AMHARA NATIONAL REGIONAL STATE FOOD SECURITY

RESEARCH ASSESSMENT REPORT

Prepared by

USAID Collaborative Research Support Programs Team

May 2000

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RESEARCH ASSESSMENT

Executive Summary

USAID/Ethiopia has signed an agreement to assist the Government of Ethiopia, in particular the Amhara Regional Authority, to design activities that will result in increased rural income, and thereby increase food security. An important goal of the agreement is to increase rural incomes through participatory agricultural research, giving technology users an important say in technology development, and transforming a top-down, supply driven technology transfer system to a bottom-up, demand-driven one.

To this end, USAID/Ethiopia requested field support from USAID's Washington Global Bureau's Collaborative Research Support Programs.A ten-member inter-disciplinary team was convened to conduct an assessment into the availability of technology in the region and the capacity of regional research centers to generate and disseminate technology. This report outlines the team's findings and suggests an action plan designed to strengthen the research component of the agreement. The action plan is followed by a set of anticipated results that should contribute to the attainment of food security in the region.

Assessment. Forty-eight of the 105 *woredas* of the Amhara region are drought-prone and suffer from frequent food shortages. Many households are only able to produce sufficient food to meet their food requirements for less than six months of the year.

The team assessed the availability of technology in the region and the capacity of those present to generate and disseminate technology in furthering the production of field and horticultural crops, livestock and apiculture. It also looked at technology related to the seed industry, agroclimatic analysis, watershed management, soil erosion and fertility, food science, socio-economic factors, and the structure of the research system.

It is clear that land degradation from overgrazing, soil erosion, deforestation, and cultivation of steep, fragile lands has resulted in loss of biodiversity, productivity, stability, and resiliency in the region. In the three ANRS research centers the team visited, the staff is young and enthusiastic. They expressed the need for more senior and experienced scientists who would provide leadership and guidance to them and the overall research programs. The research staff are also constrained by inadequate facilities, equipment, and supplies. The research capability needs to be strengthened in several ways, including increasing the research efficiency of the current system, along with strategic expansion and upgrading of the centers. In general, the efficiency of current research investments should be addressed first, followed by upgrading and expansion. Unless this situation is corrected, the lack of adequate research capabilities will continue to be a bottleneck for attainment of food security.

The extension capabilities for the transfer of technology packages are organizationally in place, and the research centers are relatively well staffed. However, considerable capability building is required to upgrade the technological expertise of the extension staff, as well as subject-matter specialists and development agents. The extension staff need much more technical support and research information if they are to be more effective in their work.

Immediate Action. Based on the assessment, the team formulated a research action plan that would contribute to the reversal of the current situation and set in motion advancement toward food security. ***The first action*** deals with institutionalizing an adaptive, participatory research methodology in which researchers, members of the extension service, and households have equal say in setting research priorities. This action will ensure that efforts of research and extension personnel are demand-driven, rather than supply-driven as it is now. This research approach should be initiated immediately and be ready for implementation in the coming cropping season.

The second action is designed to provide training, mentoring, and higher education opportunity for a young and inexperienced research staff. Isolation from the global research community, in general, and the regional and national research centers, in particular, makes it impossible for researchers to apply existing and new technologies in the region. The research libraries are virtually empty and telephones are rare. To rectify this situation, the team recommends ***the third action,*** the installation of a modern information, computer, and communication system to link every research center in the region to every other regional center and to the national and global research community.

The fourth action calls for modernizing the research laboratories and equipment, and making provisions for timely replacement of parts and supplies, and ***the fifth action*** recommends that the region initiate a plan to prepare a high resolution, geo-referenced data base that characterizes the socioeconomic and biophysical conditions down to the village level. This human and natural resource data base is needed to transfer successful technologies discovered through participatory adaptive research to other similar locations where they are likely to succeed. Without this spatial data base, technology will continue to be transferred by slow, expensive and unreliable trial-and-error methods.

The urgency of the situation, however, requires that immediate action be taken to lessen long standing food security constraints with readily available technologies. For this purpose, a list of technologies for early on-farm testing is provided. These technologies address problems which farm households have repeatedly cited as causes of crop failures. It is expected that as farmers, researchers, and development agents work together to test technologies, many more existing technologies will be found suitable for local adoption.

Technical Assistance. The regional research units will require additional support to conduct on-farm testing of the listed technologies. In particular, the young staff can benefit from working with experienced researchers invited to participate in the implementation of the on-farm trials. Such senior researchers can be invited from national and international research organizations, including USAID supported Collaborative Research Support Programs, which are designed to participate in these kinds of activities.

Results. Assuming that all components for attaining food security are in place, the action plan for research proposed above should result in attainment of four conditions that define sustainable agroecosystems. The verifiable indicators of the four conditions are:

1. Increased productivity, which refers to increased yields and increased income per unit input of land, labor, and capital. Yields and income are the indicators of this condition.

2. Increased stability, which refers to the reduction in wide yield and income fluctuation or feast to famine cycles. Risk-minimizing technologies identified through participatory, adaptive research will contribute to increased stability of the Amhara region agroecosystems. The verifiable indicator of increased stability is a decline in the coefficient of variation in the year-to-year fluctuation in yield and income.

3. Increased resiliency, which refers to the capacity of the agroecosystem to withstand and recover from stresses and perturbations imposed on the system by humans and natural events. Actions such as reforestation, erosion control, increased biodiversity, water harvesting, and elimination of over-grazing can measurably increase resiliency. Indicators of resiliency include reduced sediment load in the Blue Nile and its tributaries, increased biodiversity in field crops, trees and livestock, and expanded reforested areas and reduced hectares of overgrazed land.

4. Increased equitability, which refers to the equal sharing of benefits derived from the agroecosystem. The benefits should include access to adequate amounts of nutritious food through household production and/or purchases. Two indicators measure the status of equitability. These measures are the mean household incomes and its variance. The aim is to achieve high means and low variances which translates to high income, reduction in the number of poor households and a general improvement in the quality of life for members of the population that have traditionally suffered chronic poverty.

TABLE OF CONTENTS

NATIONAL REGIONAL STATE FOOD SECURITY

RESEARCH ASSESSMENT

1.0 SCOPE OF WORK

1.1 Scope. USAID/Ethiopia has signed an agreement to assist the Government of Ethiopia, in particular the Amhara National Regional State (ANRS), to design activities which will result in increased rural incomes, thereby increasing food security. These activities will initially focus on the 48 chronically food-insecure districts (*woredas*) of the ANRS, with the objective of decreasing the number of chronically vulnerable households over the next five years. An important goal under Strategic Objective 1 of USAID/Ethiopia, which is ***"Rural household production and productivity increased,"*** will be participatory agricultural research giving technology users an important say in technology development. An assessment will be conducted to determine the level of technology currently available, both in-country and elsewhere, that can be adapted for dissemination and use in rural, food-insecure areas of Ethiopia. Information gained during this assessment is critical to determine the levels of technical assistance and training required for achieving success and providing benchmark indicators and reasonable timetables. The Collaborative Research Support Programs of USAID's Global Bureau are to provide expertise for the agricultural and natural resource technology assessment, which will be conducted in collaboration with USAID, the ANRS Integrated Food Security Unit, the ANRS Bureau of Agriculture, other stakeholders in the Amhara region, and regional, national and international research organizations.

1.2 Deliverable. A comprehensive report will be due in draft form at the end of the visit. It will contain analyses of the current agricultural and natural resource management research and extension capabilities and make recommendations for reinforcing these capabilities through long- and short-term technical assistance and training. Recommendations of the report will support Strategic Objective 1 and include actions, the results of which will be measurable by the three principal indicators of achievement, **food availability, cash income, and nutrition** in the 48 chronically food-insecure *woredas* in the Amhara region for the next five years. The report will make specific recommendations for USAID assistance to be directed towards two principal activity areas: 1) technical and operational support for the design and implementation of *applied research* plans; and 2) the promotion of *effective interaction and communication* between researchers, extension agents, and rural households. The assessment and recommendations should include the entire Amhara region, so that successful activities may be expanded to other *woredas* within the Amhara region or to other national regional states subject to the mutual agreement of the Government of Ethiopia and USAID/ Ethiopia. Contained in this report are:

- An assessment of the availability, generation and dissemination of technology.
- An action plan for strengthening applied, agricultural research.
- The anticipated results from implementing the action plan and identification of indicators to measure success.

2.0 ASSESSMENT METHODS

The Amhara Agricultural and Natural Resource (Research) Technology Assessment was conducted by an interdisciplinary team with expertise in agro-climatology, agro-ecology, animal science, crop protection, economics, sociology, soil science,vegetable crops production and participatory watershed management (Annex 10.1). The team evaluated potentials to facilitate rural participation in developing, adapting and disseminating technology essential to increase food security in the Amhara region. The team used "household" instead of "farmer" to remove the "male farmer" stereotype embedded in agricultural research and extension and to understand the complex intra-household dynamics that influence farm and non-farm activities taken up by men, women, and children within a household. Using the household as the unit of analysis enabled the results of research and extension to be scaled up to various levels of heirarchies. A heirarchical, systems approach was used to conduct the assessment of agricultural technologies in the Amhara region. This method recognizes that the ANRS includes approximately 2.5 million households and that policies and decisions are made and implemented at many levels, encompassing different numbers of people: the household, peasant association (PA), *kebele, woreda*, zone, region, and nation.

The team's itinerary (Annex 10.2) to collect information included visits to Ethiopian organizations at the national, regional, zonal, *woreda and kebele* level as well as visits with rural household members (Annex 10.3). The team also met with members of two International Agricultural Research Centers (Annex 10.3) and reviewed published and unpublished literature (Annex 10.4). To make first-hand observations of food production in Amhara region, the team travelled both by air and on the ground. The team's itinerary began with reviewing documents and meeting in Addis Ababa with officials of the U.S. Agency for International Development (USAID/Ethiopia), the Ethiopian Agricultural Research Organization (EARO), the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), the International Livestock Research Institute (ILRI), and the Swedish International Development Agency (SIDA) (Annex 10.3) to obtain information regarding the activities of the organizations contributing to food security of the Amhara National Regional State (ANRS).

The team next travelled by air to Bahir Dar, the capital of the Amhara region, and took a ten-day road trip back to Addis Ababa to gather information by meeting with research and extension personnel at the *kebele, woreda* zone and regional levels, as well as with members of rural households in several zones of the Amhara region. During the trip, the team was briefed by ANRS officials of the Food Security Unit, the Bureau of Agriculture, the three Agricultural Research Centers, the Plant Health Clinic in Combolcha, and the Regional Sheep Breeding Center at Amed Guya, farmers and peasant association leaders (Annex 10.3). At each visit, the team was briefed, obtained documents, and interviewed employees to gain specific information relevant to the scope of work. Field visits with *woreda* and zonal officials and with rural household members engaged in agriculture and animal husbandry were included to give team members an opportunity to observe first-hand agricultural and animal husbandry activities and natural resource management.

3.0 CONTEXT OF FOOD SECURITY IN THE AMHARA REGION

Ethiopia is one of the poorest countries in the world. Per capita incomes are estimated at just over $100 per year. Estimated life expectancy is approximately 48 years. Just 3 percent of rural dwellers in the Amhara region have access to potable water. Adult literacy stands at 35 percent of the total population and only 22 percent of children in the relevant age bracket attend primary school. Between forty and sixty percent of children are chronically undernourished and in the Amhara region 80 percent suffer from stunted growth. Nationally, 23 percent die before reaching adolescence.

Per capita food consumption showed a steady decline from 1979 to 1994. This is true both in terms of consumption of domestic production as well as total consumption including imports and food aid. An erratic, but general, trend towards improvement in total agricultural production has been achieved since 1995 due to generally adequate rainfall, some liberalization of agricultural production, and increased provision of modern inputs to farm households. Surplus production, however, has led to sharp drops in prices of agricultural outputs due to limited commercialization infrastructure. Even in recent good harvest years, approximately 40 percent of Ethiopians have been unable to meet their basic nutritional requirements. In 1999, failure of the *belg* (short season) rains in many regions of the country led to a five year high of 6.8 million people depending upon food aid.

The Amhara region suffers from recurrent droughts and pest invasions. Of the 105 *woredas* in the region, forty-eight are drought-prone and chronically food-insecure. There has been no single year since 1950 where there was no drought in the eastern part of the region. Famines have been recorded as far back as biblical times. On the other hand, much of the western half of the region has good soils and adequate rainfall and typically produce agricultural surpluses.

The population of the Amhara region is approximately 15 million people of whom 89 percent live in rural, agricultural households. Cereals account for more that 80 percent of cultivated land and 85 percent of total crop production. The principal cereal crops in the Amhara region are teff, barley, wheat, maize, sorghum and finger millet. Pulses and oil crops are the other major categories of field crops. Nationally, livestock population is the largest in Africa (29.8 million cattle, 11.5 million sheep, 9.6 million goat, 3.9 million equines, 0.25 million camel and 25.8 million poultry) but is characterized by low productivity. About 27.9 percent of the livestock in Ethiopia, 30.7 percent of the poultry, and 18.5 percent of the beehives are found in the Amhara region.

Most of the region is on the highland plateau and is characterized by rugged mountains, hills, plateaus, valleys and gorges. Hence, the region has varied landscapes composed of steep fault escarpments and adjoining lowland plains in the east, nearly flat plateaus and mountains in the center, and eroded landforms in the north. Most of the western part is a flat plain extending into the Sudan lowlands. The topographical features represent diversified elevations ranging from 700 meters above sea level (m.a.s.l.) in the eastern edge to over 4600 m.a.s.l. in the northwest. Based on moisture availability and thermal zones, ten major agro-ecological zones and 18 sub-zones have been identified in the region. A little over 50 percent of the total area of the region is considered potentially arable for agricultural production activities.

A population growth rate of 3 percent a year is leading to a doubling of the human population every 25 years. This rapid population growth rate has led to severe land shortages and rapid natural resource degradation. In the Amhara region, 94 percent of households have insufficient land to meet their food needs. Rural households are compelled to clear and cultivate marginal lands on steep hillsides. Only one to three percent of the Amhara region remains forested. Overgrazing further denudes the land of vegetative cover. Forage requirements are estimated to be 40 percent below needed levels to maintain the current livestock population.

Much of Ethiopia in general and the Amhara region in particular is characterized by mountainous agriculture with slope gradients ranging from 5-45 percent. Much of the annual rainfall comes in short violent events of up to 100 mm/day. The exposure of denuded slope areas to this type of rainfall results in Ethiopia having one of the most serious soil degradation problems in the world. Annual rates of soil loss in the Amhara region in some steep lands and overgrazed slopes exceed 300 tons/ha/year, or 250 mm/year. Lesser rates of soil erosion in ANRS are also of concern, since loss of soil reduces the land's waterholding capacity and soil fertility. In the ANRS, yields are estimated to decline by 1-2 percent per year due to soil erosion. Nationally, on over 2 million hectares, the soil depth is so reduced that the land is no longer able to support cultivation. Water logging problems associated with the Vertisols in some of the plateaus and low-lying areas is another major constraint.

The traditional method of soil fertility regeneration by fallowing and use of organic fertilizer has almost completely broken down due to land scarcity resulting from overpopulation. In addition, most crop residue is removed by farmers for either fuel or construction purposes. Remaining organic matter in fields is removed by livestock stubble grazing. Dry manure is used for fuel due to the chronic shortage of firewood and lack of alternative sources of energy. In sum, increasing populations and a declining availability of land that is increasingly eroded and experiencing a chronic net decline in nutrients stocks is undermining the ability of the agricultural sector to meet the basic food requirements of the Amharan people.

4.0 SUMMARY ASSESSMENT

Individuals have food security when they have adequate access to food, in both quantitative and qualitative terms, either by producing or purchasing it. The overall objective to achieve food security should be to increase household production and productivity. Progress toward achieving food security can be measured by: increasing food availability (kilocalories/person/day), increasing household incomes, and improved nutritional status of children in the region.

Based upon the assessment methods described in Section 2.0, the following summary assessment describes key elements needed to achieve the goal of food security in the Amhara region. This summary assessment is based on the ideas and proposals encountered in the team's contacts with individuals and institutions on both the national and (Amhara) regional level. Nevertheless, this is a preliminary draft and the team welcomes comments to help modify and improve this report. The key elements are summarized in the subsections below and will be referred to throughout this document.

4.1 Diversification of Productive Activities. Three factors contribute to the need for diversification of the productive activities of rural households: 1) yield variability affected by such factors as drought, frost and pests that make rural households vulnerable when relying predominantly on cereal crops, 2) price variability in output and input markets, and 3) the overall inability of the agricultural sector in many areas to produce enough food to feed increasing populations. Diversification is therefore needed both in terms of agricultural production activities (e.g,. field crops, fruits and vegetables, poultry, livestock) and in terms of off-farm income-generating activities (e.g., artisanry, petty commerce, paid agricultural labor, small business enterprises) that allow rural households to purchase food.

4.2 Risk Management. Rural households operate in a highly risky environment due to production risks (climate, pests, diseases, etc.) and the variability of prices. The diversification of agriculture discussed in 4.1 is one strategy to minimize risk. Practices that conserve moisture for crops are another example of a useful strategy. This is particularly important to rural households who wish to invest in productivity-enhancing inputs such as improved seeds and fertilizer that need adequate moisture to be effective. Irrigation and wells, where appropriate, can also contribute to more reliable production of field crops and horticultural crops. Management of risk can also be addressed by the development of appropriate germplasm adapted to the above-mentioned production constraints. Tree crop production of fruit, fodder, and fuelwood that is less susceptible to drought is a further risk-coping strategy, as well as the access to off-farm employment.

4.3 Adaptive Research Linking Research, Extension, and Rural Households for Technology Adoption. Given the high variability of agro-ecological zones, risk, and resource constraints facing rural households, there is a need for adaptive research that takes into account the diversity of conditions facing rural households. Establishing systematic linkages between research, extension, and rural households is an effective means of generating technologies appropriate for these conditions. Researchers must have frequent feedback about what is and is not working in terms of benefits to farmers. Rural household members and extension agents can not only provide that information but are often the best source of ideas on how to adapt a technology to local conditions. In addition, linkages involving rural households to set the research agenda helps ensure that new technologies are not only technologically viable but indeed address priority problems as perceived by rural households who are the ultimate users of technological solutions.

4.4 Natural Resource Conservation Including Biological Components. Natural resources such as soils, water, plants, and animals are key factors affecting farm productivity. Massive land degradation is undermining the productive capability of the agricultural sector. Conservation efforts that have focused on physical structures (terraces, soil bunds, drainage ditches, etc.) have been only partly successful and need to be rethought and reinforced. Greater emphasis on planting trees, shrubs and grasses on a denuded landscape can result in greater resiliency of production systems. Vegetative cover not only helps control erosion and conserve water, but also serves to recycle nutrients, reduce evaporative demand on crops and soils, and increase soil organic matter. Furthermore, biological components can serve the dual purpose of natural resource conservation and can also provide income generating products such as fodder, fuelwood, fruit, and medicine. Systematic adaptive research needs to be conducted on dual purpose conservation-income-generating techniques such as grass strips, upper watershed reforestation, homestead vegetation and alley cropping.

4.5 Reinforce High Potential Successes. Ethiopia has extensive areas endowed with both fertile soils and adequate moisture that are rare in other regions of Africa. Recent experiences by Ethiopian research and extension in collaboration with Sasakawa Global 2000 showed that a doubling to tripling of yields is possible in high potential areas with good soils and adequate water with a technological package including improved seed, fertilizer and credit. Economic analysis showed that these packages also substantially increased net income for rural households in these areas. Food security cannot be achieved by focusing only on chronically food insecure zones. The production of agricultural surpluses from high potential zones can provide low cost food to deficit areas. Success in high potential areas can reduce degradation in marginal areas by reducing production pressures on degraded and marginal land. Further, high potential areas have greater capacity to generate off-farm income for household members from low potential areas by employing labor in upstream (input provision) and downstream (agriculture product transformation) agricultural sector activities and other small businesses. On the other hand, the technology packages used in high potential zones are generally not appropriate and need to be adapted for more marginal, drought-prone areas.

4.6 Need for Improved Nutrition. Food security includes both quantitative and qualitative aspects. Individuals, in particular children, may suffer from vitamin and protein deficiencies even when they have an adequate level of total caloric intake. Diversification of agricultural production and off-farm income for food purchase are proven means to enable individuals to obtain a more balanced diet. Research and extension programs need to identify and take into account nutritional shortcomings in planning their strategic objectives. Orienting small-scale horticultural promotion toward improved nutrition is one example. In general, efforts should be made to coordinate with health and educational services to address nutritional issues in a comprehensive manner.

4.7 Need for Increased Research Capability and Coordination. The current ANRS research capability is not adequate for addressing the seriousness and diversity of problems faced by the agricultural sector in the Amhara region. The research centers in general lack adequate human resources in terms of senior research personnel with advanced degrees as well as trained technical support staff. In addition, there is need for greater material resources such as vehicles to reach the field and equipment to conduct on-station experiments. Furthermore, the agricultural research system is in a period of transition due the process of regionalization. A clear division of research tasks that takes advantage of the comparative advantages of the different research centers at the regional, national, and international levels and which avoids unnecessary duplication is needed. Support for increased capability should be accompanied by greater coordination in order to be effective.

The team also identified a number of other factors that are necessary to achieve food security but which are not explicitly addressed in this document. These factors include:

- Land tenure policies to give households greater tenure security in order to encourage long-term investments to increase productivity and to promote natural resource conservation.
- Control of population pressures that are outpacing the ability of the agricultural sector to increase food production and are leading to increased natural resource degradation.
- Transportation and communication infrastructure to improve the commercialization of agricultural production and inputs as well as to improve research-extension-rural household linkages.
- Supportive economic policies such as credit, promotion of the private sector, improved marketing efficiency.

While these factors are critical for food security, they are beyond the scope of the assessment mandate and are best covered in other planning reports

5.0 TECHNOLOGY AVAILABILITY, GENERATION AND DISSEMINATION

5.1 Soil Erosion and Fertility. Approximately 39 percent of the land in the Amhara region is estimated to be used for grazing and browsing and 27 percent is under cultivation, much of it being cultivated for three millenia or longer. Many of the soils which shrink and swell have severe drainage and waterlogging problems during the rainy season. A majority of the land is steep, infiltration rates are low, and little surface cover is left after extensive cropping or grazing. Soil conservation measures are needed, but a high percentage of the land has already been severely degraded. Rainfall is variable and must be utilized effectively. If during the high rainfall period some of the excess water could be stored in or on the soil using water management technologies, the risk of crop failure and erosion associated with rainfall variation could be reduced.

Continuous cropping, loss of surface soil by erosion, and relatively little application of mineral nutrients has resulted in low soil fertility. Soil erosion and low fertility pose both long- and short-term problems. Furthermore, these conditions are often interrelated. The topsoil loss magnifies deficiencies of nitrogen (N) and phosphorus (P), currently the major causes of low soil fertility.

Ethiopia is considered to have one of the most serious soil degradation problems in the world. The average annual rate of soil loss in Ethiopia is estimated to be 12 tons/ha/yr, and it can drastically exceed this on steep slopes with soil loss rates greater than 300 tons/ha/year, or 250 mm/year, where vegetation is denuded. On over 2 million hectares, the soil depth is so reduced that the land is no longer able to support cultivation. The Ethiopian government launched a massive soil conservation program beginning in the mid-1970s. Between 1976 and 1990, 71,000 ha of soil and stone bunds, 233,000 ha of hillside terraces for afforestation, 12,000 km of checkdams in gullied lands, 390,000 ha of closed areas for natural regeneration, 448,000 ha of land planted with different tree species, and 526,425 ha of bench terrace interventions were completed. However, by 1990, only 30 percent of soil bunds, 25 percent of the stone bunds, 60 percent of the hillside terraces, 22 percent of land planted in trees, and 7 percent of the reserve areas still survived. Clearly, interventions that reduce the land degradation rate and that are localized to existing environmental conditions are necessary.

5.1.1 Available technology. The three regional laboratories are beginning to generate information regarding the rates of fertilizer applications for areas of highly variable rainfall to refine the general recommendations supplied by EARO, ICRISAT, and CIMMYT. For cereals grown under the various conditions in the region, adaptive research is needed. Adequate nitrogen (N) will increase protein in grain and forage and will aid human nutrition. Legumes grown in rotation with cereals contribute small amounts of N. Other possible means of increasing N are from green manure crops and agroforestry, but economic analysis is needed to assess their economic feasibility. Crop response to potassium fertilizer has not been studied appreciably as soil levels are not low. Additional potash may reduce frost damage, however, and this aspect should be evaluated.

Prior soil tests, such as those by H. F. Murphy, have shown phosphorus (P) deficiency to be a major problem for crop production in the Amhara region. A standard rate of phosphate is now recommended, but applications should be based on diagnostic analysis, because availability of soil P may vary. Participatory, adaptive research is needed to achieve efficient fertilization. Soil test labs exist at some of the research stations and others are being constructed. Simple procedures, common among all labs in the region and in the country, should be employed. Reports from a program, the International Soil Fertility and Evaluation Project, sponsored by USAID about 20 years ago, should serve as a guide. The national research organization, EARO, should try to standardize such procedures across regions.

In general, technology to stabilize soil on common grazing lands near stream banks using vegetation is beginning to become available at Adet and Sirinka. Additional research on tree species other than Eucalyptus is urgently needed. Many rural households have created surface drains to remove excess water to prevent waterlogging. The removal of this water has often caused gully erosion. Technology being evaluated is terrace building and reducing the land degradation rate using agroforestry techniques. Much soil conservation and water harvesting technology is available in the country from EARO and ICRISAT, and additional technology from ICRAF could be utilized.

5.1.2 Capability to generate new technology. Research on erosion, water management and soil fertility is being conducted at the research stations, substations or on the fields of rural households. Most of the researchers lack advanced degrees and training could become more effective with increased funding to conduct adaptive research programs.

5.1.3 Extension capability. The Extension Service has increased its capability to reach farmers through numerous Development Agents (DA). With common packages, the DAs, with only brief training in agriculture, can contact and advise farmers. Additional training for DAs and their supervisors would allow development of flexible extension recommendations for individual farms and actual rainfall. This training would also allow the DA to evaluate problems that need to be researched. When soil testing becomes a practice available to rural householders, the DA could assist them in getting representative soil samples.

5.2 Agroclimatic Analysis and Watershed Management. Many of the problems faced by people in the highly complex and variable Amhara region cannot be solved on a field-by-field basis or by using a disciplinary approach. The landscape is spatially variable, with steep upper slopes suited to perennial vegetation, relatively level lowlands and highlands that are primarily used for field crop production, and intermediate zones, often with mixed use of crop production interspersed with communal pastures. Human population pressures are high and increasing, with decreased landholding size per household and movement of people from lower to higher positions in the landscape. With increased human population has come decreased use of fallow land, increased livestock pressure, and degradation of the natural resource base, including soil, water, and native flora and fauna. By taking a watershed approach across a range of hierarchies, from small catchments to larger streams and even rivers, issues such as upstream-downstream effects and interactions among components of the system can be addressed. Local communities have institutional capability to implement, monitor, and enforce decisions made regarding interventions. The problems to be addressed will determine the size of the watershed selected, but in watershed research, a focus on scaling up needs to be addressed. Precipitation is one of the most variable aspects of the environment that limits productivity and food security. Due to the inherently low precipitation in many regions and the variable nature of the timing and amount of rain across food insecure regions, the indigenous producers are risk adverse. A better understanding and predictability of the weather could enhance adoption of new technologies. Irrigation can also provide stability in the water supply and therefore in production potential, but irrigation has not been developed on a large scale. Solutions to problems such as land use distribution and water management within a land-scape/watershed will require a part-icipatory, systems approach to research, extension, and development, because the research arena involves the livelihoods and lives of the people in the watershed.

5.2.1 Available technology. Although meteorological data are limited, some relatively long-term weather stations exist in the Amhara region and detailed analysis of some of these sites was reported by IAR, ILRI, and ICRISAT in the mid-1980s, giving probability distributions by month or week of the year, along with mean and standard deviation on an annual and monthly basis. Some of the sites also included temperature analysis, although analysis of risks associated with frost has been limited and should be pursued where historical data from high altitudes are available. The research centers each maintain one or more weather stations, but there appears to have been little analysis of the data. Agroclimatic analysis of geo-referenced weather records needs to be conducted for all long term stations (>10 years) in or near the region to develop maps of agroclimatic patterns and to determine if precipitation amounts and patterns (starting dates, ending dates, length of the *belg* (short season) and *meher* (long season) rainy seasons) are changing over time—as is widely believed in the region—or if recent dry seasons are within the normal range of variability of the climate. The "response farming" approach developed in the 1970s-1980s in Kenya and expanded to sub-Saharan West Africa (linear relationships between date of onset of rains to probable length of the season and total rainfall) should be evaluated to determine if simple indicators could be identified that would guide cropping and forage production toward those options having high productivity potential with the lowest risk for that particular season. If such relationships could be developed, then training of SMSs and DAs in rainfall probability along with establishment of rain-gauge sites at *woreda* or *kebele* levels could be established on a pilot basis to guide extension recom-mendations. Other approaches to weather forecasting and monitoring available from the Famine Early Warning System (FEWS) might provide useful information for implementing more flexible approaches to adaptive and demonstrative research for highly variable rainfall areas.

There has been limited development of water supplies for irrigation along streams and even less development of small ponds (along with protected source areas upstream) to capture and store water during the rainfall surplus months for use during the dry months. Technology developed by ILRI (1999) for PAs to build ponds using animal power could provide household and livestock water supply (and/or along with small scale irrigation) for gardens or high-value cash crops. It would also serve the added benefit of reducing erosion hazard from intense storms by increasing water retention capacity in the landscape. Development of such systems would clearly require the participation of households, villages and extension at several levels, as well as adaptive research, and, on occasion,Bureaus such as Water and/or Health. In addition, design (based on agroclimatic, soils, topographic, and demand analysis), engineering, and construction of dams and ponds or other irrigation schemes should be balanced with the design of the production systems that would use the water to produce high value crops or nutritive food supply for households and communities.

Research methods and approaches that can be adapted and applied to implement integrated watershed based research and development include participatory rapid appraisal techniques, visioning, system-atic benchmark surveys, simulation systems that integrate biophysical and socioeconomic models (e.g., ILRI & Texas

A&M), and monitoring tools (e.g., Water Watch in Alabama, The Philippines, and Ecuador).

Many of the intervention technologies to improve components of the system exist: for example, species and varieties for agroforestry and diversification of production, soil and water conservation technologies (particularly water conservation technologies developed for vertisols by ICRISAT and others), and plant and animal health technologies.

5.2.2 Capability to generate new technology. There was little evidence of use of agroclimatic information or analyses to guide research or extension in the region. Remote sensing technologies such as those used by FEWS could be investigated for application of early detection of regional weather patterns to guide extension recommendations. Research and SMS staff at various places in the region include some agricultural engineers, but their capability to conduct the needed adaptive research or to generate new technologies in water conservation and use or small-scale irrigation and management appears limited. Research and extension soil and water conservation programs focus strongly on soil conservation practices and may fail to capitalize on the water conservation benefits of practices such as terracing and tied-ridges.

There is demonstrated understanding of the need for watershed approach and commitment to pilot project planning in the region. An Ethiopian study team visited watershed-based research sites in The Philippines and Georgia. However, no formal training among the research centers or extension systems exists in systems research, landscape ecology, landscape hydrology or sociology. Researchers and extensionists in ANRS would benefit from formal training or experience in participatory research and extension methods. Communities would greatly benefit from training to develop institutional capabilities to implement practices within watersheds. Local governments and community groups will also need training and capability building in participatory approaches. Linkages with other departments or Bureaus (e.g., Health, Education, Water) need to be developed or strengthened for watershed-based research and development and mechanisms for cooperation across government or institutional boundaries agreed upon. Human, physical, and financial resources for implementation of integrated systems research and development at a watershed scale, even at a pilot level, are limited.

5.2.3 Extension capability. Investment in participatory, watershed-based research is for the long-term, because this type of research is new, not only in Ethiopia, but elsewhere. The pilot approach is appropriate at this time while methodologies are developed and capacities are increased.

5.3 Improved, Dissemination-Ready Genetic Material. Improved genetic resources of both plants and animals are essential in any effort to solve the food security problems of the region. In such an effort, the genetic materials must be suitable for the target ecological zones.

5.3.1 Available technology. The range of available, improved and adaptable cultivars or genetic stocks for the food deficit parts of the Amhara region varies for field crops, livestock, and trees. The crops grown in the region cover a wide range of cereals, pulses, and horticultural crops. For the major cereals, which are wheat, barley, tef, sorghum and maize, improved cultivars such as ET13, HAR 604 (wheat), HB-42 and HB-120 (barley), DZ-01-196 (tef), Meko, 76-T1-23, Gambella 1107(sorghum), maize (Katumani composite) are available. In addition, there are cultivars in the breeding and varietal release pipelines of EARO across most of the crops. Some examples which were mentioned are three Striga resistant sorghum varieties pending approval by the variety release committee. The major pulses in the region are lentil, field peas, faba beans and chickpeas, while the major oil crops are noug, safflower and sesame. Availability of improved cultivars in these crops is limited, although indigenous varieties are available in a wide range of genetic diversity. EARO and the IARCs (e.g., CIMMYT, ICRISAT, CIP, CIAT, ICRAF) are the main sources of improved germplasm.

The animal genetic resources in the Amhara region cover different species of animals existing in diverse ecological zones. These include cattle, sheep, goats, poultry, donkeys, horses, mules, fish and bee colonies. Other species of animals such as pigs are not common. The different species of animals are available in abundant numbers and diversity in the different agro-ecological zones. These animals are indigenous and have been selected for adaptive traits in the diverse ecological zones. Although some improved breeds of poultry, dairy and sheep are available, the overall availability of improved and adapted animal genetic stocks is minimal.

In trees, shrubs and forage crops, the availability of improved genetic stocks is limited. The bulk of the afforestation program underway in the region is based on planting Eucalyptus trees with sporadic planting of Cupresses species. Indigenous tree and shrub species have mostly disappeared, apart from protected and isolated church compounds where some of the indigenous tree and shrub species remain. Trials are underway at some of the research and testing sites to identify suitable indigenous and exotic tree species for various ecological conditions. Accelerated efforts are needed to identify suitable tree species for the diverse ecological zones of the region.

5.3.2 Capability to develop new technology. In the short term, screening of improved varieties from national and international sources in the different ecological zones would be the most practical and cost effective approach to develop improved genetic materials. However, over the long term, comprehensive breeding programs to meet needs identified by rural households would be necessary to meet the changing needs of the region.

5.3.3 Extension capability. Currently, the contribution of technology generated by the research centers in the region to extension efforts in the area of crop and livestock improvement is minimal, mainly because the centers are relatively new, inadequately staffed in terms of experience, and have inadequate facilities.

5.4 Field Crop Production. Cereals, pulses, oil crops and other field crops dominate the agriculture of the Amhara region. The main field crops in the Amhara region are:

Cereals	Pulses	Oil crops
Barley	Lentil Noug	(Niger seed)
Wheat	Field pea	Safflower
Tef	Chick pea	Sesame
Sorghum	Faba bean	Sunflower
Maize	Cowpea	Linseed
Finger millet		Rapeseed
Oat		

A wide range of both abiotic and biotic stresses constrain field crops production in the region. Among the major abiotic stresses are drought, waterlogging, frost, and low fertility. The main biological constraints are insects, diseases and weeds. Some examples are:

Insects	Diseases	Weeds
Aphids	Rusts (leaf, stem, stripe)	Striga
Stem borer	Smuts	Parthenium (Congress weed)
Shoot fly	Leaf blight	Grasses
Wollo-Bush cricket	Septoria	Broad leaf
Pachnoda beetle	Scald	Wild oats
Termites	Net blotch	
Migratory pests		
Weevils		
Other storage pests		

5.4.1 Available technology. The judicious management of abiotic and biotic stresses requires the deployment of both genetic resistance and appropriate management practices. For some of the important crops mentioned above, there are improved cultivars in Ethiopia which have high yield potential and resistance/ tolerance to some of the stress factors. Examples are ET13, HR604, Enkoy, Boohai, and Mamba for wheat; HB-42 and HB-120 for barley; DZ-196, DZ-354, DZ-01-99, and DZ-CR-37 for tef; Katumani composite, A-511, BH-140, Alemaya Composite for maize; and 76-TI-23, Gambella 1107, Dinkmash, Birmash, Alemaya 70, and ETS2752 for sorghum. The range of available improved cultivars for pulses and oil crops is much narrower and in some cases, there are none available. Some examples are Fogera-1 (noug), CS-20DK (faba bean), and Chilalo (linseed) Some of the improved cultivars such as Katumani maize and 76-TI-23 sorghum are early maturing and thus escape drought and produce stable yields in relatively short growing seasons. Improved crop management technologies for stable and high yield production of crops are also available. Examples are the use of tied-ridges for moisture conservation, the broad bed maker for improved drainage, row planting for more efficient weed control and fertilizer application, intercropping for minimizing pest damage and improving yield stability, legume-cereal rotation for improved soil fertility , pest control, and higher yield, and crop substitution for shorter growing seasons. Combinations of improved cultivars and appropriate management practices should give higher and stable yields from year to year. Scientists at the research centers have been working with scientists at EARO and ILRI to develop technologies for cultivation of waterlogged Vertisols. Among these techniques is a method of using 80-cm beds separated by 40-cm furrows to allow adequate drainage when the rate of rainfall exceeds the rate of infiltration of water into the soil.

5.4.2 Capability to develop new technology. The three regional research centers have personnel who can develop new technologies through participative research for field crops production, pest control and storage. Further training, linkages to researchers within and outside Amhara region, and infrastructural support will be needed to increase the efficiency of the Amhara region agricultural researchers in order to generate new and appropriate technologies through participatory research. At present, collaboration with EARO and ILRI scientists would be beneficial to the region.

5.4.3 Extension capability. The three research centers have been involved in demonstrating improved crop production and protection packages. Field days for rural households are usually held to introduce crop producers to improved technologies. Improved seeds are also sometimes distributed by the research centers to farmers to make new cultivars available to producers. The extension service also popularizes improved crop production technologies through implementing improved crop production packages on demonstration fields of rural households. The technical packages of maize and wheat usually cover improved seeds, fertilizer, pest control, and improved management practices. Although the technical production packages have given rural households' higher yields, because of higher production costs and low market values, producers have not always realized increased profitability. The extension staff need much more technical support and research information to be more effective in their work.

5.5 Vegetable Production

5.5.1 Available technology. The promotion of income generating activities in the Amhara region is a part of an integral effort to promote a market-based economy. Diversified cropping systems, including the production of cash crops, as well as off-farm activities, are considered by the ANRS Integrated Food Security Program to be important mechanisms used by households to cope with seasonal food shortage vulnerabilities. Because the ANRS economy is largely dependent upon production of cereals and livestock, wider production of high-value vegetables in the region can provide a viable mechanism to generate additional household income and to supplement nutritional intake.

Vegetables have not been grown to a large extent in Amhara region and per capita consumption is relatively low. However, small pockets of production have long existed, and minor consumption of a variety of species such as tomato, cabbage, carrot, onions, shallots, garlic, potato and the green seed of several pulses exists. These crops have traditionally been grown during the rainy season, or near riverbanks or springs where there is access to irrigation. Interventions that are required to raise vegetable production and consumption in the ANRS include: raise consciousness about the economic and nutritional value of these crops; develop appropriate technology packages for the production, postharvest handling, and marketing of these crops, based on currently available information; conduct adaptive research to introduce new potential species, varieties and technologies used in other regions/countries; expand the land under irrigation for the production of vegetables and other high-value crops during the dry season or to mitigate periods of drought; and conduct marketing research to explore expansion potentials into local and export markets.

5.5.2 Capability to develop new technology. The current ANRS capability to implement available technology used in other regions and to develop and implement new technology is minimal. The reasons are an inadequate research infrastructure to conduct horticultural research and the need for appropriately trained and experienced research personnel. Such support is essential in the areas of germplasm evaluation, seed production, fertility, irrigation, pest management, postharvest management and marketing. Nationally, EARO, and staff from other support agencies (such as the National Soils Lab), have the technical expertise to provide support on several of these areas, but specific expertise on vegetable production is clearly minimal. Nevertheless, an extensive and available international technical knowledge base for the production of vegetables does exist. Agencies such as the International Potato Center (root crops), the Asian Vegetable Research and Development Center, and CRSP would be instrumental in identifying existing crops/ technologies applicable to the Amhara region and for capability building of ANRS research staff.

5.5.3 Extension capability. Organizationally, the extension capabilities to raise awareness about new potential vegetable enterprises and for transferring “simplified” technology packages (blanket recommendations, such as kind of seed, planting densities and fertilizer rates) are established. However, considerable capability building is required to upgrade the technological expertise of the extension staff (Subject Matter Specialists and DAs) in practically all areas of the vegetable crop production, management and marketing process. This expertise will be essential to support a horticulture industry in the region.

5.6 Other High Value Crops. Income-generating cash crops and off-farm activities provide effective mechanisms for assisting households to cope with periods of food shortage. A wide diversity of specialty high-value agricultural products are already produced or have potential for small-scale production in the region. These include vegetables (Section 5.4), apiary products (Sect. 5.6), horticultural seed and seedling production (Sect. 5.7), processed products (Sect. 5.10) as well as fruits, herbs and spices, oil crops, medicinals, botanicals, wood products for fuel and construction, and non-woody forestry products, sugarcane, cotton and fiber crops, among others.

5.6.1 Available technology. Indigenous knowledge exists to ensure the production of a variety of specialty agricultural products in the region. Moreover, technology exists, both in the country and internationally, which would improve the productivity, efficiency,and ability to better market these products. Limitations that currently prevent the expansion of these localized industries, and the income that households receive from these products, include: marked seasonal price fluctuations; low productivity; poor postharvest practices, a lack of market infrastructure (e.g., credit and financial services), seasonal product consistency, enterpreneurship, market knowledge, and improved, efficient production practices. The following interventions are therefore needed to develop market niches for particular products and to improve the efficiency of production and marketability of high value crops for sale or export:

- System appraisals at local (*woreda*) level to assess market/geographical opportunities to develop niche markets for particular products.

- Market analyses studies to evaluate seasonal price fluctuations and volatility, seasonal market windows and opportunities for inter-regional trade and export.
- A synthesis of available information for each product in the form of technology production packages.
- On-going research to improve the productivity and market quality of these products on a variety of key topics including fertility, germplasm evaluation, pest management, postharvest quality and management and value-added potentials.
- Assistance in the development of community marketing programs (such as cooperatives).
- Available irrigation in some cases.

5.6.2 Capability to develop new technology. The current ANRS capability to implement available technology and to develop new technology, in terms of physical Experiment Station infrastructure and experienced research personnel, is in its initial stages of development and needs substantial improvement to fulfill the needs of the Amhara region. Support is needed in the topics listed above (under section 5.6.1). Nationally, EARO conducts ongoing evaluation trials for a variety of fruit, forestry, oil and other products. However, specialized research should be earmarked to focus on specific niche products and on particular technological and market informational needs. International research and development agencies could also be tapped to cover current informational and technological gaps in the production and postharvest management of most products. Considerable local market and production research are necessary, however, to develop appropriate localized technology packages.

5.6.3 Extension capability. Extension capabilities to raise awareness about new products and market opportunities and to transfer technology are organizationally in place, and the research stations are relatively well staffed. However, considerable capability building is required to upgrade the technological expertise of the extension staff (Experts and DAs) in the area of production and marketing of specialty cash crops.

5.7 Seed Industry. A strong seed industry that provides high quality seeds of improved or indigenous crop germplasm in a timely manner is a prerequisite for the overall food security efforts of the Amhara region. The current activities and area coverages of the Ethiopian Seed Enterprise in the Amhara region is insignificant compared to the overall regional demand for high quality seed for all crops including cereals, forages, pulses, oil crops, vegetables and trees. The research centers must play a lead role in developing or obtaining breeder and basic seed, as well as in producing foundation seed for their respective zones. The research centers should also ensure good quality seed control in both production and distribution the region. Policy and quality control issues are the responsibility of the National Seed Industry Agency, and the ANRS must develop regional capacity regarding seed regulatory policies, strategy and enforcement.

5.7.1 Available technology. The availability and effectiveness function of seed production, processing, storage and marketing in the Amhara region is minimal at present, and these functions should be strengthened and expanded. Since comprehensive plans to establish or strengthen the overall seed industry in the region are essential prerequisites for a sustainable food security effort, both the public and the private sector should participate in a complementary manner to establish and nurture a viable seed industry that serves the entire region.

The public sector could play the key role to the development and production of breeder, basic and foundation seed stocks and take a leadership role in quality control. The private sector, in turn, could be encouraged to use this technology to produce, process, and market commercial seed. The extension service could continue to assist and facilitate the dissemination and marketing of commercial seed. Showa Robit is an example of a private seed and agricultural inputs supplier who meets the demands of seed producers. Such suppliers should be encouraged to establish agricultural supply businesses throughout the Amhara region.

5.7.2 Capability to develop new technology. Currently, the capability to develop and establish a viable seed industry, both in the public and the private sector, is minimal because of inadequate investment in and attention to this important sector. Also at the infant stage is the capability of the research sector to generate new seed based technology because sufficient personnel with the required experience are not in place. This limitation is especially critical for the production of improved seed for high value crops, such as potatoes and other cash crops. Support is needed at all stages of the seed technology process, beginning with the development of breeder and basic seed to the processing, storage, marketing and dissemination of commercial seed. Critical for this process are linkages with organizations that have advanced seed-technology capabilities, such as CIMMYT, ICRISAT, CIAT, ICARDA, CIP, ICRAF, AVRDC and the CRSPs.

5.7.3 Extension capability. Extension capabilities to raise awareness about seed technology and for the dissemination of seeds to producers are organizationally in place, and in most situations, farmers save their own seed and exchange seeds with their neighbors. The dissemination of improved seed to farmers is at times restricted, however, by lack of availability and by the high production costs of seeds for some crops, such as horticultural crops.

5.8 Livestock Production. Livestock management includes the introduction of new genetic material and types, rangeland management, land-carrying capacity improvement and enhanced forage and feed crop production.

5.8.1 Available technology. Tremendous animal resources exist in the Amhara region, including cattle, sheep, goats, camels, fish, honeybee, poultry and equine species, while the genetic composition of these resources have wide variability. However, productivity of the animal resources has not been effectively utilized, so a great need exists to improve productivity and conserve the available animal genetic resource. In some instances, the introduction of genetic materials from outside the region, which might include exotic dairy breeds for improvement of the dairy sector and sheep breeds for improved mutton and wool production, would be beneficial. Availability of improved genetic materials could then be enhanced and expanded to benefit rural households through the selective and systematic application of reproductive biotechnology, like artificial insemination and embryo transfer.

Animal power: Almost all agricultural activities depend on animal power. In most *woredas* of the region, however, up to 75 percent of the farmers have either one or no ox, and the extension package for cereal crops production does not include any strategy to ensure the availability of oxen to farmers at the right time of the year, drastically affecting agricultural production, particularly under unpredictable environmental conditions. Other traditional arrangements (e.g., sharing, borrowing, pairing, renting) to enable animal power also interfere with the right time of land preparation and cultivation. The zebu oxen are suitable for animal traction and, thus, do not need improved genetics. However, alternative sources of animal power other than oxen (e.g., horses, donkeys, cows) need to be investigated, as do appropriate implements associated with different on-farm and off-farm operations. The use of animal power in soil and water conservation activities, and the technologies developed by ILRI and EARO in this regard, need further examination.

Milk production: Zebu animals have been naturally selected for their ability to survive stress rather than for their ability to produce meat and dairy products. As a result, the milk production potential of these animals is generally lower than the improved dairy breeds. However, they are hardy animals with relatively high disease and drought resistance, low feed and management requirements and high butterfat content. Improved milk production in the region, particularly around urban centers, ensuring adequate supply of fluid milk, is needed. One possible strategy to improve milk production potential may be crossbreeding the indigenous zebu cows with exotic dairy breeds, although any such effort needs to be an integrated one, since it would require intensified animal production. Technologies using improved genotypes, feed resource development, feeding systems and strategies, breeding and reproductive management, artificial insemination, animal health management, water resources development, manure handling and management, milk handling and hygiene management, milk processing and marketing are critical components in the success of such an operation. Moreover, a number of policy issues, such as land use, price, credit and marketing, need to be addressed in order to create a conducive environment for the success of this type of operation.

Sheep and goat production: Enormous potential exists for improved sheep and goat production in the region, since the cool tropics are exceptionally suitable for sheep production of both mutton and wool. Current efforts should be strengthened to encompass production, processing and marketing, particularly for wool, while appropriate animal genotypes in adequate numbers are determined for the different agro-ecosystems. There would still, however, be a strong need to develop a market-oriented breeding and feeding strategy for sheep and goat production.

Poultry production: Although backyard poultry production is quite common in all agro-ecological zones, modern poultry production for both egg and meat needs further intensification. Special attention should be paid to the access of dependable genetic material, feed resources, health services and markets, and organizing and strengthening the processing and marketing component should be made.

Fisheries: Lake Tana and other fresh waters in the region contain a variety of fish with a great potential for fisheries development in the region. Strengthening current efforts and developing fish farming, processing and marketing in other natural and man-made water bodies are essential.

Rangelands management: Although the proportion of grazing lands is shrinking in many of the farming systems due to high population pressure and a dearth of land use policy, communal grazing is a common practice in many parts of the region. These grazing lands, however, are overstocked and the land is overgrazed and degraded. Loss of biodiversity is of a major concern. Developing strategies to improve the carrying capacity of grazing lands, such as regulation of stocking rates and preventing oversowing during the rainy season would improve these land areas.

Improved forages and feed crops production: As well as depletion of the feed resource base, improved forage and feed crops production has not been integrated into the farming systems. Genetic materials suitable for the various agro-ecologies are available. For example, ILRI has a global collection of over 13,000 accessions of different forage genetic resources. The need exists to quickly screen and identify suitable grass, legume crops and multi-purpose tree species and to develop strategies for integrating them into the farming systems. Developing seed production capacity and availability of forage crops would increase the availability of seed and cuttings and augment the expansion of forage crops in the region.

5.8.2 Capacity to develop new technology. At present, the three research centers focus on cereal crops research, lack a production systems approach and have a limited capacity to develop new animal science technologies. The animal science sections are maintained at a nominal level, and in some cases, only animal feeds and nutrition sections exist. Insufficient attention has been focused on research facilities and research staff, and a strong need exists to assess the relevance and suitability of technologies developed by ILRI regarding genetics, management, feed resources and feeding systems, animal power and farm implements. The regional research system should be strengthened to develop and advance technologies in animal power, dairy production, small ruminants production, poultry, fisheries and apiculture that are suitable to the diverse agro-ecological zones in the region..

5.8.3 Extension capabilities. The extension service's main focus is on cereal crop production and natural resource management. At all levels, animal science extension experts are few and in most instances are heavily involved in implementing soil conservation and cereal crops extension activities. Benefit would accrue from additional staffing in animal science with strong links to research in order that appropriate technologies for the rural household are developed. Improvement of the Menz sheep for mutton and wool production in on-farm activities are encouraging and should be expanded, improved, and strengthened. Available technologies in animal power, dairy production, small ruminants production, poultry, feed resources, fisheries, and apiculture need to also be increased, encompassing the production-to-marketing continuum. Projects involving follow up and expansion of breeding activities need to explore alternative supply systems involving farmers. Such activities might include mechanisms of farmer participatory delivery systems, such as “heifer in trust” or “passing the gift”, for expanded use of improved genotypes of animals.

5.9 Apiculture. Considering that honey-bee production is a relatively low input operation and that the Amhara region is one of the major honey-producing regions in the country, a large potential for improvement exists. Honey production occurs in all zones in the region, reflecting the suitability of many ecosystems in the ANRS, as well as the existence of a long tradition of honey production. Current estimates indicate that over 692,000 beehives in the region produce about 3.3 thousand metric tonnes of honey annually. The estimated amount of wax produced is also substantial. Since over 95 percent of the honey is produced and processed by the traditional system,there exists tremendous potential for improving both the quantity and quality of honey and honey by-products. It is thought modern honeybee production techniques could increase honey yield by over 50 percent. The highest proportion of modern honeybee production in the region is in the Western Gojam Zone, and according to some farmers in the region, annual income from sale of traditional beehive honey is estimated at 1500 Birr. Strengthening apiculture activities in the region would contribute to substantial increases in rural household income, although efforts to improve apiculture in the region would also need to examine the production, handling, processing and marketing aspects.

5.9.1 Available technology. Even though there are a substantial number of bee colonies in the different agro-ecosystems of the region, and traditional honey production is a common practice, the indigenous apiculture knowledge has not been supported by adequate research and extension efforts. Moreover, modern apiculture, including product handling, processing and marketing, has not been well developed and organized, nor has diversifying the production of honeybee products, such as nectar production. Improving the design of hives so that beekeepers in the ANRS could extract the honey and wax without destroying them, as is currently done, would greatly increasing the productivity of honey and wax production.

5.9.2 Capability to develop new technology. Programs, staff and facilities for apiculture research do not exist at the three research centers. It would be necessary to develop research center capacity to undertake apiculture research in strategically selected locations. Meanwhile, available technologies developed by the Holetta Apiculture Center in modern honeybee production, processing and marketing could be appropriately packaged and delivered to farmers in the region. Balancing natural resources available to bees and the human capability to develop and expand apiculture in the region needs careful consideration.

5.9.3 Extension capability. The extension system requires strengthening in modern honeybee production and processing, and a farmer’s training center on apiculture, providing short-term training in various aspects of apiculture, would be invaluable. Also needed is advice on how crop production systems could improve the quality of honey, and conversely how the honeybees would contribute to better crop production. Loss of biodiversity, expansion of weeds such as “congress weed” and unregulated use of agro-chemicals, which endanger honeybee production, are important considerations to address.

5.10 Food Science

5.10.1 Current technology. At the household level in the highlands of the Amhara region, grain is processed into flour by dehulling and grinding, using simple means such as mortar and pestle and manual grinding stones. Processing of agricultural products by smallholders offers an opportunity to add value to harvested crops and slaughtered animals. Value-added technologies which are not capital-intensive and which are within the financial means of smallholders could offer opportunities both to increase food security and raise rural incomes. Food processing (e.g., simple mills) serving groups of households at the *kebele* level could also decrease the time consumed at the household level in processing grains for food preparation. Large mills are located in larger cities such as Debre Zeit to serve the needs of large baking enterprises. This technology, however, is inappropriate to serve the needs of geographically dispersed small holders in food-insecure areas of the Amhara region.

Technologies are available in Ethiopia for improved processing and preparation of food, including techniques for plant and animal products. EARO has laboratories at Nazret and Holetta which have been developing improved methods of food processing, such as methods to substitute sorghum flour for wheat flour in baked goods. For example, in 1997/98, EARO food scientists evaluated the food-making qualities of thirteen sorghum varieties with different characteristics for Ethiopian food types (*injera, kitta, nifro, genfo, tella and kollo*). EARO scientists also evaluated ten finger millet varieties for food making qualities, and popularized and promoted, through lectures and training, a haricot bean variety, Roba, for five different food types. In addition, EARO scientists transferred the following food technologies: 1) bean food preparation methods to twelve women farmers at Melkassa during five days; 2) bean food preparation methods and bean food tasting to about 100 field day participants at Melkassa Research Center; and 3) theoretical training regarding bean food preparation methods to thirty-five subject matter specialists. The Melkassa food science research group has also conducted organoleptic testing of a wide range of foods to determine consumer preferences. Establishing linkages between Amhara Regional Agricultural Research Centers and the EARO food science laboratories at Melkassa and Holetta could potentially improve food security and nutrition of many in Amhara region.

Food science research with livestock and development of technologies for milk and meat processing has been conducted for many years at ILRI and its predecessor, ILCA. ILRI conducts research and develops technologies for processing of milk both at the smallholder level and for larger-scale processing. Focusing on smallholder processing of milk into butter and cottage-type cheese, ILCA has developed and modified a wooden internal agitator that can be fitted to the usual clay pot used by the smallholder. This agitator reduces churning time from an average of 139 minutes to an average of 57 minutes. ILRI's Dairy Technology Unit is based in Debre Zeit, and one of its objectives is to introduce more processing options and more efficient processing methods. Pear-shaped, woven containers (*gorfa*) are used for milk storage and souring as well as churning on the semi-arid Borana Plateau of Ethiopia. ILRI research has quantified the importance of milk products to rural households to assure consumption of essential vitamins and amino acids which are absent in grain, confirming that a balance of milk and grain is desirable in the diets of rural households. Drought, by decreasing available forage, decreases milk production and thus decreases the availability of vitamins and amino acids on which rural household members depend, resulting in, or exacerbating vitamin and amino acid deficiencies in rural areas affected by variable and low amounts of rainfall. As resources become available, linkage of ANRS research centers with food processing laboratories of EARO and ILRI could contribute to food security of the region in food processing and preparation. Nutritional issues in food-insecure areas of Amhara region are complex and involve the production, processing and consumption of crops, forage, and livestock.

5.10.2 Capability to generate technology. There is apparently no current capability at the three Amhara region research centers to do research on processing and preparation of food. To better serve the needs of the food-insecure *woredas* of the region, and the region as a whole, the Amhara Regional Agricultural Research Centers could initially develop food science research capabilities, and, by linking with such organizations as EARO, ILRI, and the Ethiopian Health and Nutrition Research Institute, gain access to presently available technologies. Building on these linkages and with training, personnel of the Research Centers could develop the capacity to do participatory adaptive research and, in the long term, generate technologies with a participatory process.

5.10.3 Extension capability. At Adet Research Center, the team viewed a demonstration potato "seed" storage facility, and at two of the *woredas*, the team observed grain storage facilities which are used for demonstrations. These indications of extension capability in post-harvest technologies are encouraging, although the team did not find evidence of extension ability to transfer technology for food preparation or processing. Emily Frank's report of interviews at the household level indicates that there had been a national-level home extension program, separate from the farm extension program, carried out by general development agents in Amhara region. This program included home gardening techniques, family nutrition, family planning, and food preparation. According to the report, those programs have been discontinued in favor of a "family-centered approach." The Frank report indicates that respondents viewed the present program as not providing adequate information regarding nutrition, family planning, and food preparation..

5.11 Socio-Economic Factors. The ultimate goal of agricultural research is to generate improved technologies that are adopted by rural households. Socio-economic support in the research stations should ensure the generation of technologies that are appropriate for the conditions of rural households. A number of factors may contribute to the nonadoption of a technology showing promising results in research trials. These factors include household resource constraints, risk, compatibility with household priorities, and technical viability under household production conditions.

Resource constraints of a rural household can impede the adoption of a new technology. An improved seed-fertilizer package that requires additional and timely field preparation only feasible with two draught animals may not be adopted by a farm without access to this resource. Similarly, agroforestry tree planting that requires substantial labor early in the rainy season when household labor is occupied with planting subsistence crops may not be adopted by households.

Members of households living in extreme poverty often prefer lower but stable production over higher but variable production. The basic livelihood of farmers barely producing enough to survive can be threatened by increased variability. Agriculture in the Amhara region faces many risks such as drought, frost, pests, price fluctuations, and input availability. New technologies may not be adopted by farmers if they increase risk.

A technology may be effective, for example, in decreasing soil erosion. However, if soil erosion is a long-term concern of farmers in a given context, households may put greater priority on technologies that increase production in the short term. Also, agricultural production concerns may be secondary to issues such as access to potable water or improved family nutrition.

A technology that performs well under experiment station conditions may encounter problems under farm household production conditions. Experiment stations typically have access to machinery and/or paid labor to overcome production bottlenecks facing rural households. Furthermore, the simple fact of having a fence around an experiment station may allow, for example, the control of livestock that otherwise might damage late-maturing crops or tree seedlings.

5.11.1 Socio-Economic Analysis and Adaptive Research. It is difficult for socio-economic analysis to foresee all the obstacles to the adoption of agricultural technologies by rural households based on research station trials. When farmers fail to achieve expected results, refuse to implement a technology, or adapt the recommended guidelines of a technology developed on the research station during a participatory trial, it becomes easier for socio-economic research to identify the above-mentioned farm-level constraints to adoption (resource constraints, risk, differing priorities, technical viability). This enables the process of adaptive research.

The experience of rural households implementing a technology gives insights into how to make a technology more appropriate for farmer conditions. If, for example, a socio-economic researcher notes that farmers in a drought prone area or those without two draught oxen have low rates of adoption of an improved seed-fertilizer package, then research can begin to focus on adapting the technology so it is more resistant to drought and can be used without access to draught equipment. Rural household members are not only the best sources of information about obstacles to adoption, they also are frequently the best source of suggestions about adaptations to make a technology viable.

5.11.2 Integrative Aspects of Socio-Economic Research. Most recent research has focused on increasing yields. However, if yield increases require additional technology, labor and/or capital, the gains in output can be offset by additional costs. Socio-economic analysis therefore should focus on the impact of a new technology on net farmer income. This analysis accounts both for the additional costs of raising yields as well as the potential diversion of resources from other economic activities.

Intra-household analysis is also helpful to enable researchers to obtain a better understanding of the impact of a new technology within the household (e.g., women's labor, child nutrition) and to match technologies with available resources within households. Socio-economic research could also include an examination of the informal networks within a community or *kebele*. Understanding how these networks operate can help in the process of organizing participatory research as well as in disseminating new technologies on a farmer to farmer basis.

Team building that brings together rural household members, extension agents and researchers as well as individuals from diverse disciplinary backgrounds is also critical for the success of participatory research. Socio-economic research should analyze the most appropriate mechanisms and institutional arrangements for facilitating team building with individuals of diverse backgrounds and make recommendations on how to best facilitate this process.

5.11.3 Socio-Economic Research Capability. Socio-economic analysis in the context of adaptive, participatory research trials is key to the process of generating technologies that will be adopted by farmers. The Integrated Food Security Unit of the Amhara region has conducted research eliciting rural households' research and extension priorities. Household members themselves identified criteria for determining wealth categories of households in their *woredas*. Priorities were identified based on wealth and gender and short, medium, and long-term research and extension activities were identified as potential solutions. This approach serves as an example of how to involve households in the setting the research and extension agenda in order to ensure a greater socio-economic representation of households.

The three research centers in the Amhara region all include a socio-economic research division. Currently, however, these divisions are understaffed and lack individuals with sufficient training to carry out the needed research to make adaptive, participatory research successful.

5.12 Capability and Structure of the Research System

5.12.1 Current Research System and Future Plans. The capability to develop new technology is located mainly at the three regional agricultural research centers (Adet, Sirinka, and Sheno). Each of these centers has researchers with expertise and responsibilities across a range of disciplines, such as agricultural economics and farming systems, animal production, health, feeds and nutrition, agronomy and/or crop physiology, crop protection, field crops improvement (breeding and genetics), horticulture, soil science and water management, agro-forestry (resource management) and research-extension. **The Adet Agricultural**

Research Center is located in the M2.5 agroecological zone (moist, tepid to cool, mountainous and plateaus) that serves 15 drought-prone *woredas*, as well as other *woredas* which are normally food-secure. The center is located at 2200 m.a.s.l. and includes 131 ha plus eight testing sites. Of the 26 researchers at the center, one has a PhD, 10 have MS degrees, and 15 have BS degrees, with a total staff of 163. The **Sirinka Agricultural Research Center** was established as a research center in 1987 but was closed during the civil war and re-opened in 1995. It is located in the SM2.5 agro-ecological zone and serves North and South Wollo, Oromia, and Wag-Himra Zones. The center is located 1850 m.a.s.l., in a 900 mm precipitation zone and manages a 30-ha sub-center at Kobo at 1470 m.a.s.l. with 667 mm precipitation, and several additional test sites. It has 156 technical and support staff, of whom none have a PhD degree, three have MS degrees, and 23 have BS degrees. Five are presently on study leave. The **Sheno Agricultural Research Center** is also located in the SM2.5 agro-ecological zone, located at 2800 m.a.s.l., with 903 mm of average annual precipitation. The center consists of 142 ha plus six additional testing sites distributed across a range of altitudes from 2500-3100 m.a.s.l. The current mandate has been restricted to the high altitude areas of N. Showa, but is expanded to include additional areas. The research staff consists of one PhD, five MS, 13 BS, two DVM, with two researchers in training at the PhD level, and one at the MS level.

The research capability needs to be strengthened in several ways, including increasing the research efficiency of the current system, along with strategic expansion and upgrade of the centers. In general, the efficiency of current research investments should be addressed first and then upgrades and expansion should be addressed. To increase efficiency, there is a need for short-term and long-term training, improved access to communication technologies, and development of a performance based reward system that will improve morale and retention of scientific and technical staff.

Across all centers, the research staff is young and enthusiastic, and all expressed the need for more senior, experienced scientists who would provide leadership and guidance to the junior scientists and to the overall program. The team's visits within the region identified the need to provide academic training to raise the training level from predominately the BS level to more PhD and MS level scientists. This additional, long-term training is necessary to achieve the regional objective of improved capability to develop better technologies to support agricultural sustainability and food security goals. The assessments also identified the need to increase the numbers of researchers in the areas of economics, agro-forestry, and food science, as well as to develop new research centers in critical agro-ecological zones.

The capabilities to do research at all ARC's would be enhanced by such factors as more trained scientists (particularly senior scientists who are needed to direct research), reduced employee turnover, better access to current scientific literature and improved communication infrastructure (at present, no telephone or fax at Adet and lack of e-mail and Internet access at all sites), improved equipment, instruments and supplies to conduct research, more vehicles and spare parts for vehicles which have broken down. Low salaries and lack of incentives were identified as a problem in attracting and retaining qualified research and technical staff, as were isolation of the living conditions for researchers and inadequate personal access to transportation, communication, recreation, schooling and medical services for families. Access to current journals and lack of communications with scientists outside the center were also cited as impeding progress in doing research that contributes to food security. Expensive equipment items at each center were underutilized, or not used at all, because of lack of trained technicians, inadequate supplies, lack of spare parts and inacces-sible repair services. This indicates that strategic planning and budgeting to maintain an appropriate balance between capital expenditures for major equipment purchase and annual expenditures of operating expenses could increase the efficiency of the research system.

The extension system to disseminate available technologies is well-developed and structured. Currently, the extension system is organized and relatively well-staffed at the *kebele, woreda*, zonal and regional levels. Subject matter specialists assigned to the various levels are the main sources of technical information and guidance for DAs, who are the basic operational units of the extension system. The subject matter specialists assigned to the different levels of the extension system need more experience and training to handle the urgent and difficult problems facing rural households. Although the extension system in the Amhara region is well-organized and adequately staffed in quantity, the technologies available to extension agents for dissemination need a substantial improvement.

5.12.2 Research linkages. Research centers should improve linkages across disciplines within a center, linkage across the region between centers and support institutions, and linkage with other Ethiopian, African, and other international scientists. The linkage should occur on two levels: 1) informal scientist-to-scientist communications with a minimum of restrictions, and 2) formal organization-to-organization linkages which may require better articulation of channels of communication and protocols for establishing agreements.

From the team's discussions with ANRS research staff, it appears that the centers' research is organized along disciplinary lines, rather than being oriented around multi-disciplinary problem areas. Most of the problems facing the people of the Amhara region in producing food and meeting household food needs transcend disciplinary boundaries and will require an integrated systems research and extension approach to identify new technologies that can contribute to solutions of these problems. There is a strong potential for interdisciplinary research, because of the mix of disciplinary strengths that are located at each research center. However, the current strengths in some key areas such as animal production, natural resource management, and socio-economics appear to be weak compared to capability in agronomic sciences. Additional training in systems research design and methodology is needed in order that research conducted will feed into planned watershed research and management activities within the region.

Informal interaction to exchange information pertaining to planning, methodology, and preliminary results across the research centers exists but appears to be minimal. This is due to lack of communication facilities such as telephone, fax, email, and Internet connection; geographic distance between research centers and limited travel and communication budgets. Annual research reviews conducted with the regional researchers and national commodity research leaders with EARO provides a formal structure for interaction among scientists from the research centers, as well as with national researchers, extension, and end users of the research.

Universities and agencies undertaking agricultural and related research include the Alemaya University of Agriculture, Addis Ababa University, Awassa College of Agriculture, Mekele College of Agriculture, the Institute of Biodiversity, EARO, Regional institutions (e.g., plant and animal health clinics, multiplication centers for animals and plants) Ethiopian Institute of Health and Nutrition Research, Coffee and Tea Development Authority, and research systems in other Regional States. There is little evidence that the ANRS research centers have undertaken collaborative activities with the above institutions. Likewise, minimal formal collaboration exists between the regional research centers and the international agricultural centers (IARCs). National professional organizations provide the opportunity for informal scientist-to-scientist interactions and networking, and establishment of regional chapters of such organizations might increase networking opportunities.

The team is aware that several donor organizations such as SIDA, the World Bank, the Governments of Japan and the Netherlands contribute to various aspects of strengthening agricultural research in Ethiopia. It is important to consider these contributions and ensure that the USAID support is complementary to them and does not duplicate and overlap what they are supporting.

5.12.3 Research-extension linkages. A major restructuring of Ethiopia's research system took place in the mid 1990s, giving regional states responsibility in research management. Decentralization of research management from a federal system to regional research centers has encountered several challenges, one of which is the absence of backstopping in technical leadership which resulted in inadequacy in generating technological innovations (Amhara National Regional State Bureau of Agriculture: Agricultural Research Master Plan 1999). In this transitional phase, the regional government and the research centers have developed official mechanisms for program management and coordination, although much remains to be done to efficiently respond to the region's food security program. Strategies to establish linkage among the centers and with the national/international research organizations and to upgrade research capability, infrastructure, and support services at the regional level need to be defined and implemented.

The regional and zonal Research and Extension Liaison Committees (RELCs) have served as the mechanism to coordinate research and extension programs. Linkages between research and extension need to be strengthened. Strategies are being developed to address this need with the proposed creation of the Research Extension Advisory Councils. Another strategy that may be considered is to build the capability of the DAs, since they play an important role in articulating research and extension needs by working with household members at the household/watershed level. The current focus on blanket recommendations with little flexibility to modify package recommendations based on 1) household conditions or 2) year-to-year variability in rainfall patterns has limited the effectiveness of extension of technologies in drought-prone areas. The primary challenge concerning the development and adoption of technologies to improve food security in the ANRS will be to undertake a transformational change from a supply-driven system of extension to a demand-driven system that allows smallholders to exercise choice in selecting technological options to meet household objectives within their resource limitations. Because of the complexity of issues surrounding food security in the Amhara region, a concerted effort among government agencies such as health, education, water, environment, and agriculture will be needed when problems are addressed at the watershed level. Inter-agency cooperation to support information exchange, resource sharing and joint action are among the many mechanisms to facilitate this synergy.

6.0 BUILDING A PARTICIPATORY RESEARCH PROCESS

6.1 Why Participatory Research? There are three practical reasons for involving stakeholders, including rural households, in research and extension. First, technologies are not reaching a wide range of households. A uniform set of techno-logical packages may not be appropriate to rural households' specific objectives or may be inappropriate to their unique social, economic, cultural (including indigenous knowledge systems) and biophysical environments and, hence, may not be adopted. Technological innovations have to "fit" household livelihood and survival strategies by reducing vulnerability to crop failure or livestock loss, improving resilience particularly from environmental shocks and increasing rural incomes.

Second, participation paves the way for enlisting household members' commit-ment to the goals of the research/ extension project. When they have a sense of ownership of the project, they could serve as valuable agents of change, for disseminating information as well as community mobilization. Tapping into informal local social networks could be useful in planning extension strategies.

Third, household members are the primary users of technology, information, and other resources. By interactively involving household members in research and extension, they can gain the capability to evaluate current practices, options and visualize the outcomes of implementing a practice or a technology.

6.2 Facilitating Stakeholder Partici-pation. Participatory research and extension is not a novel idea in Ethiopia's research and extension system. While there is awareness and effort to use a participatory approach in on-farm exper-iments/demonstrations, improve-ments could be introduced to maximize intended benefits to stakeholders and households.

Household participation is critical in the following stages of research and extension: 1) on-farm diagnosis, 2) identification of possible solutions, 3) design and implementation of interventions and solutions, 4) verification, and 5) monitoring and evaluation. Realistic mechanisms are needed to:

- Include a wide range of stakeholders: individuals, groups or organizations who have influence or can have an impact, either positive or negative, in ensuring food security in the region.
- Fully involve stakeholders and rural households through their organizations.
- Strengthen the research and extension system so that they are bottom-up, demand-driven, and based on in-depth diagnosis of the agroecosystem.
- Facilitate regular researcher-extension agent-household interaction in on-farm trials.
- Consult household members individually in on-farm trials, but also provide a forum for them to meet as a group with researchers and extension agents to facilitate feedback and information exchange.
- Strengthen mechanisms to promote a timely, two-way feedback across hierarchical levels.
- Involve the private sector and non-farm groups in the delivery of inputs and other services that are currently under the responsibility of government line agencies. This will hopefully stimulate and diversify the rural economy as well as provide off-farm income generating opportunities.
- Build capability among development agents to appreciate and support participatory approaches to research and extension
- Establish periodic participatory monitoring and evaluation systems to monitor outputs and measurable indicators of impacts, defined and agreed upon by the stakeholders.
- Employ social scientists in research and extension who have an appreciation for participatory research and gender issues in development.
- Establish a performance-based reward system that offers incentives for delivery of research impacts and builds confidence on using a participatory approach to research

Facilitating rural household participation in research and extension involves a high degree of transaction costs and flexibility. It demands continuous interaction with households, genuineness to learn with them, and sensitivity to their conditions. Participatory research provides an enabling mechanism for households to exercise choice. It requires clearly articulated institutional arrangements, defining the roles and responsibilities of stakeholders and implementors as well as flow of information, to strengthen the linkage between research, extension and households. Using a participatory approach to research and extension promises to introduce innovations in research methodology and develop models that could be applied in other *woredas*, zones, and regions of the country.

7.0 ACTION PLAN

The action plan consists of five parts. The first action plan concentrates on *adopting an adaptive participatory approach* to increase research efficiency and benefits to households. This approach is designed for immediate implementation and early results. Guiding principles for designing and implementing participatory adaptive research are offered as well as examples of results produced by adoption of this approach.

The second action plan is designed to *increase research efficiency* and output of researchers. Short-term training and long-term higher education are the primary means to raise staff performance. Since the absence of researchers for training and education will create critical personnel shortages, the immediate implementation of participatory adaptive research to sustain and even increase technology by farmers is needed.

The third action plan focuses on *modernizing computerized information retrieval* and communication capacity of the research centers. This plan is given a higher priority than to increase the number of library holdings, owing to the swift obsolescence of information.

The purpose of the fourth action plan is to *modernize the research laboratories* with adequate equipment and supplies to support the design, implementation and monitoring of applied research.

The fifth action plan calls for the *systematic, georeferenced biophysical and socioeconomic characterization* of the Amhara region, since the principal aim of agricultural research is to match the biological requirements of crops and livestock products and practices to the resource characteristics of households and the physical attributes of their land. A georeferenced database on socioeconomic condition and physical land attributes will facilitate technology transfer to all locations in the region and is essential to scale up technology adoption from a few participating farmers to the *kebele, woreda, zone* and regional level.

A more detailed description of the five action plans follows.

7.1 Action Plan 1. Institutionalizing Adaptive, Participatory Research. The guiding principle of participatory adaptive research in ANRS is that all concerned stakeholders, including rural household organization representatives, Bureau of Agriculture, Amhara region Integrated Food Security Unit, Research Centers, NGO's and other relevant institutions, should be involved in the prioritization, planning and implementation process.

Further key principles of participatory research are listed as follows.

- Immediate attention should be given to adapting existing technologies to local conditions while longer term research capabilities are being enhanced.
- Research trials should be concentrated on households' fields and be managed by household members under farmer conditions.
- Trial sites should be representative of agroecological conditions and stakeholder-identified problems.
- Research trials should include a representative cross section of rural households, based on factors as availability of resources, education and gender.
- Households, through their organizations, and other stakeholders, should be systematically included in setting research priorities, as well as in the monitoring and evaluation of the research trials.
- Rural households should be able to choose from a series of technology options. Each technology option should allow for flexibility in implementation. For socio-economic analysis, although yields are an important component of profitability, the focus of technology evaluation should be on profitability and the impact on net household income.
- Finally, while participatory research requires that household members be involved in setting research priorities, there are a number of priorities that are so frequently repeated by so many

individuals that researchers and households can immediately begin to design and implement trials in areas where the problem stands as a major bottleneck to achieving food security.

An example of a rural household-identified priority is the desire to reduce yield loss from frost damage. Wheat crop in the highlands of the Amhara region that appear healthy and vigorous have often been rendered sterile by frost. Rural households express concern that frost damage is occurring more frequently now than in the past. They believe that the region is undergoing temperature changes and they would like frost-resistant varieties to be developed. While frost-resistance in wheat and barley may be developed by breeding, it would be many years before such varieties can be released.

The purpose of adaptive participatory trials is to find solutions to problems such as frost damage, that can be implemented in the next cropping season. For example, it is known from work conducted elsewhere in the world that frost damage can be substantially reduced by providing adequate amounts of potassium to grain crops. A simple trial can be installed which compares yield and profit from trials employing conventional farmer practice with and without the addition of potassium. If the results are negative, the household's losses will be minimal if little additional labor was required to install the trial and the fertilizer cost was borne by the research unit.

But if the result is positive, as it might very well be, it will show that the increased incidence of "frost damage" is not related to a gradual lowering of air temperature but to declining levels of potassium in the soil. It is worth noting that the fertilizer recommendation for most, if not all of Ethiopia, does not include potassium. While the potassium levels may have been adequate several decades ago, that may no longer be the case, and now low potassium levels could be contributing to frost damage and low yields.

Another example of participatory adaptive trials involves finding technologies that reduce the dependence on manure as fuel, thereby allowing this source of organic fertilizer to be reincorporated into fields. Simple improved stoves fitted to traditional cooking pots have been shown to reduce fuel consumption needs by 30-50 percent as well as substantially speed up the cooking process. Solar cookers have also shown potential as an alternative source of energy for food preparation. Fast growing trees such as leuceana that have the properties of regrowth after cutting can by planted in strategic areas to reduce erosion as well as supplying a renewable source of fuelwood. By reducing the fuel needs as well as providing alternative sources of energy, the dependence on manure for fuel can be minimized. In addition, simple improved corrals that serve as collection points for manure can further increase the availability of this source of organic matter to be reincorporated into crop fields.

The example of alternative fuel sources and improved stoves also illustrates important gender issues that can be addressed by adaptive, participatory research. A substantial amount of many rural women's time is taken up by fetching firewood and cooking. By reducing fuel needs, providing readily accessible alternative energy sources and decreasing cooking time, women's labor can be spent in other activities, such as quality time with household members, recreation, off-farm income generation, or horticultural production to improve family nutrition and to sell as a cash crop.

The examples cited above illustrate the need to be creative in designing adaptive trials with rural household members. The trials must be inexpensive and easy to install, monitor, and evaluate, and produce good results quickly.

7.2 Action Plan 2. Training, Mentoring and Higher Education. Short-term training to acquire specific skills such as applying analytical methods, operating new instruments and computers or conducting on-farm adaptive trials must run parallel with long-term efforts to increase the number of researchers with advanced degrees. Short-term training, whenever possible, should be conducted under conditions normally encountered by the researcher. The aim is to reduce dependence on sophisticated laboratory equipment and to rely on adapting existing equipment to achieve the desired results.

Mentoring of young and inexperienced researchers by locally-stationed experts from the national and international agricultural research centers can make up for the lack of senior researchers with leadership capabilities. The purpose of mentoring is to give direction and purpose to young researchers and the work they produce.

Long-term higher education serves as the foundation for achieving excellence in research. It is expected that young researchers enrolled in advanced research institutions will return to their centers to conduct their research. Provisions should also be made for the students' research advisors to accompany them so that the advisors are made aware of problems and conditions in the region. Student advisors can also serve as mentors to prospective students, as well as a source of answers for questions raised by local researchers. Since the quality and relevance of a student's research depends on his or her advisor's appreciation and understanding of conditions to which the student will return, the simultaneous education of students and their advisor should add to the relevance of higher education.

While trainees are away from their research centers for training for extended period, or where mentoring is needed in selected areas of research for young scientists, the employment of technical assistance could be very useful. Senior scientists serving as mentors or experts in selected areas could come either from local or international sources. Locally, retired Ethiopian scientists, who have decades of experience and may be available, could be a very valuable resource of expertise for this purpose. If senior scientists from abroad are desired, the CRSPs collectively could be a valuable source of expertise and provide local scientists opportunities for collaborative research. In any case the need for mentoring or technical assistance and its implementation should be determined in a participatory manner by all stakeholders.

7.3. Action Plan 3. Modernizing Computer and Communication Technology. The gap in computer and communication technology between research centers in the Amhara region and advanced research institutions is huge. Researchers at advanced research institutions have access to the global knowledge base and achieve high research efficiency by their ability to communicate nearly instantly with researchers around the world. Researchers in the Amhara region must exploit this technology to enable them to perform useful applied research based on sound understanding of biophysical and socioeconomic processes.

A modern communication system will also enable research centers in the Amhara region to coordinate their work, reduce duplication of effort, develop annual work plans and communicate results of on-farm adaptive trials to others.

Installation of a modern computer and communication system does not necessarily guarantee effective use of the system. Short-term training will be necessary for on-station staff, but returning students from advanced institutions can further encourage researchers to rely not only on local knowledge, but also on the global knowledge base now accessible to users of the Internet.

7.4 Action Plan 4. Modernizing Research Facilities and Supply Delivery System. Helping households to deal with problems requires that each prescription to cure a problem is preceded by a proper diagnosis. Recommending a prescription without a thorough diagnosis can be likened to a doctor who prescribes aspirin for all headaches. Top-down transfer of technology from research centers to farm households prescribes one cure for all households. A good example of this situation is the fertilizer component of technology packages distributed by the ANRS Bureau of Agriculture. For each crop, there is one rate of phosphorous and nitrogen for all households. This is a wasteful and ineffective way to correct yield-reducing, nutrient deficiencies. The law of the limiting warns us that applying nitrogen or phosphorus to a soil lacking in potassium or any one of the 16 essential nutrient elements will do little to increase yield and render investments in fertilizer unprofitable. A modern research laboratory is essential to diagnose the cause and magnitude of problems farm households face. Development agents need diagnostic services to help them design, install and monitor on-farm, adaptive trials. Without a proper diagnosis, on-farm, adaptive trials are reduced to slow, expensive and unreliable, trial-and-error research.

A modern research center should be able to analyze large volumes of samples submitted by development agents, interpret the analytical results and communicate them to development agents anywhere in the region in a timely manner. It is also true that no research center can generate new technologies for adoption by farm households without access to diagnostic services.

7.5 Action Plan 5. Creating a Georeferenced Spatial Data Base. A new technology successful in one location is likely to succeed in other locations with analogous socioeconomic and biophysical characteristics. This method of technology transfer by analogy requires that all sites within the Amhara region with similar characteristics be identified. If the site characterization data are georeferenced and displayed using a geographic information system, that would instantly show the real extent over which the technology could apply. A technology, no matter how outstanding, is of little value if no analogous sites to receive the technology exist.

While participatory adaptive research increases adoption among participating households, it is not designed to transfer technology to other analogous locations in the region. A large-scale, georeferenced data base will enable extension agents to abandon slow, expensive and unreliable trial-and-error technology transfer in favor of technology transfer by analogy. Improvements in research facilities, staff education and adoption of participatory research will do little to alleviate poverty or raise rural incomes unless the capacity to disseminate proven technology to other, similar locations in the region is in place. For example, the transfer of technology by Sasakawa Global 2000 to other locations in the region or country can be dramatically improved by limiting transfer to analogous sites. Technology transfer from its site of origin to other locations with dissimilar socioeconomic and biophysical characteristics remains an expensive obstacle to agricultural development.

8.0 TECHNOLOGIES FOR IMMEDIATE ON-FARM TRIALS

Participatory research requires that researchers, development agents and household members all have equal say in defining the purpose of on-farm trials. The technologies for immediate on-farm trials listed below were not selected by a participatory procedure, but were chosen because farm households have repeatedly asked for help in these areas, without success. Problem areas identified by farm households include yield loss from frost, drought, soil erosion, pests, soil fertility, and water logging. Technologies to combat or avoid the six problem areas are given below.

- Frost—Farmers seem to believe that the frequency of frost damage in cereal grains has been increasing over the last few years. This belief, however, does not seem to be supported by temperature data from the region. One explanation for frost damage is potassium deficiency in the cereal crop. There is evidence that potassium is involved in cold hardiness. Because potassium is a very soluble ion, high potassium levels increase solute concentration and lower the freezing point of water in plant tissue.

  It is recommended that with and without potassium trials be conducted in areas where farmers have experienced severe yield loss from frost damage.

  If potassium is deficient in the soil, adding it will not only reduce frost damage but may also increase the crops resistance to insects and diseases.

  As in all on-farm trials, success will not only depend on yield increases, but primarily on the farmers' decision to adopt the technology.

- Drought—Rainfed agriculture is risky because drought can wipe out investments in fertilizer, seed and labor. For this reason, many households choose not to invest in yield increasing inputs. There are two ways of reducing the risk of yield loss from drought. The first way is to select drought tolerant and/or drought-escaping cultivars. Drought-escaping cultivars do so by producing few tillers in dry seasons, thereby enabling a smaller biomass to compete for the lower amount of available water. In

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- Striga—The parasitic weed, Striga, has been identified as one of the main constraints in sorghum production in the Amhara region. An integrated Striga management (ISM) technology has been found effective elsewhere in Africa. Using an ISM composed of tolerant cultivar, intercropping with a legume, planting in rows, hand weeding prior to flowering to deplete the Striga seed bank in the soil, use of modest levels of nitrogen fertilizer, and use of improved moisture conservation practice such as tied ridges result in significant yield improvements of sorghum.

- Soil fertility—Although application of chemical fertilizers is known to consistently increase yield when rainfall is adequate, few farmers use fertilizers because fertilizer costs and the risk of crop failure from drought remain high. One reason for the high cost of fertilizer is that the same fertilizer recommendation is applied to all farms in the region. It is almost certain that non-optimum rates of fertilizers are being applied in the majority of cases. Near-optimum fertilizer rates can be applied if diagnostic tests are conducted to identify which of the major nutrients are deficient in a field. Without a proper diagnosis, it is not possible to prescribe a cure for nutrient deficiency. The soil analyses may need to be performed by EARO initially, but the local units must be upgraded to take on this task.

  From on-farm trials, farmers will be able to compare yields and profits between current practices of applying no fertilizer or, depending on the government's fertilizer recommendation, with yields and profits from the plots receiving fertilizer based on diagnostic tests.

  Another way to increase fertilizer use efficiency is to place the fertilizer in a narrow band near the seed. The current practice is to broadcast seed and fertilizer evenly over a field. This makes weeding difficult and dilutes the fertilizer. ILRI is currently experimenting with a combination seeder and fertilizer applicator. It is animal drawn and should be affordable and beneficial to most farmers in the region.

  The combination seeder and fertilizer makes weeding easier between rows and increases fertilizer use efficiency by concentrating fertilizers near the seed. The beneficial effect of banding fertilizers is especially high at low rates of application. The reduction in time spent on weeding and the increase in fertilizer use efficiency may be sufficient to create household demand for this technology.

- Water logging—This condition is a consequence of water runoff from higher ground into local depressions. The area affected by water logging should decrease with adoption of contour-ridge tillage, tied-ridges and planting of vertiver grass.

  Even with the above practices, runoff will occur during heavy downpours, and some means to capture the excess water in village or household ponds should be considered. The stored water can be used to irrigate high-value crops and provide drinking water for livestock.

- Intercropping—Use of traditional crop production practices result in very low yield levels. Agronomists at EARO have shown that properly planned and executed agronomic practices, such as intercropping cereals with legumes, can give 50 percent yield increase over the sole crop, accompanied by the added advantage of reduced weed and pest incidence.

- Improved crop production practices—Use of ERO-developed improved crop production packages, such as improved variety, fertilizer, early weeding, tied ridges, combined with IPM-based crop protection can contribute to significant yield increas-es. Such packages should be adjusted and tailored for the specific ecological condition of each area. A blanket recommendation of a uniform package can not work under all conditions of the Amhara region.

- Alley cropping—Dry season feed shortage is a chronic problem in the Amhara region. Alley cropping maize or sorghum with leguminous species, such as Sesbania sesban, Cajanus cajan, Leucaena, can give up to three tons of biomass from the perennial legumes, which can then be used as animal feed.

9.0 TECHNICAL ASSISTANCE FOR TECHNOLOGY IDENTIFICATION, ASSESSMENT, AND DISSEMINATION

There still remains the question of how the regional research units staffed with mostly young and inexperienced researchers might implement the program described in this report. The food security situation requires immediate attention, but it will be several years before the region will benefit from the planned long-term training and education efforts. One way to ensure that the program functions properly from the beginning is to enable regional researchers to work in concert with experienced counterparts from local, national, and international research institutions. Many such institutions are already operating in the region, but the USAID/Ethiopia program fills a much needed void in the area of strengthening local capacity for participatory research in technology development, evaluation and dissemination. There are two areas where the regional research units can benefit from collaboration with experienced specialists. The first is in identifying suitable technologies, including new livestock, crops, varieties, products and practices for local testing. Experienced researchers bring to the region an understanding and appreciation, which young researchers often lack, of genotype by environment interactions, and the art and science of matching the biological requirements of crops and livestock to the physical characteristics of land.

The second area where help is needed is in matching the socioeconomic requirements of a technology to the resource and cultural characteristics of the intended customer. In the Amhara region, as elsewhere in the world, the biophysical has received greater attention than the socioeconomic aspect of agriculture.

There is also need for assistance in integrating the biophysical with the socioeconomic components through interdisciplinary, participatory research.

Given the current situation, several subject matter areas require technical backstopping in most regional research units. These areas include livestock management, pest management, crop management, soil fertility, soil and water conservation, agricultural economics and participatory research.

To be effective, one to two individuals should be stationed in the region to support local staff, but primarily to work with regional researchers to identify problem areas needing the attention of outside experts. Dependence on outside technical services can be effective if there is a large pool of specialists, experienced with developing country problems and conditions, who can be called upon for assistance on a timely basis. Fortunately for the Amhara region, EARO, the IARCs and the large pool of U.S. scientists involved with USAID's Collaborative Research Support Program can be called upon.

The one advantage the CRSPs have over other research organization is that the CRSPs are research, education and extension institutions. For this reason, when U.S. scientists are invited to assist in short-term technical assistance assignments, they should also be viewed as potential advisors to prospective students from the region. The technical assistance effort should not be an end in itself, but should be used as a basis for initiating long-term relationships between U.S. universities and the people of the Amhara region. While it is for the regional authorities to determine whether such relationships develop, the CRSPs are geared to operate in this way.

10.0 ANTICIPATED RESULTS AND INDICATORS OF SUCCESS

The purpose of the action plan is to strengthen the capacity of the Amhara regional food and agricultural research unit to design and conduct adaptive farmer-identified, on-farm research. The means to strengthen research capacity includes:

- Institutionalizing participatory adaptive research to transform a top-down, supply-driven technology transfer to one that is bottom-up and demand-driven.
- Training research staff to apply modern information and communication technology to promote effective interaction and communication with other researchers, development agents and households in the region and to enable researchers to access the global knowledge base needed to increase research productivity and efficiency.
- Enhancing research productivity and efficiency by upgrading research facilities, modernizing outdated laboratory equipment and analytical methods and ensuring a reliable supply of laboratory chemical supplies.

The results stemming from implementing the action plan will be verified by four indicators of food security. These indicators are quantitatively linked to four properties of sustainable agroecosystems. *The first indicator* is increased production and productivity. This indicator is measured in terms of yield increases (production) and increased profitability (productivity).

The second indicator measures reduction in yield fluctuations (feast or famine) under the new research paradigm. The