules in the soil, recycled more N back to the soil. A farmer participatory assessment of the effect of different chickpea harvesting methods and residue management practices was conducted at Jole Andenga with the assistance
of the Peasant Association (PA). The participatory research allowed local farmers to assess the success of the revised harvesting practice directly.

The results of research on land preparation methods and sowing dates on yield and yield components of chickpea revealed that land preparation methods significantly influenced all agronomic parameters, except days to flowering and physiological maturity, whereas the use of broad bed furrow increased seed yield by 204 and 7.2% compared to ridge-furrow and flat bed, respectively. Sowing dates had also significant influence on pods per plant, seeds per plant, biomass yield, harvest index and crude protein content.

The assessments of nutrition status of infants, young children and adolescent girls and the role of pulses in improving nutrition have shown that adolescent girls were shorter than the 2007 WHO reference population standards and the diets of adolescents were grossly deficient in energy and other nutrients. The infants and children, similarly, had high prevalence of wasting and stunting. In assessment of households, the majority of households studied were food insecure households, defined as mild, moderate and severe. Approximately 17% were mildly insecure, 54% were moderately insecure, and 16% severely insecure. In one study, pulse consumption was measured and shown to be “rarely eaten”. In all studies, barriers for not consuming pulses were determined from focus group discussions. Currently a study, on acceptability from one of the initial three to determine the effect of promoting complementary feeding with porridge made from barley/maize and added broad bean is in progress. Furthermore, a study on nutrition education intervention found that use of the Health Belief model in nutrition education increased consumption of pulses. *A Conversation Map – Pulses and Food Security*, an interactive tool designed by the UoS nutrition team in collaboration with the HU nutrition team engaged the participants in discussions related to healthy eating as it relates to pulse production, processing, preparation and consumption of pulse crops. Additionally, two nutrition education interventions expanded knowledge and raised awareness of women’s groups of the importance of healthy eating, which includes incorporating more pulse in the diets.

Results show that haricot bean is the most widely grown pulse crops in all project sites, occupying between 0.12 ha and 0.39 ha. Chickpea is the second important crops grown widely following haricot bean. It is particularly economically important cash crop in Jole Andegna and Taba. Lentil and faba bean are growing on a limited extent in the project site with the exception of lentil which is not grown in Jole Andegna. About 73% of households produce haricot beans in the study areas on about 17.2% of total cultivated land. Haricot bean is an important component of the household cash source as about 56% of haricot bean production is sold for a monetary value of about ETB 1022. Chickpea is produced by about 26.8% of the households, on about 16.8% of the total cultivated area. On average a household allocates about 0.26 ha of land for chickpea. A household also sold about 242 kg of chickpea, about 69.5% of total chickpea produce for total revenue of ETB 1760.6. The proportion of chickpea produce sold is ranged between 33% and 100%. Results further show that consumer’s purchase decision of pulse crops are influenced by a number of markets related and social factors. The finding indicates that consumers’ purchase of haricot bean is attributed to its cheap price compared to other pulse crops, easy availability in the market and it is staple food. Whereas consumers purchase of chickpea is attributed to its food quality, it is a festive food and easy for cooking.
As the monthly consumption figure indicates that the majority of respondents (45.8%) consume less than 10 kg pulses per month.

An important outcome of this project is the building of research capacity at Hawassa University through the training of 4 PhD and 19 students at the masters’ level. Researchers from Hawassa University increased their skills and knowledge during their research stays at the University of Saskatchewan where they had access to modern world facilities in molecular biology and soil sciences laboratories. The project resulted in the upgrading of laboratory facilities and the boosting of the analytical capacity of the soils science laboratory at Hawassa University. The project has increased capacity of 40 Faculty and technicians in the handling of laboratory equipment, and graduate students in scientific writing to produce scientific articles out of their research findings. As output of the training, Research Booklet encompassing areas of research accomplished in the project.

Project results have been widely disseminated through workshops, seminars and scientific conferences in Canada and Ethiopia. An international Conference on Linking Agriculture, Nutrition, and Health - From Field to Fork: Improving Human Nutrition in Vulnerable Societies using an Agro-Systems Approach was conducted at the University of Saskatchewan boasts the successful conclusion of the CIFSRF Call-1 Project and offered the opportunity to share the emerging results of the projects to incorporate nutrition objectives into agricultural interventions. This conference explored ways to synthesize the contribution of CIFSRF projects to nutritional outcomes and created a productive forum to explore nutrition linkages in agriculture and food security research. The conference was applauded as a great success attended by close to 100 participants from eleven of the 19 CIFSRF Team, as well as other researchers from around Canada, policymakers, private industries, graduate and undergraduate students, and chief scientist on Nutrition from FAO in Rome, CIDA and IDRC officials. Visiting faculty and graduate students from Hawassa University also participated in the conference. Project findings were presented during the Canadian Pulse Research Workshop, the 13th World Congress on Public Health and Nutrition, and the international conference on integrated soil fertility management.

The project has identified new areas as potential sites for chickpea production. Growing chickpea allows double cropping on a particular land and thereby increase the income of farmers. There is need for a research development initiative that will bring together the university and regional research and extension institutions, farmers organisations and the private sector to promote large scale adoption of pulse production technologies and about the fundamental change in terms of large scale adoption of chickpea by more households leading to yield increase, area expansion in chickpea production and thereby improved household income that leads to the betterment of livelihood of small holder producers. We propose a pre-scaling up project called “Promoting Adoption of Chickpea Technologies (PACT) in southern Ethiopia. PACT will aim to directly reach 600 farmers as seed producers in four districts each cultivating 0.25 ha of land in one growing season. It is expected that the project will reach more than 3000 other farmers in the subsequent season. The overall aim of the PACT project is to understand and promote the key drivers and processes that will facilitate and accelerate large scale adoption chickpea production technology in the southern highlands of Ethiopia. Specifically this pre-scaling up intervention will address the following specific objectives: (i) To further adapt and validate best practices (varieties, soil fertility, agronomy) for chickpea production within the region; (ii) to test and compare successful models, strategies and system approaches for large
scale adoption of chickpea production in the region; (iii) to establish and operationalize multi-stakeholders partnership platform for large scale adoption of chickpeas in the southern highlands of Ethiopia; and to (iv) to use research results to inform food security policies and programs in Southern Ethiopia.

2. The Research Problem

Ensuring food security needs a multidimensional approach, which includes physical availability of food, appropriate knowledge and access to food and a sustainable environment in which food can be produced. Producing sufficient quantities of food is still one of the prime goals of food security strategies in the country. Fragmented holdings (as low as 0.25 ha per farm), land degradation, lack of fertilizer, removal of plant residues, lack of appropriate agronomic technologies, poor adoption of available technologies, erratic rainfall and drought are some of the contributing factors leading to low productivity. Some of the crucial strategies, which could be used to realize the goal of food self-sufficiency a regenerating appropriate crop production technologies that both promote food production and contribute to sustaining the productivity potential of the soil, and facilitate their dissemination. Pulses are the second dominant crops next to cereals in the intermediate and highlands of Ethiopia. Moreover, pulses demand less input in terms of fertilization because of their biological nitrogen fixation ability and hence help maintain soil fertility by contributing fixed N to subsequent crops. Interestingly, a handful study on indigenous rhizobia indicated that Ethiopian soils harbour tremendous biodiversity in these microsymbionts, which can be tapped to improve N fixation, soil fertility and thus to promote sustainable agriculture. Some of the pulses like chickpea and lentil could also help in maximizing land use efficiency and reducing risk in rain fed agriculture by allowing double cropping. Thus, enhancing productivity of pulses could help address the food security issue in many dimensions by increasing the physical availability of food, improving human nutrition and maintaining soil fertility. Thus, this project was initiated with a hypothesis that it is possible to enhance food security of the country by improving the productivity of pulses and sustaining soil health. This is because successful pulse production will lead to N fixation and nutrient accumulation, which ultimately improves system productivity, food security and human nutrition.

One important goal of the project was to address soil quality and sustainability issues in Ethiopia. Our aim was to enhance the production potential of soils in the highlands by enhancing nitrogen (N) inputs via biological N fixation using *Rhizobium* bacteria as inoculants for pulse crop production. By enhancing N inputs into existing farming systems, we hope to improve protein production, and enhance the N returns to the soil. We recognized the link from soil quality, through food production, to human health, and our research contributes to achieving improved human nutrition and health through improved soil health. Production technologies that promote the maintenance of soil quality, such as harvesting techniques that conserve soil organic matter were explored.
3. Progress towards milestones

The achievements are presented in the following table.

<table>
<thead>
<tr>
<th>No.</th>
<th>Milestone</th>
<th>Activity</th>
<th>Goal</th>
<th>Output</th>
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<tbody>
<tr>
<td>1.1</td>
<td>Report of Inception Workshop (including results and performance evaluation framework).</td>
<td>Inception workshop</td>
<td>Prioritization of research problems in the target areas. Face-to-face meeting of project participants. Receive input from stakeholders regarding planned research and incorporate suggestions into overall project plan. Visit potential sites and discuss site selection strategies.</td>
<td>Inception workshop was conducted on 14 and 15 October 2010. Over 100 participants from different stakeholders and policy makers participated in the workshop. Key pulse (chickpea, lentil and bean) were identified. UofS faculty met PhD students and together with HU faculty, research proposals developed. Sites identified and confirmed. (Workshop proceedings and reports submitted March 2011)</td>
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<tr>
<td>1.2</td>
<td>Analytical technical report of site selection and site characterization.</td>
<td>Determine target areas for research and present on Inception workshop. Receive comments from participants in the workshop.</td>
<td>Select sites of greatest relevance or potential, but are not self-sufficient in the staple crops of pulses. Determine suitable sites for pulses according to key stakeholders, including end-users (farmers) and Development Agents. Ensure that farmers are fully engaged and supportive of the research and will be willing and helpful participants.</td>
<td>HU team made the survey and four sites were selected. The process was presented on the inception workshop and comments were received. Site selection survey report included in first interim report, submitted March 2011.</td>
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<tr>
<td>1.3</td>
<td>Recruitment of graduate students and PhD and M.Sc. research proposals.</td>
<td>Select high calibre students; preparation of MSc and PhD Theses proposals on thematic areas of the project. Academically prepared students to complete PhD (HU or UofS) were selected.</td>
<td>Engage graduate students in research towards improving food security and sustainable agricultural management practices.</td>
<td>Four PhD students selected (2 each Plant Science and Soil Science students) and 19 M.Sc. students were recruited. Plant Science PhD students will receive their degree from UofS, whereas Soil Science PhD and all MSc students will receive their degree from HU. The PhD programs are still ongoing and students are making excellent progress.</td>
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<td>1.4</td>
<td>Upgrade of research facilities at</td>
<td>Improve and upgrade research</td>
<td>Research equipment, including an Atomic</td>
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<tr>
<th>research facilities at HU.</th>
<th>Hwassa University</th>
<th>facilities at HU to ensure that current and ongoing research activities are adequately supported by essential research equipment, and that the success of this, and subsequent projects is not compromised by the lack of essential equipment.</th>
<th>Absorption Spectrophotometer has been purchased and installed at HU. Project vehicle was also purchased to solve transportation problem. Some small pieces of equipment (soil augers; soil testing hydrometers, cylinders; GPS units; parts for leaf area meter; etc.) were purchased.</th>
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<tr>
<td>1.5</td>
<td>Communication Strategy for the project</td>
<td>Develop a communication strategy for the project, including the development and implementation of a variety of communication vehicles (e.g., direct communication at farmer field days, brochures, web page development, etc.) Following the completion of the research, pertinent results from the germplasm testing and evaluation and sustainable agricultural production practices will be shared with local farmers and Bureau of Agriculture Specialists with the aid of translators.</td>
<td>Brochures prepared and distributed, stakeholders participated in 2011 and 2012 farmers’ field days. Webpage “<a href="http://www.usask.ca/food_security_ethiopia/Food_Security_in_Ethiopia/Welcome.html%E2%80%9D">http://www.usask.ca/food_security_ethiopia/Food_Security_in_Ethiopia/Welcome.html”</a> developed. Results were communicated through mass media (HU radio, FM, and ETV, CBC, CTV) Meeting with NGO’s (e.g. UNICEF, WORLD VISSION, Alive and Thrive, SAVE THE CHILDREN etc.) and Agricultural Transformation Agency were made. This goal has been achieved through field days (November 2011 &amp; December 2012), and a workshop (May 2012). Agreements were reached to pre-scale up the results and project proposal on Promoting Adoption of Chickpea Technology in Southern Ethiopia, where Bureau of Agriculture will be the major actor, was developed.</td>
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<tr>
<td>2.1</td>
<td>Baseline study report on Ethiopian farmers’ capacity for growing pulse crops.</td>
<td>Assessment of farmers’ capacity for growing pulse crops. Identify existing trend of pulse growing, opportunities and constraints and develop new low-cost technologies and management practices that improve productivity and can be readily adopted by</td>
<td>Baseline survey, together with the inception workshop, identified a number of issues surrounding adoption of pulse crops that need to be addressed by the research. Specifically, lack of awareness of farmers in production and benefits of pulses; incorrect perception about pulses (considered as secondary); weak seed supply system; lack of technology &amp; insufficient adoption of available technologies; lack of proper storage; potential</td>
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<td>Ensure that the practices under investigation are relevant to stakeholders.</td>
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<tr>
<td>2.2</td>
<td>Research protocols on pulse crops (soil fertility, agronomy, nutrition).</td>
<td>Develop specific protocols for research.</td>
<td>Ensure that the research is conducted in a manner that is scientifically defendable (i.e., publishable) and meets the specific needs of the project and ultimately, the stakeholders.</td>
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<td>2.3</td>
<td>Strategies for minimizing environmental impacts.</td>
<td>Work towards achieving environmental sustainability.</td>
<td>The project aims to achieve greater environmental sustainability than currently exists in Ethiopia. We hypothesized that including pulse crops in rotations will enhance sustainable crop production by improving the nutrient status of the soil (particularly N fertility), or at least remain “N neutral”, i.e., N inputs via N fixation are balanced by outputs via harvesting seed.</td>
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<td>2.4</td>
<td>Gender analysis of pulse crop production, nutrition and utilization.</td>
<td>Conducting gender study as it relates to pulse production</td>
<td>Working with and empowering female farmers, and developing gender sensitive technologies and innovations to increase agricultural productivity</td>
</tr>
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</table>
| 2.5  | Technical report of soil fertility survey and analyses of field test sites. | Characterize soils of the target sites and analyse their quality. Germplasm introduction and testing at various field locations. Field and growth chamber studies to isolate and test local rhizobial strains. | Characterize the soils, identify their quality and recommend appropriate management practices. Identify and introduce advanced lentil, chickpea and haricot bean lines. Assess performance under different environments. All selected advanced | The soils at the experimental sites have been characterised. Indigenous isolates for lentil and chickpea have been identified and characterized using molecular techniques. Effects of land use systems and land preparation methods on soil quality; harvesting methods and residue management on decomposition; identification of growth limiting
breeding material was evaluated for nutritional characteristics and quality. nutrients in chickpea were completed. All field experiments were completed in December 2012. Growth chamber studies to assess rhizobial populations and isolate effective rhizobia have been completed. One article has been submitted to peer-reviewed journal, and three others are prepared and will be submitted soon.

| 3.1 | Graduate thesis research on human nutrition, soil fertility and agronomy. | Graduate students involved in various components of the project. | Graduate students provided the hands required to complete the many aspects of the project. The PhD students contributed significantly to the overall program and the proposed works were partitioned between the various Ph.D. projects. M.Sc. projects provided data to address related issues, and to “fill in the gaps” of the overall project, not otherwise addressed by the Ph.D. work. | The PhD Theses writing are on-going and will extend beyond the life of Call 1. However, components of the research directly related to Call 1 were completed. Eleven MSc projects works are complete and have been defended. Of the remaining 8 M.Sc. projects to be completed, 7 only the final defense remain to be completed in June 2013 and one will take place September 2013. Growth chamber studies to assess rhizobial populations and isolate effective rhizobia have been completed. |

| 3.2 | Implementation of intervention program of nutrition education | The nutrition intervention program consists of several components collectively designed to improve the health and nutrition and food security in Ethiopia. | The goal of the intervention program of nutrition education is to develop various means of engaging members of households and communities in active learning that ultimately informs decisions key to improving nutrition and health. | The intervention program has been implemented using a number of means including M.Sc. research projects completed, theses defended; invited session presentations @ the Worlds Federation of Public Health Association (WFPHA), April, 2012. One manuscript has been submitted for publication in Peer-reviewed journal and two others are Prepared, will be submitted soon. A joint farmer training workshop on pulse production, utilization and consumption was carried out in May with 30 farmers from two of the three project sites. 15 additional stakeholders, including district agencies from the local Bureau of Agriculture were also in attendance. Community partners participated from 2 of the three project sites. |
| 3.3 | Technical report on market and consumer studies. | Conduct a market and consumer survey using an approved survey tool. | The goal of the market and consumer survey is to identify seasonal variations in local food availability and prices. This information will be used to determine “best buy” foods which ultimately will inform intervention strategies. | The study on Market and Consumer study was completed and the report is annexed. |
| 4.1 | Assessment of the potential impact of enhanced pulse availability and consumption on food security and nutrition. | End of project evaluation on the impact/uptake of the study on new cropping practices, improved soil management practices, and improved human nutrition. Farmers will be interviewed by hired surveyors. | The goal of the final interviews is to assess the farmer perceptions and evaluate the success of the project in terms of farmer acceptance and interest. | Part of this activity was covered in market and consumer studies as well as acceptability study of the nutrition intervention program. However, consensus was reached that two-year is short and it is too early to assess the impact. The impact study will be completed towards the end of CIFSRF Call 3 project. |
| 4.2 | Soil fertility management for pulse crops. | Assess soil fertility and develop management practices that best fit the production and sustainability of pulse crop production. Included is the isolation and development of indigenous rhizobium for development as inoculants. | The goal is to ensure that appropriate and sustainable management practices are identified and recommended. | The soils at the experimental sites have been characterised. Indigenous isolates for lentil and chickpea have been identified and characterized using molecular techniques. Effects of land use systems and land preparation methods on soil quality; harvesting methods and residue management on decomposition; identification of growth limiting nutrients in chickpea are complete. |
| 4.3 | Technical reports on intervention programs on nutrition and health. | Implementation of intervention program of nutrition education | The goal is to ensure that households receive support and empowerment to practice nutrition skills. | A joint farmer training workshops were conducted at two sites with farmers, development agencies and community partners participating in May 2012. Acceptability study has started and will be complete within the Call 3 project. |
3.1 Assessment of Farmers capacity for growing pulse crops and their productivity across target production regions

The project work was started by selecting four sites in southern Ethiopia for implementation of the activities. The selected sites include: Jole Andegna and Ele in Meskan district, Huletenga Choroko in Halaba special district, Taba and Teticha in Damot Gale and Hulla districts, respectively. Jole Andegna, Ele and Taba were potential sites for chickpea production, whereas Huletenga Choroko and Teticha were for lentil and faba bean, respectively. The communities in the study areas are dependent mainly on rain-fed agriculture, crop production being the main livelihood strategy followed by cattle production for milk. Diversification of crops is also a strategy to fulfill family demand for food while using some crops as cash sources. Baseline survey identified Jole Andegna as a good potential for expanding chickpea production, Ele and Taba for lentil, Huletenga Choroqo for both, and Teticha for broad beans.

Generally, the farmers in all Kebeles were willing to produce chickpea as well as lentil if they could get access to improved varieties. They anticipate higher yield from improved seeds of these crops and an increased income from the sale in addition to using them to supplement family food consumption. The incorporation of these crops into household food habits will have a great nutritional importance for protein supplement in the family diet.

The major constraints to pulse (chickpea, lentil and broad beans) production at the sites include:

- Lack of awareness in pulse production and its benefits,
- Wrong perception about pulses (considered as secondary)
- Low productivity of local varieties, weak seed supply system,
- Insufficient adoption of available technologies,
- Lack of proper storage,
- Drought, disease, weeds,
- Weak market linkage,

A two day inception workshop conducted with stakeholders also identified three pulse crops (chickpea, lentil and faba bean) to work on and gaps in the areas of pulse productivity, human nutrition and gender equality. After receiving the inputs from the workshop, the team members from UoS and HU have worked a common strategy in implementing the project. The findings of the baseline survey and the inception workshop are organized into a report and proceeding, respectively.

Majority of the graduate students used the results of the baseline survey to develop their research proposals.

3.2 Enhanced farm productivity and sustainability through establishment of low-input pulse crops in participatory approach

Research on the response of chickpea varieties to low input agronomic practices demonstrated the yield benefit of improved varieties over the local check. Varieties Habru and Ejere yielded 20% and 7% above the check, respectively. The yield advantage coupled with their earliness is important criteria for successful double cropping system of cereal and chickpea in the area.
Research on nodulation indicated that the late maturing variety such as Natoli was more responsive to Rhizobium inoculation compared to the early maturing varieties. As such, variety Natoli produced more yield (42.1%) under inoculation compared to the early variety Ejere. Wheat crop yield seeded in the following year on the plot of Natoli was equal to the wheat that received inorganic N fertilizer. In general, the use of improved varieties, appropriate seeding date and the use of rhizobium bacteria will help to expand and increase chickpea production in the region.

Participation of farmers in research activities (Table 2) has facilitated the adoption of technologies like optimum sowing date and the use of improved varieties; this was evidenced by the interest and participation of farmers in selecting best performing varieties (Habru and Mastewal) that suit their environments. Participated farmers are also interested to adopt cereal-chickpea rotation as part of their cropping system. Farmers at Halaba area in particular were new to chickpea but during the two growing seasons of research more than one hundred household heads have expressed an interest to grow the variety Habru. Sixty-five household heads at Wolaita also requested to get initial breeder seed to start seed multiplication.

<table>
<thead>
<tr>
<th>No</th>
<th>Activity</th>
<th>Butajira Male</th>
<th>Butajira Female</th>
<th>Halaba Male</th>
<th>Halaba Female</th>
<th>Wolaita Male</th>
<th>Wolaita Female</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PhD research</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td>Activities were in 2011 and 2012</td>
</tr>
<tr>
<td>2</td>
<td>Training on Chickpea agronomy</td>
<td>18</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>11</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Experience sharing on community seed production</td>
<td>5</td>
<td>-</td>
<td>8</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sub-Total</td>
<td>25</td>
<td>8</td>
<td>16</td>
<td>12</td>
<td>18</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>59 Male</td>
<td>26 Female</td>
<td>85 farmers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The research on snap beans demonstrated that under rain-fed conditions locally developed snap bean variety (Melkassa 1) was superior to currently grown varieties. This variety is also highly responsive to Rhizobium inoculation suitable for low in put production system in the areas. Commercial varieties on the other hand were better for green pod quality, especially texture and appearance for export markets. Rhizobium inoculation with HB 429 strain resulted in 17.6% yield increase compared to the control. Productivity of snap bean varieties under rain-fed was highest at Hawassa followed by Debrezeit and Zeway. Snap beans produced at Hawassa had highest zinc concentration, whereas snap beans produced at Zeway had high iron and calcium concentrations. Rhizobium inoculation was most effective at Debreziet under both rain-fed and irrigated conditions. Rhizobium inoculation was not effective under irrigation during the dry season at Hawassa and Zeway.

The study demonstrated that high quality sustainable snap beans production with low input production system using rhizobium inoculation as nitrogen source under rain-fed conditions can be achieved using locally developed variety (Melkassa 1) by small scale resource limited farmers in the areas.
3.3 Germplasm introduction and testing

One of the most tested means of enhancing productivity with minimized cost is through introduction of adapted high yielding crop varieties. Thus, a participatory variety selection was conducted in 2011 and 2012. The combined evaluation by farmers and researchers showed that the introduced cultivars especially chickpea gave an outstanding performance compared to the local cultivars. For instance, the selected cultivars at Taba exceeded the local cultivar under production by 62% while that in Jole Andegna by 89%. Improved cultivars, which include Habru, Mastewal and Ejere were selected from the PVS that were conducted in 2011 and 2012. The PVS program not only resulted in the selection of cultivars but also increased the farmers’ awareness and interest to grow chickpea. For instance, farmers at Huletegna Choroko requested for a PVS after participating in a field day at Taba in 2011. The successful completion of PVS at 2011 led to a start of limited pre-scaling up and seed increase activity. All these activities culminated with an agreement to launch a pre-scaling up program on chickpea to be conducted in four districts with the involvement of the Bureau of Agriculture as a major actor.

3.4 Soil quality and sustainable agricultural production

The research demonstrated the enormous potential for developing effective N-fixing inoculants for enhanced N fertility in pulse crop production systems. Chickpea and lentil rhizobia isolated from Ethiopian soils were diverse in their capacity to infect respective host plants and to fix atmospheric N. Indigenous rhizobia are uniquely adapted to the environmental conditions encountered in the various regions. The apparent genetic diversity of the Ethiopia isolates was a surprising and encouraging result. It is possible that low input agriculture has maintained a wider genetic diversity than typically is reported for intensive production systems utilizing high chemical/fertilizer inputs. The diversity represents a valuable resource both for Ethiopian farmers, and also for wider markets seeking rhizobial strains that are adapted to the relatively harsh soil conditions (i.e., temperature, pH, salinity) from which these rhizobia were isolated. Not all soils supported indigenous rhizobia compatible. If farmers in these regions want to maximize production of pulse crops, an appropriate rhizobial strain must be introduced via inoculation. Thus developing inoculants for farmers in Ethiopia is an essential component to developing sustainable pulse production systems.

The research demonstrated the benefits of growing a well nodulated N-fixing pulse crop to soil N fertility. Nitrogen fixation can contribute N to subsequent crops – but only if sufficient residues are returned to the soil. Traditionally, chickpea is harvested by an uprooting method, removing all residues from the field. Research demonstrated that cutting the plant at the soil surface, and leaving the roots and associated nodules in the soil, recycled more N back to the soil. A farmer participatory assessment of the effect of different chickpea harvesting methods and residue management practices was conducted at Jole Andenga with the assistance of the Peasant Association (PA). The participatory research allowed local farmers to assess the success of the revised harvesting practice directly.

Soil quality parameters were assessed, both before and after inclusion of pulse crops in the rotation. Research indicates that pulse crops contribute to both soil physical and biochemical characteristics, and may enhance long-term sustainability. Additionally, soils from the sites (Butajira, Halaba and Taba) were characterized in situ (FAO, 2006) and later analyzed.
Research findings indicated significant effects of topography and land use systems on physicochemical properties of the soils.

The results of research on land preparation methods and sowing dates on yield and yield components of chickpea revealed that land preparation methods significantly influenced all agronomic parameters, except days to flowering and physiological maturity, whereas the use of broad bed furrow increased seed yield by 204 and 7.2% compared to ridge-furrow and flat bed, respectively. Sowing dates had also significant influence on pods per plant, seeds per plant, biomass yield, harvest index and crude protein content.

3.5 Research opportunities and advanced study for Ethiopian Agricultural and Food Nutrition Scientists and Graduate students

The project has contributed to capacity building of HU and the country in different aspects. Hawassa University Faculty got the opportunity to conduct advanced research and publish findings with scientists from UofS. The MSc graduates are serving in different sectors of the government and NGO’s with better capacities.

3.5.1 Research leaves and short term visits to UofS

Five HU Faculty have visited UofS to conduct research and/or work on the research activities of the students they co-supervise. Accordingly, Drs. Walelign Worku, Bizuayehu Tesfaye and Sheleme Beyene spent research leave, whereas Dr. Endalkachew Woldemeskel and Mr. Alemzewd Chala made a two-month visit to UofS.

Dr. Walelign Worku, as a member of the advisory committee of one of the PhD students, had spent six months as a visiting scientist at UofS. The objectives of the visit included manuscript preparation, conducting research, involvement in project activities and do work that supports the PhD student. He ran an experiment in collaboration with Dr. Bunyamin Tara’n of UofS entitled ‘Effects of Genotype, Temperature, Photoperiod and Moisture Supply on the Micronutrient and Phytic Acid Contents of Kabuli and Desi Chickpea,’ for which most of the data were collected. He also presented a poster entitled ‘The Effect of Waterlogging at Different Phases on Growth, Productivity and Nodulation of Desi and Kabuli Chickpea (Cicer arietinum)’ on the 9th Canadian Pulse Research Workshop that was held between 6 and 9 Nov 2012. Additionally, he has been engaged in helping MSc and PhD students who are sponsored by the project.

During the visit (August 2012 – Feb 2013), Dr. Bizuayehu Tesfaye had completed training and research of development of linkage map of tepary bean (P. acutifolius) using cutting edge molecular techniques. During the visit Dr. Tesfaye involved in DNA preparation, completed single nucleotide polymorphism (SNP) Illumina Golden Gate assay and data analysis using Genome Studio and JoinMap® and other statistical genetic programs. As the results, linkage map of P. acutifolius has been constructed with 679 SNP markers. The maps consist of eleven linkage groups corresponding to the haploid number n = 11. The map displayed high synteny
and colinearity with the common bean reference map in all eleven linkage groups. Dr. Tesfaye also completed the analyses of population structure and genetic diversity among 118 tepary bean (*P. acutifolius*) accessions. All data analysis has been completed and writing an article for publication has been initiated. Dr. Tesfaye also involved in other activities: participated and presented two posters at the ninth Canadian pulse research workshop held in Niagara Falls, Ontario from Nov. 6-9, 2012; supervised and reviewed the academic and research progress of Hussien Mohammed, a PhD student at University of Saskatchewan.

Dr. Sheleme Beyene had spent a five and half months leave at UofS, where he conducted experiment on Effects of Arbuscular Mycorrhizea on growth and nutrient concentration in maize at increasing levels of P application in collaboration with Drs. Jeff Schoenau and Fran Walley. Data on root infection and dry weight yield of the plants were collected, and soil and plant analyses were made. The results revealed that both mycorrhizae and P application improve growth and dry weight of the plants. Currently, the experiment is being repeated at HU with higher volume of soil. Dr. Sheleme has also prepared an article entitled” Effects of topography and land use on soil characteristics along the toposequence of Ele watershed in southern Ethiopia” from the work MSc student sponsored by the project and submitted to a journal for publication. Additionally, he has also presented a seminar at UofS on “Management of Ethiopian Problem-prone Soils: Acid Soils and Highland Vertisols” (Annexed).

Dr. Endalkachew Wolde-meskel had a short research visit at U of S, in connection with the work of a PhD student, whom he is advising together with a U of S staff (Prof. Fran Walley). While his main task was to give practical training for the student on laboratory techniques for the task of genetically characterizing the Ethiopian isolates, he has also attended a bio-safety and laboratory safety courses (which is mandatory to work at the research laboratories at the Canadian universities). At the same time (while attending courses and waiting issuance of the certificate), he had identified and ordered reagents, primers, enzymes and DNA isolation kits that will be required for the genetic analysis experiments on the test strains. In addition, he was engaged on purification of the test strains (sent via DHL from Ethiopia) by repeatedly streaking on appropriate diagnostic media (standard procedure before DNA isolation). The PhD student (Wondwosen Tena) received training on:

- The general set up and functioning of a molecular biological laboratory (on maintaining standard aseptic conditions, operating PCR machines and gel documentation equipments, centrifuges and incubator devices etc.). Wondwosen has no previous exposure to the biological molecular laboratory. Thus, has no experience on how to conduct genetic experiments and everything has to start from the scratch.

- DNA isolation procedures and PCR amplification of the 16S rRNA gene. (The visit time was short, but mastering the procedure for 16S rRNA helps for working on other genes)

During his stay, Dr. Wolde-meskel drafted a poster which he later finalized and presented at the ISFM (Integrated Soil Fertility Management) workshop, held from 22 to 26, October 2012, in Nairobi, Kenya (annexed). In adaptation, he has presented a seminar (to the staff and graduate students of Plant and Soil Science Department at U of S) on the “untold” rhizobial biodiversity resources resident in Ethiopian soils and their potential to enhance soil fertility and sustainable agriculture (annexed)
As part of the project’s protocol, Mr. Alemzewed Chala has made a short-term visits to UofS is generally to gain broader research insight from UofS research communities and upgrade faculties’ research experiences, particularly on data analyses, manuscript preparation and publishing results, which otherwise could have not be carried out in Ethiopia. The visit was took place for two months from December 28 to February 28, 2013. Mr. Alemzewed has developed two manuscripts, “Nutritional status and Dietary Intake of rural adolescent girls in Southern Ethiopia” and “Pulse Consumption Patterns among Adolescent Girls in Southern Ethiopia” for submission. In addition, he has prepared and presented two posters entitled “Nutritional Status and Pulse Crops Consumption Patterns Among Adolescent Girls In Rural Communities of Halaba in Southern Ethiopia” and “Curricula Linking Nutrition, Agriculture and Health for Improved Food Security and Capacity Building: Partnership between UofS and Hawassa University” at the Global Food & Nutrition 2013 conference, Feb 6-8, 2013, UofS.

3.5.2 Graduate studies

Four PhD students (two each in Agronomy and Soils) have completed their field works in Ethiopia and currently taking courses at UofS. The students specializing in Agronomy will receive their degrees from UofS, while those in Soil Science will graduate at HU. All students are expected to complete their studies in 2015.

Fifteen MSc students (7 female) in areas of Soils, Agronomy and Crop Protection have completed their Theses projects with support of the project. Additionally, four female students in Applied Human Nutrition (AHN) completed their project work with support of the project. Three of the AHN students had successfully defended their Theses. The research works of the students were compiled in “Research Booklet” in scientific paper forms. The papers are presented under two broad categories (completed studies and studies in progress) and four major thematic areas. The completed studies included three papers each in the areas of soil characterization and classification, soils and crop management, crop breeding and weed control and crops and human nutrition; and the studies in progress included six papers all grouped under soils and crop management.

The work of one female student is still on-going and will be partially funded by Call 3 Project. The Masters of AHN program were supervised by Canadian faculty. Three of these students had two Canadian faculty member each, as supervisors. This close contact with these students resulted in high quality research that was presented at the 13th World Congress on Public Health Nutrition in 2012. Second, team members taught in the Applied Human Nutrition program. The Community nutrition course is used for training in assessment, planning, and evaluation, which is important for the Masters students in their subsequent research work. Further, each year these students complete their degrees and become highly trained nutrition personnel in government, NGOs and universities in Ethiopia. Third, Canadian students continue to find opportunities to go to Ethiopia. In 2012, AUCC provided funding for 5 students to spend 10 weeks in Ethiopia, where they worked with HU team members in several projects.
3.6 Improved research facilities at Hawassa University

The Atomic Absorption Spectrophotometer (AAS) has been acquired for chemical analyses. Purchase of the equipment by the project has boosted the analytical capacity of the soils science laboratory. Two rounds of seven day training were conducted on handling of the AAS, wherein a total of 40 Faculty and technicians (20 each) participated. This is a great achievement to enhance the research activities in agronomy, soil science and human nutrition. Prior to purchase of the AAS, researchers were forced to send their samples to laboratories in Addis Ababa for analyses, which had resulted in delay of acquiring analytical data and thereby extended time to complete activities according to plan.

3.7 Implementation of intervention program of nutrition education

The project integrated several activities to promote agriculture-nutrition and social relations. One nutrition education carried out during farmers two field days conducted in May and June, 2012 at two different sites (Hallaba&Butajera). At total of 56 farmers (28 male & female, each) from four of the study sites (Hallaba, Wolaiyta, Butajera and Zeway) participated. *A Conversation Map –Pulses and Food Security*, a new and innovative teaching tool provided allowed participants to engage facilitator on issues related to improving human nutrition and food security on community-based participatory methods. Local district agents from the Bureau of Agriculture served as translators. When asked about what they learned from the session, participants said they learned how to prepare different meals from pulses which can replace meat, how to prepare balanced diets, the importance of different food groups, different new knowledge –“previously I used to think that haricot bean is bad for human health but now I learned about the health importance of haricot bean”, the possibilities of preparing different meals from pulses for children by mixing them with different foods in order to get full protein, the important nutrients available in pulses, and to use our own produced foods for consumption. The Conversation map was an effective tool to engage participants and gain insights about their knowledge, and practices related to pulse consumption.

4. Synthesis of Research Activities and Results

4.1. Assessment of Farmer capacity for growing pulse crops and their productivity across target areas

In 2010, about 42% of the households produced chickpea in Jole Andegnakebele, but most of them used local seed. As a result, the farmers showed high interest to grow chickpea if they get access to improved variety. Some of them were using an improved variety, known as ‘dubie’ which was released from Debrezeit research center. On the other hand, about 25% of the households in Taba and 17% in Huletage Choroqo reported to have produced chickpea during the 2009/10 production year, whereas only 17% of the households in Ele produced lentil during
the same growing season (Table 3), although most of them showed interest to produce it if they get improved variety and associated technical advises.

### Table 3 Characteristics of the selected sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Population</th>
<th>HH</th>
<th>Family size</th>
<th>Land holdings</th>
<th>Altitude</th>
<th>Major pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>JoleAndegna</td>
<td>3,892</td>
<td>745</td>
<td>5</td>
<td>0.25</td>
<td>2,300</td>
<td>Chickpea (42%), Haricot Bean</td>
</tr>
<tr>
<td>Ele</td>
<td>3,764</td>
<td>671</td>
<td>5.6</td>
<td>1.07</td>
<td>1880-2000</td>
<td>Haricot Bean, Chickpea, lentil (17%)</td>
</tr>
<tr>
<td>Taba</td>
<td>5,074</td>
<td>878</td>
<td>5.8</td>
<td>0.72</td>
<td>1850</td>
<td>Haricot Bean, Chickpea (25%)</td>
</tr>
<tr>
<td>HuletegnaChoroko</td>
<td>2,897</td>
<td>515</td>
<td>5.6</td>
<td>1.55</td>
<td>1700 – 2000</td>
<td>Soya Bean, Chickpeas (17%)</td>
</tr>
<tr>
<td>Teticha</td>
<td>4,833</td>
<td>764</td>
<td>6.3</td>
<td>1.00</td>
<td>2200 - 2800</td>
<td>Broad Bean</td>
</tr>
</tbody>
</table>

### 4.2 Enhanced farm productivity and sustainability through establishment of low-input pulse crops in participatory approach

Research on chickpea was done at three locations (Halaba, Wolaita and Butajira) using three desi (Natoli, Worku and local cultivar) and two kabuli (Habru and Ejere) varieties in 2011 and 2012. Results indicated that sowing date had no significant effects on grain yield with the mean yield across varieties was 0.95 t/ha. The response of chickpea varieties to Rhizobium inoculation depends on locations; all improved varieties responded better to inoculation compared to local check as reflected by nodulation related parameters. Grain yield difference was not significant between the inoculated versus the non-inoculated plots. Percent yield advantage over the local check (Table 4) indicated that under inoculation the late variety (Natoli) produced more yield (42.1%) over the local check compared to the early maturing variety such as Ejere.
Table 4 Yield of improved varieties as influenced by inoculation and in comparison with local cultivar in 2011

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield advantage (%) over the local check</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ejere</td>
</tr>
<tr>
<td>Inoculated</td>
<td>79.4</td>
</tr>
<tr>
<td>Non-inoculated</td>
<td>94.3</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>1.4</td>
</tr>
</tbody>
</table>

The residual amount of nitrogen in the soil after chickpea that can be used by succeeding wheat crop was examined at two locations. Although application of 50 percent recommended nitrogen produced higher yield, percent yield advantage of plots with no additional nitrogen to plots with 50% nitrogen was comparable indicating that the residual nitrogen after chickpea was sufficient to produce successful wheat crop (Table 5).

Table 5 Average yield of wheat with and without N on plots of different varieties of chickpea in chickpea-wheat rotation trial in 2012

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treat.</th>
<th>Ejere-0</th>
<th>Ejere-I</th>
<th>Habru-0</th>
<th>Habru-I</th>
<th>Local-0</th>
<th>Local-I</th>
<th>Natoli-0</th>
<th>Natoli-I</th>
<th>Worku-0</th>
<th>Worku-I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With N</td>
<td>2.3</td>
<td>2.2</td>
<td>2.5</td>
<td>2.2</td>
<td>2.4</td>
<td>2</td>
<td>2.3</td>
<td>2.2</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Without N</td>
<td>1.7</td>
<td>1.9</td>
<td>2.2</td>
<td>1.9</td>
<td>2.1</td>
<td>1.9</td>
<td>1.7</td>
<td>2.2</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>straw yield t/ha</td>
<td>With N</td>
<td>3.5</td>
<td>3</td>
<td>3.8</td>
<td>3.4</td>
<td>3.8</td>
<td>3</td>
<td>4.4</td>
<td>3.2</td>
<td>3</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Without N</td>
<td>2.3</td>
<td>2.3</td>
<td>3</td>
<td>2.6</td>
<td>3.1</td>
<td>3.3</td>
<td>3</td>
<td>2.6</td>
<td>2.2</td>
<td>2.7</td>
</tr>
</tbody>
</table>

0 = no inoculation; I = inoculated with Rhizobium

Participatory variety selection for eight chickpea varieties was conducted on six farmers’ fields in Halaba. Group of farmers (18 male and 7 women farmers) performed selection of varieties based on agronomic performance, cooking quality and taste. The result showed that variety Habru was selected by 93% of the farmers for its earliness, branch number, podding characters and quality. Seed multiplication and scaling up of the selected varieties such as Mastewal (in Butajira) and Habru (in Wolaita) were in progress. Farmers were trained for the necessary crop management practices.

Eight varieties of snap bean were tested at three locations (Debrezeit, Zeway and Hawassa) for their response to rhizobium inoculation under rain-fed conditions. There was significant difference on yield and yield components of snap bean as influenced by agroecologies, nitrogen sources and varieties. Among the eight varieties, Volta and Melkassa 1 produced the highest yield (Figure 1). Melkassa 1 produced the highest marketable yield. Research also revealed that applied nitrogen increased the total and marketable yield followed by Rhizobium inoculation (Figure 2A). Locations exerted significant influence on total yield and marketable yield (Figure 2B). The highest yield and yield components were observed at Hawassa followed by Debre Zeit and Zeway.
Figure 1 Total and marketable yields (Qt/ha) of eight varieties of snap beans grown with under rain-fed conditions. 
**Bars with different letters are significantly different at \( \alpha=0.05 \). TYQPH=total yield quintal per hectare, MYQPH=Marketable yield quintal per hectare**

![Figure 1](image1.png)

Figure 2 Total and marketable yields (quintals per hectare) of eight varieties of snap bean grown with 100kgN/ha, Rhizobium inoculation (strain HB 429) or with no nitrogen application (A) or grown at three different locations (B). **Bars with different letters are significantly different at \( \alpha=0.05 \).**

![Figure 2](image2.png)

Nutrient analyses showed that varieties Andante and Contender blue had the highest zinc concentration in the pod followed Boston and Lomami; whereas Contender blue, Andante, Boston and Lomami had the highest iron concentration. Snap bean produced in Hawassa provided higher Zn concentration followed by Debrezeit, and Zeway. Results demonstrated that nutrient concentration in snap bean pods were not affected by nitrogen application or Rhizobium inoculation.

All the snap bean varieties, except Andante, performed equally well under irrigation during the dry season. The highest yield was obtained at Hawassa site. No difference in pod yield between Debrezeit and Zeway. Nitrogen application improved yield of snap bean across all locations followed by Rhizobium inoculation.
Faba bean is usually hand-broadcasted on the field and planted on poor fertile lands without fertilization. Thus, a field study was conducted during the 2011 main cropping season under rain fed conditions at Teticha in SNNPRS to investigate effects of two inter-row spacings (40 and 50 cm), three intra-row spacings (5, 10 and 15 cm) and four P levels (0, 23, 46 and 69 kg ha\(^{-1}\)). The design was split-split plot with three replications. Application of 46 kg P ha\(^{-1}\) significantly increased number of pods per plant and grain yield by 21.4 and 23.5% over the non-P fertilized treatment, respectively. Similarly, intra-row spacing of 15 cm resulted in 14.6, 43.6 and 18.2% increase in number of pods per plant, harvest index and grain yield, respectively over 5 cm intra-row spacing. Significant improvement of 100-seed weight (2.8%) and harvest index (11.5%) were also observed at inter-row spacing of 50 cm as compared to 40 cm. Most of the measured yield and growth parameters were significantly affected by intra-row spacing than inter-row spacing. Phosphorus levels of 46 and 69 kg ha\(^{-1}\) achieved statistically similar grain yield of 4.42 and 4.43 t ha\(^{-1}\), respectively but, partial budget analysis identified 46 kg P ha\(^{-1}\) to give the highest net benefit of Birr 28504 ha\(^{-1}\) together with 235.03% acceptable marginal rate of return. Intra-row spacing of 15 cm, which gave the highest grain yield of 4.36 t ha\(^{-1}\), was selected. Because of similar grain yield at both spacings, 50 cm inter-row spacing, the one with the minimum variable cost, was selected. Therefore, P level of 46 kg ha\(^{-1}\), 15 cm intra and 50 cm inter-row spacing were found to be economical and recommended for variety Gabelcho faba bean producers in the study area.

4.3 Germplasm introduction and testing

Lack of adoption of improved production packages for chick pea and lentil is one of the main reasons for the low productivity of these crops in the region. Farmers are still using low yielding local varieties of chickpea and lentil. In order to boost productivity participatory variety selection with objectives of selecting high yielding and acceptable chickpea varieties adapted to the growth environment was conducted at Taba, Jole Andegna and Huletegna Choroko. For lentil it was conducted at Huletegna Choroko. At Taba, where the growth environment was more optimal, the Kabuli types, Habru and Chefe had shown excellent performance and were chosen by farmers as first and second choices (Fig. 3). At Jole Andegna kebele, where the environment was sub-optimal, the variety Mastewal was chosen by farmers for its high grain and straw yield, earliness and vigor (Fig. 4). At Huletegna Choroko, varieties Habru and Ejere were selected as first and second choice by participant farmers (Table 6). The selected cultivar exceeded the local cultivar under production by 62% at Taba and by 89% at Jole Andegna (Figs. 3 and 4).

The following were the key achievements of the PVS program:

- Identified two kabuli and one desi type cultivars, which are adapted and high yielding in the target areas.
- Increased farmers’ interest to grow chickpea even in a district where chickpea is not currently growing. This happened in Halaba district in Huletegna Choroko. After a successful PVS in 2012 based on farmers’ request, 95 farmers are already registered volunteering to grown chickpea in the next cropping season.
- The promising results of the 2011 PVS led to an early start of a preliminary seed increase in two kebeles and also limited pre-scaling up activity by farmers in one kebele. It was clearly shown that the southern region is a potential chickpea area which should be given more emphasis in terms of extending improved technologies and research.
A consultative meeting with stakeholders on 27 January 2013 reached an agreement to carry out a full pre-scaling up program for chickpea in three districts with the involvement of the Bureau of Agriculture as a major stakeholder. It was agreed to start the pre-scaling up activity with 500 farmers. Two farmers’ field days were conducted in 2011 and 2012, one in each year, which facilitated information exchange among farmers.

Figure 3 Chickpea participatory variety selection at Taba kebele of Damot Gale district showing (A) grain and straw yields and (B) farmers’ preference evaluation in 2011.

Figure 4 Chickpea participatory variety selection at Jole Andegna kebele of Meskan district showing (A) grain and straw yields and (B) farmers’ preference evaluation.
Table 6 Days to flowering, Plant height, yield components and straw and grain yields q/ha.

<table>
<thead>
<tr>
<th>Var/trait</th>
<th>DF</th>
<th>PH (cm)</th>
<th>PPP</th>
<th>SPP</th>
<th>SW</th>
<th>SY</th>
<th>GY</th>
<th>Rank for yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habru</td>
<td>52</td>
<td>46.5a</td>
<td>54.17ab</td>
<td>60.13b</td>
<td>25.28c</td>
<td>16.67a</td>
<td>2.0a</td>
<td>2</td>
</tr>
<tr>
<td>Mastewal</td>
<td>59</td>
<td>39.67bc</td>
<td>54.77ab</td>
<td>62.57b</td>
<td>19.00f</td>
<td>15.68a</td>
<td>1.93a</td>
<td>4</td>
</tr>
<tr>
<td>Natoli</td>
<td>61</td>
<td>44.65a</td>
<td>40.57b</td>
<td>41.43c</td>
<td>22.77d</td>
<td>15.66a</td>
<td>1.74a</td>
<td>6</td>
</tr>
<tr>
<td>Chefe</td>
<td>52</td>
<td>44.84a</td>
<td>46.57b</td>
<td>51.90bc</td>
<td>26.68b</td>
<td>17.71a</td>
<td>1.87a</td>
<td>5</td>
</tr>
<tr>
<td>Ejere</td>
<td>52</td>
<td>45.84a</td>
<td>49.67b</td>
<td>51.87bc</td>
<td>28.97a</td>
<td>16.46a</td>
<td>2.4a</td>
<td>1</td>
</tr>
<tr>
<td>Arerti</td>
<td>57</td>
<td>37.49c</td>
<td>53.23b</td>
<td>54.97bc</td>
<td>20.96e</td>
<td>15.74a</td>
<td>1.65a</td>
<td>7</td>
</tr>
<tr>
<td>Shasho</td>
<td>56</td>
<td>43.59ab</td>
<td>45.00b</td>
<td>46.33bc</td>
<td>23.35d</td>
<td>16.80a</td>
<td>1.61a</td>
<td>8</td>
</tr>
<tr>
<td>Local</td>
<td>52</td>
<td>37.99c</td>
<td>67.37a</td>
<td>92.33a</td>
<td>9.92g</td>
<td>14.24a</td>
<td>1.99a</td>
<td>3</td>
</tr>
<tr>
<td>+LSD 5%</td>
<td></td>
<td>4.87</td>
<td>14.83</td>
<td>18.26</td>
<td>1.31</td>
<td>4.74</td>
<td>0.59</td>
<td></td>
</tr>
</tbody>
</table>

where DF, Days to flowering; PH, Plant height in cm; PPP, pods per plant; SPP, seeds per plant; SW, 100- seeds weight in gm; SY, stover yield in q/ha; and GY, grain yield t/ha.

### 4.4 Soil quality and sustainable agricultural production

The population of chickpea and lentil rhizobia was assessed in diverse agroecological locations in central and southern Ethiopia, to isolate, characterize and evaluate the symbiotic effectiveness of selected isolates on different cultivars (Chickpea varieties Nattoli and Shasho; Lentil varieties Teshale and Alemaya) under greenhouse and field conditions. The population size of indigenous rhizobia compatible with lentil and chickpea varied at different locations, and ranged from 0 at Ele and Alaba to a few hundred at Bodity and $1.7 \times 10^4$ cell g$^{-1}$ of soils at Jole, indicating the need for inoculation where rhizobial populations were either low or non-existent. A total of 104 chickpea and 114 lentil nodulating rhizobia were isolated. Phenotypic characterization showed that indigenous rhizobia constituted physiologically and metabolically diverse groups, thus indicating the potential for developing efficient rhizobial inoculants.

The efficacy of indigenous Ethiopian strains were compared to elite national (EAL 029A) and EAL600) and imported commercial (2006005A and 2006001A) inoculants available in Canada. Screening for symbiotic effectiveness revealed that several chickpea and lentil strains were as good as, or better than fertilizer N or the commercially available inoculants (Fig.5 and 6). Fourteen percent of the lentil isolates were found to be highly effective (80 - 100% effectiveness), 20% of the isolates were effective (50-80% effectiveness), while 29% and 37% of the isolates were either poorly effective or ineffective at enhancing lentil growth (effectiveness rate of 35-50% and less than 35% effectiveness, respectively). Relative to the uninoculated and N fertilized (positive) controls, several test isolates resulted in greater than 30% increase in dry matter (DM) accumulation. Several isolates outperformed the national elite inoculant (Lt139) and the Canadian commercial inoculant (Lt137) (Fig. 5).
Similarly, 3% of chickpea rhizobial isolates were highly effective (80 - 100% effectiveness), 23% of the isolates were effective (50-80% effectiveness), while 56% and 18% of the isolates were either poorly effective or ineffective. Isolate Cp 41 resulted in 20% more dry matter production compared to the imported Canadian inoculum (CP113) and produced as much dry matter as the N fertilized control (Fig. 6). Many of the chickpea rhizobial isolates outperformed the current Ethiopian NSRC strain (Cp114). Ethiopian soils hold a rich reserve of effective and adapted rhizobial strains, capable of enhancing N-fixation and subsequent biomass production of lentil and chickpea.
Figure 6 Symbiotic effectiveness of selected rhizobial strains on chickpea biomass production (45 days after seeding).

Greenhouse and field experiments indicated that indigenous isolates (Cp 41 and Lt 29) excelled over elite inoculants (Tables 7 and 8). Accordingly, Cp41 and Lt29 produced 10X and 5X more nodules dry mass over the control treatment (elite inoculants) on chickpea and lentil roots, respectively. Similarly, chickpea and lentil inoculated with Cp41 and Lt29 yielded 18% and 41% more grain over the control treatments under field conditions, respectively. These results, while showing inoculation with appropriate rhizobia inoculants enhanced grain yield, also indicated the potential to select efficient strains from indigenous biodiversity resources to promote BNF among small-holder producers in Ethiopia.
Table 7 Effect of Rhizobium inoculation and N fertilizer application on grain yield, shoot dry weight, nodule number, and nodule dry weight of lentil varieties at Alaba (field trial).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (kg ha(^{-1}))</th>
<th>Field trial at 50% flowering</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SDW (g plt(^{-1}))</td>
<td>NN plt(^{-1})</td>
<td>NDW (mg plt(^{-1}))</td>
</tr>
<tr>
<td><strong>Strains</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninoc.</td>
<td>636(^{D})</td>
<td>1.02</td>
<td>2.5(^{B})</td>
<td>2.82(^{B})</td>
</tr>
<tr>
<td>Nfertilizer</td>
<td>890(^{ABC})</td>
<td>1.14</td>
<td>2.5(^{B})</td>
<td>3.07(^{B})</td>
</tr>
<tr>
<td>Lt5</td>
<td>918(^{AB})</td>
<td>1.15</td>
<td>64.0(^{A})</td>
<td>36.68(^{A})</td>
</tr>
<tr>
<td>Lt29</td>
<td>1012(^{A})</td>
<td>1.19</td>
<td>62.2(^{A})</td>
<td>43.72(^{A})</td>
</tr>
<tr>
<td>Lt87</td>
<td>839(^{ABCD})</td>
<td>1.04</td>
<td>7.5(^{B})</td>
<td>3.63(^{B})</td>
</tr>
<tr>
<td>Lt136</td>
<td>762(^{BCD})</td>
<td>1.17</td>
<td>9.0(^{B})</td>
<td>7.67(^{B})</td>
</tr>
<tr>
<td>Lt137</td>
<td>699(^{CD})</td>
<td>1.09</td>
<td>19.5(^{B})</td>
<td>6.23(^{B})</td>
</tr>
<tr>
<td>Lt139</td>
<td>739(^{BCD})</td>
<td>1.09</td>
<td>15.8(^{B})</td>
<td>8.20(^{B})</td>
</tr>
<tr>
<td>LSD.05</td>
<td>309</td>
<td>NS</td>
<td>32.1</td>
<td>25.9</td>
</tr>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teshale</td>
<td>865</td>
<td>1.21(^{A})</td>
<td>24.9</td>
<td>16.9</td>
</tr>
<tr>
<td>Alemaya</td>
<td>759</td>
<td>1.01(^{B})</td>
<td>20.9</td>
<td>11.1</td>
</tr>
<tr>
<td>LSD.05</td>
<td>NS</td>
<td>0.18</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letter are not significantly different at \(P < 0.05\). LSD- Least significant difference, CV- coefficient of variation, NN-Nodule number, NDW- Nodule dry weight, SDW-Shoot dry weight, plt-plant and NS-non significant at \(P < 0.05\).

Table 8 Effect of Rhizobium inoculation and N fertilizer application on grain yield, shoot dry weight, nodule number and nodule dry weight of chickpea varieties at Ele Kebele.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (kg ha(^{-1}))</th>
<th>Field trial at 50% flowering</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SDW (g plt(^{-1}))</td>
<td>NN plt(^{-1})</td>
<td>NDW (mg plt(^{-1}))</td>
</tr>
<tr>
<td><strong>Strains</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (N(^{-})&amp;Inoc(^{-}))</td>
<td>2167.2</td>
<td>5.38(^{D})</td>
<td>0.0(^{D})</td>
<td>0.0(^{B})</td>
</tr>
<tr>
<td>N(^{+})</td>
<td>2207.4</td>
<td>7.58(^{A})</td>
<td>0.0(^{D})</td>
<td>0.0(^{B})</td>
</tr>
<tr>
<td>Ch8</td>
<td>2583.9</td>
<td>6.55(^{ABC})</td>
<td>28.8(^{A})</td>
<td>185.3(^{A})</td>
</tr>
<tr>
<td>Cp41</td>
<td>2537.0</td>
<td>7.34(^{AB})</td>
<td>30.7(^{A})</td>
<td>199.7(^{A})</td>
</tr>
<tr>
<td>Cp97</td>
<td>1916.2</td>
<td>7.14(^{ABC})</td>
<td>14.0(^{B})</td>
<td>24.8(^{B})</td>
</tr>
<tr>
<td>Cp105</td>
<td>2265.8</td>
<td>6.46(^{BC})</td>
<td>6.3(^{C})</td>
<td>23.6(^{B})</td>
</tr>
<tr>
<td>Cp113</td>
<td>2135.3</td>
<td>6.25(^{CD})</td>
<td>18.5(^{B})</td>
<td>26.2(^{B})</td>
</tr>
<tr>
<td>Cp114</td>
<td>2177.9</td>
<td>6.10(^{CD})</td>
<td>4.5(^{CD})</td>
<td>7.3(^{B})</td>
</tr>
<tr>
<td>LSD.05</td>
<td>NS</td>
<td>1.51</td>
<td>7.59</td>
<td>78.4</td>
</tr>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shasho</td>
<td>1722.0(^{B})</td>
<td>6.91(^{A})</td>
<td>12.42</td>
<td>58.1</td>
</tr>
<tr>
<td>Natoli</td>
<td>2775.6(^{A})</td>
<td>6.29(^{B})</td>
<td>13.29</td>
<td>58.6</td>
</tr>
<tr>
<td>LSD.05</td>
<td>909.4</td>
<td>1.74</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
Field study on effects of topography and land use systems on soil properties at Butajira showed that topography affected the structure, organic carbon, C:N ratio and CEC of the soils. Organic carbon, total N, available P and CEC increased while the C:N ratio decreased from the upper to the lower slope positions. Soil color and particle size distribution were also influenced by topography. Moreover, the topography has influenced soil depth, rootability and soil development at large. The chemical properties of the soils, particularly soil OC and exchangeable bases are also conditioned by the land use types.

Additionally, study at Taba on effects of land use systems on soil properties indicated a decline in soil quality as a result of agricultural activities following conversion of natural vegetation to agricultural land. In this regard, cultivation severely reduced the soil pH, OM, total N, available P, CEC and exchangeable bases which are taken as an indicator of sustainability.

Furthermore, a study on management practice revealed that broad bed and furrow was superior over the other land preparation methods, especially on yield and yield components, revealing that the practice of improved land preparation method on Vertisols enables to achieve higher yields. Early planting also enabled the plant to use longer vegetative and grain filling time and resulted in higher yield. Thus, it can be recommended that the use of BBF combined with sowing in mid-August is worth testing by development agents in farmers training centers as well as by farmer.

MBY = Biomass yield; GY = Grain yield; BBF = Broad bed and furrow; RF = Ridge and furrow; FB = Flat bed
Figure 7 Interaction effects of land preparation method and sowing date on chickpea biomass weight and grain yield
4.5. Research on nutritional status and food security

In this project, we investigated the inclusion of pulses, which are high in protein and essential nutrients, as a vehicle to improve nutrition and food security status in vulnerable groups. Our research methodology included nutrition and dietary assessment, measurement of food insecurity, and the use of complimentary feeding practices and indigenous knowledge to ameliorate nutrient deficits in children, adolescent women and young mothers. Three baseline studies were conducted in the three study sites (Huletegna Choroko kebele, Halaba Special Woreda Taba kebele Damot Gale District, Wolayita Zone, “Titecha” kebele, Sidama Zone”).

In conducting baseline studies in traditional pulse growing communities, we identified undernutrition as a problem: Adolescent girls (15-19 y, n=188) had intakes of energy, calcium, vitamin C and zinc of 70%, 13%, 5% and 65% of requirements, respectively, and the prevalence of stunting was 31% (National average 30%). In another group of infants and young children (6-23 months, n=128) 38% were stunted and, except for vitamins A and B2, median intakes of micronutrients were below requirement. In these communities, and others in our study, pulses already contributed to the nutritional value of the diet, yet increased consumption would improve nutritional status. Results, however, vary when introducing complementary pulse-based foods. In the second study above, mothers showed little interest in integrating kidney bean into their complementary feeding practices even though it was regularly consumed in the household (43% once/twice monthly). Yet in another group of mothers with young children (19 months, n=169) where 40% reported providing pulse-based food to their children, a porridge of 30% added broad bean was found acceptable. The studies found that pulses can effectively be used as a suitable and inexpensive addition to traditional starch-based foods; however, community education in the appropriateness and nutrition value of pulses would be beneficial.

Building on the third study, Anthropometric and dietary assessment of young children consumption of broad bean and its use for nutritional improvement of diet at “Titecha” kebele, Sidama Zone” a nutrition education intervention is in progress at the same study site. In that intervention a recipe with 30% broad bean has been shown to be acceptable in this region (Kekebu et al., submitted). A quantitative baseline survey was conducted in 200 mother-child pairs on socio-demographics, food security status, knowledge and practices of complementary feeding, food group intakes of children, interactive 24h recalls, anthropometric data of children, and wealth index. Results from this intervention study are currently being analyzed. Early indications suggest that addition of broad beans to a starchy complementary food improvise protein content but effectiveness studies are needed to determine if consumption is sufficient enough to prevent wasting and stunting that is common in Ethiopian children.

4.6 Market and consumer studies

Studies have shown that pulses on an average contribute 15% of total protein intake, account for 13% of the cultivated land and 8.5% of the total crop production in Ethiopia (Chilot Yirga, et
In recent years pulse sector shows a steady increase in productivity and total volume of production despite a slight decline in land allocation. The SNNP region stands third next to Amhara and Oromia in overall production of pulses by producing 10% of the faba bean, 18% of the filed pea, 3% of chickpea and 15% of haricot bean.

Market and consumer study was conducted from early July to end of August, 2012 in three project sites namely Huletegna Choroko, Taba and Jole Andegna and three local markets surrounding these project areas. A two stages sampling procedure was employed to select a total of 183 producers and A total of 120 consumers were selected using accidental sampling procedure and interviewed about their household characteristics, pulse consumption pattern, desired pulse grains attributes and their major food related expenses.

Both descriptive and econometric methods were used to analyze the data. Econometric methods were used to examine the production structure of chickpea and haricot bean using Cobb Douglas type of production function while Tobit model is employed to examine the determinates of chickpea and haricot bean market orientation.

4.6.1 Pulse crops production

Results show that haricot bean is the most widely grown pulse crops in all project sites, occupying between 0.12 ha and 0.39 ha. Chickpea is the second important crops grown widely following haricot bean. It is particularly economically important cash crop in Jole Andegna and Taba. Lentil and faba bean are growing on a limited extent in the project site with the exception of lentil which is not grown in Jole Andegna. A unit increase in seed and fertilizer expense and land allocation positively contribute to chickpea production while labour contribution is negatively. The chickpea production return to scale value was 0.634. It means chickpea production exhibit decreasing return to scale, for instance doubling of the inputs use from the current level only lead to 63% increase in chickpea output. The fitted production function of haricot bean show that all the inputs included in the model contribute positively to haricot bean outputs. The haricot bean production return to scale value was 1.34 implies haricot bean production exhibit increasing return to scale. If farmers double inputs use from the current level they would get 134% increase in output.

4.6.2 Pulse crops market orientation

Haricot bean is an important market-oriented commodity in project sites. About 73% of households produce haricot beans in the study areas on about 17.2% of total cultivated land. Close to56% of haricot bean production is sold, suggesting that haricot bean is an important component of the household cash source. On average a household sold about 185 kg of haricot bean for a monitory value of about ETB 1022. About 33% of households sell only 26–50% of their produce, while about 32% sold 76–100% of their produce. In the project sites, chickpea is produced by about 26.8% of the households, on about 16.8% of the total cultivated area. On average a household allocates about 0.26 ha of land for chickpea. A household also sold about 242 kg of chickpea, about 69.5% of total chickpea produce for total revenue of ETB 1760.6. The proportion of chickpea produce sold is ranged between 33% and 100%. The Tobit estimation result show that household head education level, access to credit and land per capita
were positively influenced by chickpea market orientation and significant at 10% level of probability. On the other hand household head sex and fertilizer expense were negative and significant at 10 and 5% level of probability respectively. The Tobit estimation of haricot bean indicates that being male head of a household and access to credit increase the predicted value of haricot bean market orientation by a factor of 0.239 and 0.207 respectively and the result was statistically significant at less than 1% probability level. Land holding, TLU and age of the respondents are negatively related with haricot bean market orientation.

![Figure 8 Producers’ market orientation of haricot bean and chickpea crops](image)

**4.6.3 Consumers study**

Out of the total respondents interviewed for the consumer study 60% was females while the rest 40% was males. The mean age of a typical consumer is about 33.23 years with the youngest being 18 and the oldest 80 years old.

The majority of the consumers were visiting market one per week (87.5%) while some of them did so only every fourteen night (12.5%). About 84% of respondents reported that they visited other markets for reason viz., more products available (32%), better value for money (22%), closer location (18%), more sellers (4%) and other reason (20%). This study unveiled that consumers get market information from neighbor (4.2%), trader (18.3%), friends (7.5%) and combination of sources (62.5%).

Consumers purchase decision of pulse crops are influenced by a number of markets related and social factors. The finding indicates that consumers’ purchase of haricot bean is attributed to its cheap price compared to other pulse crops, easy availability in the market and it is staple food. Whereas consumers purchase of chickpea is attributed to its food quality, it is a festive food and easy for cooking. As the monthly consumption figure indicates that the majority of respondents (45.8%) consume less than 10 kg pulses per month. This partly for most of the respondents is making a living from farming and cover part of their consumption requirement forms their own production.

The majority of female respondents consumed less 10 kg pulses per month compared to their male counterparts. The finding shows that there is statistical difference in pulse consumption
among consumers with different education level at 10% level. Consumers who belong to the different wealth categories consume different amount of pulse. The low income consumed less amount of pulse per month compared to the better of and the middle income group. This difference is found to be statistically significant at 10% level. The study also investigates consumers’ expenses in various agricultural commodities. It came out that the major expenses consumer made were on cereals such as maize, wheat and barley. While expenses on pulses came second, haricot bean and chickpea took the lion share of the consumers’ expense.

Figure 9 Major market actors along the market channel

5. Synthesis of Results towards AFS Outcomes

5.1 Generation of new technologies

The objectives set to achieve this outcome include:

- Assessment of farmers’ capacity for growing pulse crops and their productivity across target areas
- Enhance farm productivity and sustainability through participatory establishment of low input pulse crops
- Introduce and test improved germplasm, soil quality and sustainability for pulse crops

The target research sites were identified and farmers’ capacity for growing pulse crops and their productivity across the sites were assessed. The selected sites include: Jole Andegna and Ele in Meskan district, Huletenga Choroko in Halaba special district, Tabia and Tetic in Damot Gale and Hulla districts, respectively. Jole Andegna, Ele and Tabia were potential sites for chickpea production, whereas Huletenga Choroko and Tetic were for lentil and faba bean, respectively. Assessment of the farmers’ capacity to grow the pulse crops has also confirmed that Jole Andegna is a good potential for expanding chickpea production, Ele and Tabia for lentil, Huletenga Choroqo for both, and Tetic for broad beans.
Participatory variety selection involving seven improved chickpea and four lentil varieties were carried out on farmers’ fields in three project sites in 2011 and 2012. The combined evaluation identified the kabuli type variety, Habru, at Taba and the desi type Mastewal at Jole Andegna. Cultivars Habru and Mastewal out yielded the local cultivar consistently on all farmer sites with an average yield advantage of 62 and 89%, respectively. At Huletegna Choroko the kabuli type varieties, Habru and Ejere were selected as first and second choices, respectively. All these new improved varieties have not been introduced before in all the three districts. When these new varieties are used by farmers through the planned pre-scaling up program it will increase chickpea production and enhance land use efficiency in the areas.

Technologies in pulse agronomic management that were not in use in the area were also identified at two project sites. Chickpea and faba bean are grown under broadcasting and without fertilizer inputs and weeding in the areas. In chickpea, farmers even believed that weeding is harmful for yield as indicated in the discussion during a field day in 2011. Experiments made in 2011 at Jole Andegna and Teticha district identified that in chickpea two times weeding and a planting density of 333333 plants ha$^{-1}$ significantly improved yield with economic feasibility while in faba bean row planting (50 cm x 15 cm) and 100 kg ha$^{-1}$ di ammonium phosphate fertilization, two times weeding and use of improved cultivar (Gebelcho) can be used to increase yield economically.

The efficacy of indigenous Ethiopian Rhizobium strains were compared to elite national (EAL029A and EAL600) and imported commercial (2006005A and 2006001A) inoculants available in Canada. Screening for symbiotic effectiveness revealed that several chickpea and lentil strains were as good as, or better than fertilizer N application or the commercially available inoculants. Many of the chickpea rhizobial isolates outperformed the current Ethiopian NSRC strain (Cp114). These results strongly support the contention that Ethiopian soils hold a rich reserve of effective and adapted rhizobial strains, capable of enhancing N-fixation and subsequent biomass production of lentil and chickpea. Broad bed and furrow was superior over the other land preparation methods, especially on yield and yield components, revealing that the practice of improved land preparation method on Vertisols will further promote higher yields.

The project has identified new areas, Halaba, Ele, and JoleAndegna, as potential sites for chickpea production. Growing chickpea allows double cropping on a particular land and thereby increase the income of farmers. Productivity of the crop was increased by introducing high yielding varieties and applying improved soil and agronomic management. The farmers at the research sites have applied for improved seeds. Regional, zonal and district offices of the Ministry of Agriculture have taken the responsibility to lead improved seed increasing involving 500 farmers in four districts (Halaba, Damot Gale, Meskan and Silte) in 2013 growing season. It is anticipated that over 3,000 farmers will produce improved chickpea varieties in the coming three years.

5.2 Dietary diversity and nutrition

The project started with designing and implementing a nutrition program for health promotion and improved food security as objective to achieve outcome in dietary diversity and nutrition. Assessment of the consumption pattern of broad bean and its use for nutritional improvement of
young children diet at Teticha kebele indicated that the majority of children had diets in the lowest diversity group (< 3 food groups) which means that most of them are not consuming a diversified diet needed for their growth and development. Additionally most mothers are preparing food in the form of gruel and its major ingredient is cereal. Additionally, crops that have high protein content like pulses are not consumed. The study also showed that applied processing methods like germination have improved the quality of food by increasing protein and iron content, and decreasing phytate content. The products prepared by incorporating broad bean with cereals can effectively be used in traditional cereal based weaning foods as an acceptable protein supplements. The study also showed that applied processing methods like germination have improved the quality of food by increasing protein and iron content, and decreasing phytate content. The products prepared by incorporating broad bean with cereals can effectively be used in traditional cereal based weaning foods as an acceptable protein supplements. The process parameters and formulation developed through this study successfully produced a high protein energy weaning food with acceptable functional and sensory characteristic as well as excellent nutritional quality.

Community-based nutrition intervention utilizing an interactive tool raised consumer awareness of the relationship between healthy dietary choices, including incorporating more pulse dishes into the diet for increased protein and other nutrients. Nutrition education and the design of new education materials was viewed as important in seeking to communicate nutrition messages for improved food security among farmers and farming households.

### 5.3 Engagement of Canadian researchers with Southern Research Organizations

The project provided opportunities for Canadian researchers to engage in various activities to strengthen the agriculture-nutrition and health link, through research, capacity building and knowledge exchange. Both Canadian and HU researches participated jointly in supervision of graduate students field work (PhD & MSc) (study design, implementation and evaluation); and knowledge exchange through conferences and workshops at the local and international levels. HU Faculty and staff have also benefited from training and research collaboration and visits to the UofS. The co-supervision of graduate students and joint research work between UofS and HU faculty are paving the way for joint publications. Seminars by HU faculty and HU graduate students presented during their stays at the U of S, increased awareness of agriculture challenges in Ethiopia, and promoted shared research interests.

The project has created opportunities for pulse research with multidisciplinary team collaboration from the fields of soil science, agronomy and horticulture, human nutrition, gender and social relations for researchers at Hawassa University. The project contributed by creating new opportunities for collaboration, new partnerships and resources to address the multifactorial context of food security.

The project has contributed to capacity building of HU and the country in different aspects. Hawassa University Faculty got the opportunity to conduct advanced research and publish findings with scientists from UofS. The MSc graduates are serving in different sectors of the government and NGO’s with better capacities. A total of 23 research projects were conducted by PhD and MSc students on the existing problems in the farming communities. They will continue working on the challenges, and hence the project has contributed in capacity building of agricultural and human nutrition experts.
Acquiring Laboratory equipment through the project improved the physical capacity of the institution. Quality services in soil, plant and water could be provided and these will positively contribute to the teaching and research undertakings at the university. Three HU Faculty were granted research leave, whereas two more made a short term visits to UofS with the support from the project. The Faculty have had chance to utilize advanced laboratory, particularly for the works pertaining to molecular analyses. Additionally, the visits created a good opportunity for HU and UofS Faculty to work closely together and prepare articles for publication.

5.4 Risk mitigation

One of the major project crops, chickpea, will be useful in risk-mitigation and will contribute for sustainable food security because the crop is grown at the end of the rainy season after the harvest of the main season crop. This will enable farmers to get additional produce and also minimize risk of total crop failure due to unfavourable weather. Moreover, lentil is also suitable for double cropping especially after short cycle crops of tef (*Eragrostis tef*) and potato. In Halaba special district, where the project has introduced chickpea production almost all farmers in Huletegna Choroko peasant association have requested for the selected variety, although the Development Agent has accepted only 95 farmers petitioned for it.

5.5 Food production

The technologies are being tested and developed with small farmers irrespective of wealth or social status. Thus, a technology that would enhance productivity could be used by any interested farmer. The high yielding varieties selected by farmers will be used to increase food production. The improvement on production would be sustainable since farmers are able to save their own seed of chickpea since it is a self-fertilizing crop. Introduction of chickpea as double cropping is benefit to the farmers in terms of increasing income and protein in their diets.

5.6 Policy options

Chickpea has been considered as one of the strategic crops by the federal and regional government. Success in the chickpea variety adaption and selection trials at Taba, Jole, Andegna and Halaba led these sites to be included by the national Chickpea improvement team of the Ethiopian Institute of Agriculture and also by Hawassa University. Experts from Zonal and district Beausros of Agriculture have developed interest to get involved and start seed multiplication after participating in Farmers’ Field Day demonstration. Vice Heads of the regional Beausro of Agriculture, Zonal and districts’ Heads, Southern Agricultural Research Institute and have agreed to get involved in pre-scaling up activities and further research. The project has therefore contributed to the policy issue in identifying potential sites of production for one of the strategic crops.
5.7. Environment

The project work is centered on pulses production and because of their capacity in fixing molecular nitrogen, pulses help maintaining soil fertility. They minimize the need for chemical N fertilizer application, which contributes for maintaining a healthy environment. Moreover, the work on biological nitrogen fixation (BNF) technology will be important to improve productivity of the pulses without impacting the environment negatively.

6. Problems and Challenges

The project started in September 2010 just at the end of growing season for all pulses. This situation has delayed the start of the field research by almost one year. Consequently, the PhD students in Agronomy were forced to travel to Canada for course works twice. The duration of PhD studies is also much longer compared to the life of the project. However, the students managed to complete all their fieldworks before the project phases out.

Despite original agreement and repeated encouragement, five students have not yet completed their studies. They have completed the fieldworks, which are compiled in the “Research Booklet” as work in progress. The full theses works of these students will be reported at the end of June 2013. Two of the MSc research projects were delayed due to failure of the experiments.

Theft of chickpea around physiological maturity at Jole Andegna in 2011 severely affected the plots of two participating farmers. Similar cases were experienced at Halaba in 2012. It was discovered that the theft took place by those neighbours of the participating farmers who badly need the variety for seed. The coefficient of variation in the results from farmers’ replicated trial is high due to the differences in plot management. The project tried to provide training on Agronomy and took the farmers to Debre Zeit for experience sharing.

7. Recommendations

The project life should be increased to minimum of four years, particularly when it involves graduate work. Additionally, the starting time the project should be adjusted to allow repeating experiments in the field, collecting the data and writing report. The team also feel that an annual progress report instead of 6 month progress report would be preferable.

While the project has been successful in identifying improved varieties and soil management practices and nutrition interventions for pulse production and consumption, it was however limited in scope, geographic area and partnership. There is need for a research development initiative that will bring together the university and regional research and extension institutions, farmers’ organisations and the private sector to promote large scale adoption of pulse production technologies in the potential areas of southern Ethiopia. We propose a pre-scaling up project called “Promoting Adoption of Chickpea Technologies (PACT) in southern Ethiopia. PACT will aim to directly reach 600 farmers as seed producers in four districts each cultivating 0.25 ha of land in one growing season. This project will address the problem of seed system, knowledge and skills gap on chickpea package of production technologies, weak linkage among innovation system partners and efficiency gap between model and follower
farmers. It is expected that the project will reach more than 3000 other farmers in field days, training and exchange visits and other extension activities. It will also identify a model that has worked successfully in the project area context or problem to be scaled up/out to another context or problem in agricultural development of the region/nation. The intention is to make existing innovations-technological solutions- better known and more widely accepted by decision makers and potential users. With its development dimension, it will contribute to building capacity- create the institutions, skills, physical infrastructure or systems towards sustainable changes in the level or quality of service delivery.

The overall aim of the PACT project is to understand and promote the key drivers and processes that will facilitate and accelerate large scale adoption chickpea production technology in the southern highlands of Ethiopia. Specifically this pre-scaling up intervention will address the following specific objectives: (i) To further adapt and validate best practices (varieties, soil fertility, agronomy) for chickpea production within the region; (ii) to test and compare successful models, strategies and system approaches for large scale adoption of chickpea production in the region; (iii) to establish and operationalize multi-stakeholders partnership platform for large scale adoption of chickpeas in the southern highlands of Ethiopia; and to (iv) to use research results to inform food security policies and programs in Southern Ethiopia.

In the process of achieving its objectives, this project aspires to bring about the fundamental change in terms of large scale adoption of chickpea by more households leading to yield increase, area expansion in chickpea production and thereby improved household income that leads to the betterment of livelihood of small holder producers
ANNEX 1: TEAM COMPOSITION

List key members of ALL applicant research teams (add more tables and rows as needed). For type of organization, indicate: government, university, private sector, NGO (national), NGO (international), or other.

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<td>Dessalegn</td>
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<td>Woldemeskel</td>
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### Organization 2 (University of Saskatchewan, Governmental, Ethiopia).

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<th>Male (M) / Female (F)</th>
<th>Job title</th>
<th>Address (mailing address, phone number, fax, email)</th>
<th>Project role/responsibility (please indicate if lead PI and identify if consultant)</th>
<th>% of time committed on this project</th>
</tr>
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<tbody>
<tr>
<td>Taran</td>
<td>Bunyamin</td>
<td>M</td>
<td>Assistant professor</td>
<td>Dept. of Plant Sciences, College of Agriculture and Bioresources, University of Saskatchewan 51 Campus Drive, Saskatoon, SK Phone: 1-306-966-2130; Fax: 1-306-966-5015 (<a href="mailto:bunyamin.taran@usask.ca">bunyamin.taran@usask.ca</a>)</td>
<td>Co-PI; Pulse crop research and development</td>
<td>15</td>
</tr>
<tr>
<td>Walley</td>
<td>Fran</td>
<td>F</td>
<td>Professor</td>
<td>College of Agriculture and Bioresources, Univ. of Saskatchewan. Phone: (306) 966-6854; Email: <a href="mailto:fran.walley@usask.ca">fran.walley@usask.ca</a></td>
<td>Co-PI; Soil quality and soil fertility; nitrogen fixation in pulses</td>
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</tr>
<tr>
<td>Henry</td>
<td>Carol</td>
<td>F</td>
<td>Associate professor</td>
<td>College of Pharmacy and Nutrition, Univ. of Saskatchewan. Phone: (306) 966-5833; Fax: (306) 966-6377 Email: <a href="mailto:cj.henry@usask.ca">cj.henry@usask.ca</a></td>
<td>Human Nutrition</td>
<td>10</td>
</tr>
<tr>
<td>Zello</td>
<td>Gordon</td>
<td>M</td>
<td>Divisional head and professor</td>
<td>College of Pharmacy and Nutrition, Univ. of Saskatchewan. Phone: (306) 966-5825; Fax: (306) 966-6377 Email: <a href="mailto:gordon.zello@usask.ca">gordon.zello@usask.ca</a></td>
<td>Clinical nutrition and dietary assessment</td>
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</tr>
<tr>
<td>Whiting</td>
<td>Susan</td>
<td>F</td>
<td>Professor</td>
<td>College of Pharmacy and Nutrition, Univ. of Saskatchewan. Phone: (306) 966-5825; Fax: (306)</td>
<td>Nutrition intervention, micronutrients assessment</td>
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<tr>
<td>Kaler</td>
<td>Amy</td>
<td>F</td>
<td>Associate professor</td>
<td>Department of Sociology 5-21 HM Tory Building University of Alberta Edmonton, Alberta. Phone 780-492-7579; fax 780-492-7196; email: <a href="mailto:amy.kaler@ualberta.ca">amy.kaler@ualberta.ca</a></td>
<td>Sociology and Gender equity</td>
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**Organization 3 (University of Alberta, Government, Ethiopia).**

**Vandenberg**
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- **Breeding pulse crops**
- 5

**Maule**
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- **soil-water-plant relationships**
- 5

**Jaffe**
JoAnn F

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- **Socio-economic aspects**
- 5
ANNEX 2 – MONITORING AFS EXPECTED OUTCOMES

1. New technologies

Participatory variety selection involving seven improved chickpea and four lentil varieties were carried out on farmers’ fields in three project sites in 2011 and 2012. The combined evaluations identified the kabuli type variety, Habru, at Taba and the desi type cultivar Naatolii at JoleAndegna. The cultivars Habru and Mastewal out yielded the local cultivar consistently on all farmer sites with an average yield advantage of 62 and 89%, respectively. At HuletegnaChoroko, the kabuli type varieties, Habru and Ejere were selected as first and second choices, respectively. All these new improved varieties have not been introduced before in all the three districts. When these new varieties are used by farmers through the planned pre-scaling up program it will increase chickpea production and enhance land use efficiency in the areas.

Technologies in pulse agronomic management that were not in use in the area were also identified. Chickpea and faba bean are grown under broadcasting and without fertilizer inputs and weeding. In chickpea, farmers even believed that weeding is harmful for yield as raised in the discussion during a field day in 2011. Experiments made in 2011 at Jole Andegna and Teticha Kebeles identified that in chickpea two times weeding and a planting density of 333,333 plants ha\(^{-1}\) significantly improved yield with economic feasibility while in faba bean row planting (50 cm x 15 cm) and 100 kg ha\(^{-1}\) di ammonium phosphate fertilization, two times weeding and use of improved cultivar (Gebelcho) can be used to increase yield economically.

2. Dietary diversity & nutrition

Results of assessment on the consumption pattern of broad bean and its use for nutritional improvement of young children diet at Teticha indicated that the majority of children had diets in the lowest diversity group (< 3 food groups) which means that most of them are not consuming a diversified diet needed for their growth and development. Additionally most mothers are preparing food in the form of gruel and its major ingredient is cereal. Additionally, crops that have high protein content like pulses are not consumed. The study also showed that applied processing methods like germination have improved the quality of food by increasing protein and iron content, and decreasing phytate content. The products prepared by incorporating broad bean with cereals can effectively be used in traditional cereal based weaning foods as an acceptable protein supplements. The process parameters and formulation developed through this study successfully produced a high protein energy weaning food with acceptable functional and sensory characteristic as well as excellent nutritional quality. Community-based nutrition intervention utilizing an interactive tool raised consumer awareness of the relationship between healthy dietary choices, including incorporating more pulse dishes into the diet for increased protein and other nutrients. Nutrition education and the design of new education materials was viewed as important in seeking to communicate nutrition messages for improved food security among farmers and farming households.

3. Engagement of Canadian researchers with Southern researcher organizations
The project provided ample opportunities for Canadian researchers to engage in various activities to strengthen the agriculture-nutrition and health link, through research, capacity building and knowledge exchange. Both Canadian and HU researches participated jointly in supervision of graduate students field work (PhD & MSc) (study design, implementation and evaluation); knowledge exchange through conferences and workshops at the local and international levels. Canadian researchers participated in local participatory farmers training at the local community levels. HU Faculty and staff has also benefited from training and research collaboration in visits to the UofS.

4. Research groups

The project has created opportunities for pulse research with multidisciplinary team collaboration from the fields of soil science, agronomy and horticulture, human nutrition, gender and social relations for researchers at Hawassa University. The project contributed by creating new opportunities for collaboration, new partnerships and resources to address the multifactorial context of food security.

5. Food distribution

How is the project contributing to more equitable food distribution for environmentally sustainable food security?

6. Food processing and storage

How is the project contributing to improved food processing and storage for environmentally sustainable food security?

7. Risk-mitigation

One of the major project crops, chickpea, will be useful in risk-mitigation and will contribute for sustainable food security because the crop is grown at the end of the rainy season after the harvest of the main season crop. This will enable farmers to get additional produce and also minimize risk of total crop failure due to unfavourable weather. Moreover, lentil is also suitable for double cropping especially after short cycle crops of tef (Eragrostistef) and potato.

8. Access to resources.

How is the project contributing to improved access to resources for environmentally sustainable food production? E.g. land tenure, extension and credit, market access.

9. Food production

The technologies are being tested and developed with small farmers irrespective of wealth or social status. Thus, a technology that would enhance productivity could be used by any interested farmer. The high yielding varieties selected by farmers will be used to increase food production. The improvement on production would be sustainable since farmers are able to save their own seed of chickpea since it is a self-fertilizing crop.

Success in the chickpea variety adaption and selection trials at Taba and Jole Andegna may lead these sites to be included by the national Chickpea improvement team of the Ethiopian Institute of Agriculture and also by Hawassa University.

Though data were collected only for one season, lack of superior improved lentil cultivars that outperform the local cultivar at Huletenga Choroko may lead to new crop improvement activities by the lentil team of the Ethiopian Institute of Agriculture.

11. **ICTs.** Has the use of ICTs contributed to increase access to information and improved environmentally sustainable food security for the most vulnerable?

12. **Gender.**
How is the project considering women’s specific needs in the design of the research, participation of women in the research, and potential impact of research on women?

Targeted gender research was carried out throughout the project as it relates to participatory pulse crop variety selection processes, baseline data considerations and nutrition interventions. It is also worth mentioning the courageous stands taken by women at Halaba who are participating in testing eight varieties of chickpeas and has also shown interest in participating in seed multiplication or scaling up best practice technology. This is especially significant in the Halabaculture where female farmers are generally not to be at front in such activities. One particular farmer, (Sofiya Heliso) is seen as an “agent of change” to break such social stereotypes. She has even decided to adopt the idea of selling green maize cob and plant chickpea on the same field. Selling green maize is un-acceptable according to their culture.

13. **Environment.**

The project is work is centered on pulses because of their capacity in fixing molecular nitrogen, they help maintain soil fertility. They minimize the need for chemical N fertilizer application, which contributes for maintaining a healthy environment. Moreover, the work on biological nitrogen fixation (BNF) technology will be important to improve productivity of the pulses without impacting the environment negatively.
### Annex 2: DigitalFileFormatsSupportedbytheIDRCDigitalLibrary

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Each research outputs submitted to IDRC must include a title page, abstract, and keywords. The kind of information that should be included is listed below. Items marked with an asterisk are particularly important and must appear.

*Title:
Subtitle:
*By: Full Name(s) of Author(s)
Report Type: e.g., Final technical report, workshop report, research paper, research study, etc.
*Date:
Published by: Full Name of Publisher
Location: Name of Place of Publication
Series Name:
Number of Series part:

*IDRC Project Number, and component number (if applicable):  
*IDRC Project Title:
*Country/Region: Country(ies) or region(s) where project was carried out  
*Full Name of Research Institution:

*Address of Research Institution:

*Name(s) of Researcher/Members of Research Team:

*Contact Information of Researcher/Research Team members:

*This report is presented as received from project recipient(s). It has not been subjected to peer review or other review processes. 13

*Abstract: Research outputs should include an abstract of 150-200 words specifying the issue under investigation, the methodology, major findings, and overall impact.

*Keywords: Include up to six subject keywords separated by commas. Research outputs submitted to IDRC must include a title page, abstract, and keywords. The kind of information that should be included is listed below. Items marked with an asterisk are particularly important and must appear. A blank title and abstract page follows.
ANNEX 5 – GRADUATE STUDENT INFORMATION