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The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: A Review

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Abstract

This paper is a review article on the impacts of technology adoption on agricultural productivity in smallholder agriculture in the sub-Saharan African region. The use of agricultural technologies determines how the increase in agricultural output impacts on poverty levels and environmental degradation. Experience and evidence from countries within and around the sub-Saharan African region indicate that returns to agricultural technology development could be very high and far reaching. The factors affecting technology adoption are assets, income, institutions, vulnerability, awareness, labour, and innovativeness by smallholder farmers. Technologies that require few assets, have a lower risk premium, and are less expensive have a higher chance of being adopted by smallholder farmers. There are certain traditional smallholder agricultural technologies in sub-Saharan Africa that also have their own merits. Some of these technologies are more efficient in their use of scarce production resources than modern technologies. Modern researchers should therefore seek to understand the rationale behind traditional smallholder farmer behaviour in technology use. This will make their future technological interventions in smallholder agriculture more effective.

Keywords: adoption, technology, agricultural productivity, smallholder, sub-Saharan Africa

1. Introduction

Over the past few decades, a number of writers have presented a rather abysmal picture of the agrarian experiences of the sub-Saharan African region as a whole (Mkandawire & Matlosa, 1993). Food production levels for the majority of the countries in the region have either declined or remained stagnant, while population growth continues to soar. Levels of malnutrition and infant mortality rates remain the highest ever recorded. Life expectancy at birth remains relatively low compared to other regions of the world (Mkandawire & Matlosa, 1993).

Many observers are questioning why the Green Revolution which transformed agriculture in Europe and South East Asia has not been able to achieve the same results in sub-Saharan Africa (Mkandawire & Matlosa, 1993). The majority of the victims of the agrarian crisis in the region are peasants living in rural areas. Peasants in this region may be worse off than they were in the 1960s (Mkandawire & Matlosa, 1993). The vast majority of the peasants and their families have become part of the cycle of poverty in Africa, and many of them are now unable to feed themselves (Mkandawire & Matlosa, 1993). There is a looming shadow of a food and agriculture crisis threatening millions of people in sub-Saharan Africa. For a continent in which more than 70% of the labor force ekes out a living from agriculture, the region is doubtless experiencing a deep-seated crisis of food production (Mkandawire & Matlosa, 1993). Self-sufficient in production at independence, sub-Saharan Africa is now a net food importer (Mkandawire & Matlosa, 1993).

Over 70% of the maize production in the majority of countries in the region is from smallholders that use traditional methods of production (Saudi, 1989). These farmers generally obtain very low crop yields of less than 1 tonne per hectare (Shao, 1996). The reasons are as follows: the local varieties used by farmers have low potential yield; most of the maize is grown under rainfed conditions and irrigation is used only in limited areas; little or no fertilizers are used; and stem borer control is not adequate (Shao, 1996). The average maize yield in

sub-Saharan Africa is only 50% of the average yield in all developing countries, and 20% of the average yield for developed countries (Diallo, 1989).

Limitations to increased agricultural productivity in smallholder agriculture in sub-Saharan Africa include unreliable and/ or poorly distributed rainfall; low and unattractive prices; lack of small scale irrigation facilities; insufficient selection of suitable crop varieties, especially for the marginal areas; pest and disease problems; large post-harvest losses; poor research-extension linkages; poor supply of inputs, especially seed and fertilizers; infertile soils; and failure of the smallholder farmer to adapt to changing environments and adopt new technologies (Shao, 1996; Moyo, 1995; Muza et al., 1996).

Well above 80% of the smallholder farmers are located in areas where rainfall is low and erratic, and soils tend to be infertile (Muza et al., 1996; Moyo, 1995). The unfavourable trends in population, poverty and the environment and the relationships among them have been used to justify the importance of food production technology in developing countries, sub-Saharan Africa included (Hess, 1996). Smallholder maize production in sub-Saharan Africa is constrained by declining soil fertility, high fertilizer costs, poor crop and fertilizer management, and inadequate pest and disease control (Kabambe et al., 1996). Biotic, abiotic, institutional and socio-economic constraints, and the underutilization of improved germplasm, are the contributors to low crop yields in the smallholder sector.

2. The Role of Technology in Addressing the Agrarian Crisis

There is a large gap between what the smallholder farmer gets and what is feasible with the available technology in sub-Saharan Africa (Muhoho, 1989). In looking at what has gone wrong, a fundamental issue of concern relates to the technologies and institutional arrangements that are being promoted by governments in the region to increase agricultural productivity (Mkandawire & Matlosa, 1993). The use of agricultural technologies affects the rate of increase in agricultural output. It also determines how the increase in agricultural output impacts on poverty levels and environmental degradation (Meinzen-Dick et al., 2002). Therefore the focus of recent research has been to find better agricultural practices. New strains of crops have been discovered. The focus of research has also been on improvements of land, soil and water management practices (Meinzen-Dick et al., 2002). However, the only way for smallholder farmers to benefit from these research station technologies is if they perceive them to be appropriate and proceed to implement them on their farms (Meinzen-Dick et al., 2002).

Increased agricultural productivity, technology adoption rates, and household food security and nutrition can be achieved through improved agricultural practices, expansion of rural financial markets, increased capital and equipment ownership by rural households, and development of research and extension linkages (von Braun, 1999). Increased technology development and adoption can raise agricultural output, hence improve household food intake. Improved food intake can also improve the functioning of the human body and the performance of a healthy, normal life which will increase work output. However, increased technology adoption may result in high labour demands and less time available for other household activities by women (e.g. household chores like child care, and fuelwood and water collection) (Kennedy & Bouis, 1993).

Overally, the experience and evidence from countries within and around the sub-Saharan African region indicates that returns to agricultural technology development could be very high and far reaching. This would transform not only the smallholder sector, but also in the entire national economies of countries in the region (Mazonde, 1993).

3. Agricultural Technologies

3.1 Crop Breeding

One of the strategies for poverty reduction through increased agricultural productivity is to promote the production of high yielding crop varieties (Nkonya et al., 2004). Significant increases in crop production in sub-Saharan Africa can be achieved from improved and open-pollinated varieties developed with a comprehensive breeding system (Eberhart, 1989). The breeding should incorporate multi-sage selection for important agronomic traits such as disease resistance, insect resistance, drought and stress tolerance, high yield, and high response to improved cultural practices (Eberhart, 1989). Farmers seek both risk avoidance and high yields in the hybrid and open pollinated varieties they select to grow. Hybrids can be expected to be the commercial product whenever conditions permit the production and sale of high quality hybrid seed (Eberhart, 1989). Breeding strategies are being used by research organizations such as CIMMYT and ICRISAT to reduce the impact of drought stress, low nitrogen availability, aluminium toxicity, diseases and insects in sub-Saharan Africa (Diallo et al., 1989).

The rate of investment in crop breeding targeted to rainfed environments is crucial to future crop yield growth (Rosegrant et al., 2002). Continued application of conventional breeding and recent developments in non-conventional breeding offer considerable potential for improved cereal yield growth in rainfed environments (Rosegrant et al., 2002). Cereal yield growth could be further improved by extending research downstream to farmers and upstream to the use of tools derived from biotechnology to assist conventional breeding (Rosegrant et al., 2002). It has been demonstrated in numerous experiments in sub-Saharan Africa that the performance of improved maize varieties is superior to the traditional varieties in most farmers' fields (Sitch et al., 1996). The yields of maize on smallholder farms are often limited because farmers do not have the improved seed varieties (Sitch et al., 1996). One of the major limitations to crop productivity is the acute shortage of improved varieties (Fumo & De Vries, 1995).

To improve productivity in the agricultural sector will, among other things, require a concerted effort in providing the farming community with high yielding varieties that are drought and pest resistant (Mazonde, 1993). Higher crop yields, which lead to sustained development of the arable sector because they reduce costs per unit of output, should form a major technological challenge for sub-Saharan African countries (Mazonde, 1993).

3.2 Agronomic Practices

Significant increases in crop production require improved agronomic practices in addition to improved hybrids (Eberhart, 1989). Good soil fertility management, timely date of planting, optimum planting rate, good weed control, good soil and water management, and the rotations of a legume with a cereal, are important factors in increasing yields with no additional cash expenditures (Mwania et al., 1989; Eberhart, 1989; Nguluu et al., 1996). Application of modest amounts of fertilizers is needed for further yield increases which require a cash input.

3.2.1 Weed Control

The weed problem in smallholder agriculture is not just late weeding. Weed management is complicated by rainfall patterns and cultural practices which lead to a build-up of weeds, costly multiple weedings, and poor quality weeding (Mwania et al., 1989). In addition, the mode of seedbed preparation, onset of rains, intercropping, and labor or cash availability bear significance on the timing, quality and cost of weeding (Mwania et al., 1989). Firstly, smallholders do very few tillage operations, usually just one breaking, where weed seeds are shallow covered, thereby germinating easily (Mwania et al., 1989). Furthermore, smallholders usually preserve some volunteer plants which they use as vegetables, and these haphazardly growing plants affect weeding. Some farmers delay weeding deliberately to allow these vegetables to germinate, thus encouraging heavy growth of real weeds (Mwania et al., 1989).

Weed control is a widely adopted technology among smallholder farmers in sub-Saharan Africa (Bisanda & Mwangi, 1996). Most farmers use hand hoes for weeding, and a small minority use herbicides (Bisanda & Mwangi, 1996). Herbicide use in weed control is limited under smallholder farming systems. Smallholders have limited resources for the purchase of sprayers or herbicides and in addition water is not readily available (Mwania et al., 1989). Furthermore, use of herbicides requires skills and involves risks which peasant farmers cannot afford (Bisanda & Mwangi, 1996). Weeding of any intensity among smallholders will increase crop yields (e.g. for maize), but this could be conducted only once during the season to make more efficient use of scarce labor resources (Sitch et al., 1996). Although weeding results in significant productivity gains, survey and experimental results indicate that the extent of the benefit gained from weeding varies across seasons and locations (Sitch et al., 1996).

3.2.2 Soil Fertility Management

For efficient utilization of fertilizers, application rates should be given with consideration of cultural practices and factors such as the inherent fertility of the farm, organic sources of manure, method of application, time of planting, spatial arrangements, crop rotations and cropping sequences (Mwania et al., 1989).

In smallholdings, intercropping offers a diversity of organic sources of manure which may be added to the soil directly as crop residues or in the form of farm yard manure (Mwania et al., 1989). Leaf litter falling from crops such as beans, groundnuts, potatoes and bananas, may serve to restore soil organic content and soil structure (Mwania et al., 1989). Livestock droppings are frequently swept into the farm and in the long run could contribute significantly to the soil organic matter status. However, smallholder farmers are not making full use of organic sources of manure (Mwania et al., 1989).

The expensive inorganic fertilizer option in raising agricultural productivity should be combined with cheaper local alternatives (Nkonya et al., 2004). For example, research in some sub-Saharan African counties found that

use of livestock manure in the local farming systems leads to higher nutrient balances on the farm (Nkonya et al., 2004). In most sub-Saharan African smallholder farming systems, organic manure application to crop production systems is constrained by low biomass production, coupled with limited availability of land or small landholding sizes (Nkonya et al., 2004). This problem can be resolved by incorporating high quality legumes in the nutrient recycling system on the farm (Kaizzi et al., 2000; Ndakidemi et al., 2002). But low rainfall, infertile soils, and intense population pressure on land are likely to limit the effectiveness of the legume option, leading to lower adoption in many smallholder farming areas (Kaizzi et al., 2002; Gladwin et al., 2002; Place et al., 2002).

Although some smallholders in sub-Saharan Africa use inorganic fertilizers, they do not necessarily apply recommended doses (Bisanda & Mwangi, 1996). The majority of those who apply are doing so at well below the recommended rates, due to the high cost and unavailability of such fertilizers.

3.2.3 Soil and Water Management

Farmers who have been resident in a particular natural region will be aware of soil management problems like soil physical and chemical deterioration through effects such as low yields, soil salinity or sodicity (Scherr, 1999). Therefore, if a new technology in land or soil management is availed to the farmers, they are more likely to adopt it because they can predict beneficial effects arising from its subsequent implementation. Such technologies may include terrace construction, land leveling, construction of drainage works, reforestation or afforestation of devegetated areas, mixed cropping, crop rotation, planting trees on agricultural land, silvicultural practices on land bordering croplands, use of grazers and browsers in livestock-bush management systems, or use of appropriate farm implements (Sherr, 1999).

The conservation community has discovered that farmers' decisions about conservation practices and investments are inextricably linked to production (Sharxson et al., 1997). If good land husbandry practices are to be widely adopted, they must not only replenish soil resources, but should also contribute to increased productivity and farm income in the short term (Sain & Barretto, 1996; Partap & Watson, 1994).

Increased water management, and water harvesting have the potential in some regions to improve rainfed crop yields. These technologies could provide farmers with improved water availability and increased soil fertility in some local and regional ecosystems, as well as environmental benefits through reduced soil erosion (Rosegrant et al., 2002).

4. Factors Influencing Technology Adoption

The main factors affecting technology adoption among smallholders in Sub-Saharan Africa are assets, vulnerability, and institutions (Meinzen-Dick et al., 2004).

4.1 Assets

These factors deal with whether farmers have the requisite physical (material) and abstract possessions (e.g. education) essential for technology adoption. A lack of assets will limit technology adoption (Meinzen-Dick et al., 2004). Researchers, policy makers and development practitioners therefore need to put more emphasis on the development of technologies with little requirements for such material and abstract possessions (Meinzen-Dick et al., 2004). Policy makers and development practitioners should also promote technologies with low asset requirements as they are likely to have higher adoption rates among poor farmers (Meinzen-Dick et al., 2004).

4.2 Vulnerability

Vulnerability factors deal with the impact of technologies on the level of exposure of farmers to economic, biophysical and social risks (Meinzen-Dick et al., 2004). Those technologies that have a lower risk have a greater appeal to smallholders who are naturally risk-averse (Meinzen-Dick et al., 2004). It has been conceded that traditional smallholder farmers have their reasons for not adopting untried technologies. Most of the time, such reasons are quite rational (Mazonde, 1993). These farmers are well aware, for instance, that a sudden upswing in the productivity of their fields is likely to deplete the soil nutrients, which would result in much lower returns in the following agricultural season (Mazonde, 1993). In other words, use of high yielding crop varieties is consciously or sub-consciously perceived with prejudice by most traditional farmers (Mazonde, 1993). Application of pesticides is also less frequent for that reason.

4.3 Institutions

Institutional factors deal with the extent or degree to which institutions impact on technology adoption by smallholders (Meinzen-Dick et al., 2004). Institutions include all the services to agricultural development, such as finance, insurance and information dissemination. They also include facilities and mechanisms that enhance farmers' access to productive inputs and product markets. Institutions also include the embedded norms,

behaviours and practices in society (Meinzen-Dick et al., 2004). Researchers and development practitioners should also consider issues that relate to the farmers' exposure to economic, agro-meteorological, biophysical and social shocks in designing technologies for smallholders. Care should be taken to avoid technologies with a high investment cost structure which smallholders cannot afford because they are poor and lack the necessary resources (Meinzen-Dick et al., 2004). Crop insurance can to some extent lessen the risk of farmers' exposure to external shocks (Meinzen-Dick et al., 2004).

Embedded norms, behaviours and practices in society can encourage or discourage adoption of a particular technology by members of that society (Meinzen-Dick et al., 2004). For example, the practice that the production of certain types of crops are the preserve of male members of society can limit the adoption of a particular technology in Sub-Saharan Africa if the crop to be promoted is grown mainly by men. This is because women constitute the majority of rural dwellers in this part of Africa. Clearly therefore, an understanding of local cultural practices and preferences is important if they are to benefit from agricultural research (Meinzen-Dick et al., 2004).

Results of studies in sub-Saharan Africa have shown that male headed households have more access to land, education, and information on new technologies (Bisanda & Mwangi, 1996). There is a strong association between the gender of the household head and adoption of technological recommendations (Bisanda & Mwangi, 1996). In some countries female-headed households are discriminated against by credit institutions, and as such they are unable to finance yield-raising technologies, leading to low adoption rates (Mkandawire, 1993). There is clearly a case for improving current smallholder credit systems to ensure that a wider spectrum of smallholders are able to have access to credit, more especially female-headed households (Mkandawire, 1993). This may, in certain cases, necessitate designing credit packages that are tailored to meet the needs of specific target groups (Mkandawire, 1993).

It is imperative that agricultural training and extension programmes be intensive enough to promote adoption not only of improved yield-raising technologies, such as improved seeds, but also of fertility-restoring and conservation technologies (Nkonya et al., 2004). Synergies need to be created between government departments, non-governmental organizations, researchers, donors and local communities in implementing programs that promote smallholder farmers' adoption of technologies which can increase agricultural productivity and reduce environmental degradation and the deterioration of soil quality (Rosegrant et al., 2002; Nkonya et al., 2004).

Measures that can be taken to increase adoption of yield-enhancing technologies include: (i) lowering fertilizer costs; (ii) lowering the price of other inputs and raising agricultural product prices; (iii) improving smallholder farmers' access to finance for agricultural development; (iv) adopting a "package" approach to provision of agricultural development technologies; and (v) development and rehabilitation of infrastructure for agricultural inputs and product markets (Nkonya et al., 2004; Rosegrant et al., 2002).

A major problem in sub-Saharan Africa is that year after year extension workers who are hardly afforded in-service training, and are loosely linked to research, continue to disseminate the same messages repeatedly to the same audience (Mkandawire, 1993). A situation has consequently arisen where the disseminated messages to the majority of the extension audience, have become technically redundant and obsolete (Mkandawire, 1993). An additional problem is that most extension services tend to focus on the well-resourced, wealthier farmers and perceive farmers as simply agents of change (Mkandawire, 1993).

The major option for increased adoption of technology is to overcome the income/ capital constraint through increased credit provision (Mkandawire, 1993). However, one of the most discernible features around credit in most sub-Saharan African countries is the lack of an educational package linked to credit for small rural producers (Chidzonga, 1993).

The cost of technology is a major constraint to technology adoption (Bisanda & Mwangi, 1996). The elimination of subsidies on prices of seed and fertilizers since the 1990s due to the World Bank-sponsored structural adjustment programs in sub-Saharan Africa has worsened this constraint (Chidzonga, 1993; Bisanda & Mwangi, 1996; Nkonya et al., 1996; Akulumika et al., 1996).

4.4 Other Adoption Factors

Additional constraints inhibiting increased fertilizer use among smallholders include lack of knowledge and ability to differentiate between various nutrient sources; and lack of understanding of cost-effective methods of soil fertility management (Mwania et al., 1989). It has also been found that income from off-farm sources is important in the financing of purchased farm inputs (e.g. seeds, fertilizers, labor) (Mwania et al., 1989). In addition, cash proceeds from crop sales, and income obtained from the sale of livestock and livestock products,

also provide cash for the purchase of inputs in crop farming (Mwania et al., 1989). Higher levels of income from each of the above sources will lead to higher rates of adoption of yield-raising technology. Labor bottlenecks, resulting from higher labor requirements that new technologies often introduce, and seasonal peaks that may overlap with other agricultural activities, are important constraints to technology adoption (Meinzen-Dick et al., 2002).

In the short term, governments may wish to consider bringing some of the marginal lands under increased cultivation through the use of inorganic fertilizers. However, given the low levels of both on-farm and off-farm income among smallholder farmers in sub-Saharan Africa, it is not feasible for most smallholders to purchase inorganic fertilizers (Mkandawire, 1993).

Studies in some areas have shown that smallholder farmers do not adopt all components of "packaged" technologies (Nguluu et al., 1996). When exposed to innovations, smallholder farmers only take those components that they perceive as useful and economically within their reach (Nguluu et al., 1996). Those that require a substantial cash outlay are not taken up easily (Ockwell et al., 1991). There are also technologies that do not require high investment costs and still exhibit low adoption. Rukandema (1984) and Muhammad and Parton (1992) have described other socio-economic factors such as farmers' innovativeness, age, off-farm income, risk and uncertainty that may result in low technology uptake. Lack of awareness of improved practices is another reason, particularly in remote areas (Nguluu et al., 1996). Other farmers do not adopt fertilizer use because they believe their farms are still fertile (Nguluu et al., 1996).

5. Merits of Traditional Agriculture Technologies

5.1 Some Misconceptions about Traditional Agriculture

There is a widely held belief that traditional technologies and institutions are to blame for low agricultural productivity and food insecurity in the sub-Saharan African region (Mkandawire & Matlosa, 1993). There is the notion that "backward" peasants can only be made more productive and food secure through technological and institutional transfer from the North to the South, and from the modern sub-sector into the peasant sub-sector (Mkandawire & Matlosa, 1993). Many governments in the region still believe in the importation of western technologies and institutions, such as tractors, high analysis fertilizers, and modern seeds as well as in changing the prevailing customary land tenure arrangements (Mkandawire & Matlosa, 1993). Traditional technologies and tenure arrangements and other institutions are perceived as pseudo-scientific, backward, primitive, valueless, crude, mistaken, fallacious and a stumbling block to increased agricultural productivity (Mkandawire & Matlosa, 1993). Literature which favours large-scale modern agriculture tends to claim that if land were returned to traditional farmers, millions would starve to death (Innis, 1997). Traditional farmers, when they are presented in textbooks and analytical research papers, are portrayed as very "rigid" in their ways, unable and unwilling to respond to new ideas or opportunities (Innis, 1997).

Among policy makers in the sub-Saharan African region, there is a thinly disguised contempt of traditional systems and technologies. Mixed cropping, for example continues to be condemned (Mkandawire & Matlosa, 1993). Farmers who continue to plant mixtures are branded as conservative, ignorant, obtuse, lazy and unprogressive (Mkandawire & Matlosa, 1993).

5.2 Efficiency of Traditional Agriculture

Without taking anything away from what has already been said about the impact of modern (research and science based) technologies on agricultural productivity, some of the traditional agricultural activities practiced by smallholder farmers in Sub-Saharan Africa also have their own merits. Some authors have even gone further to suggest that smallholders using traditional technologies are more efficient in their use of scarce production resources than large scale farmers utilizing modern technology (Innis, 1997; Mkandawire & Matlosa, 1993; Seboka, 1996).

5.3 Productivity

Many researchers have now come to realize that mixed cropping is a sophisticated and appropriate practice for most smallholder farmers (Mkandawire & Matlosa, 1993). The late Professor Donald Q. Innis of the State University of New York also supported this observation. He noted from his observations and experience of twenty-five years in smallholder research and his extensive work on traditional agriculture, that, "In fact, peasant farmers grow much more from given resources of land, water and sunlight and make better (more efficient) use of mineral fertilizers if they were available, than do large-scale farmers" (Innis, 1997). He adds that smallholder farmers are observant and innovative when it comes to developing or accepting new plant material or other

technologies. They tend not to accept poor ideas or technologies (Innis, 1997). Most traditional agriculture produces far more food per unit of available plant nutrient than does modern agriculture (Innis, 1997).

Despite the trend towards increased sales of hybrid seed, research work is now beginning to emphasize development of open-pollinated (traditional) maize varieties. This is done largely on the grounds that an efficient hybrid seed production and delivery system is lacking in most countries of the sub-region (Lyimo, 1996). Results from trials carried out among smallholder farmers in sub-Saharan Africa indicate that without fertilizer, the unimproved local maize varieties are probably as productive as the hybrids (Ojiem et al., 1996). However, when fertilizer is used, hybrids are the more productive (Ojiem et al., 1996). Given the rapidly increasing prices of hybrid seed and fertilizer, farmers seem to be justified in selecting their own local seed for production under low input conditions (Ojiem et al., 1996). Future maize improvement research should consider the development of local, traditional open pollinated varieties for low input conditions (Ojiem et al., 1996).

5.4 Cost-effectiveness

Moreover, the cost of hybrid grain production is more than double the cost incurred in the production of maize under traditional practices (Seboka et al., 1996). In certain scenarios of different agro-ecological, input and product market conditions, it has been shown in profitability analyses that there is no economic advantage of growing hybrids without either minimum floor price guarantee after harvest, or support in post harvest technologies (Seboka et al., 1996). The evidence underscores the need for government intervention in promoting post harvest technologies, credit, marketing and grain price support strategies (Seboka et al., 1996).

5.5 Suitability to Local Conditions

Most of the maize in sub-Saharan Africa is grown by smallholder subsistence farmers (Hess, 1996). These farmers sometimes market part of their production (Hess, 1996). This group of farmers no doubt account for the major share of farmers who grow unimproved maize cultivars (Hess, 1996). These farmers are usually cash poor, if not resource poor in all respects (Hess, 1996). They are often located in ecological niches that are unique in one or more ways and often too small to justify the establishment of a scientifically based crop breeding program (Hess, 1996). Such farmers typically plant unimproved seed because it meets their needs without requiring the use of scarce or non existent cash resources (Hess, 1996). Moreover, the local variety may meet their perceived grain quality or other needs better than other modern varieties available at any price (Hess, 1996). Such farmers frequently select the best ears from their harvest and use the seed for planting the next season (Hess, 1996).

5.6 Introgressiveness of Improved Varieties

Improved maize varieties or hybrids are finding their way to smallholder farmers in sub-Saharan Africa (Hess, 1996). But, rather than being used directly, the improved varieties are being introgressed into the local varieties by the farmers themselves (Hess, 1996). A variation of this approach that could extend the advantages of improved seed more to the poorest farmers would be some form of "in-situ" conservation or improvement (Hess, 1996). In this situation scientists identify weaknesses in local varieties and suggest germplasm that can be introgressed to improve the local material for one or more specific traits (Hess, 1996). Either case is of little interest to commercial seed enterprises, but could significantly improve productivity in some poor and remote rural communities in sub-Saharan Africa (Hess, 1996).

6. Conclusion

Agricultural technology development is an essential strategy for increasing agricultural productivity, achieving food self-sufficiency and alleviating poverty and food insecurity among smallholder farmers in sub-Saharan Africa. This strategy is particularly relevant for the smallholders in the sub-region because they are disadvantaged in many ways, which makes them a priority for development efforts. These farmers live and farm in areas where rainfall is low and erratic, and soils tend to be infertile. In addition, infrastructure and institutions such as irrigation, input and product markets, credit and extension services tend to be poorly developed. It is recommended that further research and rural development efforts should focus on the development of infrastructure and institutions in these areas.

The technologies people use play a significant role in determining how fast agricultural productivity grows and how that growth affects the poor and the condition of natural resources. The development of agricultural technology for both food and non-food crops, rural financial markets, the dissemination of assets and information, developing agricultural research and extension facilities targeted towards the smallholder farmer all work together to prevent long-term famine through increased agricultural productivity.

Overally, the experience and evidence from countries within and around the sub-Saharan African region indicates that returns to agricultural technology development could be very high and far reaching, not only in the

smallholder sector, but in the entire economy as well. However, improved technologies are of little value unless farmers judge them to be appropriate and subsequently adopt them. It is therefore imperative not only to develop new agricultural technologies, but also promote their adoption by smallholder farmers.

The main factors affecting technology adoption are assets, vulnerability and institutions. A lack of assets, such as land, education or equipment, will limit technology adoption. That means more attention of further studies and development efforts needs to be paid to technologies that require few assets. Decision makers also need to recognize that technologies that build on assets which the poor farmers already have are more likely to be adopted.

To encourage adoption of new technologies, pro-poor agricultural researchers must look beyond simply boosting productivity. They should emphasize certain variables which reduce the farmers' vulnerability to loss of income, bad health, natural disasters, and other factors. In addition, an understanding of local cultural practices and preferences is important if smallholder farmers are to benefit from agricultural technologies developed through research. All these form a potentially useful area of study for future research.

In some countries female-headed households are discriminated against by the local communities and/ or credit institutions. There is clearly a case for improving current smallholder credit systems to ensure that a wider spectrum of smallholders are able to access credit, more especially female-headed households. Other steps that may be taken to encourage the adoption of technologies that increase agricultural productivity and reduce land degradation include reducing the prices of fertilizers, offering credit, and waiving some of the taxes levied on input trading businesses. The promotion of greater research-extension linkages will also improve technology adoption. Stronger partnerships between agricultural researchers and other agents of change, including local organizations, farmers, community leaders, NGOs, national policy makers, and donors, are also important in stimulating technology adoption for increased agricultural productivity.

Promotion of various smallholder income sources such as off-farm employment, remittances, and livestock production, can lead to higher total household income to finance the purchase of inputs such as fertilizers, seed, and hired labor. Introducing technologies that require less labor is also likely to lead to their adoption because the smallholder farming sector in the sub-region is beset with chronic shortages of labor during the agricultural season.

It has also been highlighted in this paper that there are some rational, positive aspects in certain traditional agricultural practices implemented by smallholders in sub-Saharan Africa. Modern researchers should therefore seek to investigate the reasons why smallholder farmers do the things they do, and attempt to improve on them. This is a more effective strategy than the prevailing approaches which seek to displace traditional technologies outright on the grounds that they are irrational, unscientific, primitive and backward.

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