Modernizing Agriculture: A way out of food insecurity?
Proceedings of a National Workshop
Organized by
The Biological Society of Ethiopia

February 19–20, 2004
Faculty of Science, Addis Ababa University
Addis Ababa

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Seyoum Mengistou
Ensermu Kelbessa
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ACKNOWLEDGEMENTS:

The Biological Society of Ethiopia (BSE) is very grateful to the Christian Relief and Development Association (CRDA), the Ethiopian Science and Technology Commission (ESTC), the Environmental Protection Authority (EPA), Ethiopian Agricultural Research Organization (EARO), the Department of Biology (Addis Ababa University), the Institute for Sustainable Development (ISD) and Meta Brewery for their financial, material and logistic assistance that made this Workshop a reality.
WELCOMING ADDRESS BY DR. ENSERMU KELBESSA, PRESIDENT OF THE BIOLOGICAL SOCIETY OF ETHIOPIA

Dear invited farmers from Axum and Zeway,
Dear members of the Biological Society of Ethiopia,
Distinguished guests,
Ladies and gentlemen,

The Biological Society of Ethiopia is a professional society of biologists that has about 500 members to date. One of the objectives of our Society is to create awareness on development issues in the formal and informal education sectors and amongst the general public. Therefore we believe that it is imperative for a professional society of our kind to contribute its share in the national endeavor towards attaining food security and sustainable use of natural resources.

Therefore, the main theme of this year's (XIVth) Annual Conference is 'Modernizing Agriculture: A Way Out of Food Insecurity?'.

The major aims of the Conference are:
1. To raise the level of awareness among the public in general and the Workshop participant institutions in particular about the current status of Ethiopia's agricultural system and its potential to bring about food security;
2. To assess the economic, social and environmental feasibility of relying on modern agricultural inputs;
3. To assess the problems of modernizing agriculture in relation with ecological impact and eventually suggest some corrective measures;
4. To create a forum about the roles played by peasants, agricultural investors, the scientific community, the government and all other stakeholders in addressing the problems and suggesting possible solutions;
5. To review the national policies and legislations pertinent to modernizing agriculture and food self-sufficiency, and discuss about the problems associated with their implementation;
6. To compile all relevant information on the development of agricultural systems in Ethiopia for future use;
7. To exchange available information on agricultural practices and potential resources in Ethiopia;
8. To suggest directions for new research and conservation programmes; and
9. To produce a document that would contribute towards future endeavors of agricultural development, food security, and conservation of natural systems.

During this two-day Conference, more than 40 papers will be presented on issues related to modernizing agriculture and other biological disciplines. Some of the topics to be dealt with during the Workshop include:
1. Traditional agriculture: opportunities and pitfalls
2. The pros and cons of using chemical inputs in agriculture
3. Animal husbandry and biotechnology: opportunities, prospects and drawbacks
4. GMO technology: a relevant technology to bring about food security?
5. Breeding / tissue culture: prospects and challenges
6. Aquaculture: a good alternative?
7. Agricultural mechanization in Ethiopia: an opportunity or a threat?
8. Irrigation and food security
9. Can organic farming present a solution to the food insecurity problem?
10. Integrated pest management
11. Agricultural Development Led Industrialisation (ADLI) policy in the context of agricultural modernization
12. Voices of peasants

Over 300 participants including BSE members, as well as invited guests from various relevant governmental and non-governmental organizations are expected to attend this Conference.

Finally, I would like to extend my sincere appreciation and gratitude to our collaborators in this Workshop: Christian Relief and Development Association (CRDA), the Ethiopian Science and Technology Commission, the Environmental Protection Authority, Ethiopian Agricultural Research Organization, the Department of Biology (Addis Ababa University) and the Institute for Sustainable Development. Our heartfelt thanks also go to Meta Brewery for its material contribution towards the social evening of the Workshop.

I bid all of you welcome on behalf of the Biological Society of Ethiopia and the Organizing Committee of this Workshop and now call upon Ato Gemechu and Ato Abadi, farmers from Zeway (Oromia) and Axum (Tigray) to give us a keynote address.

Thank you.
MODERNIZING ETHIOPIAN AGRICULTURE: THE WAY TOWARDS FOOD SELF SUFFICIENCY

Takele Gebre

ABSTRACT

It helps to remember that everything is connected. Without adequate natural resources conservation, soils become depleted. Without fertile soil, food production declines and the threat of hunger increases. Without secure food supplies, Ethiopia cannot prevail as a viable nation. It is thus essential that the social, environmental and physical conditions in Ethiopia remain conducive in order for this generation and also for the generations that follow to prevail. However, nothing less than a new agricultural production system, a system that is intentionally intended to be different from the traditional method of farming, is more suitable for use at the present time. We must understand that the traditional agriculture production system in Ethiopia is incapable of feeding the ever-growing population mainly because most of the soil has become depleted as a result of the mining of the soil nutrients throughout centuries of cultivation. We know our choices are limited. We have either to produce or to buy or to beg the food we eat. This generation knows quite well that to beg the food one eats is dehumanizing and therefore it is not a viable choice. We know that more than enough food is being produced elsewhere in the world with the use of modern agriculture production techniques, the viability and wisdom of which we seem to be debating about currently, but we do not have the resources to buy this food. The most viable alternative, therefore, is to opt for the domestic production of the food we need to eat, while at the same time maintaining healthy social, environmental and physical environment. The cruel truth is Ethiopian traditional agriculture is no longer able to feed the growing population. It is in fact sliding below the level of subsistence agriculture. It is high time indeed that we stop romanticizing peasant agriculture in Ethiopia. It has failed even to prevail as a way of life. It has no hope and no future since it does not offer any certainty to human and environmental well-being and health.

INTRODUCTION

This paper tries to point out the need for the modernization of agriculture in Ethiopia. It also highlights the origins of the debate for and against the modernization of agriculture and argues that Ethiopia, as a country, must take a rational decision in favor of modernization.

It also tries to caution intellectuals in Ethiopia who engage in such debates and who may happen to have been caught between the fights of interest groups in the

1 Program Coordinator, Sasakawa Global 2000 Agriculture Project in Ethiopia.
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West to judiciously balance the possible effects of their contributions in such debates on the overall performance of the agriculture sector in the country. It stresses that there is an urgent need to modernize agriculture in Ethiopia. It emphasizes that this fact must be properly understood by all concerned as the gravity of the level of poverty and food insecurity in this country is so severe that there is no alternative to modernizing agriculture in the short and medium term, as peasant agriculture is no more able to supply the food necessary for the growing population in the country. The paper also provides some recommendations that may help in transforming peasant agriculture to market oriented small-scale agriculture.

THE FUTURE OF PEASANT AGRICULTURE IN ETHIOPIA

Ethiopia is one of the poorest countries in the world where economic development has stagnated over the last five decades. The political and economic structures of the country have been subjected to repeated and profound changes during the last three decades. These frequent changes have become cause for instability in political and socio-economic policies and have contributed to the problems of poverty and food insecurity. Per capita food production has declined. In consequence, about 30 million people (nearly 43 per cent of the population) are chronically undernourished and cannot live healthy and productive lives and over 50 per cent of the population suffers food insecurity. Many of the poor live in rural Ethiopia. Most rural households operate under the threat of poor rainy season. Many of them are able to manage the shock of a single poor rainy season and transit in and out of food insecurity when the rains resume the following season. But cumulative shocks of consecutive poor seasons push some households into chronic food insecurity or even destitution (USGS et al., 2003).

In Ethiopia, smallholdings or family farms provide almost all of the agricultural output, and employ the bulk of the population. This has been the case in the past when the population was much less than what it is today and land holding per farm family was much larger than it is today. It is also the case today where about 85 per cent or close to 60 million people directly or indirectly depend on agriculture for their livelihood. The truth, however, is that the current mode of rain-fed traditional agriculture production by present day smallholder farmers has not been able to feed the population.

An estimated 11 million smallholder households farm about 10 million hectares of land applying traditional low-input/low-output rain-fed farming practices. This accounts for almost all of agriculture output in the country. Warm temperatures, abundant sunlight, and vast land areas can permit Ethiopian agriculture to thrive. Yet agriculture in this country displays one of the lowest yields in the world.

We all know that present day small-scale and traditional agriculture producers in Ethiopia have failed to produce enough food and to contribute to poverty reduction and national food security. The present physical, social, economic and cultural environments in rural Ethiopia have not provided the necessary conditions to
enable them to achieve this. Current practices in agriculture have not and will not in the future be able to support the food needs of current and future generations.

In the years to come many impoverished Ethiopians without adequate access to food will face debilitating hunger and malnutrition, as seen in the high rate of stunting in children, and increased susceptibility to disease.

Population growth plays a significant role in food shortage. Average population growth in Ethiopia has been about 1.8 million people a year from 1995 through 2002, adding in full about 3.3 million q.t. a year to the national food grain requirements. Even in a year of average crop production, Ethiopia is unable to meet its own food crop requirements with present production techniques, based entirely on traditional mode of production and unreliable rainfall. The increasing population simply aggravates these already substantial production deficits.

If present trends in population growth, food production, rural poverty and natural resource degradation continue, it is conceivable that Ethiopia would need to import between 2.2 to 3.4 million metric tons of food stuffs every year to feed its population. The country will not have the economic capacity to procure such huge volumes of food on commercial basis, nor is it likely that the international community will be willing to provide food aid of this magnitude on a long-term basis (Sasakawa-Global 2000, 2003).

The peasant agriculture production system that has prevailed in Ethiopia for centuries has, since the last three decades, picturesquely failed to provide the food necessary to feed the producers themselves, leave alone to provide the food for urban consumers. It cannot, at least from now on, seriously be expected to outlive its own failure. Efforts directed at reforming subsistent agriculture will not help much because the very basis for its prevalence - subsistence – makes it incapable of undergoing significant change. It can only be transformed and as a result it has to go through gradually.

Similarly, life in rural Ethiopia is not at all enviable. It is not thus fair at all to try to romanticize low input-low output hand-to-mouth subsistence agriculture. It has to become transformed to at least small-scale commercial agriculture. Transformation of peasant agriculture to small-scale market oriented commercial agriculture entails the use of modern agriculture technologies. It asks for agriculture modernization.

**AGRICULTURE MODERNIZATION: A VIABLE WAY-OUT FOR ETHIOPIA**

There is need for departure not necessarily from a smallholder model of agricultural development but from subsistence and hand-to-mouth mode of agriculture production. This implies that there is need for the introduction of a major discontinuity of the most common mode of agriculture production in this country. Many people are concerned about possibilities of many unforeseen consequences if change is to be introduced to the Ethiopian traditional agriculture
production system but the alternative - maintaining the status quo - is not the answer either because current day Ethiopian agriculture has not successfully adapted to increase in production in response to rapid population growth. It is also clear that the competitiveness of Ethiopian agriculture will have to improve for it to fulfill expectations in the face of international trade liberalization. Above all, the fact of the matter is that small-scale traditional low input/low output family farming which has supported Ethiopia for thousands of years is now vulnerable under conditions of recurrent drought, growing population, uneconomic size of landholding and also under conditions of open competitive global markets and processes of globalization.

The UN Millennium Development goals call for a 50 per cent reduction in global hunger - from 22 per cent to 11 per cent by 2015. Unless there is a dramatic improvement in current trends, it is highly unlikely that Ethiopia will be able to achieve such a target. Only sustainable and modern agricultural development can reverse this bleak scenario.

In Ethiopia, technologies to increase agricultural productivity have been generated and made available by national and international agriculture research institutions. There is also fairly well organized agriculture extension system that can disseminate the use of these technologies among smallholder farmers. However, it has not been possible, so far, to effectively achieve technology transfer at a satisfactory level.

Many observers have provided different reasons for the repeated failure to effectively transfer improved agriculture technologies among peasant farmers in Ethiopia. Some associate the reasons for failures with the “lack of political will (both national and international) to create the conditions necessary to transform agriculture”. This implies that unless serious efforts are made to transform subsistence agriculture to some form of market oriented modern agriculture, Ethiopia may not solve the chronic problem of inadequate food production. It is important to understand that subsistent farmers produce primarily for their own and family subsistence. They perceive their activities as a way of life and not as an agricultural enterprise or a business in agriculture. To say the least, interventions primarily directed at introducing small reforms to peasant agriculture are not much better than hoping to prevent a house from collapsing due to old age through having it whitewashed. This will never solve the chronic problem of inadequate food production in this country.

Efforts made so far in Ethiopia to reform peasant agriculture through the introduction of improved agriculture technologies only - without giving due attention to other components of agriculture development at the same time - have not resulted in sustainable development. Such efforts were focused at enabling smallholder farmers to increase production so that they would be able to produce enough for the family consumption and perhaps some more for the market. Such interventions have fallen short of ensuring the realization of the proper functioning
of the entire continuum of agriculture development—production, input supply, input credit and output marketing.

In fact, the availability, proper functioning and synchronization of these components of agriculture production system bring about the modernization of agriculture. Modernizing agriculture is the use of science-based agriculture production technologies. It is the adoption of modern farm management principles and it is the introduction of efficient and profitable business management systems. Modernizing agriculture is more than just using agro-chemicals and inorganic fertilizers.

There seems to be no choice for Ethiopia but to work hard and set a vision at gradually transforming peasant agriculture to modern agriculture at the medium and long term. Only modernization can get agriculture moving in Ethiopia. A number of conditions are necessary to realize this goal. These include ensuring the availability of improved agriculture inputs and the provision of services such as input credit and output marketing along with making a serious effort at creating off-farm job opportunities and enabling farm households to operate on a more economic size of farm land.

**THE ISSUES IN THE DEBATE**

There have been some serious debates, first among intellectuals and interest groups in the West, and currently among some intellectuals within the developing world, including Ethiopia, over the merit of modernizing agriculture.

There seems to be no major disagreement over the critical role of agriculture in Ethiopia’s economic development. It is generally accepted that agriculture has been growing more slowly than population and that this has resulted in decreasing income in real terms.

However, there is considerable difference in opinion over the strategy that needs to be adopted to produce food and other agricultural products for the growing population. While some advocate for the use of modern (science based) agricultural technologies to produce enough food and other products others believe that the use of modern agricultural technologies, particularly agro-chemicals and inorganic fertilizers, is too dangerous to the environment and therefore, must be avoided.

There are historical backgrounds that have lead to the rise of these opposing schools of thought. In the 1950s combating hunger by raising agricultural productivity was the sole mission of governments and rural and agriculture development organizations. During that time agricultural research and development organizations had a clear strategy for spreading technical innovations. Crop breeding programs developed improved varieties of the major cereals. Together with appropriate crop management practices these varieties were disseminated on a huge scale, particularly in more uniform and favorable environments, mainly through national extension services. This “classical” technology transfer approach gave extraordinary results, boosting food crop
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production, bringing down the price of key staples, and thus generating enormous economic benefits. This activity also delivered large environmental payoffs by making it less necessary to bring fragile marginal lands to food production (Fig. 1).

![Cereal Production Area Saved Through Improved Technology, 1950-1999](source: FAO Production Yearbooks and AGROSTAT)

At the same time though, agriculture intensification put pressure on the environment, as reflected in declining soil fertility and contamination of water supplies through excessive use of agrochemicals. Moreover, despite large gains in agriculture productivity, hunger persisted in some regions of the world. Most disconcerting, though, rural poverty proved very difficult to control throughout the tropics, casting a long shadow on the great technological, economic, and social achievements of the 20th century.

This lead to the rise of pressure groups, since the late 1970s, who engaged in advocacy against the use of agrochemicals and inorganic fertilizers. These advocacy groups, now generally known as “environmental” groups have become more and more vocal since then and have been able to greatly influence decisions at all levels world wide. A considerable number of environmental groups have emerged with some diverse views. While some of the environmentalists tolerate the judicious use of inorganic agricultural inputs, others totally reject the use of external inputs. Some environmental groups are openly pro-traditional subsistence agriculture.

People in this category assert that it is important to critically assess the cost benefits and sustainability of high input production strategies for resource-poor farmers. They also observe that “increased dependency on inputs and on cash...
income for food production increase farm household vulnerability and raise fundamental questions about the sustainability and desirability of high input production strategies” (Abiye Alemu and Williamson, 2002).

On the other hand, in response to challenges of modernizing agriculture, some R&D institutions and many other organizations have embarked, since the 1990s, on new initiatives aimed at achieving a new wave of economic impact that would reach into previously neglected corners of the tropics while preserving the natural resource base on which rural livelihoods depend. This new school of thought is moderate in outlook in that it advocates for the combined use of organic and inorganic sources of plant nutrients to produce food in the tropics.

At the same time the “Technology Transfer” model of agriculture development still maintains firm believers and followers who affirm that environments in the tropics that enjoy favorable moisture can produce the food required to feed the growing population with the use of science-based improved agriculture technologies.

ETHIOPIA MUST HARNESS SCIENCE AND TECHNOLOGY IN AGRICULTURE

This country must try its best to harness what science and technology could offer in order to transition to sustainable agriculture development. The world already has crops that produce greater yields and soon these crops will resist pests and diseases while offering positive nutritional, health and environmental attributes (Amoako, 2003). Although the future is too far away, Ethiopia can and should benefit from such products of science and technology. We must take advantage of current and future products of science and technology.

MODERNIZING AGRICULTURE ENTAILS GOOD SOIL NUTRITION MANAGEMENT.

Traditional farming systems result in mining soils of plant nutrients by removing both the grain and crop residues without replenishing these nutrients by fertilizers or organic nutrient sources. Nutrient leaching and soil erosion further aggravate the problem. It is estimated that N-P-K nutrient loss from Ethiopian highland soils per year due to plant uptake and soil erosion is 2.25 million tons. The calculated annual loss due to soil erosion is 649,000 tons N-P-K plant nutrients. When crops are starving from nutrient depletion, no matter what the husbandry practice is, the yield will invariably be low.

Soil Fertility. Most agricultural soils in Ethiopia are low in fertility or they have been depleted of the mineral plant nutrients to the point that under traditional agriculture, crops growing on such soils produce one ton or less of grain per hectare. Such “starvation yields” continue to further degrade the soils and are insufficient to assure food security for the rural population themselves, let alone provide the food necessary to feed urban dwellers. Unless soil fertility is brought back into the production equation, there is no way that yields will be increased. The
fertilizer nutrient consumption per hectare of arable land in Ethiopia is estimated at 18 kg (Fig. 2). Ethiopia needs to develop a national action plan for soil fertility restoration and maintenance. The single-most important biophysical factor that constrains food production and land productivity is depleted soil fertility over most of the Ethiopian agricultural landscape.

In addressing the challenges of soil fertility recapitalization, it is wise to combine the best-available scientific knowledge with pragmatic interventions. From a biological standpoint, it makes no difference to the plant whether the plant nutrient it requires comes from a bag of fertilizer or decomposing organic matter. Too many people in the developed world and some elites in this country hold romantic views of sustainable agriculture through organic farming. These views have polarized discussions as to the importance of organic fertilizers versus chemical fertilizers and this could negatively affect the thinking of decision makers at government level in setting the right priorities for the development of agriculture. The debate should be shifted from the biological—where either inorganic or organic nutrients can supply needed plant nutrients—to the economic, where issues of risk and cost are the most relevant factors to consider.

Under reliable moisture conditions in environments with high production potential, chemical fertilizers are the best option to increase yields and must be strongly recommended, while in low-moisture, marginal rainfall conditions, reduced levels of chemical fertilizers (particularly P and sometimes K) and rotations of grain crops with nitrogen-fixing leguminous plant species, may be the best-bet technologies to use.
After low soil fertility, water availability is the second most-serious limiting biological constraint for agricultural production in Ethiopia. Only about 5.5 percent of the arable land base in Ethiopia is irrigated (roughly 0.2 million ha out of 5.6 million ha,) compared to 40 percent in South Asia and 25 percent in East Asia. In addition, roughly 60 percent of Ethiopia’s agricultural lands frequently experience serious moisture stress and the remaining 40 percent moderate moisture stress. Thus, there is a compelling need to develop Ethiopia’s water resources. Most economic studies on large-scale irrigation projects conclude that they are too expensive, and not cost-effective. However, much can be done with small-scale irrigation systems, which include rain-water harvesting techniques, shallow lift pumping along rivers, lakes and streams and shallow underground aquifers. Clearly, a greater expansion of irrigated area in Ethiopia can do much to increase production and reduce food insecurity provided that this is coupled with improving the fertility-base of the soils and improved crop husbandry practices.

The present situation in chemical fertilizer consumption in Ethiopia requires urgent attention. At present, average consumption of fertilizer nutrients per hectare of arable land in Ethiopia is not more than 30 kg/ha, compared to rates 6 to 60 times higher in other regions of the world. Fertilizer consumption in Ethiopia has been.

Fig. 2. Fertilizer nutrient consumption per hectare of arable land in selected countries, 2000 (Source: FAOSTAT, July 2002)
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stagnant since 1996—at around 160,000 metric tons of nutrients—despite the addition of more than 6 million people and the continuing decline in soil nutrient balances. Unless this disastrous situation is changed radically, there is little hope for accelerating agriculture production at the pace—5-6 percent per annum—that is generally agreed to be needed to produce enough food and contribute to poverty reduction and national food security.

THE WAY FORWARD

To modernize Ethiopian agriculture a number of interventions must be considered. First, the entire farming enterprise—food and cash crops, livestock, and cash crops, livestock and value added processing—needs to be recognized in agricultural development strategies. Second, greater attention must be given to post production market linkages—especially grain markets and agro processing—industrial production. Third and most important, commercial food production and processing must be profitable if farmers and agribusinesses are to invest in agricultural intensification.

At the other end of the production continuum are extremely resource poor farmers located in less favored environments where production is more risky and costly. Here technologies that require fewer externally purchased inputs must be used to secure minimum levels of family food security.

Technologies are needed for both lower- and higher-risk production agro-ecologies of smallholder farmers. However, it is important to underline the need to give priority attention to develop and intensify production in the higher production environments first, not only as a means to ensure national food security, but also because over time, prosperity in the higher production environments will generate the resources needed to pay for the development of the most marginal environments.

Farmers in Ethiopia must also have secure access to the land resources if agriculture intensification is to be accelerated. Access to land and security of tenure are two necessary conditions for farmers to invest on improving the soil resource base for sustainable agricultural intensification.

Ethiopia has a major challenge to face. It is going to be tough to meet these challenges successfully unless it harnesses science and technology for sustainable agriculture development. Although sustainability is a direct function of institutional development, human and physical capital accumulation and productivity, it is possible to address the major problems of Ethiopia’s agriculture with existing agriculture technologies. Recurrent drought and other factors make it very difficult for rural Ethiopian households to manage their own food security. If we also consider additional factors such as climate variability, rapid population growth, poor infrastructure, rugged terrain and soil degradation, it becomes obvious that reliance on low-input, low-yield rain-fed agriculture on small plots will not solve the pervasive problem of rural hunger and poverty. This makes it
imperative for Ethiopia to boost crop and livestock productivity and rural incomes to address food insecurity in the short term.

To intensify agriculture farmers must provide to the crops, adequate plant nutrients by increasing the use of mineral fertilizers. This can be combined with organic sources of inputs that build up soil organic matter, and the complementary process of using improved seeds, proper plant population, weed control, and other husbandry practices (Palm et al., 1997). Increased fertilizer use in Ethiopia, particularly in high moisture localities, can create a win-win situation by promoting a very efficient crop production system and reducing soil degradation. If, however, farmers do not replenish the nutrients that are removed from the soil by harvested grain and straw, agriculture will simply die, as we are currently witnessing agriculture dying in parts of northern Ethiopia. This is not a new lesson. It is a lesson as old as agriculture itself. Entire ancient civilizations prospered when they had good agriculture soils and collapsed when their soils were degraded to the point that their agriculture could not feed the population. It is absolutely important to realize that this lesson is still valid today.

Plants grow and animals flourish where there is water. There can be no agriculture where there is no moisture. Therefore, for agriculture to prevail, the availability of adequate amount of moisture is absolutely important. Modernizing agriculture entails making sure that water is made available. The medium and long-term strategy of Ethiopia must, therefore, focus at making water available to agriculture areas in the semi arid and arid regions of the country where small, medium and large-scale commercial agriculture can be developed.

The fact that the environment must be properly protected cannot be overemphasized. We have only one planet and we must keep it safe. We also have responsibilities to feed ourselves. Other nations have successfully managed to produce their own food and at the same time maintain healthy environment by judiciously benefiting from what science and technology have provided them. Ethiopia cannot become any different. Excessive use of agro-chemicals must be avoided. Judicious use of organic and inorganic sources of agricultural inputs must be encouraged.

Most of all, Ethiopia cannot afford the luxury of engaging in debates over the merits of modernizing its agriculture. There is not much choice but to do whatever is possible to increase agriculture production in this country. We must work hard to transform agriculture. Agriculture in Ethiopia must be modeled and formulated in a way that it is able to provide food and a decent income to those engaged in the enterprise.

SUMMARY AND RECOMMENDATION

The government of Ethiopia must focus on domestic food production through agricultural modernization as one of its priorities. Agricultural modernization must be a focal point in any rural development program. Soil fertility restoration must
be a central point to any strategy to intensify agriculture production. Judicious use of chemical fertilizer can play a major role in this endeavor. The Ethiopian government needs to ensure that input supply systems for fertilizers improved seeds, crop protection chemicals, veterinary medicines, etc. are made available for agriculture producers. Development of roads and transport systems must be accelerated in order to speed up the transformation of agriculture and the markets.

Increasing food productivity and production in Ethiopia is necessary but not sufficient for poverty reduction and national food security. Access to food and improved nutrition are also equally important. Sustainable agricultural intensification can help to increase the supply of food and lower real costs through the adoption of technologies that increase labor productivity.

REFERENCES


MODERNIZING ETHIOPIAN AGRICULTURE THROUGH SPACE TECHNOLOGY APPLICATIONS AIMED AT PRECISION CROP MANAGEMENT

Daniel Kassahun

ABSTRACT

The Ethiopian agriculture is well documented for suffering from biophysical factors like water stress (due to inadequacy and poor rainfall distribution), menacing disease and pest infestation, unwise land-use system, and the likes. These problems are further worsened by the dearth of objective, accurate, and timely information induced from various bottlenecks of conventional data acquisition system, like expansiveness and ruggedness of the Ethiopian topography, inaccessibility of the prime agricultural areas, scarcity of skilled personnel in many disciplines, and the likes. When such circumstances are coupled with the diverse agro-ecological conditions of the country, it is practically difficult to promote site-specific crop management through modern approach of precision farming, which requires higher volume of data. Coping with these age-old challenges calls for the need for modern alternative approach.

Acquisition of pertinent data through earth orbiting satellites has demonstrated tremendous advantages due to possibilities of wider area coverage, fast data acquisition, access to inaccessible areas, and the objectivity of obtainable data. Through multi-spectral sensors, parameters like crop acreage, biomass, yield, incidence of pest and diseases, dynamics of land cover and land use, could be detected, monitored, and analyzed effectively. Such digital spatial information could be stored, manipulated and presented through the modern tool of Geographic Information System (GIS).

In Ethiopia, there is a growing interest to harness satellite data for agricultural applications. Therefore, it is high time to examine the sensor-induced specifications (spatial, radiometric, and temporal resolutions) and environmentally induced factors (prevalence of cloud cover, size of target parameters, size of farm plots, spectral response of target parameters, dynamics of the phenomena, etc.) that are fine-tuned to the Ethiopian agro-ecosystems. To this effect, this paper offers the conceptual framework of the specific contributions and of the inherent pitfalls from applying space technology to advance precision farming, which are tailored to the Ethiopian condition. Results obtained from this study helps not only to guide the future exploitation of satellites from the right perspective, but also for saving unnecessary expenditures induced by unforeseen drawbacks.

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INTRODUCTION

Agriculture is a key and dynamic resource. In Ethiopia agriculture is the mainstay of the economy, where about 85 percent of the population is engaged and makes 50 percent of the GDP. This shows the unbearably heavy dependence on the land, water and climatic resources of the country. The salient features of Ethiopian agriculture include subsistence orientation, fragmentation and small-sized land holding, vulnerability to man-made and natural disasters.

Elsewhere in the world, crop production is a function of the biophysical, socioeconomic, and agricultural management factors. These factors do vary both spatially and temporally. Such apparent variations are highly pronounced in the Ethiopian context, where there are widespread and diversified agro-ecological settings. Hence, an emerging agricultural concept called Precision Crop Management (PCM) becomes a vital issue in Ethiopia.

In a bid to ensure food self-sufficiency through enhanced productivity, PCM targets crop and soil inputs in accordance with the fine tuned requirements within the field. It is the convergence of biotechnologies and other agricultural technologies with space and informatics, such as Global Positioning System (GPS) and Geographic Information System (GIS). Moreover, PCM optimizes profitability, agricultural inputs (fertilizers, pesticides, water etc.) at a variable rate technology (VRT), and environmental protection. Such wide function of PCM makes it to be data-hungry, with acute demand for crop- and soil-based information.

According to Moran et al. (1997), PCM requires three basic types of information, which include: (i) information on seasonally stable; (ii) information on seasonally variable (such as soil moisture, weed or insect infestations and crop disease); and (iii) information required to diagnose the cause of the crop yield variability and develop a management strategy. These call for sustained data acquisition system, where the conventional systems of data acquisition are hardly enough. On the contrary, the conventional acquisition of agro-information suffers from drawbacks of limited area coverage, long time requirement, and is prone to errors and subjectivity (Jenson, 2000). Therefore this paper is primarily aimed at bringing the potential of satellite generated digital data for efficient and timely information acquisition system in the Ethiopian context.

SPECIFIC OBJECTIVES

1. To illustrate the concept of agro-data acquisitions through space technology applications;

2. To assess the potentials and constraints of space technology applications in the Ethiopian context; and
3. To propose ways of harnessing space-based technologies in a bid to modernize the Ethiopian agriculture.

**BASICS OF AGRO-DATA ACQUISITIONS THROUGH REMOTE SENSING**

**Digital data from satellites**

Remote sensing is a process, which detects, identifies, and monitors surface phenomena without actually coming into contact (Jensen, 2000). Satellites acquire digital data in the reflectance, thermal or microwave portions of the electromagnetic spectrum (EMS). Measurements of EMS are either from satellite-, aircraft- or ground-based systems. The height of satellites varies from approximately 700 km (sun synchronous), which orbit the earth (Fig. 1) to some 36,000 km, which are geostationary. The sun-synchronous orbiting satellites are employed for natural resource monitoring. They are orbiting the earth from north to south (Figure 1). The most widely used sun-synchronous orbiting satellites are outlined on Table 1.

![Satellite and Earth's Rotation](image)

**Fig. 1 A near-polar sun synchronous orbit.**

Remote sensing has a global coverage. Since 1972, after the launching of the first satellite called Landsat, every part of the world has been detected and monitored at various temporal resolutions. This satellite data could be purchased from commercial and/or government agencies. The data is obtainable either digitally or as black and white or in color prints.

Through satellites, targets can be detected at different resolutions, comprising temporal (the repeat characteristics of the satellite), spatial (the area covered by the image), and spectral (refers to the bandwidths) resolutions. Satellites are
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extraordinarily flexible in spatial coverage, and acquire timely information over a large area at a moderate cost. It is more detailed than field surveys. The images can be manipulated by computers to highlight features of soils, vegetation and clouds.

Table 1 The spectral, spatial and temporal characteristics of commonly used sun-synchronous satellites (Source: Modified from Moran et al., 1997).

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Number of bands (spectral resolution)</th>
<th>Pixel resolution (spatial resolution)</th>
<th>Repeat cycle (temporal resolution)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA 5</td>
<td>5</td>
<td>1.1 and 4 km</td>
<td>12 hrs</td>
</tr>
<tr>
<td>Landsat 7</td>
<td>7</td>
<td>30 m and 120 m</td>
<td>16 days</td>
</tr>
<tr>
<td>SPOT 4</td>
<td>4</td>
<td>10 m and 20 m</td>
<td>26 days</td>
</tr>
<tr>
<td>IRS-1C 5</td>
<td>5</td>
<td>5.8, 23, &amp; 70 m</td>
<td>24 days</td>
</tr>
<tr>
<td>ERS 5</td>
<td>5</td>
<td>1 km and 30 m</td>
<td>3 days</td>
</tr>
<tr>
<td>JERS 8</td>
<td>5</td>
<td>20 m and 18 m</td>
<td>44 days</td>
</tr>
<tr>
<td>RADARSAT 1</td>
<td>1</td>
<td>28 m</td>
<td>24 days</td>
</tr>
<tr>
<td>MODIS 18</td>
<td>18</td>
<td>0.25 km, 0.5 km, 1 km</td>
<td>1-2 days</td>
</tr>
<tr>
<td>ASTER 14</td>
<td>14</td>
<td>15 m, 30 m, 90 m</td>
<td>5 &amp; 16 days</td>
</tr>
</tbody>
</table>

Spectral characteristics

A spectral characteristic is a non-destructive data acquisition system. The optical properties of crops and soils are wavelength-dependent (Fig. 2). Variability in reflectance are caused by biophysical and biochemical makeup of crops and soils (Jensen, 2000). The plant EMR interaction is dictated by the plant architecture, density, and distribution. Moreover, it is dictated by pigmentation, and thermal emittance, where such characteristics could be best indicators of the well being of crops (Fig. 3 and 4).

The reflective portion of the EMS ranges from 0.4 to 3.75 μm, which can be further subdivided into the visible 0.4-0.7 μm, near infrared (NIR), 0.7-1.1 μm, and mid-infrared 1.1-3.75μm. The pigment in plant leaves, chlorophyll, strongly absorbs red light for use in photosynthesis, while the NIR light is strongly reflected by the internal spongy mesophyll leaf structure, which leads to the higher values in the NIR channels (Jensen, 2000). The more leaves the plant has, the more these wavelengths of light are affected. Most satellites have channels in the red and NIR where most vegetation indices are combinations of these two reflective bands.

Normalized Difference Vegetation Index (NDVI) is the commonest index (Kriegler et al., 1969; Rouse et al., 1973, quoted in Silleos et al., 2002), which is calculated as NDVI = (NIR - R)/(NIR + R). The value of NDVI ranges from -1 to +1. The NDVI estimate has empirical correlation with LAI, percent vegetation cover, drought condition, impacts of moisture deficiency on vegetation, vegetation primary productivity, vegetation phenology, fraction of absorbed photosynthetically active radiation, and crop yield (Tucker, 1979; Sellers, 1985; Tian, 1989; Kaufman and Tanre, 1992; Thenkabail et al., 1994; Leprieur et al., 1996). This empirical correlation allows monitoring the seasonal variability of soil
moisture content and crop parameters, like crop nutrient deficiencies (Buschmann and Nagel, 1993; Fernandez et al., 1994), crop disease (Toler et al., 1981; Malthus and Madeira, 1993), weed infestation (Brown et al., 1994; Brown and Steckler, 1995), and insect infestation (Vogelmann and Rock, 1989; Penuelas et al., 1995).

Fig. 2 Spectral reflectance curves of vegetation, soil, and water (After Jenson, 2000).

Fig. 3 Spectral signatures of normal and diseased crop

Vegetation Index

Besides crops, multispectral satellite data can be effectively used in soil erosion assessments. This is due to the strong interrelationship between EMR and soil properties, which enables to detect and assess the soil texture, soil moisture, soil organic matter, macronutrients (Moran et al., 1997; Daniel et al., 2003, 2004), etc. Satellites could generate essential input data in erosion models, characterize the land cover management (C) and the practice (P) factor in the Universal Soil Loss Equation (USLE) model (Lantieri et al., 1990; Pilesjo, 1992). Among different
components of the USLE, the C facto varies markedly, and satellite sensors can
detect and monitor it at a faster speed on a wider area coverage. Determination of
soil properties through satellite data are good source of information for sheet
erosion detection (Asrar, 1989).

![Image of crop vegetation stress and improper planting practices]

**Fig. 4** Crop vegetation stress and improper planting practices

**OPPORTUNITIES FOR MODERNIZING ETHIOPIA'S AGRICULTURE THROUGH SPACE TECHNOLOGY**

The efficient utilization of the satellite-generated data could play vital role in
modernizing the agro-data acquisition system of Ethiopia. The following are some
of the areas of applications.

**Selection of suitable expansion areas of cultivable lands.**

The land use pattern estimates of Ethiopia by FAO/UNDP (1984) puts that
currently only 15 percent of the total area of Ethiopia is being under arable
farming. The estimate further indicates that still 17 percent more of the country
could be utilized for cultivation. Those unutilized and potential areas need to be
adequately surveyed and assessed for their use potential before any settlement or
expansion is implemented. Currently, the Ethiopian government is undertaking a
wide range resettlement campaign (*mainly to westward of Ethiopia*), with an
objective of easing the overstress in most of the existing farmlands due to the high
agricultural population density and persistent crop failure in those areas. Such large
campaigns undoubtedly require fast and objective resource information over a wide
geographical coverage, where satellites could come into picture.
Identification of suitable irrigable lands.

Ethiopia is splendidly endowed with abundant water resources. Paradoxically, the crop cultivation in Ethiopia is predominantly of rain fed, which is at the mercy of the rain. Therefore, it repeatedly suffers from the striking variation in the amount and distribution of rainfall. Estimates indicate that the twelve major rivers of the country have a potential to irrigate a total of 3,495,795 ha, of which only a net area of 161,010 ha (4.6%) is under irrigation (Demel Teketay et al., 2003). This palpable gap calls for the possibility of promoting irrigation agriculture in Ethiopia. This, in turn, calls for fast and objective land resource information, which is reasonably accessible from earth orbiting satellites.

Development of early warning system

Early warning system is a commonly employed technique of assessing the impending hazard ahead of instance. Information obtained through such system allows the user to take the needed action and therefore substantially reduces the hazard. The Ethiopian agriculture is recurrently exposed to most of the yield limiting factors, viz., water stress, crop disease, pest incidence, etc. These incidences might happen at any moment of the cropping season. Due to the wide area coverage and instant data acquisition possibilities of satellites, continuous system of monitoring of such incidence is possible before the problem gets critical (McVicar and Jupp, 1998; Silleos et al., 2002).

Assist agricultural and regional planning

Regional and local planners are fond of figures. Unfortunately, the agro-data acquisitions through conventional system are not compatible enough to the precision sought by planners. Planning would be futile with inaccurate and delayed input data. Kinfe Abebe (2003) stressed the need for strengthening initiatives that ensure the availability of high quality information, which would assist decision-making and management. He pointed out that the available information on the forest and wildlife resources of Ethiopia is quite crude, and it is impossible to make accurate proximate estimate on the lost and existing ones. Information like crop acreage, biomass, and yield (Quarmby et al., 1993) could be processed in a near-real-time manner from the satellite data,

\[
\text{Yield}_{(t)} = A_{(yearX)} + B_{(YearX)} \sum \text{NDVI}_{(t)}
\]

where, \( t \) is the year being analyzed, \( A \) and \( B \) are constants for each crop type and from year-to-year, given a typical growing season. Such possibilities also ease the precarious nature of transportation services in Ethiopia. Besides, the computation of LAI during the grain filling period is very important in planning ahead of the time through yield predictions. NDVI has been proved a responsive indicator and key independent variable for estimating maize production in East Africa, where 36 agricultural districts of Kenya were considered and a robust linear regression was
produced (Lewis et al., 1998). In Ethiopia too, Krause (1992) had successfully
developed a regression model which relates NDVI to crop yield.

Enable precision farming

Precision farming is a concept, which plans to target specific requirements and challenges at farm level. Satellite sensors, coupled with GPS could assist such activities, especially in large farm conditions, due to noticeable inner variations. In Ethiopia the ecological diversity is immense and one can’t apply a blanket approach (as employed currently) of fertilizer, insecticide, seed and herbicide dosage over a large portion of the country. Variations occurring in short distance justifies the need for Variable Rate Technology (VRT), which is the best-developed part of PCM (Moran et al., 1997). Remotely sensed images obtained from aircraft and satellite-based sensors have the potential to provide the maps of the whole field needed for PCM.

Assist resource management schemes

The natural resources of the country are being devastated at an alarming rate. According to Daniel Gamachu (1988), 34% of the total area of Ethiopia (including Eritrea by that time) and about 87% of the total area above 1,500 m, was originally covered by dense forests. A further 20% was covered by woodland savanna. Currently, less than 3% of the total land area is under forests. The Ethiopian Forestry Action Plan (EFAP, 1994) concluded that the deforestation rate in Ethiopia was 150,000 to 200,000 ha per year. Annually, fires decimate large areas of lowland forests and grasslands particularly during dry seasons in dry parts. However, the extent of such consequences has been difficult to acquire and the statistics pertaining to such events has been lacking in Ethiopia (Kinfe Abebe, 2003).

In the highland, the accelerated soil loss is reaching up to 400 tones/ha/annum. Ermias Bekele (2003) noted that approximately 17% of the country’s potential agricultural GDP are being lost because of the soil degradation. Before two decades, when the Ethiopian population was estimated at 42 million, about one quarter of the highlands were seriously eroded, another quarter were moderately eroded and only 20% were free from the erosion hazard (IUCN, 1986). Currently, one can imagine how those figures could have changed after the population has risen to 70 million. The ecology is changing drastically mainly induced by man’s harmful practices. Exact information on the rate and extent of such resource degradation is the primary step towards the solution through effective planning. This information could be obtained from satellite sensors, with their capability of capturing the dynamics of biophysical parameters.
Extrapolate *in-situ* researches to larger area

Ethiopia is a very big country and endowed with diverse agro-ecological conditions. The *in situ* research undertaken by agronomists, ecologists, and other agriculturalists of Ethiopia can't cover up the whole country even in the foreseeable future. RS could easily expand the knowledge gained from few but intensive *in-situ* ecological researches to larger geographical areas at more frequent intervals and over a longer time series (Jensen, 2000).

In general, from the potentials justified above, it is safe to presume that RS is more of a necessity to Ethiopia. However, those possibilities are not without difficulties.

**CHALLENGES OF SPACE TECHNOLOGY APPLICATIONS IN ETHIOPIA**

1. Hard currency requirement for digital imagery;
2. Higher startup: hardware, software, mindware;
3. Terrain conditions: shadow prevalence, due to steep slopes (Table 2); and
4. Cloud and haze contamination in wet seasons (Table 2).

From Table 2, it could be well observed that lowland areas have better opportunities to employ space technology than highlands.

**Table 2 Site-specific challenges and opportunities of satellite applications in Ethiopia.**

<table>
<thead>
<tr>
<th>Highlands of Ethiopia</th>
<th>Lowlands of Ethiopia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small size holding of agricultural fields</td>
<td>Bigger field size</td>
</tr>
<tr>
<td>Commonly crop intermixing system <em>(and variable crop schedule)</em></td>
<td>Mainly of mono-cropping <em>(irrigation based and of little risk)</em></td>
</tr>
<tr>
<td>Dominated by hilly landscape <em>(and maze of valleys and gorges)</em></td>
<td>Dominance of plan surfaces with little hilly areas</td>
</tr>
<tr>
<td>Higher cloud prevalence in most of the year</td>
<td>Clearer atmosphere due to little cloud contamination</td>
</tr>
</tbody>
</table>

**BASIC FEATURES OF HITHERTO APPLICATIONS OF REMOTE SENSING IN ETHIOPIA**

1. Compared to the potential, the application so far is insignificant, which is employed only in small pocket areas of the country. Due to this reason, the potential of satellite application is very little known and applied by agriculturalists.

2. The application has been mostly conducted by foreign-based projects where local experts were insufficiently involved.
3. Comparatively, the application thus far has been essentially on the use of aircraft generated air photo (through visual interpretation) than digital manipulation of satellite imageries.

CONCLUSION AND RECOMMENDATIONS

1. RS can detect and measure several of the biological and physical features of agriculture. This however, doesn’t imply that remote sensing alone is enough to do the business of agro-data acquisition. Therefore, it should be supplemented by ground-based observation.

2. RS observation could provide accurate input information for agricultural DSS and time-critical crop management applications.

3. RS could expand the knowledge gained from intensive in-situ ecological research to larger geographical areas, at more frequent intervals and over long time series.

From the foregoing conclusion, this paper recommends that:

1. Since agriculture is where the bulk of the Ethiopian economy is built upon, developing the economy has a direct relationship with the modernized agriculture. Therefore, it should be given the maximum merit from the satellite technology application.

2. Agriculturalists should be acquainted with space-tech applications, and work in collaboration with space-tech experts. Such multidisciplinary activity helps to gain a value added information system on agriculture (Fig. 5).

3. Many countries have passed through the redundant purchase of satellite imageries, software, and hardware, which demanded them thousands and million of dollars annually by different institutions and organizations. In order to bring efficiency and minimize the unnecessary costs, they are currently trying hard to develop a data sharing system. Ethiopia shouldn’t commit the same mistakes. Therefore, precautionary measures should be taken through the control of redundant data purchase through data sharing scheme. For instance, a single remote sensing imagery of Awash National Park could provide information for various purposes, viz., forest fire risk assessment needed by foresters, quantification of tourist impacts by park rangers, mapping soils and rock formations by geologists and pedologists, and estimate grass biomass available for grazing by biologists.
Fig. 5 An infrastructure that may lead to widespread adoption of image-based remote sensing for precision crop management (Source: Moran et al, 1997).

REFERENCES


ABSTRACT

Biotechnology may be understood as any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for a specific use. In the form of traditional fermentation techniques, biotechnology has been used for decades to make bread, cheese or beer. It has also been the basis of traditional animal and plant breeding techniques, such as hybridization and the selection of plants and animals with specific characteristics. The difference with modern biotechnology is that researchers can now take a single gene from a plant or animal cell and insert it in another plant or animal cell to give it a desired characteristic through the application of in-vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection. These applications produce genetically modified organisms (GMOs). GMO is defined as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology. Genetic engineering promises remarkable advances in medicine, agriculture, and other fields. These may include new medical treatments and vaccines, new industrial products, and improved fibres and fuels. Genetic engineering is a very new field, and much about the interaction of GMOs with various ecosystems is not yet known. Some of the concerns about the new technology include its potential adverse effects on biological diversity, and potential risks to human and animal health mostly in the aspects of allergenicity, toxicity, food contamination and increased antibiotic resistance to disease-causing microorganisms. Other potential areas of concern might be unintended changes in the competitiveness, virulence, or other characteristics of the target species; the possibility of adverse impacts on non-target species (such as beneficial insects) and ecosystems; the potential for weediness in genetically modified crops (where a plant becomes more invasive than the original, perhaps by transferring its genes to wild relatives); and the stability of inserted genes (the possibilities that a gene will lose its effectiveness or will be re-transferred to another host) and several ethical and socio-economic concerns. In this presentation the different methods of gene transfer, the successive developments of the technology and the achievement, hazards, perils and concerns

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will be raised. The convention for biodiversity, the Cartagena Biosafety Protocol and the need for the development and implementation of a National Biosafety framework will be discussed.

INTRODUCTION

Biotechnology promises remarkable advances in medicine, agriculture, and other fields. These may include new medical treatments and vaccines, new industrial products, and improved fibres and fuels. Biotechnology is as old as the history of mankind, but the recent advances compared to the traditional methods outstrip developments in other fields of science.

APPLICATIONS OF BIOTECHNOLOGY IN AGRICULTURE

Biotechnology can be applied to promote or facilitate efficient utilization of plant genetic resources, thereby contributing significantly to the enhancement of socio-economic development, improvement of people's livelihoods, ensuring food security and safeguarding the environment. Some of the main applications of biotechnology in agriculture include the following.

Tissue culture and micro-propagation is the science of growing plant cells, tissues or organs isolated from selected mother plants on defined artificial media under aseptic conditions.

DNA marker-assisted breeding is becoming an increasingly important tool for the identification of crop varieties with improved yield, tolerance or resistance to a number of biotic and abiotic stresses. Through the DNA marker technology, it is possible to identify markers that flank a gene determining a particular qualitative or quantitative trait in the genetic material, thereby simplifying the genetic improvement by conventional breeding method. Molecular markers are not influenced by the environment, and therefore many of the problems associated with breeding programs based on the phenotypic estimation of an agronomic trait can be eliminated by using DNA-based techniques.

Introducing new traits through genetic engineering can enhance the quality and productivity of some crops. In conventional plant breeding, breeders have been introducing genes coding for a particular trait, e.g. drought tolerance from one crop variety to another by crossing two different varieties followed by a number of generations of back crossing to eliminate as much as possible unwanted genetic material that is passed to the offspring. Through genetic engineering however, it is now possible to isolate, clone and introduce genes coding for particular traits into another plant or animal of the same or even different species to produce a transgenic plant or animal, popularly known as genetically modified (GM) organisms. The technique can provide plant breeders with genes coding for higher yield, resistance to pest and diseases, resilience in hostile environments (e.g. salt, cold or drought) and improved nutritional and storage characteristics.
GM Technology has been hailed as a miracle to solve problems such as world hunger, health and environmental degradation, particularly by biotechnology companies, some scientists and governments.

But, one needs to examine the socio-economic and political context in which the technology has been developed.

To do this we need to ask questions such as: What was the purpose of developing the technology? Who controls the technology? How much does it cost? What is the trend of GMOs being developed and for whose benefit?

Genes are short segments of DNA that code for a protein. In essence, they contain the instructions for how to make a certain protein, which is called the gene product. Most genes do not have characteristics specific to the organism in which they are found. Identical genes are regularly found in organisms that are only remotely related. The uniqueness of the organism lies not only in the DNA sequences of its genes, but also the organization of the genes which are present, and at what time and to what extent they are expressed.

In conventional cross breeding techniques, the DNA of two organisms is randomly combined in the hope that the desired trait will be transferred. However, undesirable traits are also transferred and must be removed through selection in the next several generations.

Genetic engineering techniques break down these barriers and offer plant breeders the ability to introduce genes from non-traditional organisms (i.e., organisms outside the gene pool).

Common vectors for gene transfer are *Agrobacterium tumefaciens* and *Agrobacterium rhizogenes*. These bacteria are usually found in the soil and if they infect plants will respectively cause galls or hairy roots through introducing some of their own DNA into the plant. Genetic engineering makes use of this natural transfer of the construct to the DNA of the vector after disabling its capacity as a pathogen.

Biolistics or particle bombardment involves shooting new genes into the potential host. Microscopic particles of Gold or Tungsten that are coated with the construct are loaded in a cartridge, similar to shotgun cartridge, which are then fired at the plant cells.

Particle bombardment is often used to transform monocot plants such as corn, rice and sorghum. Inappropriate wound and hormonal responses render the vector method ineffective for monocots.

Widely used transformations include Round-Up Ready, Starlink and Bt or *Bacillus thuringiensis* toxin carrying crops. Round-Up Ready and Starlink crop plants contain a herbicide-resistance gene that protects the crop from treatment with the broad-spectrum herbicide. These GM crops can be sprayed repeatedly with Round-Up or Starlink to eliminate weeds without harming the agricultural product.
Bt-crops carrying the *Bacillus turingiensis* toxin will debilitate and eventually kill the insect by being activated in the insect gut upon ingestion. Bt toxin specifically binds to cell receptors in the insect intestine and forms pores resulting in loss of membrane integrity.

**Table 1** Genetically modified crops and their altered traits currently available in the market.

<table>
<thead>
<tr>
<th>Input traits</th>
<th>Output traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide resistance</td>
<td>Sugar beet, Soya beans, Corn, Canola</td>
</tr>
<tr>
<td>Insect/herbicide resistance</td>
<td>Corn</td>
</tr>
<tr>
<td>Insect resistance</td>
<td>Tomato, Corn, Potato, Cotton</td>
</tr>
<tr>
<td>Virus resistance</td>
<td>Squash, Papaya</td>
</tr>
<tr>
<td>Modified oil</td>
<td>Soya bean, Canola</td>
</tr>
<tr>
<td>Modified fruit ripening</td>
<td>Tomato</td>
</tr>
<tr>
<td>Provitamin A enriched</td>
<td>Rice</td>
</tr>
<tr>
<td>Iron fortification</td>
<td>Rice</td>
</tr>
<tr>
<td>Detoxification of mycotoxins</td>
<td>Corn</td>
</tr>
<tr>
<td>Detoxification of cyanogens</td>
<td>Cassava</td>
</tr>
<tr>
<td>Caffeine free</td>
<td>Coffee beans</td>
</tr>
<tr>
<td>Vitamin A enriched</td>
<td>Canola</td>
</tr>
</tbody>
</table>

**DEVELOPMENT OF SPECIFIC TECHNIQUES FOR THE DETECTION OF PATHOGENS**

Apart from Enzyme-Linked Immunosorbert Assay (ELISA) and monoclonal antibody techniques, disease specific DNA probes and PCR (Polymerase Chain Reaction) primers have been developed for the detection of specific pathogens in both plants and animals. The DNA based techniques are more precise and efficient than the immuno-serological techniques, and are also used in the development of appropriate forecasting and control mechanisms, as well as in screening germplasm accessions to ensure safe exchange of genetic materials within and between boundaries.

**APPLICATION OF BIOTECHNOLOGY IN ENVIRONMENTAL PROTECTION AND REHABILITATION**

Environmental biotechnology can be used to transform pollutants into benign substances and develop environmentally safe manufacturing and disposal processes. It may be of particular relevance to environmental protection in urban development. One example is bioremediation, which involves the use of living organisms or their products to degrade waste into less- or non-toxic products, or to remove heavy metals like Mercury from polluted soils. Another example is the use of biotechnology to create new biodegradable materials that have the properties of plastics.

In terms of industrial biotechnology it is important to note that the demand for new and improved commercial products will increasingly be met through bioprocessing,
which is manufacturing that employs the chemical, physical and biological processes performed by living organisms or their cellular components. Genetic engineering could create transgenic organisms with commercially useful biosynthetic pathways leading to novel products for industrial uses. Molecular genetic screening techniques will also help scientists involved in fields like biological prospecting to find novel and useful genes and organisms. This involves plants, microorganisms and algae generating commercially attractive compounds (e.g. cosmetics, fragrances and flavours based on natural products) and industrial crops for bio-fuels, fibres, starch products, biodegradable plastics, oils, lubricants and detergents.

APPLICATIONS OF BIOTECHNOLOGY IN MEDICINE

In medicine, bacteria have been altered genetically for mass-production of specific proteins, such as insulin used for treatment of Diabetes mellitus or human growth hormone used to treat children suffering from growth disorder. Another significant advance in medicine is the production of factor VIII, a blood-clotting protein that is not produced or has greatly reduced activity, in people with haemophilia. In this biotechnological procedure, human gene that codes for the blood-clotting protein is transferred to hamster cells grown on tissue culture, which then produce factor VIII in large quantities. Though still at an experimental stage, gene therapy has shown promise in treating some devastating conditions, including some forms of cancer and cystic fibrosis. Genetically engineered vaccines are being tested for possible use against the human immunodeficiency virus (HIV), the virus that causes acquired immunodeficiency syndrome (AIDS).

TRENDS IN BIOTECHNOLOGY

The trend in biotechnology development is becoming more reliable and offers a very promising future. The possible development of drought tolerant crops is very irresistible for a country like Ethiopia where recurrent spell of drought is becoming the rule rather than the exception.

However these developments in biotechnology pose a number of risks and concerns which should be addressed carefully to balance and tradeoff the advantages that can be reaped against the disadvantages that can be accepted.
Modernizing Agriculture: A way out of food insecurity?

Zerihun Woldu

Abiotic stress
- cold tolerance
- drought tolerance
- salinity tolerance

Plants as factories
- vitamins
- long-chained fatty acids
- omega-fatty acids
- industrial fatty acids
- production of enzymes
- biopolymers
- color pigments

Fig. 1 Various promises of crop biotechnology.

HAZARDS, PERILS AND RISKS OF MODERN BIOTECHNOLOGY

Arguments in the use and inappropriate application of crop biotechnology revolve around three major categories and twelve minor categories.

Genetic engineering is a very new field, and much about the interaction of GMOs with various ecosystems is not yet known. Some of the concerns about the new technology include its potential adverse effects on biological diversity, and potential risks to human and animal health mostly in the aspects of allergenicity, toxicity, food contamination and increased antibiotic resistance to disease-causing microorganisms. Other potential areas of concern might be unintended changes in the competitiveness, virulence, or other characteristics of the target species; the possibility of adverse impacts on non-target species (such as beneficial insects) and ecosystems; the potential for weediness in genetically modified crops (where a plant becomes more invasive than the original, perhaps by transferring its genes to wild relatives); and the stability of inserted genes (the possibilities that a gene will lose its effectiveness or will be re-transferred to another host) and several ethical and socio-economic concerns.
Evidence shows that there are potential risks of eating such foods as the new proteins produced in such foods could act themselves as allergens or toxins; alter the metabolism of the food producing plant or animal causing it to produce new allergens or toxins or reduce its nutritional quality or value (Lappe and Bailey, 1998).

There is potential for vector recombination to generate new virulent strains of viruses, especially in transgenic plants engineered for viral resistance with viral genes. In plants containing coat protein genes, there is a possibility that such genes will be taken up by unrelated viruses infecting the plant. In such situations, the foreign gene changes the coat structure of the viruses and may confer properties, such as changed method of transmission between plants. The second potential risk is that recombination between RNA virus and a viral RNA inside the transgenic crop could produce a new pathogen leading to more severe disease problems. Some researchers have shown that recombination occurs in transgenic plants and that under certain conditions it produces a new viral strain with altered host range (Steinbrecher, 1996).
RISKS TO BIODIVERSITY AND ENVIRONMENT

In contrast to natural mutations, which could result in formation of new species only over a long period of time, tend to involve small changes, are entirely random and have negative impacts on fitness of the organism, the "creation of new mutations by man" (transgenes) occur rapidly, do not occur at random and the transgene normally confers some advantage to the organism.

In this regard, the use of herbicide resistant crops undermines the possibilities of crop diversification thus reducing agrobiodiversity in time and space (Altieri, 1994). The potential transfer through gene flow of genes from herbicide resistant crops to wild or semi-domesticated relatives can lead to the creation of superweeds (Holt and Le Baron 1990; Lutman, 1990; Duke 1996). There is potential for herbicide resistant varieties to become serious weeds in other crops. Massive use of Bacillus turingiensis (Bt) crops affects non-target organisms and ecological processes (Hilbeck et al., 1998). Recent evidence shows that the Bt toxin can affect beneficial insect predators that feed on insect pests present on Bt crops. In addition, windblown pollen from Bt crops, found on natural vegetation surrounding transgenic fields, can kill non-target insects such as the monarch butterfly. Moreover, Bt toxin present in crop foliage ploughed under after harvest can adhere to soil colloids for up to 3 months, negatively affecting the soil invertebrate populations that break down organic matter and play other ecological roles (Donnegan et al., 1995; Palm et al., 1996).

RISKS TO SOCIO-ECONOMY

In countries where farmers intend to sell their product at premium prices in certified non-GMO markets, unintended introgression of transgenes may pose a threat to the commercial position of these farmers. Gene flow therefore could result both in loss of markets and in additional costs associated with labelling and separation of GM-free produce because developing countries are usually dependent on a few agricultural products for export, they could not afford market loss through GM gene flow, given that there is a current preference for GM-free products.

If one owns the gene, and it escapes and causes economic and social damage, then the owner should be held responsible. It is the risk of ownership. However, this is not the reality with gene flow i.e. in the environmental field, the concept of "polluter pays" is well established. However, in agriculture, the onus has generally been on the producer of the crop (products) to sufficiently isolate their fields so as to produce a "pure" product.

A patent owner of a GMO may enforce intellectual property legislation if gene flow has taken place i.e. that introgression of patented genes may sooner or later lead to claims by the holder of the patent, even where the genes were introduced unintentionally. In developing countries, because of small farm sizes, it would not be possible to prevent gene flow from GM to non-GM crops and that if farmers were sued by seed companies for breach of patents following gene flow, they
would suffer serious economic consequences. The difficulties of setting standard isolation distances for GM populations as "pollen- and gene-flow are inherently variable phenomena" (potentially influenced by factors such as wind speed, atmospheric stability and turbulence, pollen viability and other biological factors) meaning that "it would be unwise to base decisions on a few field trials." Because farm sizes are small in developing countries, there will not be any space left to set up a refuge.

**ETHIOPIA'S CHOICE**

Over 50 years ago, Vavilov (1951) alerted the scientific community to the value of conserving plant genetic resources to identify useful genes for breeding programs. More recently, other researchers have also highlighted the usefulness of molecular tools to plant breeders. In Ethiopia, there is an urgent need to build the capacity in gene discovery, where in the absence of such programs, many of the crop genetic engineering ambitions would be "copycat" applications borrowing existing genes from developed countries. These may not necessarily provide the most effective solutions to local problems in the country. In addition to this, Ethiopia has an abundance of untapped, indigenous knowledge and genetic wealth, which could be beneficial for the economy. There has also been concern expressed that the Biodiversity Convention does not clearly entrench adequate intellectual property right (IPR) protection for indigenous knowledge. There is also a school of thought that IPRs are inappropriate when applied to plant genetic resources in developing countries, since this benefits industrialized countries. A more practical approach, however, would be to build local capacity in developing the country, in collaboration with developed countries, in order to identify local genetic wealth, and then use this to address specific local problems.

It is obvious that Genetically Modified Plants (GMP) and a GMP-free future are mutually exclusive. If for example some administrative zones in Ethiopia want to introduce GMPs while others want to stay GMP-free, GM-free zones will eventually be contaminated. A GMP future is also irreversible, because GMPs cannot be recalled. The whole country must therefore decide as one whether to choose a GMP or a GMP-free future in agriculture.

As it stands now GM technology is either wrong or unnecessary for Ethiopia because the majority of the available GM crops are equipped with inserts conferring resistance to some Lepidopteran insects such as stem borers attacking maize or bole weevils attacking cotton. With the huge labour force in the rural communities for hand weeding of crops and the low level of insect infestation as a result of the indigenous knowledge of pest management Ethiopia does not need to go into the health and environmental risks of introducing GMP crops just to gain very little in return.

Ethiopia's advantage is its valuable biodiversity, which can earn revenue for its people not only through tourism, but also through bio-prospecting, if the value-
addition remains in Ethiopia. Programs to build capacity in laboratories in Ethiopia to identify, classify, and utilize the country’s biochemical and genetic diversity will go a long way towards bringing the promise of biotechnology to Ethiopia.

The GM technology, however, has huge unmet promises such as crops that can withstand environmental stresses such as drought resistance or cold resistance or salt tolerance. When such crops are either released in the market or engineered locally, Ethiopia might be tempted to consider these crops for green house and field trials. Until such time that the offers of GM technology are irresistible from the strategic and economic point of view, Ethiopia’s choice would be to stay GM-Free.

At the moment being GM-free is a huge competitive advantage in the market. Furthermore, if this decision should turn out to be wrong, the freedom to change it in the future is reserved. However, decisions whether to continue being GM-free or to join the GMO world should be made through awareness and public debate.

Meanwhile Ethiopia is developing its capacity to engage itself in GM technology and make informed decision on a case-by-case basis. Plant biotechnologies that don’t pose risk and are affordable such as tissue culture techniques could be used in horticulture and forestry. Neighbouring countries are making efficient use of tissue culture techniques to distribute disease-free banana and citrus propagules to farmers at affordable cost. Potatoes, enset and coffee are also very good candidates for vigorous tissue culture application. However, private investors have to be attracted to take up this task and there must also be concerted extension program for profitable and sustainable application of the technique. To help biotechnology in general and tissue culture technique in particular flourish in Ethiopia, the modest beginning at EARO, AAU and other research institutions should be encouraged through support and promotion.

REFERENCES


POSITIVE AND NEGATIVE ASPECTS OF IRRIGATION DEVELOPMENT

Tesfaye Abebe

ABSTRACT

Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset drought in semi-arid regions. Irrigation development is the utilization of suitable and available land and water to produce agricultural products for consumption and raw materials for industries. It requires available amount and quality of water, in addition to suitable land and its characteristics. Additionally sufficient amount of capital and skilled manpower are required to develop this sector of agriculture. The need for irrigation development becomes non-neglecting choice for the problem of food security exacerbated by the rapid growth of population and hence of food demand.

Development of this technology is not simply a mechanical task of delivering water to crops, but it has its own procedures (steps) to bring it to fruition, such as different levels of studies, construction, operation and maintenance. All the above steps require the proper handling of technical, social, economical, environmental and political conditions.

In addition to the direct positive aspects of irrigation attained in the form of intensification of food grains and forage production, the most favorable lands are currently under rain-fed cultivation or grazing.

Despite its production increase of high quality and variety crops with sustainable development and food self sufficiency, irrigation does have many negative impacts. Poor irrigation management causes many serious water supply and water quality problems. Greater food security, higher income, economic and social progress are the positive consequences. Moreover, food insecurity, poverty, famine and displacement may be caused by improper use of irrigation. Potentially negative environmental impacts or irrigation development may occur off-site as well as on-site.

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INTRODUCTION

Agriculture is the main economic and social background of almost all countries. Agricultural products are used for daily food consumption, source of income for individuals and countries economy, and raw materials for many industries. Predominantly farming plays the main role in agriculture. In farming practice, food crops vegetables and fruits are produced and cover cultivated land widely.

Many of agricultural practices are dependent on rainfall. The absence or reduced amount of rainfall affects individuals, nations, and even the world’s economic and social status by shortage of food items, drinking water and others. For that reason, irrigation can and should play an important role in raising and stabilizing food production, especially in the less-developed countries.

United Nations predict that the global population increase in the year 2025 requires an expansion of food production of about 40-45%. Irrigation agriculture currently comprises 17% of all agricultural land, yet produces 36% of the world’s food supply. Currently 75% of irrigated land is located in developing countries. By the year 2000 it was estimated that 90% would be in developing countries.

The world food summit in 1996 estimated that 60% of the extra food required to sustain the world in the future must come from irrigated agriculture. Much of this increase must come from improvements in existing schemes, as new sites for development are scarce. Three-quarters of the total irrigated area of 260 million hectares are in developing countries where smallholder agriculture still predominates. The bulk of improvements in food supply from irrigation are expected to come from changes in a sector still dominated by small producers. The rural poor are not simply people deserving help and justice: small-scale irrigators are, and will continue to be, a vital part of future world food security.

Irrigation development may have both positive and negative impacts on the environment and on social, economic factors etc. To be sustainable, irrigation must avoid the negative impacts, there for this paper tries to show the positive and negative impacts of irrigation development and shows the measures to be considered to reduce or avoid the manageable negative impacts.

Irrigation features

Irrigation is the supply of water to agricultural crops by artificial means, to complement for the absence, deficiency or poor distribution of rainfall (Bruce and Staintey, 1988).

Generally irrigation is meant to be an intensive production system. This is justified by the following rationale: Irrigation development requires a certain level of investment. To make it a profitable enterprise, the output in terms of yield should therefore be high. Hence, a high level of inputs use such as improved seeds, fertilizers and pesticides characterizes irrigated agriculture.
Benefits of irrigation

1. Increased agricultural production:
   • Irrigation addresses the problem of food security especially in the context of rapid growth of population and hence of the demand for food;
   • In countries such as Ethiopia, where traditional rain-fed farming is a high-risk enterprise, irrigation can help ensure stable production;
   • Irrigation permits multiple cropping (two or three, and sometimes four, crops per year) where only a sample crop could be grown under rain fed conditions.

2. Diminished pressure on agricultural land
   • Widespread denudation and accelerated erosion diminish the productivity of both cultivated and grazed rain-fed lands. Especially semi arid regions are vulnerable to climatic instability and frequent droughts.

3. A way to encourage more intensive agriculture
   • Irrigation reduces the risk of the lack of moisture and also reduces the losses of expensive inputs being wasted by crop failure resulting from lack of water.

4. Job and income generation

Because it is a more intensive system and because it enables the cultivation of land that could not otherwise be cultivated due to inadequate rainfall, irrigated agriculture can be a source of employment in rural areas. It thereby reduces migration of rural poor to urban areas where they would be jobless.

Irrigated agriculture may bring additional incomes to households in that it enables them to produce a surplus for the market. In addition, irrigation helps the development of other economic activities locally, such as inputs’ supply, transport industry, and in some cases food processing industry.

METHODS OF IRRIGATION WATER APPLICATION

The practice of irrigation consists of applying water to the part of the soil profile that serves as the root zone, for the immediate and subsequent use of the crop (Phoacaidel, 2001).

1. Surface irrigation
   • Running or improving water on the surface and allowing it to saturate the soil to some depth.
2. **Sprinkle irrigation**
   - Spraying water into the air and allowing it to spread on to plants and soil as simulated rainfall.

3. **Drip irrigation**
   - Dripping water on to a traction of a ground surface so as to infiltrate it into the root zone.

4. **Sub-surface exudes**
   - Introducing the water directly into the root zone by means of porous receptacles.

5. **Sub-irrigation**
   - Raising the water table from below (in places where the ground water is shallow and controllable) so as to moisten the root zone by capillary action.

**MAJOR IMPACTS OF IRRIGATION DEVELOPMENT PROJECTS**

When considering impacts, two perspectives must be taken into account. Those of

- The project on the environment, and
- External factors on the project (externalities).

Intensification of agriculture can lead to ground water pollution related to the increased use of pesticides and fertilizers. During the construction period, there may be specific health and other social risks due to an influx of migrant workers living in temporary and unsanitary accommodations.

Positive aspects of irrigation

The positive aspect of irrigation is that by intensifying food and forage production in the most favorable lands, it can allow a country to reduce excessive pressure on marginal lands under rain-fed cultivation or grazing. Such lands are already undergoing a process of degradation (known, in semiarid areas, as desertification). The transition of people who have subsisted for generations on rain-fed lands to irrigated farming may be a difficult social change. However, change in any can be unavoidable in areas where land degradation becomes acute. When the opportunity exists for irrigation development, it can serve as a constructive alternative to either famine or mass migration.

Additionally it does have more positive impacts such as:

- Conservation of water,
- Human consequences,
- Greater food security,
- Higher income, and
- Economic growth.

**Negative aspects of irrigation development**

Poorly managed irrigation systems are those which waste water and energy, deplete or pollute water resources, fail to produce good crops and/or pose the danger of soil degradation.

The negative impacts of irrigation development may occur off-site as well as on-site. The off-site effects may take place upstream of the land to be developed, as where a river is to be dammed for the purpose of supplying irrigation water. Another set of problems may be generated downstream of the irrigation area by the disposal of excess water that may contain harmful concentrations of salts, organic wastes, photogenic organisms and agrochemical residues.

Of most direct concern are the potential on-site impacts. Irrigated lands, especially in river valleys prone to high water-table conditions, typically require drainage. Otherwise, they are subject to the twin scourges of water logging and salinization. Because groundwater drainage is a complex, exacting and expensive operation (often more expensive than the initial development of irrigation itself), there is a temptation to start new irrigation projects while ignoring the need for drainage or delaying its installation until it is actually needed. The trouble is that by the time the need for drainage becomes inescapable, then the cost of implementing it may be prohibitive.

For people without past experience, irrigation is a very difficult task that may result in very low application efficiency, drainage problems and water logging. Very low irrigation efficiencies and water logging problems arise through poor water management and inadequate maintenance.

Irrigation is not simply a mechanical task of delivering water to crops. It is a human activity and a social undertaking. No consideration of irrigation development should fail to note that, ultimately, the success of every project depends on the quality of the human efforts invested in it. Moreover, an irrigation project is not only a system for producing crops but also, and perhaps even primarily, a place for a community of people and families to live healthy lives while working cooperatively and contributing to the food security of their nation (FAO, 1986).
A wide range of activities associated with an increased intensity of production can contribute to reduce soil fertility. Soil salinity is probably the most important issue although mono cropping, without a fallow period, rapidly depletes the soil fertility. A reduction in organic content will contribute to soil's erodability. An increased use of agro-chemicals, needed to retain productivity under intensification, can introduce toxic elements that occur in fertilizers and pesticides.

In the long-term, one of the most frequent problems of irrigation schemes is the rise in the local water-table (water logging). Low irrigation efficiencies (as low as 20 to 30% in some areas) due to poor water distribution systems and main systems management are the main causes of rise of water-table.

Moreover some negative impacts are summarized below.
- Salinization of soil (problems of sodicity and alkalinity that are often irreversible),
- Elevated water table,
- Land degradation,
- Human consequences (due to degradation and becoming out of use),
- Food insecurity,
- Poverty, and
- Famine and displacement.

The major effect of irrigation is water logging. Briefly an agricultural land is said to be water logged, when a high water table affects its productivity. The productivity of land may become affected when the root zone of the plant gets flooded with water, and thus become ill aerated.

According to Punma and Pande (1998), the causes for and effects of water logging are described as:

**Causes of water logging**
- Over and intensive irrigation,
- Seepage of water through the canals and water from the adjoining high lands,
- Impervious obstruction,
- Inadequate natural drainage,
- Inadequate surface drainage,
SOLUTIONS FOR MANAGEABLE NEGATIVE ASPECTS OF IRRIGATION

- Well managed irrigation systems are those which control the spatial and temporal supply of water so as to promote growth and yield, and to enhance the economic efficiency of crop production such systems apply water in amounts and at frequencies calibrated to answer the time-variable crop needs;
- A concentrate effort to improved on-farm water management;
- Modernizing some traditional irrigation schemes so as to achieve higher yields as well as better resource utilization;
- Sound principles and techniques for efficient water use and for optimizing irrigation in relation to all other essential agricultural input and operation; and
- Conservation of water (reduce loss of water due to deep percolation, runoff and reduce loss of water due to evaporation).

Potential health hazard resulting from the use of open water channels of drinking, bathing, washing of clothes, and the disposal of human and animals wastes.

Among factors that may contribute to the control of water-borne diseases are the following (Dougherty, 1995):

- Concreted lining and shaping of the conveyance and drainage channels to prevent stagnation along the bank as, incidental, to reduce seepage losses;
- Control of riparian vegetation within the cannels, to prevent clogging, stagnation and harboring of diseases;
- Protection of the channels from wading animals that may breach the banks and pollute the water;
- Control of waste disposal by humans, who must be provided with environmentally safe sanitary facilities; and
- Treatment of the water used directly for human needs (filtration and, where necessary, use of chemicals to control parasites).

Irrigated agriculture has been a strategy for poverty reduction and there is evidence that this can be achieved. Lessons have been learnt about appropriate design and support in irrigated agriculture, and there are options to meet new challenges. Improved sharing of research results and a greater cooperation among professionals can aid these understandings.

Designs that are sensitive to environmental and societal conditions will be essential to prevent repletion of past weaknesses in irrigation development. This is important as future attention will be directed to the improvement of existing systems with new developments focused on small-scale smallholder schemes.
Excessive rain,
Submergence due to floods, and
Irrigation or flat topography.

Water-logging effects
- Difficulty for normal cultivation operations;
- Some water loving plants/weeds and grasses/grow; and
- Salinity may happen (prolonged water logging).

Controlling mechanisms of water-logging (Dahlgoankar, 1985)
- Lining of canals and water courses;
- Reducing the intensity of irrigation;
- Introducing crop-rotation;
- Optimum use of water;
- Providing intercepting drains;
- Provision of an efficient drainage system;
- Improving the natural drainage of the area; and
- Introduction of lift irrigation.

Irrigation at village level requires a high level of coordination and organization among farmers. They usually need to set up a system whereby they collectively save money in maintenance, purchase of inputs if needed, participate to maintenance through labor, etc... It is only sustainable if all farmers involved play the game according to the rule. As soon as some stop doing so, it jeopardizes the system.

Water borne diseases (Onchocerciasis, malaria, guinea worm, schistosomiasis, etc...) increase because water bodies, canals or inundated paddy fields are breeding sites for intermediate of the diseases (mosquitoes, flies,...)

Overgrazing around the irrigation scheme in dry areas, where natural grazing areas are rare, due to the attraction exerted by the scheme and its immediate surroundings.

Tribal conflicts between cattle herders and farmers (often migrants) when irrigation is being developed in what was previously rangeland.
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ANIMAL HUSBANDRY AND BIOTECHNOLOGY: CHALLENGES, OPPORTUNITIES AND PROSPECTS

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ABSTRACT

The poor performance of the agricultural sector in Ethiopia has largely contributed to the prevailing food insecurity and poverty. The major development challenges are increasing productivity, attaining food security, conserving biodiversity and reducing poverty. Although the role of livestock in the livelihoods of farmers and pastoralists and in the fight against poverty is acknowledged, the sector is dominated by smallholder subsistent production system and farmers are faced with complex challenges to improve production and productivity. The productivity of animal agriculture needs to be substantially increased in order to satisfy the current and future demands. Animal biotechnology has a potential in improving production, processing and profoundly impacting on the livestock sector. Broadly, the five main components of modern biotechnology include genomics (molecular characterization); bioinformatics (assembly of data from genomic analysis); transformation (the introduction of one or more desirable genes into species); molecular breeding (identification and evaluation of desirable traits in breeding supported by marker assisted selection); diagnostics (molecular characterization for the rapid identification of pathogens and other organisms) and vaccine technology (recombinant DNA vaccines). Biotechnology presents opportunities to increase growth rate, enhance genetic improvements, assist in conservation, improve nutritional value of feeds, improve health and add value to products. Biotechnology in reproduction such as artificial insemination and multiple ovulation and embryo transfer (MOET) can increase reproductive efficiency and rate of genetic improvement; multiplication and transport of genetic material and conservation of genetic resources. However, its application in Ethiopia is non-existent. DNA technologies in genetics and breeding help in genetic characterization, identification of genetic traits of economic importance, genetic improvement and conservation. Molecular biotechnology applications in disease diagnosis, characterization and identification of pathogen isolates (virus, bacteria, parasites) are particularly important in precision of diagnosis and in identification of sources of infections. Recombinant DNA technology portrays opportunities for production of vaccines that have more safety, better specificity and stability than those produced by traditional methods. DNA technology in animal nutrition and growth lies in the use of feed enzymes, probiotics, single cell protein, antibiotic feed additives and rumen biotechnology. Rumen biotechnology can improve the utilization of fibrous feedstuffs by altering the amount and availability of

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carbohydrate and protein in plants as well as the rate and extent of fermentation and metabolism of these nutrients in the rumen. However, there are major concerns in understanding of the prospects of these technologies, their appropriateness, factors that influence their application, requirements for their applications and their impacts on the environment and human health. It should be underlined that the appropriateness of available biotechnology depends on many factors and needs to be tailored to suit the particular environment and should be driven by the needs of resource poor farmers. Intellectual property rights (IPR) that put more value on biotechnological outputs than on the genetic resources and high prices could restrict poor farmers from access to biotechnologies. The presence or absence of support is another issue that should be taken into consideration. As a result, an integrated and coordinated national capacity in agricultural biotechnology including intellectual property management with defined roles and responsibilities of higher learning institutions, research organizations, ministries, development organizations and the private sector has to be established and developed. In order to develop capacity, the country should invest and also take strategic alliances and cooperation with many actors such as regional and international agriculture research centers, agricultural biotechnology initiatives for Africa; donor organizations and the private sector. The level of capacity building and resource requirements could have implications on alternative research and development strategies and requires careful considerations. Biotechnology should not be considered as a panacea for addressing poverty reduction and food insecurity, rather as one of the modern technological tools that can contribute to protecting the asset of the poor and increasing productivity.

INTRODUCTION

In May 1992, an article entitled “Biotechnology in Animal Production: A review and highlights of opportunities for Ethiopia” was presented at the Annual Conference of the Ethiopian Society of Animal Production (ESAP) and was published in the Proceedings of the Second Annual Conference of ESAP (Azage Tegegne et al., 1993). About 12 years later, the Biological Society of Ethiopia requested a similar presentation on the same topic. In this earlier paper, the following conclusion was made “For developing countries to have capabilities and to reap the advantages of biotechnology, education, infrastructure, research and long-term commitment and support are essential. Biotechnological tools have to be refined and tailored to fit our requirements and the already available “traditional biotechnology” has to be compiled and developed. These require continued research of different scale and magnitude and strong commitment. Finally, unless know-how and capability in biotechnology are established either through protracted national, regional or continental efforts, there will be no one to develop and safeguard the unique genetic resources and interests of developing countries. Are we ready for the challenge? Some 8 years later, the Ethiopian Agricultural Research Organization (EARO) recognized the importance of agricultural biotechnology and developed a research strategy (EARO, 2000). It may also be a
mere coincidence, that in late 2003 the Ethiopian Ministry of Agriculture has taken an exciting lead to develop an Ethiopian Agricultural Biotechnology Initiative. It is with this intention that this second attempt is made with the hope and ambition that something concrete will emerge from this workshop.

DEVELOPMENT CHALLENGES

The agricultural sector is the backbone of the Ethiopian economy and engages over 85% of the population. The sector is mainly based on subsistence mode of agricultural production and overall production and productivity is very low. The performance of the agricultural sector has been poor and the sector has not been able to feed the nation due to lack of appropriate development policies and strategies. It is a well-know fact that about 50 percent of the Ethiopian population currently lives in absolute poverty. The Ethiopian agriculture is overwhelmingly dominated by smallholder production system with about 62 percent of households (1 household = 5 members) have landholdings of less than 1 ha. Smallholder farmers face challenges that include technical as well as other determinant factors such as markets, policy and institutional arrangements. Most of the farmers have limited assets with low productivity and are also unable to benefit from markets. The smallholders largely depend on local markets for their livelihoods and the local trade opportunities are strongly affected by weak infrastructure, absence of processing and preservation facilities, market taxes and distortions created through the importation of artificially cheap commodities. Other factors that enhance market failures are absence of grades and standards, poor market information system and lack of local storage facilities to improve the stability of food suppliers to overcome the ‘boom and bust’ cycles.

Policy issues that assist people to manage uncertainties linked with agricultural production are very weak in the country. Vulnerability has increased in the context of systemic collapse attributable to political disturbance and HIV/AIDS. Thus, smallholder farmers and pastoralists not only need production-focused interventions, but also safety nets. Poverty eradication was and is the central development agenda of the government. This can be achieved only through economic growth, which in turn, depends on growth in the agricultural sector. Accordingly, the country has adopted agricultural and rural-focused development strategy to foster rapid and sustainable economic development. The focus in agriculture include improvement of agricultural production, decreasing or improving the excessive degradation of the natural resource base and creating job opportunity for rural people. Rapid agricultural growth through improved technologies will contribute to the economic transformation of the country through:

- increases in productivity;
- employment opportunities for farmers and landless farmers;
- generating purchasing power among the rural population for nonfood consumer goods and services;
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- increases in migration opportunities for the poor to other parts of the country;
- empowering poor people and reducing their vulnerability to shocks;
- lowering food prices for all; and
- benefiting poor people living in rural and urban areas.

It is therefore, conceivable that rapid economic growth and food security cannot be achieved without a significant and sustained improvement in the agriculture sector.

**LIVESTOCK PRODUCTION AND ITS CONTRIBUTION TO THE NATIONAL ECONOMY**

**Resources and productivity**

Ethiopia owns about 32.8 million tropical livestock units (TLU). This comprises about 17.6% cattle, 22.4% sheep, 13.4% goats and 8.7% camels of the ruminant population of sub-Saharan Africa, the overall being about 17%. The highlands of Ethiopia represent about 42% of the total highland regions of sub-Saharan Africa, and of the 23.7 million ruminants that live in the highlands of sub-Saharan Africa, 48% are represented in Ethiopia. Livestock play a significant role in the livelihoods of a large proportion of the rural population and provide employment opportunities to a growing proportion of urban and peri-urban dwellers. The purposes of keeping livestock include income generation, diversification of farms and incomes, risk minimization, employment, farm intensification, and household nutrition. Accordingly, outputs include meat, milk and dairy products, power, manure, fibre, and skins. Livestock can readily be sold during periods of need for quick cash, as cash holdings can be easily converted to savings and investment in livestock.

Livestock production systems are determined by climate, types of crops grown, livestock species reared, and their economic importance to the producer. The main livestock production systems are crop-livestock mixed production system, pastoral and agro-pastoral production system and intensive urban and peri-urban production systems. In these production systems, livestock, especially cattle, provide traction power which is a vital contribution in the overall farm force requirement. In the semi-arid lowlands of the pastoral production system, cattle are the most important species because they supply milk for the subsistence. In the more arid areas, however, goats and camels are the dominant species reared. Livestock contribute 40% to the agricultural gross domestic product. This figure is higher if the non-monetary contributions are taken into account. Furthermore, livestock are closely linked to the social and cultural lives of several million resource-poor farmers for whom animal ownership ensures varying degrees of sustainable farming and economic viability. Animal productivity per head, however, is far below global standards, even lower than the average for sub-Saharan Africa. Lactation yield of local cows is about 300 to 600 kg, carcass weight of mature cattle is only 112 kg, a mere 7.7 kg of beef is produced annually per head of cattle and estimated off-take
is only 7.2% (Birke, 1991). Similarly, productivity from small ruminants, poultry, fish and other species is low.

DEMAND FOR ANIMAL PRODUCTS

The World Bank (1989) estimated that production of meat and milk in sub-Saharan Africa would have to increase by 4% per year to ensure adequate supply of animal protein for the regions growing population and to eliminate imports. Ethiopia is no exception to this projection. Ethiopia’s increasing human population, urbanization trends and rising household incomes would lead to substantial increases in the demand for livestock products, particularly for milk and meat (Delgado et al., 1999). The country’s human population estimated at 65 million is growing at a rate of over 3% per annum. In Addis Ababa alone, the projected human population and the corresponding demand for cereals and animal products over the coming 30 years will increase at an unprecedented rate (Table 1).

Given the agricultural policy of the country and efforts put by the Government of Ethiopia in rural development, food security and poverty reduction, is Ethiopia in a position, both technically and financially, to meet the expected growth in animal productivity over the next 30 years in order to be self-sufficient? What are the prospects for the livestock sector to contribute more to economic development of the country? What will be the role of biotechnology in enhancing development efforts?

Table 1  Projected population and food demand requirement for Addis Ababa (Source: Wolday Amha and Kifle Eshete, 2002).

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (000)</th>
<th>Cereals (tons)</th>
<th>Meat (tons)</th>
<th>Milk (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2,395</td>
<td>5,613,750</td>
<td>523,950</td>
<td>115,568,400</td>
</tr>
<tr>
<td>2010</td>
<td>3,328</td>
<td>7,488,000</td>
<td>698,880</td>
<td>154,152,960</td>
</tr>
<tr>
<td>2020</td>
<td>4,246</td>
<td>9,553,500</td>
<td>891,660</td>
<td>196,674,720</td>
</tr>
<tr>
<td>2030</td>
<td>5,080</td>
<td>11,445,750</td>
<td>1,068,270</td>
<td>235,629,840</td>
</tr>
</tbody>
</table>

BIODIVERSITY IN LIVESTOCK RESOURCES

The contribution of Ethiopia to the genetic resource of livestock species, breeds and strains to the world is significant. Although data on the number and characteristics of all livestock breeds are limited, information on the distribution and characteristics of some cattle (Alberro and Haile Mariam, 1983) and sheep (Galal, 1985) and goat (FARM-Africa, 1996) breeds in Ethiopia is available. The different species and breeds of livestock available have unique genetic traits such as high degree of heat tolerance, resistant partly to many of the diseases prevailing in the tropics and the ability to survive long periods of feed and water shortage. These properties are genetic and have been acquired by natural selection over hundreds of generations and represent unique source of genetic material for use in other parts of the world. However, most populations of indigenous livestock have
been subjected to little or no deliberate selection for productivity. Genetic improvement per generation from selection depends on the variability of the traits considered, their heritability and the intensity of selection. Intensity of selection is restricted by the reproductive rate of the species and is further influenced by the rate of early mortality, which is often high under tropical conditions. In cattle and small ruminants, rate of genetic progress from selection is further reduced by the long generation intervals.

Animals used in agriculture represent an enormous breadth of biological diversity. As development proceeds, livestock agriculture moves from subsistence to commercial farming systems and production objectives become more specialized and competitive pressures increase. The great pool of animal genetic resource could thus be endangered. This is particularly true in some cattle breeds, where artificial insemination (AI) permits very rapid replacement of existing populations. Moreover, there is an increasing social and economic pressure on animal biodiversity that could easily erode and/or dilute them before their genetic merits are realized. It is also projected that the more recent phenomenon and development of global warming will lead to extinction of a large number of animal genetic resources in the coming 50 years. Management of the animal genetic resource calls for a concerted national, continental and global effort. FAO's programme on global animal genetic resources is summarized as having five steps (i) documentation, inventory and World Watch List, (ii) in situ conservation (including development), (iii) ex situ preservation (gene banks), (iv) components of development strategies including the use of DNA technology, genetic distances, improved definition of what is unique genetically, improved cost effectiveness, and (v) legal and institutional frameworks (Steane, 1992).

**BREED IMPROVEMENT PROGRAMMES**

Ethiopia does not have livestock development policy and specific breeding policies. Livestock development is planned and implemented on the basis of the overall government policy in the agricultural sector and based on the National Livestock Development Strategy and Programme. The focus of breed improvement in Ethiopia so far has been through crossbreeding of the local stock with exotic breeds. In line with this, different initiatives have been made to promote crossbreeding schemes. These include: establishment of the National Artificial Insemination Center (NAIC) and a number of cattle, sheep and poultry breed improvement and multiplication centers. Artificial insemination (AI) service mainly focuses on cattle and is designed to boost milk production through the use of semen from exotic dairy breeds such as Friesian and Jersey. Semen from indigenous breeds, mainly Fogera, Horro and Boran has also been used as appropriate.

Cattle breed improvement and multiplication centers have an element of conserving identified cattle “breeds”/populations in their own environment. These centers include the Boran breed improvement and multiplication center in Oromia.
Region and the Fogera breed improvement and multiplication center in Amhara Region. There is a plan to establish similar centers for the Barca breed in Tigray, the Abigar in Gambela and the Horro in Oromia. Menz sheep breed improvement and multiplication centers are located at Debre Berhan and Amed Guya in the Amhara Region. The Horro sheep breeding center in the Oromia Region is established recently with the aim to address the Horro ‘breed’/population predominantly found in the western part of the country. Two other sheep breeding centers include the Kokosa for the highland Arsi-Bale sheep and the Jijiga center for the improvement of the lowland Wanke (Black-Head Ogaden) sheep. The primary aim of the sheep breed improvement programme is to increase production of mutton, which commands premium prices on both the domestic and export markets. Wool production, though less important than meat, has a valuable role to play in sheep development. There are also seven poultry breeding and multiplication centers located in different regions of the country, and mainly focus on Rhode Island Red birds. The poultry-breeding program favours distribution of pure exotic breed than crosses through the provision of breeding cockerels, pullets, chicks and fertile hatching eggs.

**MAJOR LIMITATIONS TO IMPROVEMENTS IN LIVESTOCK PRODUCTION**

The complex nature of livestock production, coupled with a low technical base and long generation intervals have slowed down progress in livestock production. Productivity of animals has been limited primarily by shortage of feed, diseases, genetic limitations for productive traits, management factors, policy and institutional problems. In addition, the subsistent mode of production has hindered technology uptake in the sector and transformation of the production systems into market-orientation. Although livestock productivity is generally low, their genetic merits in terms of survival, hardiness, drought and disease resistance, etc. under a hostile environment and poor management practices is exceedingly valuable.

**OPPORTUNITIES FOR IMPROVEMENT**

Increases in the supply of animal products could only be achieved through improvements in both horizontal and vertical components of the production systems coupled with appropriate policy and institutional support. Development of appropriate marketing systems for livestock and livestock products is a key issue in transforming the subsistent mode of production into market orientation. This will have spin-offs in natural resources management and environmental protection as well. The potential for horizontal expansion of livestock production has been checked predominantly by hostile environments such as deserts and disease threats and risks. Tsetse flies and the trypanosomiasis that they carry are distributed over one million km² in Ethiopia. The infestation of such substantial area with tsetse fly makes livestock production difficult or impossible. The vertical increase involves improvement of productivity per unit. Improvements in feed resources (including water) and feeding systems along with appropriate genetic resource and
management practices are of primary concern. The rate of genetic gain increases with the amount of genetic variation, the accuracy and intensity of selection and shorter generation intervals. Each species has its own optimal balance which depends upon variables such as the genetics of the traits involved, the reproductive rate and the technology available to adjust this rate and the particular economies of the situation (Wilmut et al., 1992).

In Ethiopia, production systems vary and range from semi intensive/intensive dairy production around urban areas to a very extensive nomadic or pastoral system. Accordingly, each production system has its unique management, feeding, breeding and disease problems associated with it. Selection, improvement, conservation and utilization of the available livestock germplasm are important issues. It is prudent to ensure that the breadth of genetic resources which have survived to the present are conserved. The call for action now is to characterize and develop appropriate germplasm conservation and utilization strategies. Considering the large untapped livestock resources and the potential for development in Ethiopia, would biotechnology help to overcome some of the major constraints in a sustainable way? What has biotechnology to offer to the development and improvement of livestock in Ethiopia? Which, how and where do we need to employ biotechnological tools in order to overcome our problems? These are some of the basic questions that need to be addressed.

**WHAT IS BIOTECHNOLOGY?**

Biotechnology embraces extensive, expansive and diverse spectrum of biological principles, phenomena, materials, organisms, reactions and transformations. Biotechnology has been broadly defined as any technique that uses living organisms, or parts of organisms, to make or modify products, to improve plants or animals, or to develop microorganisms for specific use (OTA, 1988). Biotechnology is not new and includes "traditional biotechnology" where biology has been harnessed for years with well established technologies used in traditionally and/or commercially useful operations such as the production of beer (tella and areki), tej and wines, foods, vinegar, ethanol, biological control of pests, conventional animal vaccines, and many others. Recent biotechnologies have greatly expanded this vista. According to Dart (1990), modern biotechnology encompasses the use of new technologies such as those based on recombinant DNA technology, monoclonal antibodies and new cell and tissue culture techniques, including novel bio-processing techniques. Fig. 1 shows aspects of different levels of biotechnology in relation to cost and efficiency of performance.
Fig. 1 Gradient of biotechnologies showing the relationships between cost and efficiency (Source: Persley and MacIntyre, 2002).

WHAT CAN BIOTECHNOLOGY OFFER TO HELP DEVELOP THE LIVESTOCK SECTOR?

Agricultural biotechnology cuts across important disciplines. Experience over the last 20 years has been that interesting biotechnological developments have been achieved more rapidly than was generally predicted. However, each development seems to uncover new layers of complexity in understanding, control and application. With so much known, it is still difficult to gauge the future pace and utility of biotechnology, in both developed and developing countries. It is however, clear that the new technologies available offer immense opportunities for improvement of animal production and conservation of the genetic resources. The relevancies of some of the biotechnological tools to improve animal production in Ethiopia are presented and some pre-requisites for the use of biotechnology are suggested. It should, however, be noted that biotechnology could not be all to solve the animal production problems.

ANIMAL BREEDING AND GENETICS

Modern biotechnology provides wide opportunities to help characterization of animal genetic resources. Technologies include gene mapping, identification of chromosome regions (quantitative trait loci or QTLs) that carry important traits, gene identification and isolation, genetic engineering for traits such as disease tolerance or resistance, or adaptation for environmental stresses, and others.
Genetic improvement programmes, based on marker-assisted selection and recombinant DNA technology, could also enhance animal productivity.

FEED RESOURCES

Improving feed resource is of primary importance in animal production. Methods for greater utilization of local biomass and by-products for animal feed must be developed. The entire plant should be viewed as food and feed crop. Production of parts of plants that are directly consumable by humans and parts of plants that should pass through animals for the production of high quality animal food products and utilities should be improved. It would thus be useful to integrate efforts on animal production with those of agronomists, range scientists, irrigation specialists, soil scientists, sociologists and economists. Biotechnology could contribute to genetic characterization. Feed genetic resources and technologies including cell, tissue and embryo culture, clonal propagation of disease-free plants, gene mapping, identification of chromosome regions (quantitative trait loci or QTLs) that carry important traits, gene identification and isolation, genetic engineering for traits such as disease tolerance or resistance, or adaptation for environmental stresses, greater nutritive value, and others. Conventional plant breeding could be enhanced through the application of modern biotechnology for improvements of feed resources to biotic (disease and pests) and abiotic (low soil fertility, drought, salinity) factors and increased yield and nutritional quality.

ANIMAL NUTRITION AND ANIMAL GROWTH

In animal nutrition, biotechnology aims to improve the efficiency of animal production through manipulation of the feed-base, the animal's digestive system and the animal's metabolism (Leng, 1991). In general the predominant feed resources, forages, consumed by ruminants in Ethiopia and other parts of the tropics are almost always below 55% digestibility and often contain less than 8% crude protein (Leng, 1991). Under grazing systems in the tropic without any supplementary feeding, the low levels of production per head and per hectare are due to inefficient use of available feed, with a possibility that up to 30% of the feed consumed is dissipated as heat, which has great effect on feed intake (Leng, 1991). Understanding the rumen ecology could enhance the utilization of these poor quality feed resources. Isolation, characterization and utilization of microorganisms in ruminant digestive systems allows the use of hard (high-lignin) fibers in animal feed and detoxification of anti-nutritional factors. Lignin has long been theoretically regarded as indigestible and is the main factor limiting the use of some forages. In addition, genetically engineered organisms could convert hard fibers into products that can be used by the host animal for energy (Yilma, 1989).

The subject of growth or promoters in livestock management is a complex one because of the biological complexity of the topic and the social and political issues arising from their use. There is no clear definition of growth promoters, but most people agree that they are non-food substances, administered to animals to alter the
quantity or quality of the produce. In most animal systems the products are predominantly protein and so growth promoters are essentially concerned with the retention of protein, in a desirable form, by the animal. Growth promoters in livestock production are involved with the manipulation of utilization of absorbed nutrients through the use of anabolic agents and repartitioning agents and manipulation of digestion and absorption of nutrients through gut active growth promoters and biological approaches to rumen manipulation. Under natural conditions, growth hormones play pivotal role in the development and growth of animals. Biosynthesis of growth hormones of the main livestock species by genetically engineered microorganisms could have an important impact on herd and flock management, and markedly improve their productivity, when feeding conditions are satisfactory. The use of these hormones would have significant effects in intensive livestock production systems. The gene for chicken growth hormone produced by genetically engineered microbial cells could enhance the growth of chicken by 15%. Genetically engineered porcine growth hormone (pST) is also available and decreases fat content of pigs by 70%. Furthermore, fattening of pigs only needs 70% of the feed usually given to them. However, there is concern and even reluctance of consumers to drink milk or eat pork from animals treated with bovine/porcine growth hormone.

**LACTATION**

Mammogenesis and milk synthesis are highly complex processes involving action and interaction of neural, chemical, endocrine, paracrine and autocrine factors. Detailed information on these complex processes is scarce and data on the induction of mammary cell differentiation and expression of genes coding for milk synthesis are becoming available only recently. Extensive testing of bovine somatotropin (bST) as a galactopoietic enhancer was initiated in the 1980's when large quantities of the pure hormone became available with the aid of recombinant DNA technology. Detailed information on the mechanisms of action of recombinant bST is given in a review (Stelwagen et al., 1992). A more futuristic biotechnological alternative to increase milk production is the production and use of transgenic animals carrying and expressing fusion genes coding for hormones that may increase milk production efficiency and increase milk production per animal. There has been no work done in the biotechnology of lactation in Ethiopia.

**ANIMAL HEALTH**

The use of recombinant DNA methods to identify and diagnose animal diseases will be particularly beneficial for developing countries. The technology will most likely contribute to common disease alleles, alleles arising from new mutations, genetic linkage analysis, forensic application of allele markers, neoplasia-acquired genetic alteration, infectious diseases and detection of sequences (Yilma, 1989; 1990). The four kinds of animal vaccines used to day depend on modern biotechnological techniques. These vaccines are: subunit vaccines, recombinant DNA-derived vaccines, synthetic peptide vaccines and anti-idiotype vaccines.
Modernizing Agriculture: A way out of food insecurity? Azage Tegegne and Zinash Sileshi

(Yilma, 1989; 1990). A number of products have been developed that have a direct application in animal health. Improved and cheaper vaccines against a number of diseases have been produced by recombinant DNA technology. These include vaccines against foot-and-mouth disease, enteric diseases and ectoparasites. Some details are given in Table 2. A number of agents which stimulate the immune system, and thus enhance general disease resistance have also been developed. These are generally based on interferon (which also have antiviral function) and lymphokines.

Table 2 Vaccines and their developers (Source: Cunningham, 1990).

<table>
<thead>
<tr>
<th>Species</th>
<th>Disease</th>
<th>Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avian</td>
<td>Coccidiosis</td>
<td>Genex and A.H. Robins</td>
</tr>
<tr>
<td>Avian</td>
<td>Newcastle virus</td>
<td>Codon and Salsbury Labs</td>
</tr>
<tr>
<td>Avian</td>
<td>Papilloma virus</td>
<td>Molecular Genetics</td>
</tr>
<tr>
<td>Bovine</td>
<td>Viral diarrhoea</td>
<td>California Biotechnology</td>
</tr>
<tr>
<td>Bovine</td>
<td>Brucellosis</td>
<td>Ribi ImmunoChem</td>
</tr>
<tr>
<td>Bovine</td>
<td>Rinderpest</td>
<td>USDA and University of California, Davis</td>
</tr>
<tr>
<td>Swine</td>
<td>Parovirus</td>
<td>Applied Biotechnology</td>
</tr>
<tr>
<td>Swine</td>
<td>Dysentery</td>
<td>Codon</td>
</tr>
<tr>
<td>Equine</td>
<td>Influenza</td>
<td>California Biotechnology</td>
</tr>
<tr>
<td>Equine</td>
<td>Herpes</td>
<td>Applied Biotechnology</td>
</tr>
<tr>
<td>Companion</td>
<td>Canine parovirus</td>
<td>Applied Biotechnology</td>
</tr>
<tr>
<td>Companion</td>
<td>Feline panleukopenia</td>
<td>Applied Biotechnology</td>
</tr>
<tr>
<td>Companion</td>
<td>Antifertility</td>
<td>California Biotechnology</td>
</tr>
</tbody>
</table>

Bacterial, viral and parasitic pathogens take heavy tolls in human suffering and subject livestock owners to economic loss and risk. Some of these pathogens infect both humans and animals. In many developing countries animals live in close association with humans. Animals and fowl provide reservoirs for pathogenic organisms that either infect humans and animals directly or become infective for humans or animals by means of genetic recombination mechanisms. NRC lists about 20 fatal diseases of economic importance in developing countries that need priority attention where biotechnology could play significant role in the production of recombinant vaccines and in disease diagnosis. In Ethiopia, biotechnology in the area of animal health involves development of diagnostics and vaccines against economically important diseases including zoonotic diseases. The National Veterinary Institute and the Animal Health Research Center of EARO at Sebeta are best placed to undertake these activities.

ANIMAL REPRODUCTION

Animal reproduction plays a pivotal role in the multiplication of desirable animals for production and in genetic improvement programmes. However, the inherent ability of animals to reproduce, the number of young born at a time and the generation interval pose limitations to rapid improvements. Some of the available biotechnological tools are:
SEMEN TECHNOLOGY

Artificial insemination

Artificial insemination (AI) has played an important role in increasing genetic progress by increasing the reproductive rate of the male, leading to greater selection pressure and better genetic evaluation through the comparison of widely dispersed half-sibs. To date, AI is the only biotechnological technique for increasing reproductive capacity that has received widespread application in farm animals. Effective methods for the freezing of spermatozoa were early developments that facilitated the application of the technique in the cattle industry. It is only in comparatively recent times, however, that adequate technologies have become available which permit the long-term storage of semen from swine, sheep and goats. The extensive application of AI has been estimated that the number of females inseminated on worldwide basis annually are >90,000,000 cattle, 50 million sheep, 6 million swine, and 40 million buffalo cows in India alone (Foote, 1981). Current figures could be exceedingly higher.

The introduction of artificial insemination in Ethiopia dates back to the late 1930's. The historical development and important landmarks in the progress of AI is summarized in the National Artificial Insemination Center (NAIC) Handbook (MOA, 1991). However, progress to date has been slow and the current status of AI is far below satisfactory for a number of reasons. The NAIC at Kaliti, established in 1981, has been the sole responsible body in organizing national AI activities and directing breeding program. Semen is collected from exotic (Friesian, Jersey), Zebu (Boran, Fogera, Barca, Horro and Arsi) and crossbred (50 and 75%) bulls maintained at Kaliti and Assela farms. The Center also produces and dispatches liquid nitrogen to consumers and provides a regular group or individual training on artificial insemination to technicians and farmers. So far, AI has been limited to cattle only and total annual inseminations are not more than 35,000.

Sperm sexing

Sperm sexing, whereby sperm containing X and Y chromosome are separated, would be extremely valuable in livestock production and improvement. Sperm sexing would allow breeding of only replacement females from the best dams and meat-producing males from the remainder of the breeding herd. However, the available technologies such as separation using protein enriched columns (Ericsson et al., 1973), Percoll density gradient (Kaneko et al., 1984), immunization against sex-specific sperm surface antigens, flow cytometry and florescence activated cell sorting (FACS), Y specific DNA probes have been successful to a limited extent, but they are too expensive and their application at farm level is restricted (Seidel, 2003). Research into the sexing of sperm of domestic species has hitherto been restricted by lack of a quick and cheap diagnostic test for sexed sperm. There has been no work on livestock sperm sexing in Ethiopia.
Oestrus synchronization

Achieving synchrony of insemination and ovulation is a major problem in many species. In cattle, most AI is performed at a natural oestrus, and the success of AI is dependent on accurate detection of oestrus (MacMillan, 1988). Asynchrony of AI and ovulation is probably the commonest cause of failure of AI. There is no simple and reliable diagnostic test of time of ovulation. Oestrus detection in zebu and crossbred cattle has been one of the limiting factors for successful AI and embryo transfer operations. In zebu and crossbred cattle in the tropics oestrus duration is short, intensity of oestrus is weak, oestrus behaviour is variable and there are anatomical differences in reproductive organs (Galina and Arthur, 1990). Oestrus duration in Ethiopian zebu and crossbred cattle has been reported to be 6.8 hours (Mattoni et al., 1988) and 18 hours (Sinishaw, 1991), respectively. Oestrus synchronization is achieved by the use of either natural or synthetic analogues of prostaglandins or progestagens. Prostaglandins operate by causing luteolysis of a functional corpus luteum and inducing oestrus subsequently while progestagens supply progesterone and upon withdrawal induce oestrus. A number of progestagens are available in forms of intravaginal devices and ear implants. There have been some studies on oestrus synchronization of zebu and crossbred cattle in Ethiopia (Mattoni et al., 1988; Azage Tegegne et al., 1989; Mukasa-Mugerwa; Sinishaw, 1991; Mutiga et al., 1993; Azage Tegegne et al., 1993).

Embryo transfer

Embryo transfer is already a well-established procedure, particularly in cattle. The procedure involves a host of technologies including oestrus synchronization, superovulation, embryo recovery, in vitro storage and culture as well as the actual transfer techniques themselves. The major applications of embryo transfer include increased annual reproduction of elite females, induction of twinning, to increase the population base of rare or endangered breeds of species as well as import and export of embryos. International transport of embryos minimizes the risk of disease transmission, is a cheaper means of transporting germplasm and provides opportunities for both the maternal and environmental conditions for the young to develop in places where it is destined to survive and produce.

Siedel (1989) estimated that in the dairy industry embryo transfer could enhance the rate of genetic gain from the female side by 3 to 4 fold. Recent developments include refinement of superovulation, embryo splitting, cryopreservation, IVM/IVF, embryo sexing, cloning and gene transfer. Although techniques for superovulation, embryo recovery from donors and embryo transfer to recipients has made it possible to increase the reproductive rate of the female to a significant degree, variations in embryo recovery following superovulation extends generation intervals and can reduce selection differentials. A more exact counterpart of AI is in vitro techniques of maturation (IVM) and fertilization (IVF) of oocytes. In order to reduce generation interval and enhance genetic progress, "velogenetics" which may use technologies that allow oocytes from pre-pubertal animals to be harvested,
matured and fertilized before transfer to a host animal (Georges and Massey, 1991) is available.

Embryo transfer in bovine has been applied in Africa to improve and multiply the N'Dama breed which is indigenous in Western Africa and which is resistant to trypanosomosis. Similarly, the Center de recherche sur les trypanosomes animaux, at Bobo-Dioulasso in Burkina Faso, transferred embryos from a trypanoresistant Baoule breed cow into zebu cows. In Ethiopia, ILRI initiated an embryo transfer programme at the Debre Zeit Research Station in 1990 primarily on zebu cattle with the objectives of producing animals for research purposes and the first calf was born in 1991. Subsequently, refinement of superovulatory regimes for Boran cattle and embryo splitting techniques were undertaken and eight pairs of identical twin calves were produced in 1993. Capacity and capability in superovulatory regime, embryo collection and evaluation, embryo cryopreservation and embryo splitting were developed (Azage Tegegne, 1991; Mutiga, et al., 1993; Azage Tegegne et al., 1994). This technology has not been picked up by the national research and extension systems.

Augmentation of fertility

The goals of augmentation of fertility are increased fertility and fecundity through a moderate increase in ovulation rate. The original product used is PMSG and is applicable in conjunction with synchronization of oestrus. However, responses vary according to breed, season and dose (Cognie, 1990). Suitable treatments include immunization regimes and long acting subcutaneous implants. Active immunization against ovarian steroids, particularly against androstenedione, increases ovulation rate of sheep. A commercial product, Fecundin, increases lambing rates by approximately 20% in most breeds (Cox et al., 1988). The pineal product, melatonin, available as an implant, increases lambing and kidding rates in sheep and goats by about 20% (Staples et al., 1990). Immunization against inhibin subunits and synthetic inhibin peptides has the potential to increase ovulation rate and enhance fertility (O'Shea et al., 1990; Forage et al., 1992).

Inhibition/control of fertility (chemical/immunocastration)

Castration increases growth rate and body weight in male animals. Inhibition of fertility is used to avert unwanted pregnancies in females either permanently or for a short period of time. Immunocastration involves active immunization against the hypothalamic decapptide luteinizing hormone releasing hormone (LHRH). Binding the LHRH to the pituitary gonadotrophins results in the synthesis and secretion of both gonadotrophins (LH and FSH) which in turn are required for normal testicular or ovarian function. Interference with normal hypothalamic function and/or disruption of the communication between the hypothalamus and pituitary can result in gonadotrophin deficiency and causes reproductive failure in both sexes. It caused testicular involution in the male and inhibits follicular development and ovulation in the female. Active immunization of heifers against
PGF$_{2a}$ or oxytocin also result in the maintenance of luteal function or prolongation of the luteal phase and inhibition of ovulation. Vaccination against zona pellucida proteins which are essential for fertilization induces temporary sterility in female animals. Chemical castration, such as use of immunogen against GnRH, effectively immunizes a high proportion of females against ovulation for over 6 months (Hoskinson et al., 1990). Research at ILRI examined the practical application of chemical/immunocastration in small ruminants in Ethiopia as the presence of the testes has a significant influence on the market value of small ruminants in Muslim societies.

**STATUS OF LIVESTOCK BIOTECHNOLOGY RESEARCH AND DEVELOPMENT**

The Ethiopian Science and Technology Commission has developed a draft policy document on the use and application of biotechnology in general. EARO has also developed research strategy, research programmes and projects in selected fields of agricultural biotechnology. Although there are some efforts underway on biotechnological and biotechnology-related research activities in different Universities, EARO and Regional research centers, IBCR, National Veterinary Institute (NVI), etc, there is limited organizational setup to coordinate biotechnology research, development and management in the country.

The EARO agricultural biotechnology research and development sector comprises three main programs (plant, animal and microbial). Each program is divided into sub-programs. The animal biotechnology research is organized into four main sub-programs and includes genetics and breeding, reproduction, animal health and feed resources and animal nutrition. The animal biotechnology research is being institutionalized under the provisions of the EARO Agricultural Biotechnology Research Strategy (EARO, 2000). Some activities on disease diagnosis have been initiated at the National Animal Health Research Center (NAHRC) at Sebeta and some experiments on rumen ecology are being carried out at the Holetta Agricultural Research Center. Facilities within EARO centers include basic *in vitro* techniques at the Holetta animal nutrition laboratory and facilities for DNA amplification and serotype (viral genome identification) at NAHRC. Currently there are quite few professionals involved in animal biotechnology related research in EARO.

**REGIONAL/CONTINENTAL INITIATIVES IN AGRICULTURAL BIOTECHNOLOGY**

The need to promote biotechnology at national, sub-regional, continental and international levels has been recognized due to variations in needs of different countries and also similarities in problems and agro-ecologies where transfer of technologies among countries could be facilitated and accelerated. These partnerships also serve as platforms to launch collaborative works, to increase capacity in specific shared programmes such as biosafety and intellectual property
right (IPR) and to increase awareness among policy makers about the importance of policy issues in agricultural biotechnology. In order to implement these, a number of partnerships and networking programmes have been established at Regional and continental levels in Africa. These linkages are destined to create capacities and capabilities and lead the direction of the development and use of biotechnology. Some of the initiatives include the following:

- **The Biosciences Initiative for Eastern and Central Africa under NEPAD** – This is a facility to be developed to support the national agricultural research systems in the sub-region. This will be a state-of-the-art facility in biosciences. It is supported by CIDA and to be established at the ILRI Nairobi campus.

- **The Biotechnology programme of the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA)** - This is a sub-regional organization for the NARS of 10 African member countries. The biotechnology initiative of the association focuses on establishing a biotechnology and biosafety programme for member countries.

- **East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN)**. This programme includes short-term training, graduate students, visiting scientists, organizing workshops on biosafety and policy.

- **African Agency for Biotechnology (AAB)** – This Agency serves 16 African member states including Ethiopia and focuses on biosafety and bio-policy. It aims at strengthening national capacities in biotechnology training, research, equipment and infrastructure. It also does promotion of collaborative and cooperative research, dissemination of scientific and technical information, support the production, distribution and commercialization of biotechnology products and contribute to harmonization of bio-ethics, intellectual property and patent rights.

- **Eastern and Central African Biosafety Focal Points** – Focuses on regional biosafety approaches.

- **The African Biotechnology Stakeholders Forum (ABSF) and the Biotechnology Association for Food, Feed and Fiber (AfricaBio)** are awareness creation networks.

- **The Southern African Regional Biosafety Programme (SARB)** – This programme aims at building biosafety capacity in seven countries in the sub-region to permit the safe and responsible introduction of GMOs and their products.

- **The African Agricultural Technology Foundation (AATF)** – This is a more recent initiative (2002) working towards improving access to technologies,
materials and knowledge to African smallholder farmers through public-private partnership.

- CGIAR Centers - A number of international research centers operate in Africa. These include ILRI, ICRAF, WARDA, CIAT, CIMMYT, ICARDA, CIP, IITA and are involved in the areas of biotechnology generation and capacity building on biotechnology, biosafety, risk assessment and patents.

**CHALLENGES AND THE WAY FORWARD**

Although all the available evidences suggest that biotechnology holds a promise for improving the sector, several challenges need to be addressed to achieve the desired outputs. As indicated above, the agricultural sector in general is smallholder subsistence production, challenged by biotic and abiotic stresses. Thus, the challenge is to develop animal biotechnology that benefits the poor with possible minimal inputs. Modern biotechnology could by-pass the needs of poor farmers as the technologies are promoted in a solution-oriented, rather than needs-oriented approach to the problems of developing countries. The major concerns are understandings of the prospects of these technologies; their appropriateness; factors that determine or influence their application; requirements for their applications and their impacts on the environment and human health. It should be underlined that the appropriateness of available biotechnology depends on many factors and needs to be tailored to suit the particular environment and should be driven by the need of resource-poor farmers. Introduction of technologies requires capacities for risk assessment and capabilities to manage the techniques; which is lacking today. Equity is another area in dealing with technology-transcending risks. Without proper policies and institutional support, there may be risks of increasing the poverty gap within and between societies. The presence or absence of support or backstopping after the introduction of biotechnological tools and products is another issue that should be taken into consideration. Adoption of more productive technologies is dependent on efficient performance of a range of markets (inputs, outputs, finance, labour, insurance, etc.) and rapid development of institutions for effective operations of the markets. With the current globalization, the great challenge of animal biotechnology is production of competitive products by smallholder farmers; products that fulfill the stringent quality standards and the trust for quality production.

The issue of intellectual property and knowledge management is another challenge for the adoption of biotechnology. There is a growing privatization of knowledge enterprise ('scientific apartheid?') by the industrialized countries, which in effect has skewed the benefit to the potential rich markets and thus excluding poor farmers. The same holds true for patenting and Intellectual Property (IP) in monopolization of knowledge and accessing the technologies. As much of the current investment in biotechnology research and development is by the private sector, patenting and IP are means for protecting and recouping the benefits.
Moreover, the degree of access to biotechnologies by poor farmers is hampered by IPR and high prices. In general IPRs in developed countries put more value on biotechnology outputs than on genetic resources (often used to create the biotechnology products) and contributions from communities, often in developing countries.

Ethiopia has signed and ratified the Convention on Biological Diversity (CBD). The convention’s primary objectives are the conservation and sustainable use of biological diversity, and the fair and equitable sharing of benefits arising from its utilization along with maintaining the resources in sustainable manner. Based on these opportunities, developing and implementing bioprospecting agreements have to be in place in the country more than ever before as the new developments in biotechnology and molecular biology are rapidly generating new products. Given the existence of great biological diversity in the country, the challenge is to effectively link animal biotechnology, biodiversity conservation and sustainable use. This requires many considerations including developing appropriate strategies, proper capacities, complex legal and regulatory frameworks and institutional linkages.

The outlook is that Ethiopia cannot be isolated in the effort to harness the benefits of agricultural biotechnology. The country should develop capacity across the whole spectrum of animal biotechnology including biosafety regulations, IP and policies on ethical and trade related issues. There are no trained personnel in the area of IP and there is no body who has a full understanding of IPR issues when making collaborative agreements with organizations that have their own IP. Sound policy on IP is very essential to take full advantage of animal biotechnology, to build national research and development capacity and to enhance effective partnership with different players. Therefore, an integrated and coordinated national capacity in agricultural biotechnology with defined roles and responsibilities of higher learning institutions, research organizations, Ministries, development organizations and the private sector has to be established and developed. It is also necessary to develop and strengthen national intellectual property management system. In order to undertake this task, the country should invest and also take strategic alliances and cooperation with many actors such as regional and international agriculture research centers, biotechnology initiatives for Africa, donor organizations and the private sector.

Nonetheless, the level of capacity building with associated resource requirements and implications on limited resource allocations against alternative research and development strategies have to be worked out carefully. There are certain cases where public investment in promising research areas has been penalized as a result of diverting major resources to agriculture biotechnology. It has to be realized that agriculture biotechnology is not a panacea for addressing poverty reduction and food insecurity; it is only one of the modern tools that can contribute to protecting the assets of poor farmers and pastoralists and increasing productivity. Poverty reduction and food security are complex issues and agriculture biotechnology alone
cannot be a solution to these challenges. To date, there are many controversies reported on the potential role of biotechnology in improving the livelihood of the poor farmers in developing countries. Although this issue is beyond the scope of this paper the dialogue should continue at different levels.

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PLANT TISSUE CULTURE: OPPORTUNITIES AND LIMITATIONS FOR ENSURING FOOD SECURITY IN ETHIOPIA

Legesse Negash

ABSTRACT

Plant tissue culture is a technique that heavily relies on the two basic principles of plant physiology, viz. plant nutrition and plant growth regulators. It is a procedure by which an explant is allowed to proliferate in vitro so as to produce fully-fledged plantlets. Since the demonstration by Philip White in the 1930s that tomato root cells can proliferate in a simple nutrient medium containing only sucrose, mineral salts, and a few vitamins, plant tissue culture has advanced to its current level of application for clonal multiplication of certain elite germplasm, production of disease-free planting stock, and regeneration of genetically modified plants. The technology is considered to have contributed positively in the production of fruit crops and flowers. However, plant tissue culture should only be viewed as a small window of opportunity for ensuring food security in Ethiopia, and not as a panacea for the deep-trenched food and environmental crises generated by a complex assemblage of social, economic and political factors. Furthermore, the technology will not be able to deliver the anticipated yield increments (and may even lead to frustrations!) unless the currently increasing environmental degradation, biodiversity loss and population growth are controlled.

Key words: Bananas, biodiversity, enset, natural resources, plant propagation, seeds

PLANT PROPAGATION: KEY TO BIODIVERSITY CONSERVATION AND HUMAN DEVELOPMENT

Propagation by seed

Since the origin of agriculture, humans have continuously propagated plants. The most familiar method is propagation by seed, which involves sexual recombination. The plants produced from seed are related, but not identical, to the parent plant. The extent to which an individual plant establishes itself in the soil is largely determined by the vigor of the corresponding seed (Bewley and Black, 1994).

In plant propagation endeavors, the seed is considered as an inexpensive commodity and, in the majority of cases, an effective means of propagation (Legesse Negash, 2002a, 2004). It is true that there are plants that set seeds poorly and intermittently, but with good seeder plants the cheapest method of propagation is achieved through seeds (Legesse Negash, 1992, 1993, 2004).

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Vegetative propagation

Vegetative propagation methods take advantage of the natural tendency of plants to reproduce asexually. The plants produced are genetically identical to the parent plant. Major methods of vegetative propagation include rooting of cuttings, layering, and grafting (Hartmann et al., 1990).

For plant species that can easily be propagated by cuttings, the method of vegetative propagation has the following advantages: 1) Many new plants can be raised in a limited space from a few stockplants; 2) The method is inexpensive, rapid and simple and does not require the special techniques necessary in grafting or budding; and, 3) plants can be propagated by vegetative means at any time of the year (Hartmann et al., 1990; Legesse Negash, 2002a,b; 2003a,b).

Plant tissue culture

Definition, history and concepts

Plant tissue culture is a process that exposes disinfected plant tissues to a specific regimen of nutrients, hormones, and light under sterile, in vitro conditions to produce many new plants over a relatively short period of time.

Although the idea of plant tissue culture was originally proposed in 1902, successful in vitro growth of tissue was achieved by Phillip White in 1934 from tomato root explants (Taiz and Zeiger, 1998). And the first whole plants regenerated from culture were carrots in 1958 by F.C. Stewart. Stewart also demonstrated the development of somatic embryos in liquid culture of carrot cells. Today, the number of species that can be propagated by tissue culture techniques is large.

There are three central concepts essential for the understanding of plant tissue culture and regeneration, viz. plasticity (the flexibility or adaptability of, e.g., cells or tissues to altered chemical and physical factors such as hormones, nutrient elements, fixed carbon sources, light, temperature, and culture vessels), totipotency (capacity of cells or tissues to develop into any other structure of the mature plant) and de-differentiation (in which differentiated cells get de-differentiated in order to pave way for a new line of development) (Bonga and Durzan, 1987).

Basic techniques and media constituents

The technique of plant tissue culture involves firstly the identification and/or preparation of a stockplant, severance of a plant piece (called explant) from the stockplant, surface sterilization of the explant using chemicals such as calcium hypochlorite, mercuric chloride, or alcohol. The tissue must then be rinsed several times in distilled sterile water, cut into the required sizes, and partially inserted into or placed on a culture medium. The culture medium (prepared from macro- and microelements, iron sources, organic supplements, fixed carbon sources, plant growth regulators, and solidifying agents) must be properly sterilized before using
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It for tissue culture purposes. All tissue culture operations must be conducted under aseptic conditions (e.g. within laminar air flow hood) maintained in a clean room.

A typical plant tissue culture medium (revised and published by Murashige and Skoog in 1962) is composed of the following ingredients:

- Macronutrients (derived from KNO₃, NH₄NO₃, CaCl₂.2H₂O, MgSO₄.7H₂O, and KH₂PO₄);
- Micronutrients elements (derived from MnSO₄.4H₂O, ZnSO₄.7H₂O, H₃BO₄, KI, Na₂MoO₄.2H₂O, CuSO₄.5H₂O, CoCl₂.6H₂O);
- Iron (derived from FeSO₄.7H₂O and Na₂EDTA.2H₂O);
- Organic supplements (myo-inositol, nicotinic acid, pyridoxine-HCl, thiamin-HCl, and glycine);
- Fixed carbon source (commonly sucrose or glucose); and
- Plant growth regulators, viz. auxins (e.g. 3-indolebutyric acid, 2,4-dichlorophenoxyacetic acid, 1-naphthaleneacetic acid, indole-3-acetic acid), cytokinins (e.g. 6-benzyleaminopurine, 6-furfurylaminopurine). By changing the types, amounts, and ratios of hormones in the medium (particularly those of auxins and cytokinins), tissues can be stimulated to develop into shoots or roots.

In addition to the above basic ingredients, other items such as agar, activated charcoal or PVP (polyvinylpyrrolidone) are added to the culture medium in a defined proportion. Since most tissue culture media are needed in semisolid forms, agar is commonly used for solidifying the medium. Activated charcoal or PVP is added to the medium to adsorb phenolic compounds produced at the cut ends of tissues resulting from the activities of copper containing oxidase enzymes (Torres, 1989). Explants from plants such as Cordia africana Lam. and Hagenia abyssinica (Bruce) J. F. Gmel. result in tissue browning at the cut ends, thus necessitating the removal of the phenolic compounds through various methods, including the use of activated charcoal or PVP.

Requisite conditions

Successful use of plant tissue culture technique requires reasonably clean environment and good facilities, especially in Ethiopia where aerial contaminant load (microorganisms, dust, etc.) is very high. Basic facilities required include: clean (and spacious) room, laminar-air-flow hood, double distiller, autoclave, chemicals (nutrient elements, hormones, gelling agents, and other additives), culture vessels, refrigerators, microscopes, dissecting kits, water distillers, uninterrupted power supply, as well as well-conditioned glasshouses and nurseries.

At its current state, large-scale application of tissue culture requires cheap, yet skilled, labor. That is why commercial tissue culture units from developed
countries show interest in establishing tissue culture laboratories in developing countries for the production of disease-free planting material for fruit crops such as bananas and plantains. Availability of cheap, yet skilled, labor is essential for undertaking activities that include weighing, media preparation, stockplant management, explant preparation, culture initiation and multiplication, plant regeneration, and a number of other activities.

**Explant and culture types**

Explants (suitable pieces of plant parts) can be obtained from a variety of plant parts. They can be pieces of organs such as buds, leaves, roots, or shoot tips. They can also be derived from specific cell types or poropagules such as pollen, endosperm, embryos, or seeds.

Depending upon the objective of the experiment, a variety of culture types can be initiated, including callus, cell suspension, protoplast, meristem, root tip, shoot tip, axillary bud, embryo, or microspore culture.

**Steps in plant tissue culture**

Murashige (1974) distinguished three stages in the process of micropropagating plants.

Stage I: This is the establishment or initiation phase of an aseptic culture. The stage is mainly concerned with the selection of suitable explants, washing and disinfecting these with appropriate concentration of disinfectants, and initiating them into aseptic, in vitro culture.

Stage II: The major preoccupation of this stage is the multiplication of propagules. At this stage, the in vitro plant material is portioned out and subcultured in a medium with plant growth regulators that stimulate the proliferation of multiple shoots. Subculturing is repeated until the desired number of plants is obtained.

Stage III: This is the root formation phase, and (along with acclimatization) is the most difficult stage. It usually involves the reduction of macro- and micronutrients to half strength of that used in the initiation and multiplication phases. In many species, root initiation occurs when auxins such as IAA or IBA are incorporated into the rooting medium.

**Micropropagation**

Plant tissue culture has a number of applications, but the two major ones are micropropagation and regeneration of genetically transformed cells through tissue culture.

*Micropropagation is a procedure that allows the in vitro production of large numbers of plants from a limited number of explants. Compared to the conventional propagation techniques, micropropagation offers the following advantages: 1) A single explant can be multiplied to give rise to several thousand*
plantlets; 2) Explant production does not normally destroy the stockplant; 3) Successfully established cultures can serve as continuous sources of plantlet production; 4) Propagation is independent of seasons of the year; and, 5) Micropropagation allows the introduction of selected clones for plant improvement.

Micropropagation has had some success in the provision of clean planting stock, but the process does not confer disease or pest resistance. On the contrary, tissue cultured plants are easily infected by pests and/or diseases if planted in contaminated soils. In many instances, use of tissue cultured planting stocks may delay use of chemical control measures. Unfortunately, and despite early euphoria, plant tissue culture cannot eliminate all of the viruses and bacteria that plague cultures.

Examples of micropropagated plants include: Cymbidium orchids (the first to be commercially propagated), tulips, roses, potatoes, lilies, bananas, plantains, etc.

Because commercial micropropagation of bananas and plantains has had some success in quality fruit production, and because these plants are important for Ethiopia and are also related to Ethiopia's enset (Ensete ventricosum (F. M. J. Welwitsch) E. E. Cheesman), comments will be made on the distribution, biology and propagation of bananas and plantains.

**BANANA AND PLANTAIN**

These are useful plants widely grown across the tropical regions, and are major food crops in developing countries. They are easy to grow, and production is relatively stable. Banana and plantain are important export commodities to the industrialized countries (Frison and Sharrock, 1998).

Fruits of banana and plantain are nutritious, containing carbohydrates, mineral elements (such as P, Ca, and K) and vitamins (such as vitamins A, B6 and C) (Frison and Sharrock, 1998).

African bananas are genetically grouped into three categories: AA, AB, AAA, and ABB) The African plantain bananas (AAB) is grown mainly in Central and West Africa. The East African highland banana (AAA) is used for cooking and in the preparation of beer (Karamura et al., 1998). Although not of African origin, African bananas have evolved into an important zone of secondary genetic diversity. In particular, the lowland regions of west Africa contain the world’s largest range of genetic diversity in plantain, while the highlands of East Africa are important centers of diversity of cooking bananas.

Traditionally, bananas are clonally propagated by suckers. Triploid genotypes are sterile, and develop their fruit through vegetative parthenocarpy. Diploid landraces and tetraploid cultivars (mostly artificial hybrids) are also cultivated (Picq et al., 1998).
Commercial production of banana and plantain are characterized by the use of a very limited number of varieties. Cavendish, for example, is currently the most widely cultivated variety of dessert banana, and is grown throughout the world, while Cuerno (horn) is a widely cultivated variety of plantain (Frison and Sharrock, 1998).

Major production constraints of bananas include pests (banana weevils), parasitic nematodes, diseases (black Sigatoka leaf spot disease), fungal leaf spot (Fusarium wilt), banana streak virus, banana dieback virus, and cucumber mosaic virus (Daniel Shamebo, 1998; Picq et al., 1998).

There are reports indicating that tissue culture has replaced the use of conventional vegetative suckers in many of the intensive and/or commercial banana-growing regions.

Improvement in banana fruit yields through tissue culture can persist up to 3 harvests, but this requires appropriate wombs for plant development, e.g. fertile soil, adequate water. Prolonged pest-free period for months is a relief, but does this justify the current costs (ca Birr 6/plantlet) for a large-scale domestic consumption in Ethiopia? Clearly, given the current level of the technology, and the costs involved in the production of planting material through tissue culture, there appears to be no convincing justification for being overly euphoric about the role of tissue culture in ensuring food security in Ethiopia. Unless significant subsidies are put in place, the costs of providing "clean" planting stock to the vast numbers of impoverished farmers is prohibitively high. Perhaps, tissue culture may impact on food security through focusing on economically viable and exportable commodities, including bananas and enset.

**ENSETE VENTRICOSUM**

*Ensete ventricosum* (F. M. J. Welwitsch) E. E. Cheesman is a large arborescent herb and monocot having huge paddle-shaped leaves and bearing inedible fruits that resemble bananas. It is a tall plant up to 10 m high, with pseudostem up to 1 m in diameter. The large leaves are borne in a banana-like crown, and are erect or spreading (http://www.aas.org/international/africa/enset).

*E. ventricosum* has a wide range of distribution in Eastern Africa from Ethiopia south to Zimbabwe. It is very variable in form so that, historically, it was described under different species names in different parts of its range (Baker and Simmonds, 1953; Simmonds, 1958). Given the limited geographic distribution of domesticated enset, agronomists and biogeographers have long considered the Ethiopian highlands to be the primary center of origin for enset agriculture (Vavilov, 1951; Harlan, 1969).

*E. ventricosum* is an important crop in parts of highland Ethiopia. The starch extracted from the base of the pseudostem and young inflorescence stalk is a staple food for millions of persons. Remarkably for such a drought prone country as Ethiopia, the farming areas in which Ensete is part of the agricultural system have
never known famine. Some forms of *E. ventricosum* are used medicinally and ritually (Shank, 1994; http://www.aas.org/international/africa/enset).

*E. ventricosum* (commonly called Abyssinian banana) is appreciated and described in the Web by different plant propagators. Three examples are quoted below:

"*E. ventricosum* is a magnificent foliage plant for the garden, either in summer bedding, as it was used by Victorian gardeners, or in a container, as large as you can manage! It is potentially a very large plant indeed with a pseudostem 5 m tall and huge leaves 6 m long and 1 m broad. Although it does not reach its full potential in the UK, indoors or out, it is very easy to grow and quickly becomes a large and impressive plant." (http://www.kobakoba.co.uk).

"This massive Abyssinian banana, whose trunk can reach 3 feet [=91.44 cm] in diameter, is a real botanical curiosity" (http://www.rarepalmseeds.com).

"An unbelievably fast growing banana that can reach massive proportions with a trunk diameter of 3 ft!! " (http://www.urbanjunglenursery.co.uk).

In 2002, *E. ventricosum* was awarded an AGM (Award of Garden Merit) by the RHS (Royal Horticultural Society, UK). The AGM is awarded by a committee of the RHS to plants that have the following qualities: (1) Outstanding excellence for garden decoration or use; (2) available in the trade; (3) of good constitution; and, (4) require neither highly specialist growing conditions nor care (http://www.urbanjunglenursery.co.uk).

Interestingly, there are a number of nurseries which sell different types of enset bulbs through advertising these on the Internet. For example one US-based nursery sales "Mother bulb" for US$39.00 (ca Birr 332); "Grandmother bulb" for US$79.00 (ca Birr 672); and "Goliath-size bulb" for US$149.00 (ca Birr 1,281) (http://www.info@bananagarden.com). In the UK, a plant in a 3-liter pot is advertised for sale at £10.00 (ca Birr 130) (http://www.urbanjunglenursery.co.uk).

**Current studies on *Ensete ventricosum***

Currently, quite a number of Ethiopians are working on *E. ventricosum* (e.g. Negash et al., 2002). However, at present, only one Ensete (the ornamental red Abyssinian banana, *E. ventricosum* 'Maurelii') is commonly micropropagated. It has become increasingly common to find suckers of these plants for sale, apparently as a result of the micropropagation process now used in the commercial propagation of the plants.

**STATUS OF PLANT TISSUE CULTURE IN ETHIOPIA**

It is to be noted that the first (local institution) plant tissue culture laboratory was set up in 1989 in the Biology Department of the Addis Ababa University. The laboratory was assembled (initially with the assistance of the Stockholm-based International Foundation for Science) using a minimum set of equipment with a view to achieving one of the most difficult tasks --- that of rescuing and developing
the rapidly vanishing indigenous trees of Ethiopia (Legesse Negash, 1995, 1998). Clearly, plant tissue culture is in its infancy in Ethiopia. Future development of the technology is likely to be constrained by: (1) relatively high initial investments for establishing descent labs, controlled glasshouses, and plant propagation centers, (2) lack of efficient procurement procedures; (3) bureaucratized approach to research and development; (4) scarcity of skilled labor, and, (5) absence of commercial initiatives for large scale plant propagation through use of tissue culture techniques.

FOOD SECURITY IS A MULTI-FACETED PROBLEM

Critical resources and food security

Many countries of the world ensure food security for their people by both boosting domestic agricultural productivity and buying food from other countries. The balance between imported and home produced food is determined by a number of factors, including purchasing capacity and access to global markets on the one hand, and suitable local conditions for agricultural productivity on the other. Given the current level of food variety requirements by humans and state of globalization, no country appears to be totally food self-sufficient.

In the context of Ethiopia, the maintenance and conservation of critical resources such as land, soil, water, biodiversity (plants, animals, insects, fungi, microorganisms, etc.) is extremely essential for agricultural productivity. On top of this, prevalence of favorable climatic conditions and availability of energy (for driving agriculture) is essential. In addition to the presence of skilled people and sound agricultural knowledge, availability of machinery relevant to local conditions is extremely important.

Because hunger in Ethiopia is concentrated in degraded areas, it is extremely urgent that land restoration activities are undertaken on a massive scale throughout the country, while at the same time creating conducive policy environment for sustainable farming in the remaining pockets of fertile land. Experts in land policy strongly argue that insecure land tenure perpetuates food insecurity and is a major cause for unsustainable farming practices. Additionally, insecure land tenure invariably fails to stimulate sustained natural resources conservation practices.

Biodiversity and food security

Two statements from the Executive Summary of the Global Biodiversity Outlook document run as follows: "The genes, species, and ecosystems that comprise biological diversity provide resources and services that are essential to mankind. --- From this complex web of interacting natural processes human societies derive the multiplicity of benefits that has guaranteed their welfare and development throughout their history."

The impact of biodiversity on the welfare of society is pervasive, ranging from the conversion of electromagnetic radiation coming from the sun into chemical energy
(via photosynthesis) to provision of food and feed, as well as medicine. Biodiversity is crucial for the maintenance of life support systems (including water and soil), and for moderating the impacts of adverse climatic conditions. It is necessary for improving the economic welfare of local communities through export of high-value plant/animal products and through the development of ecotourism.

**Plants, micronutrient elements and food security**

Plants, through their enormous root surface area, are efficient in extracting nutrient elements from the soil. They are effective not only in absorbing the elements that are at very low concentrations in the soil, but also at selecting, accumulating and using these for metabolic purposes. Because mineral elements enter the biosphere mainly through the root systems of plants, the latter have often been characterized as "miners" of Earth's crust (Epstein 1972, 1994; cited in Taiz and Zeiger, 1998).

Ethiopia has a number of indigenous tree species that are nitrogen fixers and/or nutrient pumps, but they have not yet been selected, domesticated and propagated to benefit this country's dilapidated agricultural (Tadesse Hailu et al., 2000; Legesse Negash, 2002c). The state of agroforestry in Ethiopia, and the potentials of some selected endemic agroforestry trees have been discussed by Legesse Negash (2002a).

According to one report, over 2 billion people worldwide suffer from micronutrient deficiency (FAO, 2002). The diets of these people (almost exclusively from developing countries) contain inadequate levels of micronutrients (such as iron, zinc, selenium) and vitamins (such as vitamins A, C, and folate), thus leading to the prevalence of a "hidden hunger".

The most dangerous consequence of iodine and/or iron deficiency is reduced mental capacity. Some 20 million people worldwide are mentally handicapped as a consequence of iodine deficiency, including 100,000 babies born each year with irreversible brain damage (FAO, 2002). Ethiopia is among the worst categories of countries suffering from insufficient supply of micronutrients and vitamins. The majority of Ethiopian children suffer from micronutrient and vitamin deficiencies. So do adults where anemia and other micronutrient deficiency diseases (e.g., apathy to do physical or mental work; fatigue, dizziness; lack of agility, alertness or orderliness; lack of attentiveness; as well as lack of motivation for undertaking essential tasks) are believed to be widespread. That is probably why many of us in Ethiopia appear to be good at narrations and arguments, but bad at practical innovations and taking quick actions on matters so important for our survival (e.g., tree planting, resource conservation, technology generation, etc.). Unless quick and all out efforts are undertaken for reversing the prevailing conditions, micronutrient and vitamin deficiencies are striking (and will continue to strike) at our intellectual resources. The short-term solution could come from food fortification and provision of supplements. The long-term solution should focus on rehabilitating
and restoring natural resources, creating (and not narrating about!) biodiversity, controlling population growth, and diversifying agricultural products.

**External debt and food security**

Ethiopia's external debt at the end of June 2003 stood at US$6.794 billion or 106.8% of its Gross Domestic Product, and the percentage is by far greater than that for sub-Saharan countries, which was 64.3% in 2002 (FAO/WFP, 2004). This situation is literally similar to an unlikely situation of a retired Ethiopian soldier earning Birr 100.00 per month and being requested to pay back Birr 106.80 in the same month for a debt he has incurred long ago. Where would the deficit (Birr 6.80) come from in order for the retired to meet his obligations? Where would he turn to for survival after all his monthly earning has been handed over by way of debt servicing? Clearly, ensuring food security in Ethiopia requires protracted negotiations with the creditors in order to get meaningful debt relief with a view to promoting agricultural productivity.

**Population growth and food security**

"Life cheapens in its own abundance". This remark was made long before the human population started inundating the earth's surface. But, unfortunately, the present author does no longer remember the name of the philosopher who made this remark, and exactly when.

In any event, it has been reiterated time and again that population pressure: (1) unleashes competition for scarce resources, (2) depletes land of its essential resources, (3) leads to the abandonment of sustainable production methods, (4) deepens poverty, (5) ushers in social strife, and (6) forces communities to mass migrations and/or deaths. It is understandable that projects geared towards controlling human population have been operative in Ethiopia for quite some time, but their impacts appear to be insignificant. It is therefore extremely important that existing programs and projects on population growth be strengthened and, at the same time, more result-oriented schemes be devised, financed, and implemented as quickly as possible. Given the current environmental crises, the humble effort made towards ensuring food security is overwhelmed by the zooming growth of population.

**A CONCLUSION AND A QUESTION**

- Until the prevailing vicious cycle is transformed into a virtuous one, no amount of tissue culture and/or biotechnology shall guarantee food security in Ethiopia.
- After all, haven’t the industrialized nations been food secure long before the advent of plant tissue culture and/or biotechnology?
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THE ROLE OF FISHERIES AND AQUACULTURE IN POVERTY ALLEVIATION AND FOOD SECURITY

Misikire Tessema

ABSTRACT

Fishes are prominent sources of livelihood and employment to millions of the world's poor people. Similarly, they have been playing vital role in the livelihood and local economies of many Ethiopians. In Ethiopia, fishing is mainly based on the natural stocks. These common pool resources are subject, in addition to several others, to unregulated capture fisheries, resulting in overexploitation of target fish species as has reportedly been observed in some of the major fishing grounds. Besides, Ethiopian aquatic ecologies are often considered as the natural sinks to all sorts of wastes, including industrial and municipal ones. Unfortunately, some of the fishes consumed in the country are captured from those waters and the effect on the health of consumers, though not yet well quantified, will be far reaching. In the faces of the above realities on one hand, and prevailing chronic drought, food insecurity, poverty, alarmingly increasing rates of unemployment and human population growth and degradation of natural resources on the other, the need for the introduction, expansion, integration and intensification of aquaculture is immense. Despite this, immediate commencement of sustainable and profitable aquaculture is bound with several limitations. This paper attempts to surface these limitations and deals with basic prerequisites for the establishment of successful and sustainable aquaculture. It also attempts to briefly chart priority issues that should critically be addressed simultaneously or stepwise if aquaculture is to flourish in the country and contribute towards poverty alleviation and food, nutritional and job securities.

INTRODUCTION

In many parts of the world, fishes are considered as one of critical cash crops. They are the major parts of staple diet and prominent source of animal protein. They play a significant role in local and regional economies providing income and employment opportunities to those involved in various activities ranging from production of raw materials to the construction and mending of fishing gears and shopping. Contribution of fishes to the global diet and animal protein are about 6% and 20%, respectively (Williams, 2000). The livelihood of about 35 million Africans depends wholly or partially on fisheries activities (http://www.fao.org/docrep) and their contribution to animal protein in sub-

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Modernizing Agriculture: A way out of food insecurity?  

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Saharan Africa is about 21% (Otte, 2000). According to estimates, the demand for fishes in the world (http://www.aquaculture.israel.com/world_trade.html.) and Africa (Otte, 2000) by the year 2010 will exceed the supply by 40 million tons and one million tons, respectively. Fishes have also been playing vital roles in the livelihood of many Ethiopians particularly to those living around major water bodies, and will remain to play even greater role. If attended, their role in contributing to national economic development and food security goals will be immense. Despite this, fishes and other aquatic biotic resources are one of the least recognized resources and are subjected to abuses.

Aquatic resources constitute reserve of renewable capital that can be withdrawn at times of need. The degree of renewal of these resources is, however, based on wise use and proper management. Unfortunately, Ethiopian fishing grounds are common pool resources that are subjected to unlimited access and are often considered as natural sinks to all sorts of land and water-based wastes. As a result, some of the water bodies are showing the signs of reduced productivity and depletion of some target fish species. It would, therefore, be wise to gradually start using farmed fish until there are tangible signs to fully return to the wild, and this can be achieved through implementation of wide range of activities such as reversing of prevailing threats, planned enhancement/management of natural stock and gradual introduction of aquaculture into the agricultural sector. Unfortunately, little attempt has so far been made to put these into practice.

Aquaculture refers to the cultivation or farming of plants and animals that are of various human uses in aquatic environments. However, this paper deals with cultivation of finfish. The main objective of this paper is, therefore, to emphasize on the need for and options to the development of aquaculture in Ethiopia. To this end, it attempts to identify major challenges hindering the immediate commencement of the sector. It also attempts to briefly highlight priority issues that should critically be addressed simultaneously or stepwise if aquaculture is to contribute towards poverty alleviation, and food, nutrition and job security goals.

STATUS AND TRENDS OF GLOBAL AQUACULTURE

Today, aquaculture is recognized as the world's growth industry, exhibiting bright potential for development and economic gain and is even asserted as the fastest growing and the most lucrative sector of agriculture of many countries. Aquaculture's favored status is reflected by what is happening in the natural fishing grounds. Once the sources of bountiful fishes, the world's outstanding fishing grounds are now yielding fewer and fewer and like the buffaloes on the plains, whose populations were once considered as limitless, some varieties of fishes are becoming scarce. This has resulted from the success of fishing industry, a success that included the seeds of its own destruction. Increasing appetites and demands for fresh, quality and safe animal products emanating from increasing population and living standards has risen the demands and prices of fishes. This has in turn caused the increase in the number of fishermen, efficiencies of fishing and improvement in
fishing gear technologies, the effects of which is over-fishing. Moreover, significant number of fish populations were decimated by environmental factors such as pollution and habitat destruction. Because of the cumulative effects of the above, indications are that fishes are unlikely to even return to being the poor man's cheapest protein sources in many countries and the gap between supply and demand is widening from time to time and this has to be bridged by the products that should come from aquaculture.

Status

A few years ago, the world trade in seafood was estimated at more than 100 billion US Dollars \textit{per annum}, and half the balance was contributed by aquaculture. In late 90's the annual global output from aquaculture was about 28.3 million tones, representing the world's fisheries and finfish production of 23 and 29%, respectively, and finfish represented 49% of total aquacultural output and 55% of aquacultural value (http://www.aquaculture.Israel.com/world_trade.html).

In Africa, aquaculture gradually followed the introduction of cold-water-trout into limited high altitude areas of Kenya and Madagascar in late 20's and the first successful pond production of tilapias in southern Zaire dates back to 1946. This was followed by massive transfer of classical European fish farming techniques into different countries and was running smoothly up to 50's. At early 60's, however, development of aquaculture in the continent not only stopped but also regressed sharply until the late 60's where it started reviving gradually, and these were attributed to several factors (FAO, 1994; Brummett, 1994). In 1995, Africa's total output from inland fisheries, inland and marine aquaculture were about 1990000, 35000 and 16000 tons, respectively, out of which about 56% came from Nigeria (15498 tons) and Egypt (5645 tons) followed by Zambia, Madagascar, Togo, Sudan, and Kenya, each of which were producing about 1000 tons and the contribution of Africa's aquacultural output to the world's total was about 0.2% (http://www.fao.org/docrep). As far as Ethiopia is concerned, aquaculture has not had any significant history and it still is virtually non-existent.

Trend

Attributed to the decline in the catch from the natural fishing grounds and increasing human population on one hand, and increasing expectations for quality and safe animal products on the other, demand for seafood is expected to increase by 0.5 - 3.0% per year. This would on average mean additional yearly requirements of about 650,000 tons in the EU and about 250,000 tons in the USA. By years 2005 and 2010, therefore, shortages in seafood will rise to 20 and 40 million tons, respectively (http://www.aquaculture.Israel.com/world_trade.html.), and it may take decades before aquaculture may meet most of the world's demand for fishes.

In Africa in general and sub-Saharan Africa in particular where more than 22.5 million children and 240 million people, respectively were subjected to severe
malnutrition in mid 90's (http://www.fao.org/docrep), the demand for fish by the year 2010 is expected to exceed the supply by one million tons (Otte, 2000).

RATIONAL FOR, AND OPTIONS TO THE DEVELOPMENT OF AQUACULTURE IN ETHIOPIA

Rationale
Like in many sub-Saharan African countries, drought and malnutrition have become chronic to Ethiopia. Not only have they affected the livelihood of millions of Ethiopians but also are expanding into areas where they were never observed before. Besides, land and other natural resources are degrading at an alarming rate and plots of agricultural lands found in many parts of the country have reached the limit beyond which they cannot produce the expected minimum, if external inputs are not applied. Moreover, human population, unemployment and poverty are growing at alarming rates.

According to a study by FAO (1986) on economic analysis of land use patterns that was conducted at household levels in all provinces of the country, holding of extra three to four heads of cattle is required to secure one ox. The above study indicated also that, under the existing farming and farm management practices and rate of population growth, the trend in need for extra plots of croplands will certainly remain increasing in the years to come and every increase by each hectare of cropland would require extra four hectares of grazing land. Realities are, however, that expansion of grazing and agricultural lands are not affordable for unforeseen periods of time. Therefore, this finding warns macroeconomic planners to look into ways of intensifying and diversifying various economic sectors. In this regard, aquaculture could be one of the potential agricultural sectors that not only requires little space but also could be conducted in areas that are not suitable for other agricultural activities. Comparison of area requirements and yields between cattle ranching and pond-fish farming in deforested grasslands of Amazon basin, for example, indicated that while an output of 2000 - 5000kgs/ha/yr was achieved from pond-fish farming, only 50-250 kg/ha/yr was achieved from cattle ranching (Werder, 1998). According FAO (1986), the annual output in meat equivalents from the Ethiopian grazing lands is 12.5 kg only. Moreover, it is one of the agricultural sectors that produce more crops/year/unit area than most other animal protein sources. Studies were conducted in different parts of the world to determine effective cycles of production of candidate fish species at different levels of intensities. Similar studies conducted on three potential aquacultural candidate fish species, namely, Nile tilapia, African catfish and common carp at two levels of intensities (small and commercial) in different African countries found production cycles of about 1.3-1.7, 1.9-2.4 and 1.6-2.0, 1.3-1.7 and 1.2-1.5 per year Individual fish weights at harvest were up to 150 g or about three harvest cycles per two years with the individual fish weights at harvest of more than 500 g was achievable for the species and levels of intensities put in the same order as above.
Unlike in the developed world, decline in catch from some of the Ethiopian main fishing grounds is not caused by the success of fish industry or by the conscious shift in food preference of Ethiopians. It was rather, among other factors, effected by over-fishing, which in turn has been emanating from increasing rate of unemployment and weak control over the right of access. Ethiopian aquatic ecosystems are, most probably, the only vacant places to all nationalities, age and gender groups that are open year round and to whatever activities. The effects of some fishing methods such as poisoning on fishes are also far reaching. Moreover, Ethiopian aquatic ecosystems are subjected to severe pollution and habitat destruction. They are considered as natural sinks to all sorts of land and water based wastes. As a result, some of the water bodies are showing signs of reduced productivity and depletion of some target fish species. Few attempts were made to quantify the effects of industrial pollution on fishes and other biotic resources (Zinabu Gebre-Mariam and Zerihun Desta, 2002). The actual effects on the whole food web in general and human consumers in particular may, however, be much worse than would one expect. In this regard, it should be stressed that Ethiopians have also the right of access to not only to quality and fresh but also to safe foodstuffs that are affordable in desired quantity, space and time.

Conditions encouraging agricultural production are generally favorable for aquaculture and vice versa. In this regard, agriculture is by far the most important economic activity of the majority of Ethiopians and is a sector that has received the utmost attention from the government. Moreover, the fact that aquaculture is one of the sectors that can easily be integrated with various agricultural and non-agricultural activities justifies that the chance for gradual introduction, expansion and intensification of this sector is immense.

In the face of realities the country is facing, contribution of aquaculture to the overall national development efforts will be multifaceted. Besides its significant role in poverty alleviation, food, nutrition and job security goals at local and regional levels, the fact that supplies for safe, fresh and of that consistent quality foods of aquatic origin at the global markets are treading far below the demand implies that the role of a well planned aquaculture in diversifying the export items of the country will be significant. Therefore, the need for gradual introduction, expansion and intensification of aquaculture in Ethiopia should not be limited to the immediate roles it could play in local and regional economies. It should also be viewed from the wise and sustainable use of resources, diversification of exportable agricultural goods and long-term national development perspective.

Requirements and options for development

Aquaculture can be conducted profitably under a variety of conditions and environments. Basic factors required to run sustainable and profitable aquaculture
are favorable physical factors, availability of culture facilities and species cultured, reliable sources of inputs and managerial know-how. An ideal aquacultural system should be flexible, multipurpose and integrated. It should involve minimum investment and operation costs and be located in serviceable and potential market areas. Likewise, an ideal aquaculture species should be those that have wide ranges of feed spectrum and simple dietary requirements. They should exhibit fast growth potential, hardiness to handling and resistance to diseases. They should be acceptable in the market and be those to which advanced and proven technology to fully control their life cycle in captivity as well as to other production and management practices is available. Whichever species, production system and strategy it may employ, aquaculture can be integrated with different economic sectors. It can be integrated either as secondary with different activities that involve water storage or as primary while other integrated economic sectors may be run as secondary. It can also be conducted alone on land or in natural water bodies.

i) Integration with other economic sectors

Integration of aquaculture with different activities is one of the most sustainable form of aquaculture. It can be integrated with any economic activities that involve storage of water such as irrigation, livestock, power plants and potable-water projects. Experiences show that aquaculture can even be integrated with such activities as waste recycling systems. Based on such factors as the purpose of construction of water bodies, culture species, availability of inputs and managerial know-how, fishes can be reared either by direct release of fry into water bodies, holding in different enclosure systems or by combinations of both. Benefits from a well planned integration of aquaculture with different economic sectors include:

- shared investment on common structures;
- partially shared operation costs;
- complementarily improving productivity/efficiency of integrated activities,
- increasing employment opportunities;
- diversification of production systems;
- ensuring food security;
- improving nutritional and income status of the local communities; and
- biological controls.

ii) Integration with irrigation

Conditions encouraging agricultural production are generally favorable for aquaculture and vice versa. Existence of developed or potential for development in foreseeable future of irrigated agriculture implies that there exists at least minimum infrastructure, agricultural by products and labor.
Sound integration of different economic activities has not yet been practiced in Ethiopia. The country has, however, a handful of reservoirs that are constructed for irrigation and are serving the purpose and several others which are either at different phases of construction or studies where integration of different activities can be conducted easily. Moreover, the ever-increasing awareness being exhibited by the country to avoid dependency on rain-fed agriculture is expected to mushroom the number of reservoirs and canals of different dimensions where aquaculture can easily be integrated.

Integration of aquaculture with irrigation involves, often, placing of aquaculture between water source and command areas. It involves the use of the reservoir, irrigation canals that will be divided, based on physical factors and production objectives, into different compartments and/or series of ponds that will be constructed along the main canals at marginal lands. In anyone or combinations of these facilities, farming of mono- or poly-culture of fish can successfully be conducted either by direct release of desired species into the structures or preferentially keeping them in enclosure systems. In such a way the water, instead of serving for irrigation only can be used twice: first for fish farming and then the water enriched with fish droppings, fish wear-outs, fertilizers and/or feeds is used for irrigation.

iii) Integration with livestock, power plant and potable water projects

Aquaculture can also be integrated with different livestock production systems. It can be integrated with poultry, fattening of ruminants, swine or in combination with any one. The integration will have a complementary advantage so that the livestock manures can serve as pond fertilizers while the leftovers from fish processing can easily be converted into protein-rich animal feeds. Likewise, careful integration of aquaculture with water-based power plants such as hydro-electricity generation projects can also be successful. In this case also the integration has complementary advantage. While fishes could aid the successes of the primary purpose in such ways as reducing floating vegetation, the water can be used for fish farming. The integration should, however, be planned in such a way that it should not have any negative impact on the primary purpose of construction.

Aquaculture can also be integrated with potable-water supply projects. As is the case with irrigation, integration of aquaculture with potable-water supply projects may be conducted using ponds constructed at nearby marginal lands, direct release of culture species into the reservoirs, using enclosure systems or combinations of any one. Unlike the reservoirs meant for irrigation, however, application of external inputs such as fertilizers in water bodies constructed for potable-water supply can seriously damage public health and structures meant for the implementation of the purpose of construction. Therefore, the choice for the strategy of production, types, designs and numbers of enclosures to be employed, species to be cultured and densities of stocking must be done with the utmost care, if such reservoirs are to be used directly.
iv) Integration with multipurpose economic sectors

Fish farming can also be integrated as a secondary activity with multipurpose economic activities such as water development projects meant for potable water supply, navigation and power generation. A good example in point is integration of fish farming in Kariba dam. Kariba Dam is constructed on Zambezi River in Zimbabwe and was meant for multipurpose economic activities. However, integration of classical aquaculture into the dam system was not thought seriously until Danish Institute for Fisheries and Aquaculture Technology (DIFTA) had it later designed. DIFTA took a portion of the canal having 650 meters in length and divided it based on the slope and production objectives, into five compartments each of which had dimension of about 100 m * 20 m * 2 m wherein breeding, nursery and fattening activities of Nile tilapias were conducted. In the Ellane Fish farm, where varieties of activities ranging from breeding to fishes processing are conducted, the yield from the fattening section is about 480t/year (Windmar et al. 2002).

Presented below is another example of integration of aquaculture with other multipurpose projects. This novel, benign and seemingly easily applicable plan was designed by Halton Borough Council (2002) in the UK. The plan was to integrate different economic activities into its solid waste recycling schemes for the years 1992 to 2012. The objectives of the envisaged plan were:

- solid waste removal,
- recycling some of the solid wastes into new products,
- composting the organic portion of the waste,
- using the compost and sludge for organic farming of vegetables, flowers and firewood,
- production of biogas from composting organic matter, and
- rearing of warm water fishes over compost structure.

According to the plan, all but the first activities will simultaneously be conducted in a single pond. To do so, a series of ponds each with the dimension of about 100 m * 50 m * 7 m will be prepared. Water tightened ponds so prepared will be fixed with thermo-regulators and biogas recovery systems. Each pond will then be filled with organic matter to the height of 5 m and will again be water tightened using polyethylene sheet and sand layers. Then, the pond height of 1.5 meters will be filled with water wherein warm water fishes will be reared using the heat generated from beneath (details available on the plan).

v) Sole production

**Ponds and tanks.** In many parts of the world, aquaculture is successfully conducted alone on land in a variety of structures such as earthen and concrete ponds of variable size and shape. In these cases also, the choice for culture species,
whether to conduct mono- or poly-culture, strategy and intensity of production are dictated by physical factors, availability of inputs, managerial know-how and other socio-economic factors.

Earthen ponds are one of the widely used aquacultural structures, where rearing of single or combination of species and any level of intensity of production is possible. In many developing countries where production is meant for subsistence, fish farming in earthen ponds is conducted mostly at extensive management levels, but it is mostly intensive in the developed countries. However, profitability of production systems that involve such structures as concrete and other tanks will be higher if production systems skew towards better intensities.

**Enclosures.** Cages, pens and hapas have long been serving as important fish culture systems and the use of these structures is increasingly becoming popular. Although cage and pen cultures were started in Asia, they have been wide spread in countries in Europe, Africa and Americas. Today, virtually all commercially important fish species are reared in these structures. They are the structures which involve relatively low initial costs, simple technology and management methods and those which provide better chance of energy transfer from aquatic plants to herbivore fishes. According to Beveridge (1984), the energy transfer of about 1.0 - 3.5% plant carbon to fish carbon is attainable from extensive cage or pen cultures, which is considerably higher than yields from managed fisheries in lentic ecologies.

The enclosure culture systems can be extensive, semi-intensive or intensive. Well-managed enclosure culture systems are highly profitable and sources of safe and fresh aquacultural products. In one of the trout-cage farming sited in the deep sea of Denmark, for example, a cage having a circumstance and length of 50 and 5 meters, respectively was stocked with about 8000 fishes/cage with the individual fish weight at stocking of about 500 gm and after the period of 9 - 12 months, organically farmed, quality and fresh fishes of up to five kilograms are harvested. Information obtained from the site (personal communication) indicates that the overall rate of survival (including survivals from earlier land based primary, secondary and extra phases of grading periods in the latter phase) was about 75%.

The choice for enclosure culture species and whether to apply external inputs are governed by climatic factors and the primary objective of the water body.

Enclosure cultures differ from land based operations such as pond and raceway cultures in that they are open systems where interaction between these culture units and the immediate environment can take place with a minimum restriction. Moreover, because they are often sited in publicly owned multipurpose water bodies, they may trigger conflict of interests with natural fisheries, navigation and other operations. They may also interfere with current and sediment transport and excessive loading of nutrients to bottom sediments, though the latter effects can be avoided by proper selection of sites and structures as well as management. Reviews
on the ranges of advantages, possible environmental impacts as well as modeling of these impacts are presented in Beveridge (1984).

Attributed to total absence of aquacultural activity, enclosure systems are not practiced in Ethiopia. However, they can easily be used in such intensely fished natural water bodies as lakes Ziway and Awassa and other natural and man-made aquatic ecosystems that are suitable to the application of the system.

CHALLENGES

Despite the urgent needs for the introduction, expansion and intensification of aquaculture in Ethiopia, the immediate commencement of sustainable and profitable aquaculture is bound with several limitations. Some of these are:

- weak control over free access to natural fishing grounds and its multifaceted implications, particularly on the initiation of investors,
- lack of expertise and experience,
- lack of information on the genetic material of strains/populations within the candidate species that could perform best under the given agro-ecological and management conditions,
- absence of basic inputs as feeds, budget, manpower and facilities,
- low attention and/or absence of incentives for those who will to pioneer the activity,
- absence of reliable source that could supply the required type, quantity, and quality of fry in space and time,
- lack of coordination between different key actors,
- absence of master plan for potential areas where aquaculture can easily flourish,
- absence of single responsible institute that coordinates and follows the development of the sector up, and
- Seasonal fluctuation in demand for fishes.

PRIORITY ISSUES

In order for aquaculture to flourish in Ethiopia, critical issues should first be addressed simultaneously or stepwise. The concept of diversification should be seen from the angle of integration of different production systems or development plans. In this regard, governmental and non-governmental agencies that are involved particularly in water harvesting and other stakeholders should work together with body/bodies responsible for coordination, monitoring and evaluation of national aquaculture development schemes starting from the planning phases.
Compared to land-based and more visible agricultural sectors, most of the fisheries and aquaculture activities are more indirect, invisible and underwater. As underwater they are, struggles for attention to aquaculture research and management activities are shadowed by the land-based priorities, and therefore they are still out of sight and mind of policy makers and other key actors. In the face of the realities stated in the preceding sections, it is firmly believed that aquaculture is one of the most productive sectors of agriculture the development of which, at least in its initial phases, will deserve the utmost attention, budget, research and coordinated action of key stakeholders. Failures to invest on research and development of the sector on time could lead to further damage on natural fisheries and other resources. It could deprive the sector of the role it should otherwise play towards general poverty alleviation and food, nutrition and job security goals. Therefore, the roles that the government, policy makers, human nutrition researchers, health institutes, learning and research institutes, mass media and other actors need to play at different fields and levels of development of the sector are crucially important. They are required to work closely and come up with future effective action plans. The following are some of the most important issues that are to be dealt with seriously, if aquaculture is to flourish in Ethiopia and contribute towards the intended goals.

1. Identify potential areas within the country where aquaculture can best flourish;
2. Exercise strict control against free access to natural stocks;
3. Establishment of dedicated support activities such as:
   - coordination and command center,
   - credit schemes and private sector encouraging mechanisms,
   - extension network,
   - monitoring and evaluation mechanism, and
   - fish feeds and hatcheries units, and other infrastructures;
4. Encourage simultaneous extensive, semi-intensive and intensive rural, peri-urban and urban aquaculture which may, at least initially, be owned by private sectors, government or both;
5. Train required manpower in different areas of practical fish farming and home economics of fish preparation, which may be realized through any one or combinations of:
   - specialized university curriculum/courses,
   - specialized secondary school,
   - practical on station training, and
   - targeted trainings abroad.
6. Support and encourage research on:
   - selection of strains/populations from candidate species that will perform better in specific agro-ecological zones (AEZ),
   - pond dynamics and fertilization,
   - better use of agricultural by products,
   - different production systems and management strategies, etc.

7. Discourage the hitherto practice of stocking of artificial water bodies by whatever fry is available but with selected populations/strains of species that perform best in that specific AEZ.

CONCLUSION

Fishes are prominent sources of livelihood and employment to millions of the world's poor. Similarly, they have been playing a vital role in the livelihood and local economies of many Ethiopians. Because of the absence of fish farming practice, natural stocks are forced to remain as the sole sources for the hitherto fish demand of the country. These common pool resources are, however, subjected to unregulated capture fisheries, resulting in overexploitation of target fish species as has reportedly been observed in some of the major fishing grounds. Besides, some of the major Ethiopian fishing grounds are serving as natural sinks to all sorts of land and water-based wastes and the effects of the pollutants on the food web in general and health of human consumers in particular, though not yet well quantified, will be far reaching. In the face of the above realities on one hand and prevailing chronic drought, food insecurity, poverty, increasing rates of unemployment and population growth and degradation of natural resources on the other, the call for the modernization and integration of different economic sectors and diversification of production systems in general, and the role of aquaculture in this regard would therefore be immense.

Ethiopia is endowed with high natural potentials that would enable her to conduct profitable and sustainable aquaculture, but has so far not been put into action. Based on the prevailing trends of socio-economic and environmental factors, however, the need for the gradual commencement of aquaculture in Ethiopia is immense, and little attention and budget can help the sector develop successfully. Despite these potentials and the needs, immediate commencement of sustainable and profitable aquaculture is faced with limitations that should wisely be tackled if the sector is to gradually develop in the country and contribute towards poverty alleviation and food, nutritional and job security goal of the locals and regions in particular and the overall long-term national development efforts in general.
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PEST MANAGEMENT PRACTICES IN THE CONTEXT OF FOOD SECURITY

Emiru Seyoum and Merid Negash

ABSTRACT

Before the advent of agricultural man, the existence/survival of organisms such as insects in an ecosystem depended on the balance between the organism's capacity to breed and a combination of natural factors that restrained their numbers. Following the advent of agricultural man, man used plants and animals for food and other purposes which led to unresolved conflict between man and the organisms. As the result, man fell victim of harmful organisms which affected the quality and quantity of plant growth, products and by-products; thus "pests". Agricultural intensification led to enlargement of agricultural fields, genetic uniformity of crops (species, cultivars, genotype), increased plant density, harvest index, specialization and mechanization and an increase in the international exchange of infected materials, plants (seeds, plant products and by-products, soils etc). Agricultural intensification gave rise to the development of crop protection which led to the need of changing pest problems faced by farmers, the options available to deal with as the result of which pesticides were used extensively and indiscriminately. Extensive and indiscriminate use of chemical pesticides led to pesticide resistance, secondary pest outbreaks, host plant resistance breakdown, non-target effects, environmental pollution (pesticide residues, pesticide escape etc). These circumstances gave birth to the idea of what we call now IPM. Discussions in this presentation will include past challenges (paradigms) and future prospects in the development and adoption of pest management strategies in general and in the context of Ethiopian conditions in particular.

INTRODUCTION

Pest refers to all biotic agents (insects, mites, nematodes, weeds, bacteria, fungi, viruses, parasitic seed plants and vertebrates) that adversely affect plant production (Steering Committee, Cornell University, 1997). Management: is the decision making process to control pest populations in a planned, systematic way by keeping their numbers or damage at economically acceptable levels.

Pest management as a component of an agricultural system

Pest management is a sub-component of an agricultural system. Changes in agricultural systems thus inevitably lead to changes in pest management strategies. Pest control in early days relied mainly on fluctuations in natural populations due
to environmental and intrinsic factors which led to natural control of pests. Thus, the relationship between man and other organisms remained in harmony.

The continuing presence of natural vegetations and their preys in uncultivated land make the uncultivated land a much more stable habitat for natural enemies than a crop land.

This type of natural control process however had to change in line with changes in human requirements which led to extensive expansion of agricultural land. The relationship between man and other organisms referred to as pests by man then became severe and continued to be so up until present days.

Now, many agricultural systems are in a continuous state of change. As the agricultural systems change, new problems emerge which have to be addressed. The solution to the problem, if adopted, then contributes to further modification of the system which itself may produce problems of a different kind. Not all modifications will however create new problems, and as a system develops and evolves, it should gradually move towards a more balanced state which meets the economic needs of the human population it sustains. However, if the economic needs of the population are not met, then the agricultural system will continue to be modified.

Agricultural intensification and pest management

The continued modifications in agricultural system/practices led to agricultural intensification after World War II. Agricultural intensification led to enlargement of agricultural fields, genetic uniformity of crops (species, cultivars, genotypes), increased plant density, harvest index, specialization and mechanization and an increase in the international exchange of infected plant materials, (seeds, plant products and by-products, soils, etc.). Thus agricultural intensification gave rise to the development of crop protection as a component of improved crop production system which in turn led to the need of changing pest problems faced by farmers along with the options available to deal with.

Each phase in the agricultural intensification had its own implications (positive or negative) on food security in the short or long terms. The main question is how the impact of agricultural intensification (on food security) in which pest management is a sub component was perceived. In the short term, intensification which relied on the deployment of new farm machinery, high yielding varieties of crop, use of synthetic agrochemicals, horizontal enlargement of farm size etc. resulted in surplus production and answered the demand for food and agricultural exports in many instances. This was however possible through searching for solutions for short term problems without appropriately addressing and searching for solutions of long term problems.

Pest and pest related problems were among other agricultural problems for which solutions for short term were designed. The solutions put in place included
extensive and indiscriminate use of chemical pesticides against a wide range of pests (insects, weeds, plant diseases, nematodes, vertebrate pests, etc). Thus pesticides replaced what one could refer to as traditional pest management practices (crop rotation, fallowing, time of planting, natural control of pests, other indigenous approaches) which helped check pest populations both indoor and outdoor without jeopardizing the lives of man himself, and other animals (wild and domestic) animals, plants and the agro-ecosystems as a whole. In many countries agricultural production was thus boosted far beyond the demand of national needs (short term economic-benefits).

However, extensive and indiscriminate use of chemical pesticides led to pesticide resistance, secondary pest outbreaks, host plant resistance breakdown, non-target effects, the environmental implications of pesticides (pesticide residues, pesticide escape, etc.) in many developed nations. Impact of pests on food security was severe in some of these countries while others learnt from those who were victims of pest attacks and adjusted their systems in time to prevent similar phenomena.

Creating public awareness on issues such as population growth in relation to food supply, integrating pest management systems with other aspects of crop production practices (agronomic, conservation of natural resources, marketing, etc.) were some of the adjustments that contributed to sustain food security in these countries although the question with regards to the long term effects of intensive agriculture based on packaged inputs supply in which extensive pesticides use remain to be a major component in pest management practices has not been resolved fully yet.

**PHASES OF PEST MANAGEMENT:**

Many crop protectionists agree that crop protection (pest management) patterns can be classify world wide into five phases:

- **Subsistence phase.** Crop is grown under non-irrigated conditions and in a classical form of subsistence farming. The crop hardly enters the world market and is therefore consumed locally. Yields are low and no organized crop protection.

- **Exploitation phase.** Crop protection programs are developed and new varieties and markets have been introduced. Pesticides are used intensively, often on fixed schedule.

- **Crisis phase.** More frequent applications of pesticides and higher dosages are required at this stage. Pests resurge rapidly and become tolerant.

- **Disaster phase.** The pesticide usage increases production costs to the point where the crop can no longer be grown and marketed profitably. Pesticide residue in the soil may be high.

- **Integrated Pest Management (IPM) phase.** Pest control programs at this stage are implemented by making sure that they are compatible with
ecosystem. The principle in this method is to optimize control rather than maximize production. This phase involves the use of multiple tactics in a compatible manner to maintain pest populations at levels below those causing economic injury while providing protection against hazards to humans, domestic animals, plants and the environment.

As far as the pest management status in Ethiopia is concerned, it is believe that currently most pest management programs in this country are more or less in the subsistence and exploitation phases as the case is true for many resource poor African countries (Emiru Seyoum, 2000)

**PESTS AS MAJOR CAUSES FOR FOOD INSECURITY**

Estimates show that more than 800 million people in the developing countries, about 20 % of their total population, suffer from chronic undernutrition. Millions more are vulnerable to food insecurity; they cannot guarantee access to sufficient food (WFS, 1996). Among many causes accountable for food insecurity are direct and indirect damages to plants (forest, forest by-products, crops and crop byproducts, livestock and their products) by different pests and diseases.

In the absence of insect pests alone world food production could be increased by about a third. *Striga,* a parasitic weed alone for instance, damages $10 billion worth of maize and sorghum crops every year, threatening the livelihoods of 100 million Africans.

Without pests in general, insect pest in particular, world food production could be increased by a third. Agricultural scientists and economists estimate that the combined cost of insect control and losses caused by insects alone exceeds $23 million/year (WFS, 1996).

**PEST MANAGEMENT PRACTICES IN RELATION TO FOOD SECURITY IN ETHIOPIA**

Similar to many African countries, attempts to shift from traditional agricultural practices including pest management which relied mainly on farmers’ indigenous knowledge and practices to input led agricultural system (mainly in the highlands) was believed to bring about sustainable food security in the country. As the result, agricultural extension systems based on demonstration and supply of agricultural inputs including chemical pesticides were in place for half a century or so.

Pest management practices in the country varied over time in such a way that where transport and migration of people and other materials were limited, movement of pests within and from outside the country was limited (regulatory pest management tactic). This however changed as transport facilities and planting material exchanges along with influx of food aids were increasing from time to time, leading to the introduction and fast spread of many aggressive and devastating pests to agriculture.
Expansion for agricultural land as the result of population explosion affected the balance of nature as the result of which some endemic plants that served as alternative hosts for different pests disappeared due to deforestation and soil erosion aggravating the pest problems over time (the impact of poor natural resources management). Similarly, the move from traditional to intensive agriculture led to monoculture, genetic uniformity in crop cultivars, repeated application of inputs, etc. which again led to the disappearance of plants that would serve as reservoirs for natural enemies of pests—biological control (the impact of monoculture as opposed to mixed agricultural system).

The move to the introduction and use of agrochemicals based pest management practices in Ethiopia (especially in the highlands) has not brought about a significant change in the livelihoods of the people. According to Tsedeke Abate (1997), the annual pesticide purchase in the country amounts more than 3000 metric tones valued at nearly USD 20 million. This does not include pesticide that enters the country through donations. Pesticide use per head in the country for agricultural purposes is however believed to be among the minimal in the continent although evidence shows that mishandling of pesticides has caused enormous damage in the country.

In Ethiopia, agricultural pests thus remain to be one of the most important limiting factors of crop production. Although no systematic assessment studies have been conducted in the country the annual pre and post harvest losses are estimated to be 30% and 10-15%, respectively (Abdurahman Abdulahi, 2000). These losses could be higher when there are outbreaks of migratory pests.

Although the move from traditional to package based agricultural practices including pest management started long time ago (mainly in the highlands), the question of food insecurity has remained unresolved. Fundamental issues such as maintenance of natural resources along with feasible agronomic practices, addressing population explosion, the importance of regulatory measures, etc. have not yet been dealt with appropriately. Thus, damage (direct and indirect) by pests has remained to be one of the outstanding causes for food insecurity in the country. The most viable solution in pest management at the moment would be that which combines sustainability in production and maintenance of natural balances namely, Integrated Pest Management (IPM) which has proved to be feasible in many countries where they have adopted their pest management practices to be based on IPM principles and strategies at different levels.

We strongly believe that adoption of IPM as a national policy and creating favorable conditions for Integrated Pest Management would help avert the devastating effects others experienced on the environment as the result of extensive and indiscriminate use of and reliance on chemical pesticides to boost agricultural production without proper consideration of the long term impacts.
REFERENCES


PEST PROBLEMS VIS-À-VIS FOOD SECURITY

Tsedeke Abate

ABSTRACT

Pests (insects, other arthropods, diseases, nematodes, vertebrates, and weeds) problems have a significant effect on the food security of Ethiopia. They cause an estimated loss of 1.9 to 2.8 million metric tons of food in this country each year. This is four to six times the average annual amount of food aid we received from the international community between 1995 and 2002. While it is not possible to eliminate, it is possible to minimize their effect using appropriate approaches.

Crop protection research in Ethiopia over the years has concentrated on the identification, geographical distribution, establishing economic importance, and devising control measures against pests. Emphasis has been given to the use of integrated pest management (IPM) approach during the last two decades. Beneficiaries of IPM to date have been commercial farms, as conditions under subsistence production system, which accounts for more than 95% of food production in Ethiopia, were not amenable for implementing the approach.

The current policy of Government emphasizes a shift from subsistence to market-oriented agriculture. This would entail introduction of large numbers of new crop varieties and therefore it is inevitable that inadvertent introductions of pests would occur. This would necessitate the strengthening of our quarantine system. Experiences from other countries that have undergone agricultural transformation indicate that ‘modernization’ of agriculture would result in increased pest problems and would require increased use of pesticides. IPM would become even more relevant as we modernize our agriculture. Implementation of IPM under modern agriculture emphasizes non-chemical control measures but would not exclude pesticides. It should be pointed out that introduction, screening, and registration of pesticides that are compatible with IPM is an urgent task ahead of us. Particular attention should be given to the so-called green industry technologies (such as microbial pesticides and pesticides of botanical origin) for registration and use, without excluding synthetics. The existing procedures for pesticide (including biopesticides) registration and crop/animal variety release need to be revised to fit the current situation as soon as possible.

INTRODUCTION

Ethiopia is a country of more than 1.1 million km², with an estimated population of close to 70 million. Approximately 31 million ha of the total area (ca. 28%) is agricultural land but an average of no more than 10 million ha of this potential

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1 Ethiopian Agricultural Research Organization, PO Box 2003, Addis Ababa, Ethiopia. E-mail: dg@earo.org.et, asai@telecom.net.et
agricultural area is cultivated annually. Agriculture is the most important enterprise, providing employment for more than 85 percent of the country’s population and accounting for about 50 percent of the total GDP and 90 percent of export earnings.

In spite of its tremendous importance and potential, Ethiopian agriculture has remained largely traditional, where subsistence farmers use traditional integrated production and protection approach of managing pests and diseases. The use of improved technologies (including improved seed, fertilizer, and pesticides) has remained very low, even by African standards (Tsedeke Abate & Fenta, 2003).

In spite of the high agricultural potential it is endowed with, Ethiopia has been faced with food deficits over the last several decades. The country has received an average of nearly 0.6 million metric tons of food aid over the period from 1995 to 2003; an average of about 5 million Ethiopians are food insecure each year, even when the rains are sufficient for a good crop harvest.

While cash crops such as coffee have shown sustained yield increases over the years (FAO 2002), it has not been possible to attain sustainable increased yield of food crops. For example, national average yields per ha of land for cereals have remained much less than 2 tons (FAO, 2004). This low productivity is in sharp contrast with what could be achieved on farmers’ fields where improved crop varieties and production technologies have been adopted.

Pests (harmful insects, other harmful arthropods, plant diseases, plant parasitic nematodes, harmful vertebrates, and noxious weeds) are the major causes of the low productivity of crops, and therefore play a significant role in food security of Ethiopia. Reliable yield data relating yield losses due to pests under farmers’ conditions are scanty, but it is roughly estimated that 20-25 percent crop loss occurs each year due to pest damage. Some estimates suggest that crop pests claim up to 40 percent of crop yields each year.

This short report presents the pests, their economic importance, available control measures, and the next steps that need to be taken in order to contribute to food security of Ethiopia.

**THE PESTS**

Large numbers of pests have been recorded attacking various crops in Ethiopia (Stewart and Yirgou, 1967; Crowe et al., 1977; Tsedeke Abate, 1988; Stroud, 1989; Gordon et al., 1995). A recent review of important crop pests in Ethiopia can also be found in Tsedeke Abate and Fenta (2003). Table 1 presents examples of major pests in this country.

In addition to pests shown in Table 1, there are several species of migratory pests and stored product pests of economic importance in Ethiopia. “Migratory pests” refers to insect and vertebrate pests whose geographical distribution and economic importance transcend national boundaries. Migratory pests have regional or international significance. In Ethiopia migratory pests include the African
Table 1  Examples of major pests in Ethiopia (adapted from Tsedeke Abate and Fenta, 2003).

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Crop(s) attacked</th>
<th>Geographical distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INSECTS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Busseola fusca, Chilo partellus</td>
<td>Stalk borers</td>
<td>Maize, sorghum</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Helicoverpa armigera</td>
<td>African bollworm</td>
<td>Cotton, vegetables, pulses</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Acrystosiphon pisum</td>
<td>Pea aphid</td>
<td>Field pea, faba bean</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Pachnoda interrupta</td>
<td>Sorghum chafer</td>
<td>Sorghum, maize</td>
<td>ANRS, Afar, parts of Oromiya &amp;Tigray</td>
</tr>
<tr>
<td>Diuraphis noxia</td>
<td>Russian wheat aphid</td>
<td>Wheat, barley</td>
<td>ANRS, Tigray, Oromiya</td>
</tr>
<tr>
<td>Decticoides brevipennis</td>
<td>Welo bush cricket</td>
<td>Tef</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Ophiomyia spp. (O. phaseoli, O. spencerella)</td>
<td>Bean stem maggot</td>
<td>Haricot bean</td>
<td>(more important in southern Ethiopia)</td>
</tr>
<tr>
<td>Phthorimaea operculella</td>
<td>Potato tuber worm</td>
<td>Tomatoes, potatoes</td>
<td>Awash valley</td>
</tr>
<tr>
<td>Thrips tabaci</td>
<td>Onion thrips</td>
<td>Onions, shallots</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Aonidiella aurantii</td>
<td>Red scale</td>
<td>Citrus</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Ceratitis capitata</td>
<td>Med fly</td>
<td>Citrus</td>
<td>Awash valley</td>
</tr>
<tr>
<td>Cryptophilebia leucotreta</td>
<td>False codling moth</td>
<td>Citrus</td>
<td>Awash valley</td>
</tr>
<tr>
<td>Antestiopsis intricata</td>
<td>Antestia bug</td>
<td>Coffee</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><strong>DISEASES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Puccinia striiformis</td>
<td>Yellow rust</td>
<td>Wheat</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Puccinia graminis</td>
<td>Leaf rust</td>
<td>Wheat</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Rhynchosporium secalis</td>
<td>Scald</td>
<td>Barley</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Helminthosporium turcicum</td>
<td>Leaf blight</td>
<td>Maize</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Cercospora zea-maydis</td>
<td>Gray leaf spot</td>
<td>Maize</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Botrytis fabae</td>
<td>Chocolate spot</td>
<td>Faba bean</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Uromyces victia-fabaie</td>
<td>Faba bean rust</td>
<td>Faba bean</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Ascochtya fabae</td>
<td>Ascochtya blight</td>
<td>Field pea</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Phytophthora infestans</td>
<td>Late blight</td>
<td>Potato</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Colletotruchum coffeaeun</td>
<td>Coffee berry disease</td>
<td>Coffee</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Pseudomonas musacearum</td>
<td>Bacterial wilt</td>
<td>Enset</td>
<td>Southern Ethiopia</td>
</tr>
<tr>
<td><strong>WEEDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Striga spp.</td>
<td>Witch weed</td>
<td>Sorghum</td>
<td>ANRS, Oromiya</td>
</tr>
<tr>
<td>Orobanche spp.</td>
<td>Broom rape</td>
<td>Tomato</td>
<td>Awash valley</td>
</tr>
<tr>
<td>Broadleaf weeds</td>
<td>Numerous</td>
<td>All</td>
<td>Widely distributed</td>
</tr>
<tr>
<td>Grass weeds</td>
<td>Numerous</td>
<td>All</td>
<td>Widely distributed</td>
</tr>
</tbody>
</table>
armyworm (*Spodoptera exempta*), the African migratory locust (*Locusta migratoria migratorioides*), the quelea birds (*Quelea quelea quelea*), and the desert locust (*Schistocerca gregaria*). The African armyworm is perhaps the most frequent of all the migratory pests; its invasion occurs as frequently as every other year. By contrast, invasion by and significant crop loss due to the desert locust in present day Ethiopia has not occurred since the 1958 plague.

The African armyworm (*Spodoptera exempta*) attacks all crops in the grass family (Tef, maize, sorghum, barley, wheat) in all areas of Ethiopia. The locusts have a much wider host range; the African migratory locust (*Locusta migratoria migratorioides*) occurs mostly in the drier eastern parts of the country. Weaverbirds (*Quelea quelea*) are a major pest of sorghum across the geographical distribution range of the crop; these are particularly serious in the rift Valley.

A large number of stored product pests are known in Ethiopia (Walker & Boxall 1974, Tadesse 1997, Getu & Gebre-Amlak 1998). Most important among these are the Angoumois grain moth, maize weevils, bruchids, grain mold, and vertebrates. Examples of major insects and diseases of stored grains in Ethiopia are shown in Table 2. The larger grain borer (*Prostephanus truncatus*), which is a major stored grain pest in many parts of Africa, is not recorded (or at least not mentioned as an important pest) in Ethiopia yet.

Most of the stored product insects (e.g. *Sitophilus, Sitotroga, Acanthoscelides* and *Zabrotes*) are more important in the warmer areas in mid and lower altitudes (below 1800 m) across the country. The pea weevil (*Bruchus pisorum*) was accidentally introduced to the country sometime in the mid 1970s and is widely distributed in Amhara National Regional State (Tsedeke Abate & Fenta 2003).

Damage by grain mold is important on sorghum (and maize, to some extent) stored in underground pits, especially in Hararge and parts of Welo. Damage can reach 90-95 percent within 4-6 weeks of storage. However, local farmers use the damaged grain for consumption or making local beer after washing. Mold damage is important not only in causing food loss but also as a potential health risk to consumers (due to production of aflatoxins). Rats are the most important vertebrate pests of stored grains. (See Boxall, 1998 for further details).

**Economic Importance of Crop Pests in Ethiopia**

As stated in the preceding section, a large number of pests attack crops, and claim a significant proportion of harvests, and therefore contribute to food insecurity in Ethiopia. Most recent comprehensive reviews on crop yield losses due to pests in this country can be found in Abate and Fenta, 2003. These are summarized in Table 3.
Table 2 Examples of major stored product pests in Ethiopia (after Tsedeke Abate and Fenta, 2003).

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Crops attacked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize weevil</td>
<td><em>Sitophilus</em> spp.</td>
<td>Maize, sorghum, wheat, barley</td>
</tr>
<tr>
<td>Angoumois grain moth</td>
<td><em>Sitotroga cerealella</em></td>
<td>Maize, sorghum, wheat, barley</td>
</tr>
<tr>
<td>Adzuki bean weevil</td>
<td><em>Acanthoscelides obtectus</em></td>
<td>Beans, cowpea</td>
</tr>
<tr>
<td>Grain mold</td>
<td><em>Aspergillus</em> spp.</td>
<td>Sorghum</td>
</tr>
<tr>
<td>Mexican bean weevil</td>
<td><em>Zabrotes subfasciatus</em></td>
<td>Beans</td>
</tr>
<tr>
<td>Pea weevil</td>
<td><em>Bruchus pisorum</em></td>
<td>Pea, faba bean, chickpea, lentils</td>
</tr>
</tbody>
</table>

Table 3 Examples of yield loss due to pests in selected crops in Ethiopia (adapted from Tsedeke Abate and Fenta, 2003).

<table>
<thead>
<tr>
<th>Crop/commodity</th>
<th>Causative agent(s)</th>
<th>Yield loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Tef</td>
<td>Grasshoppers</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Red tef worm</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Head smudge</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Rust</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Damping off</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Weeds</td>
<td>23</td>
</tr>
<tr>
<td>Maize</td>
<td>Stalk borers</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sorghum chafer</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Leaf blight</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Weeds</td>
<td>25</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Stalk borers</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Sorghum chafer</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Smuts (several species)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Weeds</td>
<td>30</td>
</tr>
<tr>
<td>Barley</td>
<td>Russian wheat aphid</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Barley shoot fly</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Scald</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Weeds</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Net blotch</td>
<td>-</td>
</tr>
<tr>
<td>Wheat</td>
<td>Russian wheat aphid</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Blotch</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Yellow rust</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Leaf rust</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Stem rust</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Weeds</td>
<td>11</td>
</tr>
<tr>
<td>Field pea</td>
<td>Pea aphid</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Ascochyta blight</td>
<td>-</td>
</tr>
<tr>
<td>Faba bean</td>
<td>Chocolate spot</td>
<td>-</td>
</tr>
<tr>
<td>Stored grains</td>
<td>Insects and grain molds</td>
<td>5</td>
</tr>
</tbody>
</table>

1 Figures in parentheses are national averages.
It can be seen that crop losses due to various pests range from nil to 100 percent. However, these figures have to be interpreted with great care. Although such data are useful as indications of the potential damage of a particular pest under the “worst-case scenario”, they do not necessarily reflect the actual importance of the pest in question. First, most yield loss estimates are obtained from on-station experiments, and therefore they do not represent the usual practices and farming systems of the traditional farmer. Second, these experiments are conducted in artificial environments with increased pest pressure. Only the data for stored grain pests are obtained from farmers’ actual storage practices. This absence of reliable information on yield loss data from on-farm experiments makes it difficult to make priorities on research and development planning (Tsedeke Abate and Fenta, 2003).

A recent study on post-harvest losses of food grain in Ethiopia due to insects and grain mold estimated an annual loss of about 9 percent (Boxall, 1998). On the basis of an estimated average annual production of 9.44 million metric tons of food grains (cereals, pulses and oilseeds)¹, this would mean an annual stored grains loss of nearly 0.85 million metric tons.

In general, it is possible that crop losses in the future may increase as more and more improved varieties (which are usually more susceptible than traditional varieties) are grown by farmers as a result of the Government’s agricultural transformation policy.

Available Control Measures

The early days

The use of cultural practices, host plant resistance and chemical pesticides dominated pest control during the early days of crop protection research and development in Ethiopia. Cultural control has remained the first line of defense against crop pests to this date. Host plant resistance has been mainly recommended for the control of cereal and other field crop pests whereas chemical control was mainly for the control of vegetable and fruit pests. The use of host plant resistance has been an important weapon against such diseases as yellow rust in wheat and coffee berry disease in plantation coffee. In addition, both options (host plant resistance and chemicals) have been used against major pests in commercial farms (Bekele, 2003; Tsedeke Abate, 2003; Tsedeke Abate and Fenta, 2003).

The current situation

The emphasis on crop pest control strategies has shifted from chemical control to integrated pest management (IPM) approach since the beginning of the 1980s. This is consistent with “Agenda 21” of the United Nations Conference on Environment and Development (Bekele, 2003). The IPM concept has evolved over the years, mostly in the context of large-scale agriculture, where the main aim has been to

¹ Source: CSA data for the period from 1987 to 2001 (does not include 1992).
reduce reliance on pesticides (Tsedeke Abate, 1997a; 2003). The success of IPM under such conditions is often measured in financial terms, such as savings on pesticides (FAO 1993) and subsequent reductions in costs to the environment and other externalities. Under the Ethiopian context, however, such savings are insignificant as pesticide use is very low (estimated at about 0.26 kg/ha of formulation). A major objective of IPM here would be not to reduce pesticide use, but to prevent (or at least to delay) breakdown of the agro-ecosystem that has existed for centuries, and to prevent unnecessary stockpiling of pesticides and the inevitable consequences of accumulating obsolete pesticides.

Subsistence farmers in Ethiopia, and elsewhere in Africa, traditionally use a combination of several pest management practices (such as cultural control, habitat manipulation, mechanical and physical control, natural biological control, host plant resistance, use of locally available materials) such that pest outbreaks of the magnitude experienced in commercial agriculture are rare1 (Tsedeke Abate and Ampofo, 1996; Tsedeke Abate, 1997a; Tsedeke Abate et al., 2000). Use of some cultural practices, particularly intercropping and methods encouraging habitat diversity, create an environment conducive to natural enemies (parasitoids and predators) and can be considered a type of natural biological control. Thus, the small-scale farmer is a general practitioner of IPM.

Defined in this context, IPM is an ecologically sound, environmentally friendly, and economically affordable pest management approach that employs optimum blends of control measures to keep pest numbers below economic level (Tsedeke Abate, 2003; Tsedeke Abate and Fenta, 2003). IPM focuses on long-term prevention of pests and their damage. It does not exclude the use of pesticides, but predicates that all other means must be explored and pesticide use should be considered as a last resort. IPM is more effective than synthetic pesticides (in the long run), generally requires less capital investment, and can be used preventatively to eliminate or minimize the need for applying pesticides after a pest outbreak occurs and much damage already has been done.

Examples of IPM practices in Ethiopia

IPM, both in traditional and modern sense, is not a new concept to Ethiopia. As stated earlier, the small-scale Ethiopian farmer is a de facto practitioner of IPM. However, the major beneficiary of modern IPM has been the large-scale production sector (mainly the then State Farms). Two examples of successful IPM use in Ethiopia are cited below. Further details can be found in Tsedeke Abate (1997b; 2003) and Tsedeke Abate and Fenta (2003).

Bollworms and leafhoppers in cotton

The bollworms (*Helicoverpa armigera*, *Pectinophora gossypiella*, *Earias* spp., *Diparopsis watersi*) and leafhoppers (*Empoasca* spp.) are some of the most

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1 Does not apply to migratory pests.
important insect pests of cotton in Ethiopia. The use of “closed season” or “dead season” has kept the pink bollworm (*P. gossypiella*) below economic level. Improved understanding of the biology of the other bollworms and the contribution of natural enemies to their control has enabled to reduce the frequency of insecticide application to the minimum possible. The introduction of long staple ‘Acala’ type cotton varieties has relegated the cotton leafhoppers to a minor pest status; the insecticide sprays aimed at the bollworms also gave additional control of the leafhoppers.

**Scale insects on citrus**

The red scale (*Aonidiella aurantii*) was the major insect pest of citrus during the late 1970s. Use of a selective insecticide (mineral oil, using the right type of spray equipment) timed at peak breeding period of the pest and highest activity of natural enemies has enabled to reduce the frequency of insecticide application from more than a dozen to one to three sprays per year. Red scale has been under effective EPM since the early 1980s. Native species of the hymenopteran parasitoid (*Aphytis* sp.) and the ladybird beetles *Chilocorus distigma* and *Hyperaspis senegalensis* are some of the most important natural enemies that contribute to the natural biological control of red scale and other armored scales in Ethiopia.

**The Next Steps**

Currently there is a good amount of knowledge on EPM techniques in Ethiopia. Important examples include stalk borers (*Busseola fusca* and *Chilo partellus*) in sorghum and maize, bean stem maggots (*Ophioniomyia phaseoli* and *O. spencerella*) in haricot bean, fruit worms (*Helicoverpa armigera* and *Phthorimaea operculella*) in tomatoes, and African bollworm (*H. armigera*) in beans and vegetables. There is also an on-going research towards developing IPM programmes against several important pests, such as the sorghum chafer (*Pachnoda interrupta*) in sorghum, and the pea aphid (*Acyrthosiphon pisum*) in field pea.

A national IPM Planning Workshop (organized by the Association for Advancement of IPM and the Ethiopian Agricultural Research Organization) that was held at Melkassa Research Centre on 13-15 October 2003 adopted the following recommendations. The Ethiopian Agricultural Research System (including EARO, regional research institutes and institutions of higher learning) should give due emphasis to these recommendations.

1. The adoption of IPM should be facilitated through:
   - Synthesis and promotion of IPM technologies;
   - Streamlining and strengthening research and development efforts for technology generation and implementation; and
   - Developing focused education, training, and demonstration programmes for stakeholders (including farmers, development agents, educators, policy makers and researchers).
2. Suggested activities were:

- Collating information on IPM experiences and identifying available technologies (through resource persons, stakeholder consultations, workshops and literature review);
- Identifying knowledge gaps and opportunities for narrowing the gaps;
- Establishing partnerships with stakeholders;
- Setting priorities;
- Developing sound project proposals;
- Adapting approaches (methodologies) to develop and disseminate IPM technologies suited to local conditions;
- Organizing training programmes and publicity campaigns;
- Promotion and fostering of local production and marketing of pest control agents (such as neem) proven to be effective and practical for local conditions;
- Production and dissemination of information on IPM technologies; and
- Establishing national and regional networks.

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AGRICULTURAL MODERNIZATION AND GENDER ISSUES

Haregewoin Cherinet

ABSTRACT

Women suffer extreme poverty among the 44% of Ethiopians who are below the poverty line, because of the gender gap that has resulted in limited access to power and resources. Of major importance is their non-involvement in decision-making including on their reproductive rights, impacting negatively on household food security. The low women's social status contributes to the country's deficit in food supply, because development programmes do not take women's vital role in agriculture into account. Modernization should thus be seen in light of the existing gender relations. The relation between men and women is such that, there is female subordination in terms of power and access to resources and social services. This affects how women benefit from development interventions.

Food security situation in Sub-Saharan Africa including Ethiopia is deteriorating as a result of population pressure, low agricultural production and degradation of natural resources. To reverse the prevailing situation of food insecurity, there is need to recognize women's increased risk of vulnerability to food insecurity, their vital role in the food system and the need to consider women in interventions to ensure food security.

Women's participation in food production is vital, with an estimated 60 and 80 per cent of the total labour expended on farming activities, although ill-equipped and underfed. In addition, as modernization reorganizes agricultural production and marketing, women are increasingly marginalized. They continue to work in production, their labour may increase, but they lose access to the new technologies that increase productivity. The process of introducing modern technologies in agricultural inputs, planning and harvesting or storage and marketing have not been gender sensitive. Agricultural extension services worked with male farmers, credit could only be extended to individuals with land titles and other collateral. Women are involved in all agricultural activities, but are not classified as farmers. Recognition of women's involvement in agricultural production is essential to include them in the modernization process. It is also vital to know whether or not the prerequisites are there for them to be involved. One example is, do they have the basic skills? Answers to the above questions will bring us to a number of gender issues, which include:

- Women's landlessness;
- The differential access of men and women to education and training;

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Women's higher illiteracy rate, which will impact on how well they can benefit from development;

- The reasons for prevailing women's limited access to agricultural extension services; and,

- Constraints on rural credit (where the demand for credit far exceeds the supply) affecting women more and which limit use of purchased input.

The vital role women play as food producers and in food security and their potential to innovate and improve their productivity has to be recognized in a policy intervention that aims at achieving national and household level food security. This paper will focus on the role of women in food production and storage, and the need for considering women as farmers in introducing modern technological inputs to modernize agriculture.

INTRODUCTION

Gender describes what it means to be a man or a woman. It is expressed in one’s behaviour and actions that are performed to fulfil society's expectations. Gender addresses the issues and concerns of both sexes and governs human interactions (BESO, 2004). The two categories are expected to play specific roles that are learnt and which can be changed over time, within and between cultures. Gender Roles are socially constructed functions fitting for men and women to do or to be. They have brought about universal status of female subordination in terms of power and access to resources. As a result of these roles, the way men and women relate with each other impacts on how the two groups access resources; receive payment for work, share income, exercise authority or power, and how they participate in cultural and religious activities (BESO, 2004).

Women lag behind men in terms of education and income earnings. They have limited economic opportunities due to their low social status, their roles and work responsibilities (IFP, 2004). And as a result they lack ownership and access to productive assets, and have low participation in decision making.

Ethiopia is a heterogeneous society, composed of different cultures, languages and religions, but all having a dominant patriarchal system, imposing sexual division of labour, making women responsible for all household chores. This is in addition to their involvement in agricultural activities. But unlike their male counterparts, women are hindered from enjoying the fruits of their contribution. As a result of this gender-based oppression and exploitation, women bear disproportionate burden of poverty.

In a document on poverty reduction submitted to Ministry of Finance and Economic Development (MoFED, 2002), poverty is defined as not having enough for subsistence and is consequent to social injustice, manifested by unequal power relations and gender inequality, as a result of which women suffer the most. It is characterized by subordination or absence of decision making capacity, inadequate
supply of food, poor housing and sanitation services. Poverty is caused by illiteracy, unemployment or underemployment, low and/or irregular income, and large family size. Using these indicators therefore, Central Statistics Authority (CSA, 1998), and Civil Service Commission (CSC, 1992 Eth. Cal.), we observe gaps between men and women in the following areas.

- **Illiteracy:** Female 75% vs. Male 52%
- **Unemployment** Female 69.25% vs. Male 30.75%
- **Irregularity of income** Women are engaged in petty trade a lot, often in marketing perishing goods, such as tela, Enjera, fresh vegetables
- **Land Ownership:** More women than men are landless
- **Large family Size:** This affects women exclusively in several ways, the consequences of repeated and frequent pregnancy, child birth and breast feeding; have to work harder to feed the large family, have to eat less to ensure that others eat.

In such socio-economic context, gender-neutral development intervention affects men and women differently. Being ill equipped with skills, suffering from time constraint, limited access to economic resources, and subjected to greater cultural restrictions, women do not receive equal benefit from economic development. The question of women is thus a fundamental issue for individuals, government and non-government organizations, as well the focus of attention at national and international levels. Socio-economic structures that have placed women at a relatively disadvantageous position need to be transformed.

Ethiopia is the tenth largest and the second most populous country in Sub Saharan Africa. The country is extremely diverse, with a reasonably good resource potential for agricultural development, but one of the least developed in the world. There is intense poverty, with 44 per cent of its population below the poverty line in 1999/2000 (FDRE, 2002). It is estimated that, the majority of the poor are women. The majority of the population live in the highlands, engaged mainly in farming, while in the lowlands, the mostly pastoral population move about with their livestock in search of grass and water. Pastoralists occupy 60% of the territory and constitute about 12% of the total population (Mohammed Musa and Associates, 2001). The majority live in regions that are least developed characterized by poverty, high level of illiteracy and inadequate infrastructure, particularly roads.

The agricultural sector is the basis of the Ethiopian economy, accounting for 46% of the GDP and 90% of total exports, and employs 85% of the country’s labour force. The vast majority of peasants are engaged in subsistence agriculture, producing food first for their own households, then for market. Food is sold
primarily to meet the cash needs of the family, and also because of the limited
capacity to store and protect their harvest from insects and spoilage (IDCO, 1995).
Although the name farmer is often used for men, women's vital role should and is
being recognized in the last few years, especially with the advent of realization of
women's role in development. Despite its significant potential, structural food
shortages have hampered Ethiopia's economic development for the past several
years (UNDP, 2003). Food scarcity affects millions of people.

Agriculture is a process encompassing all activities in the food systems namely,
production, processing and storage (IDCO, 1995). In Ethiopia food for local
consumption is processed and stored in individual homes in almost all cases by
women. Rural women play multiple roles in the world's agricultural systems.
Ethiopian women are involved in almost all agricultural activities. They are
involved in planting, weeding, harvesting, threshing, processing, and storing and
marketing farm products. Women perform most tasks related to animal husbandry,
dairy and poultry production; but this contribution is not acknowledged and
rewarded.

THE STATUS OF WOMEN AND AGRICULTURAL PRODUCTIVITY

Ethiopia suffers deficit in food supply. This is getting worse all the time because of
a number of factors, particularly the low status of women which has led
development programmes that do not take women's vital role in agriculture into
account. Traditionally men gain access to land largely as lineage members, while
women gain access to land as wives. Although land was nationalized in post­
revolutionary Ethiopia, and theoretically all peasants should have equal access, in
reality few women have either direct access to land or a role in agricultural
decisions that affect collective production. Peasant association membership is
limited to heads of households, who by cultural definition are men. It is these
associations, largely composed of male household heads, who are the agents
responsible for land distribution. With the exception of female heads of
households, women have a minimal role in decisions related to either land
distribution or agricultural production. Consequently, women's relationship to land
and production has changed little as a result of social transformation in Ethiopia.

In 1986 there were 648,000 women members in agricultural cooperatives. This
represents 11.4 per cent of the 4.7 million members in a sector, where women
make a vital contribution. In addition, increase in agricultural production especially
that of food has always been below the population growth rate. This is due to mini
land holdings, primitive farming methods, lack of farm inputs, in addition to the
successive drought hitting the country; and the poor coverage of family planning
services.

Further, as modernization reorganizes agricultural production and marketing,
women are increasingly marginalized. They continue to work in production, their
labour may increase but they lose access to the new resources that are increasing
productivity and profitability in food production. As agricultural production in the
third world was increasingly devoted to cash crops, women were left to provide for family food consumption on the least productive land, while men specialized in production of these new crops for cash sale.

The process of introducing modern techniques, whether in agricultural inputs, planting and harvesting technology, or storage and marketing has not been gender-responsive. Agricultural services worked with male farmers, credit could only be extended to individuals with land titles and other collateral, male heads of household. Even marketing an area that was female dominated at village level was taken over by men, once it became sophisticated with motorization and transport, and linkages of villages to cities and ports were established. This is because the new technology demanded greater financial resources and wider geographical linkages than women could muster. Women stayed in less profitable local marketing, as men moved into the new trade opportunities created by modernization.

**FOOD SECURITY SITUATION IN ETHIOPIA**

Food security is consumption by all members of the household (men, women, boys and girls), *at all times*; adequate in quality and quantity, for an active healthy life (Kifile Lemma and Joseph Gebre-Hiwot, 1999). Household food security is a recent and welcome development, and one, which has enabled the consideration of women in food security.

Food security thus involves available food, where in addition to food production, losses and the number of people should be considered, both of which determine the amount of food that an individual is able to consume. It is also a function of food processing, preservation and preparation as well as distribution within parts of the country, and distribution of prepared food among family members. Furthermore, the body must utilize the food eaten to ensure health. It is intimately related to poverty, at national, community and household levels. Ethiopian women are poorer than the men, and thus are more vulnerable to food insecurity.

Food insecurity in many low-income, developing countries is projected to intensify, unless agricultural productivity, foreign exchange earnings, and population growth are addressed (Shapouri and Rosen, 1999). For the poorest countries, an increase in agricultural production is the key to improving food security, because in these countries, import plays a small role in domestic food supply, because of limited foreign exchange availability. Sub-Saharan Africa is the most vulnerable with respects to food security. In this region, a combination of population pressure, low and declining agricultural production, and non-sustainable use of natural resources has brought about an increasing poverty and degradation. These problems are particularly severe in African highlands, including Ethiopia.

In Ethiopia, a combination of factors has brought about a serious and growing problem of food insecurity (FDRE, 2002). Drought, population pressure, environmental degradation, technological and institutional factors have led to a
decline in the size of *per capita* land holding. Increasing urban poverty is largely attributed to limited broad based employment and income earning opportunities in urban areas. Women who make the majority of the poor are much more vulnerable to food insecurity in towns.

Women are producers, preservers and processors of food but are ill equipped and underfed. The neglect of women in agriculture, education and health sectors has been and continues to be one of the fundamental causes of food insecurity (MOA/UNDP/UNIDO, 2002). Educated women are more likely to delay marriage, practice family planning (FP), leading to smaller family size and more available food. Informal education particularly on health ensures proper use of available food, better personal hygiene, and utilization of FP services. To reverse the prevailing situation of food insecurity, there is need to recognize a few fundamental matters, with regards to women's central position in food security. These are:

- Women's increased risk of vulnerability to food insecurity caused by poverty arising from their low status;
- Women's vital role in all aspects of the food system;
- The need to consider women in interventions to ensure food security; and,
- Interventions do not lie within the food production not even the agricultural sector alone, but requires a multifaceted approach involving education, employment, family planning and other related matters.

**DETERMINANTS OF FOOD SECURITY AND GENDER DIMENSIONS**

Several sets of variables: food production, storage and processing; population growth; housing and sanitation as well as cultural factors all have impact on food availability and consumption (Haregewoin Cherinet, 1991). Although the main factors influencing food security are domestic food productions, foreign exchange availability for food imports, and population growth; distribution within each country and purchasing power also play part in determining food security (Shapouri and Rosen, 1999).

**Food Production**

Small-scale farmers who produce 90-95 per cent of all cereals, pulses and oil seeds, and 98 per cent of the coffee dominate the agricultural sector (UNDP, 2003). Women are a critical component of rural economy and are engaged in agricultural production (FDRE, 2002). They contribute significantly to off-farm production/employment, cash and food crops. Women are involved in all aspects of agricultural and livestock production, except in ploughing. Nonetheless, they lack adequate access to extension services. Livestock farmers are part of the mixed farming system where crop production is the main economic activity of smallholder farmers, [12].
The agricultural economy is characterized by wide food gap, largely due to low productivity, compounded by storage and processing losses, high rate of population growth, and workload on women. It is estimated that the average Ethiopian woman has a working day of 12-14 hours, much of it spent in hard physical labour. In the peak agricultural season, women spend up to 10 hours per day in the field, [12].

Food Storage

Agricultural production is the key to ensure food security, through making food available for consumption and/or increasing the national and household income to enable domestic purchase and importation (Shimelis Admassu, 2003). Production increase alone would however not be adequate, but needs to be complemented with the employment of an integrated post-harvest technology. Minimization of pre- and post-harvest losses, estimated at more than 20% due to pests, outdated implements, poor on-farm transport, poor storage facilities and wastage due to traditional food processing and preservation is also a crucial element in food security (UNDP, 2003). Women in the rural areas play vital roles in food production, preservation and storage, and they are totally responsible for processing and preparing food. The widespread malnutrition in developing countries is not just because of low food production, but also due to inefficient storage and marketing practices (FDRE, 2002). Storage losses are major causes of food wastage.

In Ethiopia, food is traditionally stored in granaries, mud-built silos, pottery, and woven grass, all made by women, a job that is long, tiring, and hard. A survey conducted by the same author (Haregewoin Cherinet, 1984) to find out who was involved in making containers, processing foods, and storing them, showed that except for granaries where mainly men were involved, women did all the jobs. These traditional methods of food storage allow attacks by microorganisms, insects and rodents. This coupled with insufficient processing practices has resulted in massive loss of food in Ethiopia.

Proper methods of food storage and preservation are thus vital components of food availability for consumption. Proper storage also helps to ensure household and community food security, until the next harvest, and helps producers to hold their produce until they can get reasonably good prices for them (Shimelis Admassu, 2003).

Food Processing

Women are engaged in the laborious and time-consuming task of food processing, especially for foods like kotcho. Traditional techniques are inefficient, tiring, labour-intensive, and do not meet the needs of the increasing population. Rural women utilize this indigenous knowledge of food processing with limited technological assistance (Haregewoin Cherinet, 1984). Their limited access to appropriate food processing and preservation technologies can have adverse impact
Modernizing Agriculture: A way out of food insecurity?

Haregewoin Cherinet

on household food security of the major part of the population (Haregewoin Cherinet, 1984).

Although women's participation in the traditional food processing is high, their participation in food processing industries is insignificant. The food products and beverages industrial group ranks first in terms of the number of establishments in the large and medium scale category. According to the statistical survey of May 1999, compared to other industrial groups, the manufacture of food products also ranks first in terms of the number of persons engaged. Of the total number of employees engaged in the manufacture of food products and beverages in the public and private, only 19% are female. Women's low status in education, income and time constraint for self-advancement have hindered them from participating in employment in industries. They are either unaware about them or are not given the required training, priority being given to men because in most instances men would have the necessary basic education to participate in the training.

Growth in Population

High population growth rates are the principal factors stimulating food demand, putting pressure on food supplies. Sub-Saharan Africa's population more than doubled between 1960 and 1990, and by the year 2008 will approach 800 million (Shapouri and Rosen, 1999). This rapid population growth, in the absence of increased sustainable agricultural production is the cause for concern in these countries. The decision to reduce family size is influenced by a large number of factors including religious and cultural beliefs in a family's demand for children, and to make decision about it.

The present age composition will also lead to continued increase in population growth. In Ethiopia, 45.5% of the population is below 15 years of age (CSA, ORC MACRO, 2001). With such a large percentage of reproductive age population about to enter the reproductive years, population growth will likely remain high, even if average fertility rates decline. Fertility control in Ethiopia is influenced among other things by culture, knowledge, and availability of services and the status of women. Decision making capacity plays a major role, as indicated in CSA, ORC MACRO (2001) where less than 25% of women stated that using contraception was mainly their own decision, while 10% cited that the husband or partner was the principal decision maker.

One of the objectives of the International Conference on Population and Development - Plan of Action (ICPD-POA, 1999) was to raise the quality of life and to promote human development by recognizing the interrelationships between population and development. It was also to address women's limited access to reproductive health services, including family planning. The POA acknowledges that the empowerment and autonomy of women with improvement of their political, social, economic and health status is a highly important goal. It calls for the elimination of all discriminatory practices and all kinds of violence, to ensure
women's ability to control their fertility. However, the majority of Ethiopian women, who have extremely limited decision-making capacity, including the control of their fertility, do not experience these rights.

The persistence of social and cultural attitudes constrains men from sharing in family responsibilities. Men are not generally engaged in the discussion on gender equality and empowerment of women either at the community or at the policy level.

GENDER ISSUES IN MODERNIZING AGRICULTURE

Modernizing agriculture involves employing improved technologies to increase production and decrease losses; application of better skills in food processing and preservation; as well as utilization of improved facilities for cooking; thereby ensuring better food availability. Population size must match with available food for attaining food security. In a study (OSSREA, 2004), available food in calories per capita: decreased with an increase in family size; was greater for male-headed households than for female headed; and correlated with utilization of modern farm inputs. Thus the food security situation of farmers who use technological inputs is better than those who do not.

Agriculture in the majority of African countries has been largely confined to subsistence farming and has been considerably dependent on the inefficient system of shifting agriculture, in which land is temporarily cultivated with simple implements until its fertility decreases and is then abandoned for a time to allow the soils to regenerate (IRTTS, 2004). The small and scattered land holdings have kept intense agricultural production low and have inhibited the rate at which capital has been mobilized for modernizing production.

The persistence of relatively low productivity agricultural systems over large parts of the continent also stems from a lack of integration between crop production and animal husbandry. Many countries have made efforts to increase crop production by introducing improved methods. The need to sharply increase food production to meet the demands of a rapidly growing population remains vital. Increasing food security in Ethiopia, at both the national and household levels, implies the need for increased agricultural productivity. Increased productivity will require improved farming technology, increased availability of inputs such as fertilizers, pesticides and insecticides, improved water sources for irrigation, the introduction and popularisation of drought resistant crops, better storage and transport facilities, availability of credit facilities, and market pricing structure that would encourage surplus production.

In order to achieve adequate production, it is necessary to think in terms of whose work should be assessed and innovations introduced. Woman's workload must be reduced which could partly be achieved by the development and introduction of technologies that lighten the load of women's work. But there is also the fundamental need for the society's attitudes towards the sexual division of labour to
evolve towards a more egalitarian position, where men will be involved in more activities.

Taking education to the rural communities is a major step in promoting agricultural development and modernization, unless farmers get a basic education it will not be possible to introduce new technologies (World United, 2004). Labour and fertile land are Ethiopia's main assets for the development of the agricultural sector, and there is need to utilize these assets. Increasing farmer's access to education should consider women, who are as much farmers as men, and whose level of education is significantly lower than men.

Agricultural extension services rendered to farmers are not always accessed by women, because women do not own land unless they are widowed. And even those who own land could not afford to pay the required down-payment for fertilizers.

Women's role in production should be recognized; should be given access to resources to enhance production. Though in many instances it has been possible to include women in programmes to provide credit, technology, and access to markets for small farmers, the gap between the work women actually do in food production, processing and storage as well as preparation, and their "visibility" to policy makers who work to increase world wide agricultural productivity, worsens the prospects for food production.

The traditional approach to improve women through the promotion of income generating activities like knitting, sewing and basket making has not responded to the needs of women, nor has it recognized their crucial role in the survival and development of children. Hence, all programmes should recognize and respond to women's need. Instead of special and separate projects for women, development programmes should have a woman's component. Inter-sectoral coordination between health, education, water and sanitation, agriculture and other relevant sectors that would promote food security is essential. Awareness and understanding of the role of women must be at the centre of the development of these programmes.

GENDER PERSPECTIVES OF THE ETHIOPIAN FOOD SECURITY STRATEGY

The 2002 updated food security strategy addresses causes and effects of food insecurity, targeted at the chronically food insecure, where women make the majority. Focus is on environmental rehabilitation to reverse degradation, and as a source of income generation. An overall objective of the food security strategy is to ensure food security at household level, while ADLI focuses at creating national food self-sufficiency. This distinction between household food security and national food self-sufficiency indicates clear understanding of the issue by the government.

Additional factors impacting on household food security like population growth rates have also been raised with the plan to improve family planning services. But
Proceedings of a National Workshop (BSE, February 2004)

gender dimensions of family planning have not been looked into, particularly women's inability to decide on contraception use, and the limited access to information, including radio.

The gender dimension of food production has been raised, although it needs more detailing out and proposing what it exactly needs to be done. Agricultural extension programmes addressing women's need have not been mentioned. Many and varied causal factors of food insecurity such as food distribution within family members, resource allocation on food, household food processing and preparation, have not been treated in enough details. The issues have not been identified among the essential elements of the strategy, except perhaps the promotion of appropriate technology of household based water harvesting and conservation.

Rural credit and marketing systems need to give the required attention to women who have limited access to these services. Identification of the need to encourage grain flows from surplus to deficit areas shows that one of the appropriate steps to translate national food self-sufficiency into household food security is being taken.

Improvement of trade, processing and distribution needs to start with the people who have been involved in the activity thus far, namely women. Women need to be addressed in micro- and small-scale enterprises. The special efforts planned to assist women in finding labour saving means to prepare food and access to fuel and water seems to focus on poor female-headed households. This of course is vital, but it must be noted that the problems associated with food processing and preparations affect all women, and needs to be approached as such. The installment of grinding mills extensively is a crucial element and needs to be given priority.

Focus in institutional capacity building on the technical vocational training should be given especially to women who must to be involved in food processing industries. This is only fair to both the industry and the women. Women have been engaged in traditional food processing and feeding the population. This outstanding women's contribution to the food system must be recognized. Secondly women would be much more experienced in foods, and the industries would benefit from their input.

CONCLUSION AND RECOMMENDATIONS

Conclusion

1) Women suffer extreme poverty among the 44% of Ethiopians who are below poverty line. Gender roles have created differential treatment for men and women where share of resources and benefits between the two sexes is unequal; women as a result are poorer than men. Food insecurity is a problem associated with poverty and women are thus at higher risk of vulnerability to food insecurity.

2) Women are involved in the entire range of agricultural activities, but not classified as farmers, hence are left out in support programmes. Recognition and
adequate compensation of women's productive as well as their reproductive labour is essential to maintaining their contribution to food production and food security.

3) The low status of women is one of the major causes of food supply deficit, and has led to gender-insensitive development programmes. Women are even more marginalized as agricultural production modernizes; as the process of introducing modern technologies has not been gender sensitive.

4) Women are illiterate, ill-equipped and excluded from agricultural modernization; and thus are unable to undertake their responsibilities in production effectively.

5) The definition of food security made at the household level has enabled to effectively include all the variables that interplay in food security, and their gender dimensions. When this was done, it became possible to examine all the steps involved from food production, storage, processing and preservation.

6) In a country where foreign exchange earnings are limited, food produced in country would essentially be the main source of food. Increased food production alone would however not lead to food security but only together with proper post-harvest management of foods.

7) The wide food gap is largely due to a combination of low productivity as well as storage and processing losses, increasing population size, and workload of women.

8) Education in the community is a major step in agricultural modernization. The neglect of women in agriculture, education and health sectors continues to be one of the fundamental causes of food insecurity.

9) Women are responsible for most activities required in food storage in terms of making the containers, processing and storing food. Women process food using inefficient and time-consuming traditional technologies, and thus the needs of the increasing population cannot be met.

10) Women's participation in food processing industries is extremely low despite their significant role in traditional food processing; the same way they are marginalized as agricultural production modernizes.

11) The limited decision making power of women influences exercise of their reproductive rights and utilization of family planning services, hence control of population growth. Cultural attitudes constrain men from being involved in discussing the issue of gender equality that would assist women's empowerment.

12) There is a gap between women's role in food production, processing and storage and their visibility to policy makers who work on increasing productivity.

13) The consequences of differential treatment of men and women, the recognition of women's contribution to food security, and their vulnerability to the problem, compels us to come up with gender sensitive intervention. Food security strategies should thus seriously consider all these relevant issues, and the gender dimensions.
Recommendations

1) Women's involvement in agricultural activities should be acknowledged, to better select the type and target of agricultural assistance. This should follow a proper assessment of who is involved in what activity. Women should be provided with extension services that are responsive to their needs, including credit. As part of the extension programme, women must be introduced to modern agricultural technology.

2) The vital role women play as food producers and their contribution to health and nutritional well-being of their families and communities as well as their potential to innovate and improve their productivity has to be recognized in a policy intervention that aims at achieving national and household level food security and a sustained and balanced socio-economic development.

3) The amount of food lost after production is significant. Reducing such post-harvest losses can make more food available as effectively as increasing production. Women's role in food storage activities must be recognized and any intervention must consider the role of women.

4) Improved food processing technology at household and community levels would ease women's workload, and greatly contribute towards the achievement of food security. A programme to develop food technologies based on the status of traditional food processing and preservation practices at the community level is crucial to the enhancement of food security. Women's indigenous technical knowledge should form a solid base for technology development activities. Since a great proportion of women are involved in food processing, there is considerable justification for upgrading their indigenous technical knowledge in the sub-sector to meet the challenge.

5) Women's education is closely related to important development issues, such as their participation in productive activities, population growth, reproductive health and health status of the family, and education including that of girls. Thus it is vital to raise the participation of women in education, skills training to promote women's employment and earnings. Improving women's education will be crucial for maintaining food security. In addition to basic education, women should be directly targeted for training on such themes as agricultural production and resource management and conservation.

6) Access to family planning services is an essential component of food security. Whether or not women can control the number and timing of their children is crucial in determining both their level of nutrition and the amount of free time that they can devote to food production and preparation. Women should be enabled to exercise their fertility control rights. Reproductive health information must be made to reach them.

7) Men have a profound effect on food security by supporting and promoting women's reproductive choices; their access to and control over land and financial
resources; their children's and their own education and level of nutrition, and through their own contribution to securing and preparing food, in order to ease women's double burden of labour.

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THE IMPORTANCE AND CONTRIBUTION OF FARMER VARIETIES OF CROPS TO FOOD SECURITY

Tesema Tanto\textsuperscript{1} and Girma Balcha\textsuperscript{1}

ABSTRACT

Ethiopia is globally recognized as one of the major centers of origin and diversity for several crop plants and their wild and weed relatives, because of its altitudinal variation, varied agro-ecological zones, climate, and edaphic variations. When the yield performances of durum wheat landrace and improved varieties across the three categorical years i.e., in good, medium and bad rainy seasons was evaluated, it was observed that farmer varieties of durum wheat gave better yield as compared to improved varieties of durum wheat at both Gumbichu and Lume woredas in bad rainy season. With application of crop rotation and using manures, a better yield and net profit were obtained from farmer varieties of durum wheat compared to improved varieties of the same species at both Lume and Gumbichu woredas. One has to bear in mind that there is no additional cost of production for fertilizer and improved seed in the production of landraces/farmer varieties. The fact that most improved seed products are sold to pay back fertilizer and improved seed loan would create seed shortages. This is one advantage for landrace producers; they keep most of their products. This would be considered as the first step towards food security. This does not mean that farmers should restrict themselves to home consumed products only. The growing demand for farmer varieties seed in the local markets, their multiple benefits including low inputs, better adaptation to marginal conditions and superior gastronomic, nutritional and straw qualities have all contributed positively to attract more poor farmers to be beneficiary from the community gene banks. We suggest the inclusion of enhanced farmer varieties of crops as an alternative extension package especially in food insecure and drought prone areas of Ethiopia.

Key words/phrases: Farmer varieties/landraces, food security, durum wheat, genetic diversity, enhancement.

BACKGROUND

Food security is an access by all people at all times to sufficient food to secure sustainable prosperity and healthy life. The major factors that cause food insecurity are change in climate that lead to more, widespread land degradation, increased population pressure, limited access to basic services, inadequate inputs to agriculture, etc. The extent of food insecurity is very high in Ethiopia. On average five million people have been enlisted for daily relief food year after year over the

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Last decades, even in years when there is sufficient rainfall in both amount and distribution. There is an immediate linkage between crop failures and household food deficit in Ethiopia with its rural population highly dependent on agricultural production.

Causes for food insecurity has not one single factor but overall global effect. Green Revolution did not contribute as much to Africa as compared to other continents, and improved varieties of crops increased little yield compared to other continents (Table 1).

**Table 1** Contribution of improved varieties to yield increase from 1960-98 in different continents (Source: Sanchez, 2003).

<table>
<thead>
<tr>
<th>Continent</th>
<th>Percent yield increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>88</td>
</tr>
<tr>
<td>Latin America</td>
<td>66</td>
</tr>
<tr>
<td>Middle East</td>
<td>69</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>28</td>
</tr>
</tbody>
</table>

Ethiopia is globally recognized as one of the major centers of origin and diversity for several crop plants and their wild and weed relatives, because of altitudinal variation, varied agro-ecological zones, climate, and edaphic variations. The country has immense genetic resources of flora and fauna. Among the large number of biological resources, about 600 plants, 23 terrestrial mammals and 26 bird species are endemic to Ethiopia (World Conservation Monitoring Center, 1991).

The Institute of Biodiversity Conservation and Research (IBCR) has the mandate of conserving biological resources of the country both by *ex situ* and *in situ* conservation strategies to safeguard the rich biodiversity resource base, which is seriously affected by recurrent droughts due to man-made and natural calamities.

To complement the *ex-situ* conservation effort, the *in-situ/on-farm conservation of crop plant genetic resources was initiated in 1994 by the Institute of Biodiversity Conservation and Research through financial grant provided by UNDP/GEF, to execute the project ‘A Dynamic Farmer-Based Approach to the Conservation of Ethiopia’s plant genetic resources’ (ETH 93/G31).

*In-situ* on-farm conservation of crops is security to farmers and serves as a source of genetic wealth which is not expressed under favourable conditions and responsive to incidental environmental changes such as drought, low soil fertility, disease, pest outbreaks, etc. Seeds of farmer varieties are very important to complement the existing Agricultural Extension Package program in the country especially in drought prone and food in secure regions.

The objective of this paper is to highlight the importance and contribution of farmer varieties of crops to national endeavors in food security as planting material in drought-prone and marginal areas in addition to their resistance to disease and pests.
MATERIALS AND METHODS

Survey on the role of farmer varieties of crops on food security was held with 40 elders (men and women) at Lume and Gumbichu woredas in October 2003. The questionnaires developed addressed the following key research questions by interviewing the farmers.

Socio-economic Profile of the farmers in the study sites

- Who uses the farmer varieties?
- What are the factors favoring diversity in crops?
- Which age group is knowledgeable about their varieties?
- What is the wealth status of the users of farmer varieties?
- What are other merits of landraces/farmer varieties apart from food and sale in the market?
- What are the factors threatening existence of farmer varieties?
- What are the quality characteristics that you prefer landrace from improved varieties?
- Do landraces enhance your livelihood (more food, more money return, less out going as labor, greater food security, less input, etc?)
- Do women prefer landrace or improved varieties for food? Why?
- What proportion of people in your village use/do not use farmer varieties and why?

Advantages of landraces in maintaining ecology

- What crops were/are grown in your village (first list all species and then their varieties)?
- Which species and their varieties give better yield?
- Which crops/their varieties tolerate/resist drought, insect pest, disease, water logging, salinity, alkalinity, etc.?
- Which crop varieties give better yield under marginal soil?
- Do you use organic fertilizer for landraces? If yes type and amount in kg/ha.

Assessing economic advantages/disadvantages of landraces

- What is the cost of local/improved seed per hectare?
- What is the cost of DAP fertilizer per hectare?
- What is the cost of Urea fertilizer per hectare?
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- What is the yield of improved durum wheat per hectare?
- What is the yield of landrace of the same species per hectare?
- How do yields landrace/improved varieties differ in good rainy year/in medium rainy year/in bad rainy year?
- What is the other cost of production for landrace/improved/durum wheat?

After collecting these data it was summarized and analyzed using basic descriptive statistics and frequency distribution.

RESULTS AND DISCUSSION

Based on this survey, it was observed that environmental changes occurred over the last three decades and the implication of these changes on farmer varieties seed conservation was assessed. It was understood that the amount of rainfall and distribution have also been reduced. Consequently, some of the durum wheat varieties were either lost or are on the verge of extinction (Table 2). Local farmers in Lume and Gimbichu woredas have been traditionally growing farmer varieties of durum wheat. Distribution of durum wheat varieties in the two woredas is shown in Table 2.

Table 2 Occurrence of durum wheat farmer varieties across the two Woredas.

<table>
<thead>
<tr>
<th>Farmer variety name</th>
<th>Woreda</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lume</td>
<td>Gumbichu</td>
</tr>
<tr>
<td>Gelano</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Gerardo</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Jalalie</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Gebre</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Aybo</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lôcco</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Arenteto</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Set akuri</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Many of the crop plants that have been locally adapted and jointly assessed and selected with farmers did relatively well, all with no external inputs, like commercial fertilizers, pesticides, herbicides, etc. This is a viable option for the poor farmers who cannot afford buying inputs. With application of crop rotation and using manures, a better yield and net profit were obtained from farmer varieties of durum wheat compared to improved varieties of the same species at both Lume and Gumbichu woredas (Fig. 1). In Gumbichu woreda, it was possible to get more net profit Birr 291 over improved varieties of durum wheat per hectare (Fig. 1).
When the yield performances of durum wheat landrace and improved varieties across the three categorical years i.e., in good, medium and bad rainy seasons were compared, it was observed that farmer varieties of durum wheat gave better yield as compared to improved varieties of durum wheat at both Gumbichu and Lume woreda in bad rainy season (Fig. 2). One has to bear in mind that there is no additional cost of production for fertilizer and improved seed in the production of landraces/farmer varieties.

The majority of productions from the landrace/farmer varieties are consumed at home, while the improved varieties are sold at market (Fig. 3). Because the farmers have to pay for loans of fertilizer and improved seed received from the extension package in the case of improved varieties, the fact that most improved seed products are sold to pay back fertilizer and improved seed loan would create seed shortages. This is one advantage for landrace producers; they keep most of their products. This would be considered as the first step towards food security. This does not mean that farmers should restrict themselves to home consumed products only.
Landraces/farmer varieties have other multiple uses apart from home consumption and sale at the market. These include additional income, household food security, less going out as laborers elsewhere and less cost of production. Besides these advantages, it has also improved their livelihood in terms of improving their living standards and enabling them to buy additional farm animals at project areas (Fig. 4).
Fig. 3 Proportion of landrace and improved varieties of durum wheat consumption and sale (in percent).

Fig. 4 Additional uses of landraces other than yield advantage.
Seed loan scheme developed through the community gene bank has enabled farmers to be more reliable on the availability of planting seed from the community gene banks. It also proved more sustainable revolving seed system schemes, which have to a large extent provided incentives to farmers. This system provides farmers with a fall-back mechanism and has enabled them to be more seed secure. The growing demand for farmer varieties seed in the local markets, their multiple benefits including low inputs, better adaptation to marginal conditions and superior gastronomic, nutritional and straw qualities have all contributed positively to attract more poor farmers to be beneficiary from the community gene banks (Table 3).

Table 3 Percent of farmers that use landrace in the two districts/woredas.

<table>
<thead>
<tr>
<th>Woreda</th>
<th>Beneficiaries</th>
<th>Non-beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lume</td>
<td>67</td>
<td>33</td>
</tr>
<tr>
<td>Gumbichu</td>
<td>63</td>
<td>37</td>
</tr>
</tbody>
</table>

Results from the studies of the on-farm conserved crop plants provided basis for landrace selection to satisfy some defined nutritional, yield or disease resistance standards; or for mixing landraces to meet desired adaptive complex, yield levels or nutritional composition. For example, the nutritional analysis test carried out at IBCR laboratory for 100 farmer varieties and two improved durum wheat varieties indicated that farmers’ varieties had maximum protein of 21.8%, average 15.6% and minimum 9.7% while, improved varieties of Boohie and DZ-14-118 of the same species had 9.7% and 10.44% protein respectively. This confirms the farmers saying “long time before one has to be hungry after eating the injera of the landraces (the injera of the landrace seeds’ last for a day) while it is short for that of the improved ones”, because farmer varieties have high protein content compared to improved ones.

Wheat production is limited by poor soil fertility and water logging conditions among others. Nitrogen and phosphorous are the two major nutrients that limit crop production. We also know that the price of fertilizer is keeping on increasing and currently very few farmers can afford to buy and apply in their fields. For the majority of poor farmers who are using landraces/farmer varieties (Fig. 5) legume rotation coupled with little application of fertilizer and using their own varieties will increase production and productivity in East Shewa and similar areas for wheat, if considered as one of the options in the extension packages.
Enhancement activities on farmer varieties consisted of adding positive elements to what are already there. This is done through the involvement of farmers, researchers and, extension workers at different conservation sites. By practicing participatory selection method with farmers in Gimbichu woreda, some 12 durum wheat farmer varieties were identified and are in use by the local farmers. These varieties showed better adaptation during drought and resistant/tolerant for some major diseases in the area. This shows that by applying the same technique the germplasm can be used in other areas of the region or elsewhere.

Through the enhancement of farmer varieties, farmers were able to control the choice of crop types and cultivars to grow, and they have ready access to planting material adapted to their local growing conditions. They are also in a position to critically evaluate the relative merits of a wide range of cultivars.

To ensure adequate seed supply of farmer varieties in the on-farm conservation sites, some 136,942 kg of sixty-four farmer varieties of different crop types were purchased and multiplied at the respective sites, are already in use in the local seed supply system in Tigrai (Ganta Afe Shum and Hawzen), in Amhara (Kalu, Were-Illu, Insaro and Wayu, and Ankober) in Oromiya (Agarfa, Goro, Lume and Gumbichu) and in South Nations, Nationalities and Peoples region (Decha and Chena) woredas, respectively. These practices proved the potential advantage of using locally adapted farmer varieties seed especially in drought prone and food insecure woredas of Ethiopia.
Since seed is the basic input in agricultural production system, lack of locally adapted seed, particularly in drought-prone and food insecure communities, is crucial especially as production is only subsistence. The seed supply system developed by the Crop Conservation Associations in the twelve woredas has provided the opportunity for farmers to take seed loan from the community gene bank with minimum interest rate (10-25%) depending on local conditions every year. Some 3883 farmers have an access to get seed loan every year for planting purposes. Lack of seed has been alleviated because of the current system. This, in addition to being constant source of locally adapted seed supply, has been able to generate resources that help them improve their livelihoods. These situations may contribute in keeping farmers from mass flow and displacement to other areas where they could move for better life because of low income or drought.

We have assessed farmers’ opinions in our conservation sites during training sessions with regard to their varieties. Farmers after some consecutive harvest of the landrace/farmers varieties, established confidence due to the following observed advantages of landraces/farmer varieties over the improved varieties:

- Resistance to stress condition and pest outbreaks;
- No loan and no credit to purchase fertilizer and different inorganic inputs while planting landraces;
- Free 'produce of seeds' without absorption-effect of fertilizer-nutrients and pesticides;
- Encouragement to organic farming and indigenous farming practices;
- Better productivity advantages under low input production condition in marginal areas;
- High productivity advantages were obvious while using crop rotation and other organic farming techniques;
- Better local price advantage especially for planting seed;
- Constant interaction among farmers and good interchanging environment of ideas among each other; and
- Good maintenance of alternative seed supply system through the community gene banks;

With regard to qualitative traits of farmer varieties, the farmers' opinions were summarized as follows:

- 100 kilogram seed of farmer varieties yield more number of injera/bread than the same amount of seed of the improved varieties;
- Long time before one gets hungry after eating the injera of the landraces (the injera of the landrace lasts for a day while it is only a short period for that of the improved ones);
Proceedings of a National Workshop (BSE, February 2004)

- The landrace cultivars have good taste for both human diet and animal feed;
- Medicinal value of farmer varieties/landraces; and
- Higher number of productive tillers and seeds per spikes in landrace/farmer varieties.

To provide market incentive to these farmer varieties/landraces, IBCR has managed to develop market options. For example at Ejere and Cheffe-Donsa, farmers growing durum wheat varieties have got an option of sale to the flour milling companies serving the confectionery industries. The milling companies used to import the wheat variety but are now contracting farmers to supply the grain, with an estimated annual demand of 10,000 quintals (1,000 tons).

Mid-term evaluation of the project by the Scientific and Technical Advisory panel of GEF has noted the significant contribution of the in situ conservation in building scientific and research capacity together with the potential profile of replicating this initiative in other parts of the country or elsewhere. The contribution of in situ conservation in sustaining the natural resource base, food security and poverty alleviation has been well recognized. The terminal evaluation and final stakeholders' conference of the project also showed appreciation to the uniqueness of the project and lessons learnt as a basis for a wider follow-up on agro biodiversity projects.

As indicated in the objective, the extension package policies, however, have not yet included seeds of farmer varieties to be one of the production input. Such practices discourage the use of potentially valuable local varieties in the production system. According to Central Statistics Authority Agricultural survey, in 2002/2003 from the total cultivated land of 9.13 million hectares, 3.54 million hectares (38.8%) land was applied with inorganic fertilizer and 329.4 thousand hectares (3.6%) planted with improved seed. This shows that very little amount of cultivated land used both inorganic fertilizer and improved seed, while 57.6% of the cultivated lands do not use both inputs. Based on our own investigation through the Analysis of Market and Socio-economic Situations Affecting Biodiversity Conservation in Ethiopia, over 90% of the food crops grown and sold are farmer varieties, there is inadequate attention given to delineating roles and contributions as well as to creating mechanisms for the promotion of these materials. Therefore, it is believed that the promotion of farmer varieties through research and the inclusion of these varieties in the extension packages are essential tools in order to assist the poor farmers who cannot afford buying inorganic fertilizer and improved seed in order to achieve the objective of food self sufficiency and alleviating poverty, especially in marginal production areas of the country.
POLICY DIMENSION

The National Biodiversity Policy and Strategy has benefited from the upstream contribution of the project in validating the *in situ* conservation approach as a viable option for farmer variety seeds in the rural community with its entire dynamic environment including pests, soil, flora, fauna and climate. The Policy is thus strengthened by the inclusion of the concept of *in situ* as a complementary mechanism to *ex situ* conservation of crop varieties in IBCR.

In addition, the project has also influenced the widening of the revised mandate of IBCR to include also non-crop, microbial, and animal biodiversity, which was initially plant specific. The catering for several disciplines by IBCR has given chance to building capacity for conservation and facilitation for sustainable use of biological resources.

Government scaling up of the agricultural extension programme will be much enhanced if the farmer variety seeds are included in the extension package to be implemented in low input agricultural production processes particularly in marginal and food insecure area of the country. The agricultural production in the country could benefit from the rich quality of farmer variety seeds and organic outputs.

The Dynamic Farmers *in situ* Conservation project has demonstrated in selected agro ecological zones that local seeds are the preferred options to make a difference in the livelihood of the farmers by maintaining the ecology in a sustainable manner and enabling the household to be food secure and. The premium price trend for farmer varieties that is just emerging is encouraging, not only for the smallholder farmer but also for the Government.

CONCUSSION AND RECOMMENDATION

1. Community gene banks with its seed loan schemes secure the local Community Gene Bank-Crop Conservation Association seed supply system. Therefore, this effort has to be expanded in more agro-ecological regions of the country.

2. The farmer varieties across the country have to be identified and enhanced in order to promote these local varieties to add value in terms of socio-economic, nutritional and ecological factors.

3. The availability of locally adapted planting seed is one of the means to food security. To this effect, the identified and enhanced farmer varieties of crops in each region have to be purchased in each locality and made available both as planting seed and grain, especially in drought prone and food insecure regions of the country.

4. The enhanced farmer varieties of crops have to be included as an alternative extension package, especially in food insecure and drought prone areas.
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ORGANIC AGRICULTURE AS A SUSTAINABLE DEVELOPMENT ALTERNATIVE TO ACHIEVE FOOD SECURITY

Tadesse Woldemariam Gole

ABSTRACT

Global food security will remain a worldwide concern for many decades to come. Even though there is surplus production in the world today, one fifth of the global population, mainly in developing countries, lives in constant under-nourishment. Agricultural production should double by 2050 in order to meet the food demands of the projected world population by then. Conventional agriculture like the Green Revolution movements failed to produce the expected results in many developing countries. Organic agriculture has the potential to produce sufficient food of a high quality. Organic agriculture is particularly well suited for those rural communities that are currently most exposed to food shortages. Some of the positive attributes of organic agriculture are increasing yields in low-input areas, conserving biodiversity and natural resources on the farm and in the surrounding area, increasing income and/or reducing costs, producing safe and varied food and sustainability in the long term. This paper discusses the roles of organic agriculture for food security, biodiversity conservation and sustainable development, by providing empirical evidences from research finding during the last decades in different parts of the world. The potentials, opportunities and constraints of organic agriculture in Ethiopia, especially in the coffee sector are also discussed.

INTRODUCTION

According to the World Food Summit (1996), food security is the physical and economic access to sufficient, safe and nutritious food by all people, at all times to meet their dietary needs and food preferences for an active and healthy life (Rundgren, 2002). Today, food security has become the major challenge that most developing countries, including Ethiopia, are facing. Even though there is surplus production of food in the world, more than 800 million people are food insecure, mainly because of social, political and economic conditions (poverty, inequality and discrimination, war or civil unrest, failure of food production to deliver economic return) and production related problems (unsustainable production methods, loss of biodiversity on the farmland degradation of surrounding environment, in efficient use of production resources, and natural disasters) (Rundgren, 2002).

Given the current population growth, the world will face even a bigger food security problem in the future. By 2025, the world population is estimated to be 8.3

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billion, out of which 84% will be living in developing countries. By 2020, demand of food is expected to be doubled in developing countries and to increase by 25% in industrialized countries. The Ethiopia's population is estimated to be about 136 million by 2025 (Bread for the World Institute, 1998), almost double of today's size. Even with the current population size, many people in the country are food insecure. During the last three decades, Ethiopia depended on food import or aid for significant proportion of its population. Hence, there is a strong need to increase food production. There are three scenarios to increase food production in the world: area expansion, increase productivity in industrialized countries and export surplus, and increase productivity in the developing countries that have food shortage.

The first two options are not viable alternatives. First, agricultural area expansion has already become the biggest threat to biodiversity, ecosystems and the future of humanity itself. About 5-10 million hectares of agricultural land are lost annually, mainly due to inappropriate agricultural practices (Oldeman et al., 1991; Pinstrup-Andersen, 1994; WRI, 1994). Second, the impact of farming practice in the developed countries on the environment and biodiversity is already too high and a radical change leading to decline in productivity is expected. The only option is to increase productivity on the existing agricultural land in the areas where there is food shortage. This needs a strategy for sustainable agricultural development, i.e, we are obliged to overcome two major challenges:

(1) Increase productivity on the existing farmland, and

(2) Minimize the risk of agriculture on the environment and biological diversity.

The major limiting factors to increase productivity are: fertility, stress (disease, pest, drought, etc.), plant biomass, and harvest index (Evans, 1998; Rosegrant and Cline, 2003). Modern agriculture tries to give chemical solution to all these limiting factors, i.e., using inorganic fertilizer, pesticides, insecticides and herbicides, along with improved varieties. In doing so, the modern farming tries to be independent of natural regulating processes and local resources. This has stimulated mono-cropping and regional specialization in the food system, which leads to more pests and increased problems with nutrient management, as natural cycles are broken. To fix the problems even more pesticides and more chemical fertilizers have to be used – a vicious circle is established. This makes the system not sustainable and has a negative implication on the environment and the conservation of biodiversity on farm.

Our future strategy should be to improve food production with cheap, low-cost, locally available technologies and inputs, without causing further environmental damage. Organic agriculture is the best option to achieve this strategy. Organic agriculture appears to be the most appropriate agricultural development option to overcome these challenges.
ORGANIC AGRICULTURE FOR SUSTAINABILITY AND FOOD SECURITY

Organic agriculture is a system of agriculture that relies largely on locally available resources and is dependent upon maintaining ecological balances and developing biological processes to their optimum. By relying on the natural capacity of plants, animals and the landscape, organic systems aim to optimize quality in all aspects of agriculture and the environment (IFOAM, 2000).

Organic agriculture can increase productivity due to its several attributes, which include:

- Improved diversity in agricultural system through crop rotation, and intercropping;
- The use of green manure crops either separately or intercropped;
- Improved on-farm recycling of nutrients by utilization of crop residues as mulch or through composting and non burning;
- Better use of organic materials in the surrounding ecosystems;
- Better use of natural resources, especially water (by mulching, water harvesting, and through the increase in soil organic matter);
- Integration of livestock and crops, leading to improved nutrient management; and
- More attention to soil and nature conservation.

There are three different approaches to the development of organic agriculture in the developing countries: (a) a development approach: for resource poor communities, to help them become self sufficient, which focuses on social sustainability, (b) an income generation approach: giving farmers access to premium market which focuses on economic sustainability and (c) a nature conservation approach: organic agriculture as a tool for biodiversity conservation, natural resources management, which focuses on environmental sustainability. The general notion in organic agriculture is to combine all of them in practice. By properly integrating all aspects of sustainability, organic agriculture can be a truly sustainable development option in agriculture.

MERITS OF ORGANIC AGRICULTURE

The merits of organic agriculture over modern agriculture for the development of the sector in developing countries like Ethiopia can be seen from different angles: productivity, health, economic, environment, conservation and long-term sustainability. Studies show that well managed organic agriculture can be much more productive than traditional rain-fed agriculture; as productive as Green Revolution and slightly less productive than industrial agriculture (Rundgren, 2002). Examples from Africa showed an increment of 50-100% in cereal yield
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(Tadesse W/Mariam) For instance, the use of organic manures for soil fertility and botanicals for pest control has increased crop yield by 60% in Cheha Woreda, Ethiopia, resulting in a 70% improvement of overall nutrition levels (Pretty, 1999). Edwards and Hailu Araya (2004, this volume) also reported that ecological or organic agriculture had comparable yield to that of modern agriculture.

Organic agriculture involves production of different varieties of crops, it leads to a more varied diet for farm families, and hence a healthier and balanced nutrition. On the other hand, the economic advantages of organic agriculture can be seen from two angles: the first is from reduced cost of production as a result of avoiding the use of chemical fertilizers and pesticides, while the second is from the premium price that can be earned from certified organic products.

Organic agriculture also has positive impact on the environment: Because it is dependent on the natural capacity of plants, it uses renewable resources, involves technologies that improve nutrient cycling, avoids the use of chemical inputs and hence reduces pollution, minimizes soil erosion, and improves vegetation cover, etc.

Table 1  Advantage of organic agriculture as compared to modern agriculture (adapted from Rundgren, 2002).

<table>
<thead>
<tr>
<th>Organic agriculture</th>
<th>Modern agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can increase productivity, especially for farmers that are most prone to food shortages.</td>
<td>Has failed to deliver food security due to: decreasing soil fertility, damage to biodiversity and the environment, degradation or destruction of water resources, the build up of pest populations and resistance. Long term effect on fertility of soils and soil erosion.</td>
</tr>
<tr>
<td>Can produce safe food and supports a varied diet.</td>
<td>Reduced food safety and negative health effects.</td>
</tr>
<tr>
<td>A means to increase income or return on labor.</td>
<td>Decreased nutritional values and deterioration of diets.</td>
</tr>
<tr>
<td>Can reduce costs of production.</td>
<td>Loss of bio-diversity and environmental degradation.</td>
</tr>
<tr>
<td>Diversification- reduces the risk of crop failures.</td>
<td>Tries to be independent of the natural regulating processes and local resources.</td>
</tr>
<tr>
<td>Creates awareness among producers and consumers about sustainable production and consumption, and the need for clean and safe food, and of the need to protect the environment.</td>
<td>GMOs as 'New' solutions to all the above problems.</td>
</tr>
<tr>
<td>Recognizes the value of traditional and indigenous knowledge and integrates this in its production methods.</td>
<td></td>
</tr>
<tr>
<td>Is sustainable in long term.</td>
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There are very interesting new innovations in organic production that can increase production while reducing pollution and other environmental and health risks. Notable examples are “induced resistance” to control different plant diseases (FiBL, 2002), the use of virus (Nuclear Polyhedrosis Virus) to control pod borer by
ICRISAT in India (Future Harvest, 2004), the push-pull method to control stem borers in *Sorghum* by ICIPE in Kenya (Pretty, 1999) and the control of coffee berry borer by natural enemies (African bethylid wasps) in Colombia (Baker, 1999). These are some of the few examples of technologies developed in the developing countries. Many more such innovations are already being applied in the organic farms in the developed countries.

Organic agriculture is also beneficial for conservation- it enables the conservation of biodiversity on farm at all levels (genetic, species and ecosystem) (Stolton, 2002). Most schemes working to conserve seed banks and indigenous varieties worldwide are linked to organic agriculture (Cooper *et al.*, 1992; LEISA, 1999). Organic farms also have higher agro-biodiversity with greater crop rotation diversity, integration of livestock and number of cultivated crops. Many of the principals of organic systems may also have a positive impact on ecosystem diversity (Stolton, 2002). These facts make organic agriculture a sustainable development alternative.

**POTENTIALS OF ORGANIC AGRICULTURE IN ETHIOPIA**

The majority of the Ethiopian agriculture can be described as *de facto* organic agriculture, since it is based on low external inputs. However, the system is not optimized by using different organic agricultural production practices for nutrient cycling, and hence is characterized by inefficient use of natural resources and unsustainable production methods which cause soil erosion, depletion of soil fertility and loss of biodiversity. On the other hand, the fact that the majority of the farms are based on traditional varieties of crops and presence of wide ranging agro-climatic conditions make Ethiopia very suitable for organic agriculture. Given the poverty level and economic capacity of the poor Ethiopian farmers, and the absence of government subsidies to purchase external inputs to increase productivity, organic agriculture becomes the most appropriate development option to increase agricultural productivity and achieve food security in the country. However, in areas of high potential for agricultural production, and with good infrastructure, organic agriculture may be used along with modern agriculture or with some levels of external inputs to maximize production, provided that there is market for the surplus production. Ethiopia has a high potential to produce certified organic agricultural products, such as coffee, honey and spices.

**Organic coffee**

Being the center of origin and diversity for Arabica coffee, *Coffea arabica* L., Ethiopia possesses different traditional coffee production systems developed over the last 2000 years of coffee culture. Four major coffee production systems in Ethiopia can be recognized (Tadesse Woldemariam *et al.*, 2001), which include forest coffee, semi-forest coffee, garden coffee and coffee plantations. These production systems represent different levels of domestication, ranging from wild population in forests to the most advanced cultivars in plantations. The first three
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are traditional production systems by small-scale subsistence farmers. In these traditional production systems, no external inputs are used for production, and hence they can be considered as de facto organic (uncertified organic). The three traditional production systems, i.e., forest, semi-forest and garden coffee production systems account for 5-6%, 20%, and 68-69% of the total coffee production in Ethiopia, respectively. In total, about 95% of the coffee produced in Ethiopia comes from these traditional production systems. Ethiopia produces over 200,000 tons of coffee every year. It also has the largest highland plateau in the world that is suitable for coffee production. Even though the country is producing one of the finest quality coffee in a more natural and environment friendly way, it did not benefit much from the coffee niche markets like certified organic or fair-traded coffee. In recent years, Ethiopian coffee has started to enter into such markets.

Ethiopian coffee entered the organic coffee market in 2002, pioneered by the Oromia Coffee Farmer Cooperatives Union (OCFCU). The Sidama Coffee Farmer Cooperatives Union (SCFCU) is also exporting certified organic coffee at the moment. The demand for the Ethiopian certified organic coffee has grown tremendously during the last two years (Table 2).

Table 2 Export of certified organic coffee by the OCFCU.

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity exported</th>
<th>Percent growth per year</th>
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<tbody>
<tr>
<td></td>
<td>No. of containers</td>
<td>Kilo grams</td>
</tr>
<tr>
<td>2002</td>
<td>27</td>
<td>484,000</td>
</tr>
<tr>
<td>2003</td>
<td>54</td>
<td>967,200</td>
</tr>
<tr>
<td>2004</td>
<td>118</td>
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The OCFCU exports the certified organic coffee to Belgium, England, France, Germany, Japan, USA and other European countries. USA imports over 70% of the certified organic coffee from Ethiopia. OCFCU has 34 member farmers' cooperatives from different coffee growing zones of Oromia.

Recent research activities in coffee have also played important roles in popularizing the Ethiopian coffee and attracting the public interest, both locally and internationally (Tadesse Woldemariam et al., 2001; Tadesse Woldemariam et al., 2002; Tadesse Woldemariam 2003a; Tadesse Woldemariam, 2003b). As a result, an interdisciplinary research project was developed and the research activities are being carried out by German and Ethiopian universities (Bonn, and Addis Ababa), research organizations (ZEF Bonn, EARO, IBCR), and private partners (OCFCU, GEO Foundation, Amber Foundation, Craft Foods Europe). The involvement of private partners has enabled to popularize the Ethiopian wild/forest coffee in Germany. The GEO foundation prepared a documentary film on wild coffee of Kaffa area and published articles in its popular "GEO Megazin". Besides, in collaboration with the Amber foundation and farmer's cooperatives in Ethiopia, the German private partners promoted the "wild coffee" on the German market. This has enabled farmers in Kaffa zone to earn 2-3 times more money from selling their
coffee. Farmers get this premium price if their coffee is wild and harvested from a well-protected forest, for which the Amber foundation has developed a testing method. Such premium price for the wild coffee, not only improves the income and livelihood of the farmers, but also promotes the conservation of the forest and the wild coffee genetic resources in the area. The idea, therefore, is to expand such practice to other wild coffee growing areas in southwestern and southern parts of the country.

HONEY AND BEESWAX PRODUCTION

Ethiopia has wide climatic and edaphic variability, which has endowed the country with diverse flowering plants, among which there are many species suitable for honeybee forage (Fitchl and Admasu Adi, 1994). Ethiopia also has the largest honeybee colonies in Africa. The country is the largest honey and beeswax producer in Africa. Most of the honey and all the beeswax are produced by small-scale farmers using traditional methods, and primarily in forest and woodland areas where there are higher vegetation cover. Ethiopia is the fourth beeswax exporter in the world, next to China, Mexico and Turkey (Fitchl and Admasu Adi, 1994). However, export of honey is very low, due to poor processing. There is a recent initiation by Harmony Agricultural Enterprise to export good quality honey and beeswax to Germany, which also fetches premium price for farmers (Greilling, personal communication). Certification of honey and beeswax can contribute to the improvement of the livelihood of the poor farmers and conservation of the biodiversity of honeybee flora.

SPICES FROM THE FORESTS

Two important aromatic spices are produced from two species of wild plants in southwest forest where wild coffee also occurs. The two species of plants are *Aframomum corrorima* and *Piper capense*. The spices from these plant species are highly demanded, both locally and abroad. However, their production is not optimized since they are harvested from spontaneously regenerating populations in the forest. Certification of these spices and optimization of the production can benefit the local farmers as well as the country to earn foreign currency.

CONSTRAINTS OF ORGANIC AGRICULTURE

Even though organic agriculture has several advantages as compared to modern agriculture, and is suitable as development alternative for resources-poor farmers, it still has several constraints and is far from being the mainstream agricultural development strategy in Ethiopia. Some of the constraints are:

- Certification based on developed country farming conditions. The certified organic agriculture movement has its root in the developed countries, and the whole concepts, interests and standards are based on the conditions in these countries;
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- High costs of certification by international (Northern based) certification organizations;
- Unfavorable national policy environments for organic agriculture;
- Researchers, politicians and extension agents focusing only on promoting modern monoculture type of agriculture;
- Lack of local technical capacity in certification;
- Undeveloped local organic markets;
- Unsustainability of some traditional farming systems - leading to degradation of the resource base and declining productivity; and
- Lack of systematic documentation and dissemination of information about the benefits of organic agriculture.

There is little doubt that when given adequate support, especially with respect to developing favorable national policy environment and appropriate institutional frameworks for supporting organic agriculture, these challenges can be overcome.

RECOMMENDATIONS

In order develop organic agriculture as one of the major strategy for agricultural development and attaining food security, the following policy measures have to be taken:

Identify and recognize already existing organic production systems. There are many notable examples of traditional organic production systems like the Gedeo system (Tadesse Woldemariam and Kippie, 2002), the traditional coffee production (Tadesse Woldemariam et al., 2001) and the like;

Incorporate organic agriculture as a core part of the overall agricultural development policy;

Support farmers to improve their traditional systems by providing certain technologies. Examples of success story from Ethiopia are compost making in Tigray (Edwards and Hailu Araya, 2004) and compost making and herbal crop protection techniques in Cheha, Guraghe highlands (Pretty, 1999);

Prioritize research into organic agriculture. Innovative research in organic agricultural technologies development can help to develop new crop protection and other techniques to increase productivity on existing land;

Support farm-based research, farmer-to-farmer exchange. Such research is helpful to build upon existing indigenous knowledge, identify gaps and complement with new technologies; and

Support producers' organizations. Support could be in certification of cash crops or introduction of new production and processing technologies that are environmentally friendly and sustainable.
REFERENCES


Rundgren, G. (2002). Organic agriculture and food security. IFOAM


Traditional land management system, which rotates cultivation periods with long fallow periods, is stable, biologically efficient, and sustainable. Population pressure was often relieved by the Malthusian weapons of famine and disease that wiped out large sections of the population in a pre-modern society. The equilibrium state changed when population density started to rise as a result of the modern medicine that significantly reduced death rates. For many communities, scarcity drove man to innovate, to create, or to apply methods of production that accommodated the increased population by quantum jump in food output. Farmers began to respond to land use pressure by intensifying agriculture. Substantial increases in agricultural productivity and eradication of pervasive poverty in medium and high income countries were associated with a transformation of a predominantly agrarian, semi-subsistence economy. Agricultural productivity growth and the associated agricultural transformation process has almost universally involved a transition from a raw resource-based agriculture to a science-based agriculture (involving new productive technologies in nutrient and water control, new seed cultivars, and/or labor-saving techniques of land preparation and harvesting). The pattern of agricultural modernization has not been successful in all countries. It all depends on how policies are shaped to take into account the specific circumstance of each country and the global environment. The Green Revolution in Asia, for instance, focused in food crops such as rice and wheat. Government subsidies and various support policies greatly facilitated the generation and dissemination of new technologies. By contrast, most African countries, including Ethiopia, have failed to modernize their agriculture. Population pressure has given rise to extreme degradation and deforestation instead of sustainable intensification and development. Famine and death are averted only because of the growing shipment of food aid from developed countries. A major explanation of the African predicament may lie in the failure of institutional capacity to design and implement effective modernization policies.

1 Department of Economics, Addis Ababa University, Addis Ababa, Ethiopia.
ECOLOGICAL AGRICULTURE WITH SMALLHOLDER FARMERS FOR FOOD SECURITY - A CASE OF TIGRAY

Sue Edwards ¹ and Hailu Araya ¹

ABSTRACT

The Institute for Sustainable Development (ISD) started from a workshop that took place in Tigray in May 1995 with the aim of launching a project to find technologies for poor rural communities to improve their physical environment and raise crop yields without becoming dependent on external inputs. Tigray has a highly degraded environment; where over 85 percent of the population are farmers who struggle to feed their families from crops producing very low yields. The four project sites established in 1996/7 are considered as core communities, but now ISD and the Tigray Bureau of Agriculture and Natural Resources are making follow-up in 15 communities while over 90 communities throughout the Region have either adopted the key components of the project, or have taken them up spontaneously. The farmers were offered a ‘basket of choices’, based on the principles of organic farming. The key components are making and using compost, harvesting both soil and water, and increasing the biomass in the farm including growing forage trees. Farmers have themselves taken up the challenges of reclaiming gullies and making ponds. Farmers have been encouraged to maintain their agro-biodiversity and diversify with high value crops, particularly vegetables and fruit trees, and herbs and spices for women farmers. The use of compost has brought attractive results with yields as good as, and often better than those from the use of chemical fertilizer. Other advantages of using compost noted by the farmers include its residual effect, i.e. the positive effect of compost is still present a year after it has been applied to the soil. Plants grown with compost tend to be taller and studier, dark green in color, with more tillers than those grown with chemical fertilizer. Women comment that the grains are heavier and the flour from composted crops has a better flavor than from those grown with chemical fertilizer.

¹ Institute for Sustainable Development, Addis Ababa, Ethiopia.
# CONFERENCE TIMETABLE

The BSE XIVth Annual Conference Programme  
19-20 February 2004  
Faculty of Science, Addis Ababa University

**Thursday, 19 February 2004**

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THE BIOLOGICAL SOCIETY OF ETHIOPIA

OBJECTIVES

- Create awareness on environment and development issues in the formal and informal education sectors and amongst the general public;
- Promote biological research and encourage biologists to strive for professional excellence;
- Contribute to the growth and development of biological education and give technical support and encouragement particularly to biology teachers;
- Enable biologists to interact with their local as well as international counterparts through seminars, workshops, symposia, publications, etc.;
- Popularize biological science through publications and the mass media;
- Provide consultancy services and conduct collaborative investigations on issues that require biological expertise;
- Publish scientific journals and other documents as media for communication among its members and the general public.

ACTIVITIES

- Organize conferences, workshops, seminars, panel discussions and film shows;
- Support the existing environmental education school clubs and encourage the establishment of others;
- Publish background reading materials on biological topics in English and the main local languages to improve the understanding of biological issues for students, teachers, and the general public;
- Create networks with sister societies and organizations at national and international levels on matters of common interest;
- Seek for funds to support the society's activities.

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