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CONSERVATION AGRICULTURE AND NATURAL RESOURCE MANAGEMENT

POSITION STATEMENT | 2007

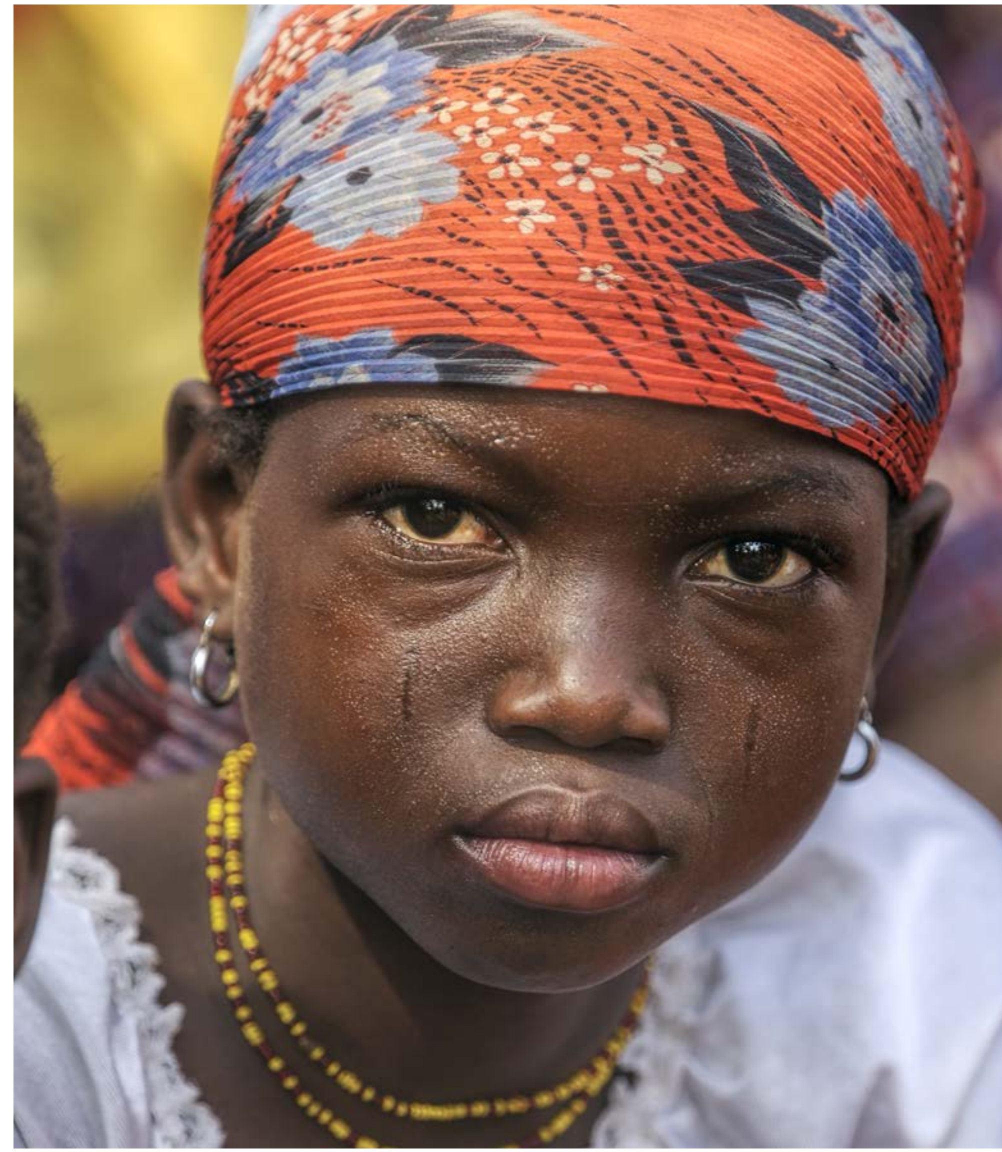
BACKGROUND

Poverty is often defined by the economic threshold of a person's financial existence. The World Bank describes extreme poverty as living on less than US $1.00 per day and moderate poverty as less than $2.00 per day. It is estimated that more than 1.1 billion people live on less than $1.00 a day and that about 2.7 billion people live on less than $2.00 a day[1] (an annual income of about $700). Three quarters of all people surviving on less than $1.00 a day live and work in rural areas.[2] A large part of the world's population of poor and undernourished people live in Africa (Figure 1). Perhaps more significantly, Africa has the fastest-growing poor population.[3] While the availability of food per person since 1990 has increased by 30 percent in Asia and 20 percent in Latin America, it has decreased three percent in Africa.[4] Between 1981 and 2001, GDP in Sub-Saharan Africa shrank 14 percent and extreme poverty increased from 41 percent to 46 percent.[5] The United Nations reported that per capita income in Africa in 2000 was ten percent lower than in 1980 and was still declining.

Many of the problems of poverty in Africa are tied to poor governance and inadequate infrastructure resulting in limited services to rural populations. Basic access to arable land, clean and reliable water, and other natural resources is not available to a large portion of the rural population. Most of the countries in the Low Human Development Index, and the lowest ranking countries in the UNDP Human Development Report 2006, are in Africa.[6] Ninety-five percent of the world's human population growth occurs in developing countries.[7] In areas such as Sub-Saharan Africa, where the greatest water scarcity is found, together with areas of significant poverty, under-nutrition, and food insecurity, the population is expected to grow from 560 million in 1997 to over 950 million in 2020, a 70 percent increase.[8] Meeting this increased demand for food while maintaining water resources will be extremely difficult, particularly since the Sub-Saharan African region has experienced negative agricultural growth on a per-capita basis since the 1970s.[9] Twenty years ago, Africa was self-sufficient in food production, now the continent imports 20 percent of its cereal requirements.[10] The focus for poverty alleviation must be to increase food production in poor rural areas, both to reduce hunger and to improve economic opportunity. No country has been able to sustain a rapid transition out of poverty without raising productivity in the agricultural sector.[11]

Agriculture accounts for 30-50 percent of GNP in most African countries and 70 percent or more of total employment.[12] In Sub-Saharan Africa, agriculture provides for 80 percent of total employment.[13] More than 50 percent of food staples in Africa are produced by small, poor farmers in rural areas.[14] Small farms account for 70-90 percent of farms in many poor countries.[15] Therefore, addressing the needs in agriculture, and particularly smallholder subsistence agriculture, is important in achieving poverty reduction.

Support to this sector of agriculture would have a significant impact on alleviating poverty and food insecurity. Many approaches to improving agricultural output do not reach this sector, while other approaches utilize techniques which are not well suited for small African farms. Although international development has recognized the importance of sound environmental practices, at times, approaches to land management are an inappropriate attempt to apply commercial or western farming practices to smallholder African farmers.



Number of Malnourished Children Under 5 (2000)

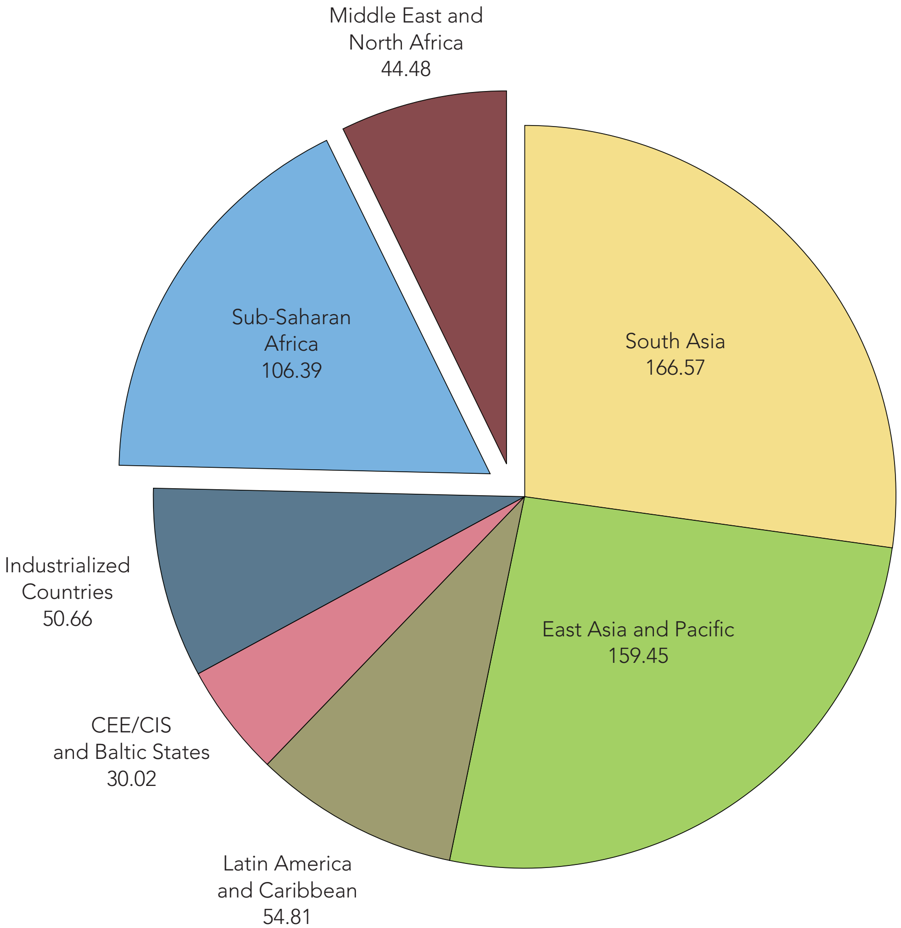


Figure 1

Source: UNICEF

The total number of malnourished children under 5 is over 600 million.

INVESTMENT

Development assistance from the Organization for Economic Co-operation and Development (OECD) countries has not kept pace with the needs facing rural poverty. Agricultural development aid fell from $12 billion per year during 1983-87 to $5 billion per year in 2000-2002.[16] This lack of investment is reflected in the total value of Africa's agricultural exports; relative to world agricultural trade, Africa's portion has declined from about seven and a half percent to just over two percent since the 1960s.[17] Private sector development has also failed to benefit poor farmers. In 2000, $36 billion was spent on agricultural research and development.[18] Most of this was spent in the developed world with private sector resources to benefit commercial agriculture in developed countries. And, only ten percent of this was spent on crop breeding, which means almost no funds were directed towards developing countries for improved crop varieties.[19] The underlying cause for this lack of investment is two-fold: there is limited commercial application for new technology in most African countries (i.e. no economic advantage to investors), and farmers, particularly subsistence farmers, are not able to pay the additional costs for companies to cover technology fees.

Compounding this problem is the fact that public and private donor funds have not been applied to the agricultural sector at the same levels as other needs. For example, in Uganda, expenditures for agriculture in 2000 were four percent, health was 11 percent and education was 20 percent.[20] A lack of investment in agriculture creates substantial future health costs, thus diminishing a child's opportunity to benefit from education. It could be argued that agricultural investment is as important as health and education. Yet, these expenditures are not always driven by local needs; they can be driven by public policy directed at more "immediate" issues such as HIV/AIDS, or by imposed donor restrictions. The profile of providing long term solutions to hunger must be raised so it is considered equally in the decision making process which establishes funding priorities. As a rule, general public funding lags in almost all sectors of Africa. For example, in agriculture, 37 countries in Africa reported an average of six full-time scientific staff members devoted to biotechnology research. The average annual expenditure on plant biotechnology research in these African countries is approximately $121,000.[21] Although this research is supplemented by international agricultural research centers, this level of research and development is not likely to be sufficient to meet the growing demands across the continent.

According to the World Bank, in 1998 direct foreign investment in Africa was $4.4 billion, while it was $64.2 billion in East Asia and $64.3 in Latin America.[22] Overall, Africa represented .007 percent of the world's direct foreign investment in 1998.[23] According to the United Nations, in 2006 the United States spent a total of $4 billion in Africa.[24] A large portion of that was spent on American consultants, so very little of it actually provided direct benefits to Africa.

Therefore, large scale development assistance, public financing, private donor investment and direct foreign investment have all failed to provide the resources to advance Africa in any meaningful way, particularly in agriculture.

WATER

Agriculture uses 70 percent of the world's water supply,[25] consuming the largest amount of fresh water. Irrigation covers about 17 percent of cultivated land, however, it accounts for nearly 40 percent of the world's food production.[26] Therefore, irrigation has played a key role in meeting the growing food demand. As the global population increases, it is estimated that food production will need to increase by 67 percent over the next 25 years.[27] In addition, anticipated climate changes, particularly in Africa, could lead to a five percent decline in food production and dehydration of ground and surface water.[28] Therefore, water management and conservation of water resources will be a critical part of future agricultural production and our ability to meet new food demands. Efforts to reduce food insecurity and mitigate hunger must recognize the importance of water conservation in any strategy developed to address these problems.

AGRICULTURE

It is estimated that prior to harvest, one-fifth to one-fourth of global cereal output is lost to pests, diseases, and weeds (cereals account for nearly 60 percent of total consumption in developing countries).[29] In tropical areas pre-harvest, losses can reach as high as 50 percent.[30] Africa has the highest percentage of agricultural population and the second highest cultivated area in the world,[31] however, average cereal yields are the world's lowest, totaling less than half of the amount of either Asia or Latin America.[32] This is one of the reasons why Africa is the only area to experience exponential growth of extreme poverty. The Food and Agriculture Organization (FAO) predicts that if soil losses continue unchecked, the potential rain-fed crop production in Africa will decline by about 15 percent in two decades.[33] Combining population growth with decreased agricultural productivity is a recipe for continued chronic hunger. Therefore, poor farmers could benefit from significant increases in research and technical support for agriculture. Important areas of focus are crop varieties that resist pests and diseases local to Africa and development of drought tolerant crops, all of which are adapted to low input farming systems. Currently, global research has focused on commercial farming directed at high input and high yield systems providing little benefit to African farmers.

Most agricultural growth in developing countries has occurred through expansion of cultivated land (not increased yields). Yet, in many areas, unsustainable land development has resulted in land degradation and desertification. Desertification adversely affects the livelihoods of over two billion people living in drylands that cover 40 percent of the earth's surface.[34] As cultivated areas increase and virgin forests, grasslands and other natural areas are reduced or degraded, long term negative impact on agricultural productivity is likely. Nature provides a whole system that makes farming viable. Certain species are natural enemies to pests, while others degrade residue, fix nitrogen, help improve soil fertility, and tilth or pollinate crops.[35] Worldwide declines in populations of pollinators are threatening the yields of major food crops and the biodiversity of wild plants.[36] Poor rural communities rely on both, natural systems to support agricultural productivity and healthy ecosystems to provide fruits, seeds, vegetation, medicine, firewood, and other natural raw materials.[37] A productive and sustainable agricultural system depends on maintaining a healthy ecosystem; as natural systems degrade, poor rural populations suffer simultaneously due to lower agricultural productivity and the depletion of valuable support resources.

Agricultural areas in developing countries often use a technique referred to as "slash-and-burn," "shifting cultivation," or "fallow-based" systems. As naturally -produced nutrients are depleted, and no synthetic replacements are available to rebuild the soil's productive capacity, farmers move to virgin ground and clear new plots of land in an attempt to "mine" the nutrients from the undisturbed soils. The new nutrients are then depleted after a few years and the cycle continues. Micro-nutrients are essential for healthy plant growth. These nutrients include zinc, copper, iron, manganese, magnesium, molybdenum, and boron which, though only form about one percent of the plant weight, control numerous plant functions. Zinc, for example, helps plants to use nitrogen and phosphorus, and a deficiency of these nutrients can affect crop yields.[38] Most commercial farming systems have inputs with the ability to replace nutrients removed by crops during the growing season. Africa is challenged in the availability, affordability, and deliverability of these inputs.

Approximately 11 million hectares of forest are cleared every year by farmers searching for more productive land,[39] much of it through slash and burn approaches. Globally, some seven million square kilometers of wet tropical forest have been cleared (about half of its original extent). Because of poor soil and inefficient agricultural practices, only two million square kilometers have become productive cropland.[40] Already three-quarters of Africa's farmland is severely depleted of the basic nutrients needed to grow crops, compared with 40 percent a decade ago. If this continues, crop yields will fall as much as 30 percent in the next 15 years.[41]

Areas that have remained in fallow-based conditions (those related to climate, soils, pests, weeds, and disease) make continuous annual crop production uneconomical, risky, or unsustainable at low input levels.[42] In more recent years, the length of fallow periods have been reduced due to less available land, and it is believed this has led to an increase in pests and diseases,[43] thus demonstrating the limits of slash and burn farming. As many as 500 million people–most of them poor–use shifting cultivation systems.[44]

In Sub-Saharan Africa, one of the regions facing some of the largest agricultural challenges, 95 percent of agricultural production is derived from dry land crops.[45] Yet, the water crisis facing much of the world necessitates the consideration of productive "green water" solutions, such as rainwater catchments and water conserved in soils and vegetation, by using best available agricultural practices. Poor farming techniques and encroachment, combined with inappropriate land use can severely limit productivity. Therefore, areas dependent upon rainfall for production will need to develop practices to conserve water and gain access to new crop varieties which are designed to provide better yields in water-stressed situations.

In the past, agricultural development in Africa has not been pro-poor. Most of the resources have benefited larger commercial farms in places where good market access already exists and infrastructure is better developed. This development is often driven by the desire to increase cash crops such as cocoa, cotton, and coffee for export. However, large commercial farming is still a small percentage of African agriculture. Comparing irrigation, fertilizer, and mechanization used in production, Africa lags well behind other developing countries. For example, in 1970, Sub-Sahara Africa had 84,000 tractors in use; by 1997, it had increased to 159,000 tractors. In comparison, in 1970, Asian developing countries had 488,000 tractors in use, and by 1997 the number had increased to 4,610,000.[46] Africa's mechanized production increased by 89 percent, while Asia's increased by 845 percent over the same time period. (For comparison data on irrigation and fertilizer, see next section.) This is not an argument for increased mechanical agricultural production, but it does demonstrate how dramatically difficult it will be to achieve productivity gains in Africa and how much faster Asia has advanced. It may also reflect Africa's large dependence on small, low input farms where mechanization has limited application.

In terms of increasing production, the emphasis has principally been on products for export, to maximize financial income and benefits. Investment in local food staples for poor communities has not been a priority. However, by concentrating on a few crops, significant progress could be achieved.

It is estimated that by improving yields 30 percent in seven staple crops (cassava, sorghum, maize, millet, rice, wheat, and sweet potatoes) and achieving adoption rates of 50 percent of these yield improvements in about 30 key developing countries, over 200 million people can be moved out of hunger. About 90 million people would also be lifted above the $1.00 per day extreme poverty line.[47] In addition, Development Policy Review reported that growth in agriculture benefits the poor more than growth in any other sector, and that yield increases of just one percent reduce the proportion of people living on less than $1.00 per day by 0.6 -1.2 percent.[48] Also, in West Africa, the multiplier effects of adding $1.00 of new farm income resulted in a total increase of household income ranging from $1.96 in Niger to $2.88 in Burkina Faso.[49]

Another challenge for Africa is maintaining a viable agricultural workforce. Since 1985, AIDS has killed approximately seven million agricultural workers in the 25 hardest hit countries in Africa.[50] FAO projects that up to one-quarter of agricultural workers may be lost by 2020 in nine countries hardest hit by HIV/AIDS in Eastern and Southern Africa. The disease affects the most productive age group in the population – those between 15 and 49 years of age. Food consumption has been found to drop by 40 percent in homes afflicted by HIV/AIDS.[51] Labor-saving agricultural technologies (such as no-till) need to be adopted to address the needs of these severely constrained rural economies. Improved land management, agricultural productivity, and improved food systems can contribute substantially to the battle against AIDS.[52] More than 70 percent of all the people in the world infected with the HIV virus live in Sub-Saharan Africa.[53] Therefore, a comprehensive approach will be required to meet the challenges ahead for African agricultural output.

Agricultural production in Africa faces many constraints. However, one of the most challenging is land ownership. Land and resource tenure lie at the heart of all agricultural activity, but just as important is to recognize that people's well-being, as well as the broader social and economic development of Africa, is affected by the current land tenure system.[54] The current distribution and control of land by traditional leaders impedes investment and stifles innovation. This is a deep rooted system that presents fundamental barriers to change.

Another fundamental difference with African agriculture is the variation in geography and climate. Therefore, in Africa, crop resiliency can be as important as crop yield. The targets for improving African production must be based on stability, which is different than most agricultural development which has occurred elsewhere in the last few decades. This will require a greater focus on regional needs and it can only be successful with research and development which is specific to African crop production.

AFRICA AND THE "NON"-GREEN REVOLUTION

The Green Revolution usually refers to the introduction of high yielding varieties of wheat and rice in Mexico and Asia respectively. It shares similarities with the agricultural development that took place in the United States during the 1940s and 1950s. There are several outcomes which normally occur with this approach. Farming systems tend to be driven towards monoculture production, and the reduction of local seed varieties can occur as a result of an increased reliance on seeds that contain a more narrow range of genetic material. These hybrids have traditionally been developed to perform in environments with access to a high availability of inputs such as nitrogen, phosphate, potash, and the ability to replenish other necessary nutrients for high yield systems. Another outcome is more uniformity which assists with equal application of inputs, more consistent pollination and regularity of maturity for harvest.

These new hybrids and standardization have resulted in significant increases in crop yields and the preservation of large amounts of land which would have been converted to cultivation if these increased yields had not been achieved. However, the scenario of high-yield, high-input agriculture does not reflect a large portion of the landscape or farming systems found across Africa. The Green Revolution is based on increasing the gross output of grain, something that is not as simple to achieve in Africa. One reason is because Asia used large quantities of commercial inputs applied to fertile lands; in comparison, many African soils are marginal uplands and are highly weathered soils. Improving yields on these soils requires appropriate resource management[55] and different techniques.

There are fundamental differences between Africa and both Mexico and India, where the primary stages of the Green Revolution began. Two significant factors have played a role in why the success of the Green Revolution has not transferred to Africa. One is culture and the other is environmental (used in its broadest definition). The impact of culture is significant, but our focus is on environmental, geographic and investment factors. A large challenge in addressing agricultural needs is that the areas found in Africa under cultivation are incredibly diverse and often fragmented. They run from the semi-arid Sahel regions to the more productive plains of Southern Africa. Farm lands border deserts, farmers cultivate crops at the foothills of volcanoes, ecosystems include vast areas of rainforests and grasslands, and agricultural development occurs alongside some of the world's largest wetlands. The variation in climates, soils, pests, and diseases are extreme. Therefore, what can be a significant improvement in one area for farmers can be of little use or benefit to farmers in other locations. These environmental factors pose a greater challenge in Africa than in many other parts of the world.

Data also reveals the use of a wider range of food crops in Africa than in Asia. In Asia, the production of only two crops, rice and wheat, account for 70 percent of human consumption. Meanwhile, the consumption of Africa's four most important crop-based food products – wheat, maize, banana, and cassava – accounts for 67 percent of its total.[56] These challenges are compounded by the fact that a number of issues related to small-scale farmers go beyond routine production problems and are in fact, intractable.[57] This is primarily because of a lack of investment, marginal crop production areas, limited (and inefficient) irrigation, very limited infrastructure, shifting recovery from conflicts, lack of production inputs, little to no research for improved local varieties of seeds, poor land management, and dismal extension services. Africa also has much greater diversity within their cropping systems. The Inter Academy Council (IAC) identified seventeen distinct farming systems throughout Africa. Combining multiple farming systems with a large variation in agro-ecological zones creates unique challenges. The IAC panel concluded that because of the many farming systems used in Africa, "regionally mediated," rather than continent-wide strategies, will be required to address the diverse problems of African food productivity and food security.[58]

When the Green Revolution occurred in India (1967 - 1978), it involved simultaneous components including the introduction of new, improved wheat and rice varieties, wider availability of inorganic fertilizers, and increased irrigation.[59] For example, in India, close to 85 percent of agricultural land is irrigated; in Africa, it is only two percent.[60] However, development of irrigation must take into account availability and sustainability, something that could severely limit Africa's potential. As far as fertilizer, Africa's 54 countries account for only two percent of the world's fertilizer consumption.[61] Fertilizer use has increased as a major component of a number of different farming systems throughout the world. How well introduction of fertilizer will or can work with small-scale farmers in rural Africa is yet to be determined. Part of the issue is related to infrastructure. India's transportation networks were significantly better in the 1950s than Africa's are today.[62] But it goes beyond infrastructure. The issues of credit and intractable indebtedness and the reliance on unsustainable inputs run the risk of disrupting rural communities. There is also the danger of diverse farming systems migrating toward monoculture systems leaving small farm families more vulnerable. Less agro-diversity means more exposure to crop failures with greater negative consequences from drought, infestations of pests, etc. This is particularly true for small farmers. The Green Revolution's success has been a result of increased irrigation, improved drainage, better cultural practices, the introduction of fertilizer, and more efficient crop varieties; all contribute to an improved production system with major results in output.[63] This approach may provide benefits at the commercial level and eventually at the level of small-scale farms converging into commercial activity; however, the areas of rural Africa with a large portion of populations living in extreme and moderate poverty do not fit the template for the original Green Revolution.

An additional fundamental barrier to success in Africa is the lack of crop research and development for specific varieties of local crops. This has not occurred because there is little incentive to invest resources in Africa. The lack of potential for profitability combined with the need to develop specific varieties adapted to small-scale farming systems with minimal or no inorganic inputs is not an attractive proposition for agro industry. In Africa, traditional crop varieties represent 70 percent of sorghum, millet, beans, and cassava, so there is no solution which can be applied across the board.[64] Also, Asia has at times provided subsidies for production, something which has not widely occurred in Africa (with some exceptions). Part of this is due to financial resources, part is a result of high domestic fertilizer costs relative to world prices as well as, basic challenges such as infrastructure and corruption which prohibit widespread success.

Several other factors influence how agriculture will develop in many African countries. In some countries, the government sets the price for crops and then purchases the production from farmers below world prices. In addition to the pricing disadvantages to farmers, sometimes farmers must wait several years to get paid from the government. Referred to earlier, land tenure is perhaps one of the most significant internal hurdles to investment in productivity. Traditional land ownership structures are often designed so traditional leaders control or heavily influence land use and distribution. Therefore, there is little incentive to invest in land improvements, and land is not available as a capital asset to build equity. These are issues which can only be overcome by changes in policy which must be driven by leadership within Africa – not dictated by foreigners.

Plant breeding for local acceptance is one consideration that must be applied to any seed development projects aimed at Africa. In addition to this issue, another major problem which affects plant productivity in tropical regions is soil acidity. Acid soils comprise approximately 40 percent of the world's arable land, affecting 27 percent of the tropical land in Africa.[65] In spite of global importance, metal toxicity and nutrient deficiency problems that affect acid soils are investigated by only a handful of scientists in developed countries.[66] With such limited resources directed towards Africa, these issues remain unresolved.

Therefore, developing crop varieties and training programs for African farmers in techniques which perform better under marginal and low input farming conditions must be a priority. Differing both in scope and methodology from initiatives which resulted in the Green Revolution in Asia, an approach in Africa must use advances in both technology and farmer-driven participation methods of plant breeding; this will require innovation in the development of plant breeding capacity across the continent.[67] It will also require an investment by governments to establish well trained staff and provide adequate resources to support effective extension services and long term investment in infrastructure.

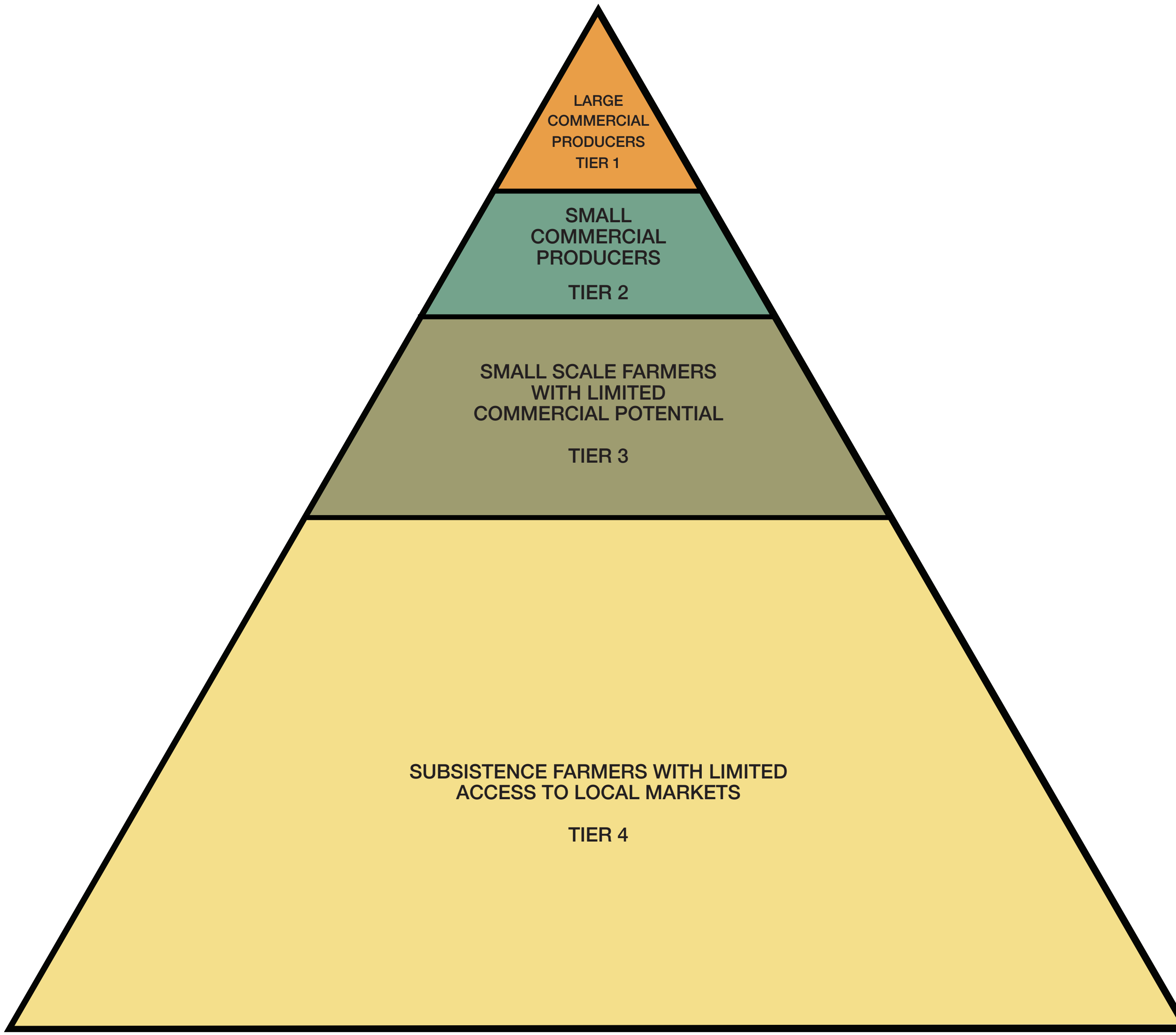
These programs cannot be effectively introduced without major policy and institutional reforms to reflect the research and organizational imperatives of diversifying food production as well as conserving the genetic base.[68]

Finally, the severity of the constraints facing African food production are underpinned by high risks of drought and floods, which can result in total crop losses. Therefore, efforts to revitalize or develop African agriculture, specifically for subsistence farmers, must recognize that the Green Revolution was driven by a philosophy to provide the highest yields in every year; a large part of Africa requires a system that will provide for stable or moderate yields in poor years.

African agricultural producers can be divided into four levels. The Green Revolution or intense agriculture production techniques apply to the top tier and also offer opportunity to the second tier. It is less clear if the third tier of producers can achieve meaningful benefits from a Green Revolution-type approach, and the impact on the bottom tier is even more difficult to predict. This is not to imply that application of Green Revolution techniques in tier 1 and tier 2 guarantees long term success. This will depend on a number of factors. Affordable access to fertilizer, sustainable and available water for irrigation, access to credit, market development, training and education for proper use of new inputs, improvement of land management and a viable government sponsored extension service are all critical components for success.

The top two tiers should be focused on raising Africa's internal production levels to reduce food insecurity in Africa and reduce reliance on imported food. If these advancements are driven by policies to exclusively develop exports of cash crops, the benefits for reducing hunger in Africa will be diminished. The two bottom tiers, particularly the bottom, should be driven by increasing production to reduce or eliminate malnutrition, hunger, food insecurity, and child mortality.

AFRICAN AGRICULTURAL PRODUCTION



NUTRITION AND HUNGER

Increased food production alone does not solve all of the problems caused or associated with hunger. Therefore, producing more nutritious food, lowering post harvest losses, achieving more equal distribution of food, and securing access to enough food all play a role in successfully reducing hunger. Africa's challenges with hunger are widespread and serious. Child nutrition and growth rates are two of the most important indicators of a child's future. Poorly nourished children will not do well in school and are especially susceptible to contracting disease. When increased hunger is combined with poor health conditions, the results are higher mortality rates, significant suffering, and loss of applied labor. It is estimated that over 35 percent of children in Sub-Saharan Africa suffer from stunted growth.[69] In East Africa, over 48 percent of children exhibit stunted growth rates, the highest in the world.[70] Under-nourished children in Africa now number over 33 million - or more than one third of pre-school aged children.[71]

Although Asia, with 70 percent of the developing world's total population, has far greater numbers of people who are undernourished, Sub-Saharan Africa has almost double the percentage (33 percent compared with 17 percent in Asia) of hungry people.[72] Within Africa, Eastern and Southern Africa account for the greatest number of undernourished people.[73] This is in part due to the fact that per capita food consumption in these regions has decreased during the periods of 1980 through 1995.[74] Africa is the only region of the world where the level of nutrition has declined in the last decade.[75]

Another factor in fighting hunger is controlling crop disease. Both crop failure and poor crop yields resulting from pests and disease can affect the resources available to fight malnourishment and hunger. Diseases in the tropics are found at higher incidence rates than most other areas. In a comparison of a number of important food crops, it is evident that the constraints of production in tropical areas are dramatic. The following examples highlight this point: sweet potatoes in temperate areas had a disease incidence of 15 compared to 187 in tropical areas; for beans, it was 54 in temperate areas and between 253-280 in tropical areas.[76] This of course poses a huge challenge in raising productivity and providing increased levels of crop production to fight hunger and poor nutrition in populations scattered across Africa, specifically but not limited to tropical zones. It is important to note, that many plant diseases found in Africa are indigenous to Africa, therefore advancements in disease control in other parts of the world do not automatically transfer to improving African yields, although biotechnology may be a new tool in addressing some African diseases. Little research has been completed on many local African diseases and viruses because they occur in areas which do not provide sufficient commercial opportunity. This will require significant investments of subsidized research from the international community.

CONSERVATION FARMING

Early civilizations often cultivated crops under reduced tillage systems, because they had no alternative. As equipment such as the plow was developed, and as animal power was applied to field preparation, tillage of soils began to develop worldwide. Originally, a primary factor in using tillage was that it was the best available means of controlling weeds and pests, and of creating an adequate seed bed on a larger scale. This is no longer true. Both inorganic and organic systems allow direct planting into previous crop stubble. Today, equipment is available to plant crops without tilling the soil, to incorporate residue without destroying crop cover and to address compaction problems with minimal disturbance to the soil surface. In the past, it was presumed that tilling the soil increased soil fertility (by reducing weeds) and increased aeration and mineralization of the soil.[77] However, over time, this process can lead to the reduction of soil organic matter.[78] This organic matter, which provides nutrients for crops, is also critical for the stabilization of soil structure. Therefore, with continual tillage, soils can degrade. Scientific data shows that under tropical and sub-tropical conditions, tillage generally has a detrimental effect on physical and biological soil properties.[79]

Tillage creates compaction, and on marginal soils and slopes, tillage often leads to soil erosion, which increases the loss of topsoil and organic matter. This process is more severe in tropical climates. In tropical climates, warmer temperatures break down organic matter more rapidly, and high volumes of rainfall and exposure to intense winds create high levels of erosion.[80] Both wind and water erosion contribute to the decline in soil quality and can contribute to the loss of the most biologically active topsoil. Under tropical and sub-tropical conditions, intensive and repeated tillage will generally damage soil structure and lead to excessively high soil temperatures in the root zones. This has negative effects on plant development, on soil flora and fauna (soil biological processes), and on soil moisture resulting in diminishing yields over time.[81] Degradation of soil can ultimately affect soil depth, organic matter content, water holding capacity, physical structure, and chemical characteristics, such as acidity and salinity.[82]

Therefore, in developing countries, inorganic and organic based no-till or conservation based programs need to be considered as a low-cost, low-input system to help maintain or increase crop yields. A recent study reviewed 286 conservation based introductions on 12 million farms in 57 countries, mostly in Africa. According to the study, adopting conservation farming approaches meant yield increases on average of 79 percent. Harvests of some crops such as maize, potatoes, and beans doubled.[83] It is essential to develop a comprehensive approach to conservation farming, including soil analysis, crop rotations, cover crops, weed control, pest management, direct seeding through crop residue, and soil fertility management.[84]

Mechanized soil tillage is particularly destructive as the tillage occurs at higher speeds and greater depths, resulting in detrimental effects on soil structure. Horizontal tillage changes soil density.[85] Consistent soil density allows water to percolate uniformly through the soil profile. Soil density is determined by a number of factors: soil types, soil particle size, soil structure, and the size of soil pores. When a sudden change in density occurs in the soil (often a hardpan created by compaction), the roots meet resistance and yield can be affected. The results of plowing can create the most dramatic loss of ecological resilience, causing accelerated biophysical cycles, lower levels of soil moisture retention for plants, slow cycles related to soil biology, and loss of plant cover (including organic matter).[86] The impact of tillage can vary by soil types and existing soil structure. A neglected aspect of tillage is its impact on the micro-organisms found in soil. Their biomass may be as much as 1.5 tons per hectare.[87] Soil faunal groups, including arthropods, earthworms, nematodes, and mollusks, facilitate movements of air and water within the soil matrix; they regulate nutrient cycling, form and destroy pests, and build soil.[88] In simple terms, no-till farming is an ecological approach to seed bed preparation.[89]

Over the last 50-70 years, many efforts have been made by farmers, extension workers, researchers, and donor agencies to address the challenges of agricultural development in poor countries. The ingredients of industrial farming systems (hybrid seeds, herbicides, fertilizers, pesticides, and mechanization) have been widely promoted. However, transfer of technology will not be enough to address the problems which exist in geographic areas which face a variety of unique difficulties. In fact, in a large portion of rural Africa, industrial farm techniques are not the answer. However, some aspects of technology, such as providing improved seeds and inputs at affordable quantities to small farmers, could result in significant benefits.

Above: Conventional tillage can cause soil erosion, depletion of moisture and loss of organic material (Mozambique). Left: A farmer adds mulch to increase organic matter and improve soil tilth (Ghana).

NO-TILL AGRICULTURE IN GHANA

Ghana provides an example of a wide adoption of no-till practices in a variety of contexts and applications. In 2000, it was estimated that no-till was used by 100,000 smallholder farmers on 45,000 hectares. A study conducted on no-till technologies in Ghana revealed that in normal rainfall years, no-till farmers obtained maize yields that were 16 percent higher than farmers who had used no-till in previous years, and 45 percent higher than farmers who never used no-till. In dry years, however, the advantages in yield for no-till were 38 percent and 48 percent respectively.

After adoption of no-till, average family labor was reduced by 31 percent (use of Round Up herbicide was a factor). No-till reduced land preparation and planting by 22 percent, and labor for weed control fell by 51 percent from an average of 8.8 man-days/ha to 4.3 man-days/ha. There was a slight increase in labor applied to harvest from 7.6 man-days/ha to 8.6 man-days/ha. However, this was largely due to higher yields.

Three risk factors were also reduced with no-till: residue cover increased water availability in dry years, the reduced transition time permitted planting of a second crop closer to optimal planting dates, and the presence of a larger number of beneficial insects facilitated pest control. Among other benefits, no-till brought increased food security to families, more time for other income generating activities and overall reduced labor and effort. Nineteen percent of farmers mentioned the ability to promptly pay school fees and 83 percent started other income generating farming or trading activities.

The earliest research on no-till began in the 1960s. It may be more important today as demand for arable land in many parts of the country has gradually reduced the resting fallow periods driving farmers to continuous and more intensive cropping. Since no-till increases the stability of soil fertility and most soil characteristics are maintained in the no-till system, it helps to address some of the issues with continuous cropping in sub-tropical and tropical zones.

In the first two years of the three year study, the cost advantage of land preparation under no-till compared to slash and burn was US $12.21/ha. In the third year, when typically a new plot of land would be cleared, the cost advantage increased to US $49.71/ha. The largest impact of no-till was to provide better food security and a higher income resulting in a higher standard of living.

Source: Information from Impact of No-Till Technologies in Ghana, Javier Ekboir, Kofi Boa and A. A. Dankyi. Produced by the International Maize and Wheat Improvement Center (CIMMYT)

NO-TILL RESULTS

A less scientific demonstration, yet a very practical example of the benefits of no-till, was provided by a group of approximately 40 no-till farmers in Fufuo, Ghana. These farmers expressed three clear advantages of using no-till. First was productivity. Under the previous cultivation system, these farmers produced four bags of maize (120 kilos per bag) per acre. Under the no-till system, they produced an average of 15 bags. There is no precise measurement for test weight or moisture content, but no other significant variables were introduced, except the use of Round Up herbicide. The second value was the ability to use the increased production to feed chickens for the purpose of selling eggs. The third benefit was the additional time made available for other labor applications through the reduced labor from the no-till system. As a result of the reduced labor, these farmers were able to cultivate additional acres to produce cocoa as a cash crop, increasing their annual income.

No-till is not a new concept in Ghana. The Akan language word for no-till is "proka" which literally means "to rot," or to recycle plant material. The original systems for cultivating crops often utilized intercropping and no-till processes. The "industrialization" of agriculture to produce cash crops, such as cotton and cocoa often for export, provided incentive to farmers to change their techniques and clear more land, convert to mono-cropping systems and abandon the no-till process. Those who are able to use no-till cropping in Ghana have in some ways, returned to a traditional system.

Source: Conversation with no-till farmers in Fufuo, Ghana, February 15, 2007, with Howard G. Buffett

TILLAGE AND MULCHING EFFECTS ON TROPICAL ALFISOL

The International Institute of Tropical Agriculture (IITA) conducted long-term experiments comparing no-till and plowed farming systems on Tropical Alfisol. During the first growing season, average maize grain yields for no-till fields resulted in 2.69 mg/ha compared to 2.23 mg/ha for plowed fields (a 17 percent increase). The second growing season continued to demonstrate higher yields for no-till. These experiments were carried out without mechanization, so the results are applicable to small-scale farm operations dependent upon manual labor. Residue mulches improved crop yields through their beneficial effects on soil and water conservation, improved soil structure and aeration, favorable regulation of soil temperature, improved soil fertility and maintenance of organic matter content.

Data was collected for seventeen consecutive seasons and the no-till system consistently out produced conventional tillage systems.

Source: Journal of Sustainable Agriculture, R. Lal

EXISTING CONSTRAINTS

1. Production Challenges

- No dominant farming system allowing for easy replication
- Lack of crop varieties adapted for local soil and climate conditions
- Limited options to overcome a variety of pests and diseases which are unique to different geographic areas
- High level of depleted soils
- Low levels of fertility
- Ineffective storage resulting in high levels of post-harvest crop spoilage and loss
- Reliance on replanting of previous crop seeds, limiting yields
- Dependence primarily upon rain fed crops
- Ineffective irrigation systems and techniques
- Limited available resources to increase irrigation
- Use of unsustainable farming techniques which can negatively affect ecosystems with no net gain to agricultural productivity
- Limited access to production inputs to assist with yield improvements

2. Economic and Market Challenges

- Poor access to rural and urban markets, leading to low prices which exacerbate poverty in rural communities
- Little or no access to credit
- Development of large scale commercial agriculture can displace incentives to support small-scale farmers and subsistence farmers

3. Land and Property Challenges

- Poor local land management leading to negative environmental impact as well as reduced crop yields
- Lack of clear title to land (discourages investment and appropriate land stewardship)
- Community-based land ownership structures
- Land parcel sizes affecting efficiency of production

4. Technical Challenges

- Limited access to extension services impeding improved production practices
- Little or no access to education for the development of farm management skills
- Minimal investment in research and development

5. Social and Political Challenges

- Lack of an enabling political environment
- Weak regional integration
- Gender and cultural issues affecting production
- Limited investment in agricultural sector
- Shifting conflict, interrupting crop cycles and reducing productivity
- Corruption
- Poor governance

OBJECTIVES OF HGBF

Primary Objectives

- Mitigate short term hunger
- Improve long term food security for poor smallholder rural farm families
- Educate and train local farmers on how to utilize conservation-based agriculture
- Improve water management of current irrigation practices
- Establish agronomy baselines (soil analysis, pH levels, organic matter, etc.)
- Develop systems to increase yields without large amounts of commercial inputs
- Develop local adaptations of no-till farming
- Increase crop yields using new technology
- Increase food production by applying new techniques
- Research more efficient systems for crop compatibility and intermixing
- Identify crops for diversification
- Construct granaries for storage of crops

Secondary Objectives

- Identify appropriate technology for use in improving inputs and developing systems to assist in production decisions
- Develop farmer associations
- Create assets for poor communities through improved farming techniques
- Increase and improve access to markets
- Improve use of irrigation practices to reduce pressure on water resources
- Identify alternative non-agricultural and/or agriculture-based income sources
- Develop systems for small-scale farmers to participate in global opportunities
- Establish community-managed nurseries and seed centers
- Preserve wildlife and habitat through education and improved farming practices
- Leverage conservation compliance through producer incentives

POTENTIAL SOLUTIONS

Based on the number of different factors which affect African food production, there are many areas which could contribute to improved food availability. The following list represents areas we feel could significantly advance food production, reduce food insecurity and provide a more sustainable operating environment for subsistence and smallholder farmers. Some of these suggestions will have better application than others in certain geographic locations; however, they all address areas that currently suffer from a deficit of resources, investment, commitment, and governance. The Foundation can not pursue all of these ideas, but we believe it is worthwhile identifying them as potential solutions.

- Develop pilot extension service programs for subsistence agriculture which can be replicated throughout developing countries. The lack of agronomy benchmarks makes it difficult to make informed production decisions such as crop rotations, alternative cropping, and compatible farming techniques. By examining and identifying characteristics of soils, climate impact, alternative crops, and basic nutrient deficiencies, better production decisions can be evaluated.

- Develop pest resistant, virus resistant, and drought tolerant crops for distribution to small farmers with no technology assessments or fees. Pests destroy over half of all world crop production[70] and severe drought occurs regularly on the African continent in many regions. Almost 35 percent of Africa's population live in arid or semi-arid environments. These factors combined are responsible for the loss of a significant portion of crops. Therefore, by using tissue culture, marker assisted, and genetic engineering to enhance crops which possess traits useful in combating pests, viruses, disease and drought, this would provide a substantial increase in available food from land already under cultivation. Figure 2 demonstrates the significant potential of drought-tolerant technology in maize. This approach must take into consideration how available crop alternatives will influence farmer behavior and the impact on indigenous varieties of crops.

- Develop farmer field schools. These in-field training sessions will help identify challenges and solutions for pest, disease, and weed management. They can assist with strategies for soil fertility and water management systems, as well as link research to in-field production solutions.

- Increase resources for research and development in Africa, such as establishing an agricultural research field station in Africa for the purpose of developing and field testing indigenous African crops, like as white maize, sweet potato, cassava, sorghum, millet, etc. It is currently a challenge to grow, propagate, and observe test materials in target African countries due to the inadequate research facilities and limited applicable regulations. Through this field station, both biotechnology and conventional methods could be used to improve African crop varieties. This will eliminate the difficulties of transporting plants and cultures onto the African continent and it will provide better access to indigenous varieties. United States and European researchers could collaborate with African-based colleagues to advance agricultural research throughout the continent. An African-based agriculture field research station would accelerate field advancements in Africa, for Africa.

- Provide the tools, education, training, and financing to implement conservation-based agriculture. Conservation agriculture focuses on resource-saving crop production techniques. By reducing or eliminating tillage, conservation-based agriculture enhances the natural biological processes. Where applicable, the use of external inputs, such as agrochemicals and nutrients of mineral or organic origin, are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes or environment. Conservation-based agriculture is most effective when the following three principles are applied:
  - Minimum mechanical soil disturbance on a continued basis
  - Maintaining permanent soil cover
  - Diversified crop rotations

- Provide resources to expand low tech, no-till conservation agriculture. This is based on the same principles as conservation-based agriculture; however, it is an alternative for very small farmers in rural areas where infrastructure is minimal, and where existing networks will not support the transportation of inputs such as nitrogen, phosphate, potash, lime, etc., and where it is not normally economical to utilize herbicides and pesticides. The crop production area is developed using compost and humus to create fertile basins for plant growth. The area used for plant growth is not tilled; it is hand weeded and mulched and is normally alternated in rows with legumes, which provide nitrogen in the soil and plant residue is recycled. This process allows for better permeability resulting in improved moisture absorption, retention of organic matter, building of soil tilth, and consistent increases in yields.

- Analyze and assess the feasibility of rewarding subsistence farmers with payments based on carbon sequestration as a result of no-till farming techniques and/or intermixing of crops.
- Increase research to identify specific benefits to Africa from crop rotation, plant intermixing strategies, and integration of perennials into cropping patterns.
- Investigate applications of remote satellite sensing technology to collect geological information for improving production options for small-scale and subsistence farmers.
- Determine the feasibility of Information and Communication Technologies Systems as an approach to providing information to smallholder farmers in rural areas.
- Review current use of Geographic Information System (GIS) in assessing land use and determine if expanded GIS use is applicable and affordable as an approach to supporting smallholder farmers.
- Research and disseminate results on key issues facing rural farmers in poor countries.
- Determine the effectiveness of farmer associations and review methods to strengthen these associations where appropriate.
- Analyze and research alternatives to current land ownership systems and the advantages of integrating property rights with agricultural development.
- Identify existing programs which are designed to advance the above solutions and can benefit from funding and support from the Foundation.

HGBF INITIATIVES

A key to achieving success will be linking research to field production. The Foundation has supported several efforts to integrate the use of new research and technology, as well as supporting programs to develop systems to identify how to incorporate new learning tools and education. The following are two examples of projects supported by the Foundation which we believe can lead to successful outcomes.

DEVELOPMENT FOR CONSERVATION AGRICULTURE PARTICIPATORY TECHNOLOGY–GHANA

Northern Ghana is characterized by extreme poverty, with people dependent on subsistence agriculture in very dry lands with poor soils. The erratic patterns of rainfall, the depletion of vegetation cover for fuelwood, the use of bush fires, population growth, and climate change are all leading to increased vulnerability and poverty for the population. Through the participatory development of appropriate technology, which takes into account environmental characteristics, the culture, and local land management practices, conservation agriculture techniques are being developed which will improve crop yields and improve reliability in production, thereby improving livelihoods and increasing food security. The participatory technology development process underscores the importance of involving farmers in the development of solutions and sharing of experiences across regions to ensure sustainability and scale.

The emphasis of the approaches tested will be on soil regeneration and water conservation. Systems will also be developed to supply productive inputs, manage bush fires and improve the facilities and techniques for grain and seed storage. Through active learning and effective monitoring of the impact of program activities on soil management practices, incomes and livelihoods, the different technologies will be tested and improved over time.

Conservation agriculture has been demonstrated to increase yields, build organic content increasing soil nutrient levels, reduce soil erosion, improve water retention in soils as well as protection of the watershed while reducing labor (especially for women). The adoption of appropriate techniques in smallholder farms in Ghana, where more that 60 percent of the population are subsistence farmers, can improve livelihoods and significantly reduce poverty.

FARMER RESEARCH FOR CONSERVATION AGRICULTURE PARTICIPATORY TECHNOLOGY–MOZAMBIQUE

Mozambique is emerging from a period of prolonged conflict and a large portion of the population still lives in extreme poverty. Ninety-five percent of the land is cropped by smallholder farmers and much of the land is poor, sandy soils with no availability of inorganic inputs. Erratic rainfall with extreme flooding, as well as regular droughts make most farmers' livelihoods precarious. Much of the land is infertile, and there is increasing competition over the existing productive soils. Conservation agriculture has enormous potential for the protection of soils and improving fertility, conserving moisture, and protecting aquifers, resulting in increased yields or protection against total crop failure.

The approach adopted for northern Mozambique is Olima Wo Suka, which means "conservation farming" in the local Makua language. The system is based on creating planting basins developed with crop residue to establish an integrated soil fertility and water management system. Crops are rotated with legumes and one year fallow periods are used to establish better soil conditions. Pests are controlled through the use of neem, which is extracted from trees used for wind and fire breaks. By applying these conservation agriculture techniques, the natural environment (and ecosystem services) will be protected through the reduction of forest and bush clearing, improved retention of water for cultivated land, and reduced soil erosion. When available, slow-release fertilizers will be used to increase soil fertility. Farmer incomes will be increased through improved yields, and labor will be reduced. The reliance on legumes and improved yields of ground nuts and sesame will also improve nutrition, especially for children.

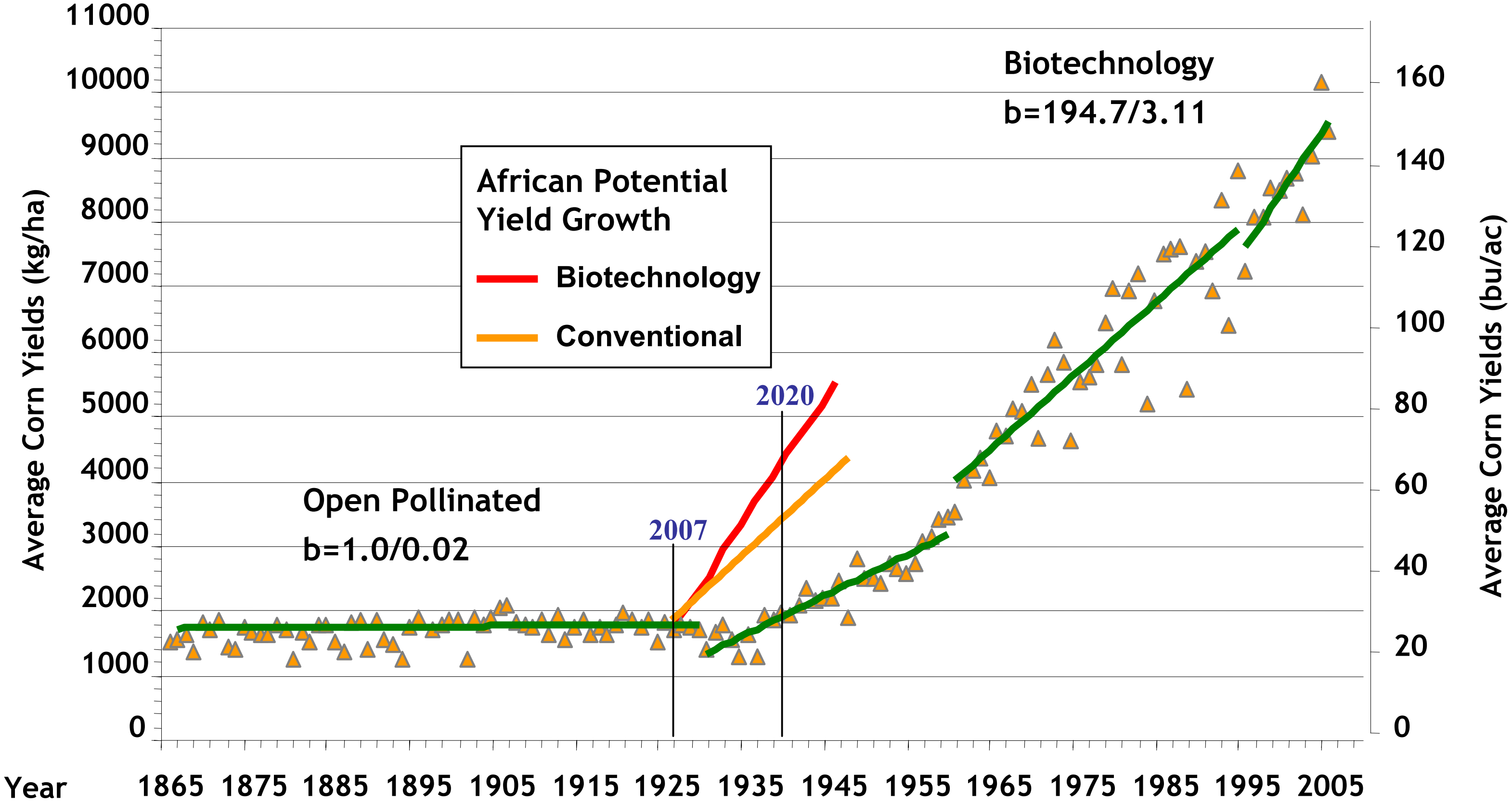
An action-learning approach will develop new technologies with farmers and scientists working together. There will be an emphasis on extension work and shared learning with other farmers. The program is in its first year of operation and is working in 131 communities within six target districts of the Nampula Province. In the first year, 146 community-based demonstrators have been trained, 5,284 farmers have learned intercropping and mulching techniques and almost 700 hectares of demonstration plots have been established. About 100 hectares of seed-multiplication fields have been planted; these fields will provide about 70 tons of improved quality seeds for key crops of sesame, groundnut, cowpea, and velvet bean.

The project will work closely with the government research organization IIAM to improve soil sampling and to identify improvements for soil fertility. The three outputs for this project are the following:

- Adopt technology that will sustain soil fertility and conserve rainfall
- Link farmer groups with researchers, allowing farmers to select technology that will sustain soil fertility and conserve water
- Develop systems for the supply of seeds and other inputs required for improved long term production

The primary goal is to combine field experience with research, which will allow farmers to identify and select solutions to their problems.

POTENTIAL OF DROUGHT-TOLERANT TECHNOLOGY
SUB-SAHARAN AFRICA



Source: U.S. Yield data, USDA

Figure 2

The green line represents actual yield gain in the United States as a result of improved breeding methodologies, better understanding of plant physiology, improved agronomic practices and increased inorganic inputs. The orange line estimates the potential increase in African yields (1.81 bu/ac/yr) with the application of current scientific knowledge and improved seed technology. The red line is an estimate of yield improvement (3.11 bu./ac/yr) by applying genetic resources.

Africa's current corn production is similar to U.S. production in the 1930s. The increase in U.S. yields during the period of 1930-1960 was primarily due to the rapid adoption of double cross hybrids and increased inputs. Further yield increases were achieved by the introduction of single cross hybrids. The next potential technology jump will result from transgenic traits used for insect resistance, herbicide resistance, disease resistance, and drought tolerant varieties. The combination of molecular markers and genetic engineering could drive the rate of yield gain faster than previous improvements.

CONCLUSION

Agriculture in rural areas in developing countries suffers from a lack of infrastructure and investment. Often, small farmers lack access to credit to purchase farm inputs or equipment. Based on a number of factors, many of these smallholder and subsistence farmers cannot benefit from the typical approach to agricultural production used in Western and Asian countries. A challenge faced by many farm families is the lack of ability to provide enough food between crop harvests to sustain minimum caloric requirements. Often inorganic inputs are not available; therefore, it will require creative solutions for subsistence farmers to achieve increased yields and to successfully eliminate "hunger periods" between harvests. Conservation-based agriculture, access to locally-designed crop varieties, and the use of new seed technology can help address some of these challenges, but all of these solutions must be designed to adapt to local needs and preferences.

Our focus will be on conservation farming techniques and advancements in technology. These two areas can add immediate value to farmers of all sizes, but particularly subsistence farmers. Conservation farming techniques address a number of inherent challenges faced by African farmers. Technology, such as improved seeds, can deliver more predictable yields with no additional investment or cost to the farmer. Therefore, we believe that the combination of these two actions can have an immediate and measurable impact. However, to succeed in the long run, many other initiatives are imperative.

The Foundation's interest is twofold; First to identify and provide financial support to existing projects which meet the outlined objectives in this document. Second, to identify, develop, or promote new approaches to addressing existing challenges. Our goals are to decrease short term hunger and malnutrition, increase food security, and provide long term solutions for sustainable agricultural productivity for smallholder farmers and subsistence farmers. Currently, our primary geographic focus is in Africa.

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