Proc. Inter. Conf. Agbiotech, Biosafety & Seed Systems (2011) 63 - 70

Proceedings of the International Conference on Agro-Biotechnology, Biosafety and Seed Systems in Developing Countries

www.scifode-foundation.org

Potential role of GMOs in adapting Agriculture to Climate change in Sub-Saharan Africa

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ABSTRACT

Sub-Saharan Africa (SSA) is the most vulnerable region to climate change in the world because of its low adaptive capacity. Over 70% of the labour force depends on agriculture, which is extremely vulnerable to climate change. The purpose of this review is to foster policy discourse on challenges of agriculture in SSA due to climate change and explore potential adaptation strategies. Ongoing studies of climate change and agriculture have recommended adoption of stress-resistant crop varieties as a feasible strategy. Genetic engineering provides tools that can be used to develop stress resistant transgenic plants. For SSA to adopt products of genetic engineering known as genetically modified organisms (GMOs) as an adaptation strategy to mitigate effects of climate change in the agricultural sector, a number of concerns must be addressed and strategies implemented. These include investing in research and development, putting in place mechanisms for risk assessment and effective governance, managing intellectual property rights (IPR), and addressing trade issues.

Keywords: *Agriculture, Adaptation, Climate change, GMOs, Sub-Saharan Africa*

Received: *11 April 2010,* ***Accepted:*** *27 November 2011*

Introduction

Climate change occurs naturally over time however its trends have been altered by human activity leading to what has often been called global warming. The major causes of global warming and associated climate changes such as shift of the precipitation patterns are increased emissions of green house gases (GHG) from fossil fuel use, waste management, industry, forestry, agriculture, buildings, and transport, and reduced sinks and increased emissions from the clearing of natural vegetation such as deforestation (IPCC, 2007a). The impacts of these climatic shifts have already been experienced by many people around the world and they present a future challenge because effects of GHG emissions will continue to be felt for decades or even millennia.

While industrial countries are responsible for majority of the GHG emissions, developing countries are likely to be most gravely affected by climate change (IPCC, 2007a). There is growing evidence that negative impacts of climate change are already being felt by many developing countries (FAO, 2008; UNFCCC, 2007). For example in 2004 severe flooding in Bangladesh caused the death of over 600 people and displaced over 20 million. Increased drought events have contributed in a rise in malnutrition, which is responsible for an estimated 3.5 million deaths each year in developing countries (FAO, 2008). More than 42 million children in Sub-Saharan Africa (SSA) are malnourished, and with continued climate change the number is expected to increase to 52 million by 2050 (Nelson *et al.*, 2009). Sub-Saharan Africa contributes only 5 percent of the total global GHG emissions, but it is considered the most vulnerable region to climate change due to limited adaptive capacity. The causes of SSA's vulnerability include: the fact that a large portion of the region is desert or dry land, high exposure to drought and floods, economies heavily dependent on natural resources, limited infrastructural and technological resources, and high disease prevalence (WDR, 2010). In this region, agriculture is vital; 70 percent of the labour force and over 25 percent of GDP in most countries' economies depend on agriculture (UNECA, 2009). In order to address SSA's vulnerability, there is need to alleviate the negative impacts of climate change on agriculture. The purpose of this paper is foster policy discourse on the problems SSA's agriculture, particularly crop production, is likely to face due to climate change. The paper uses the example of genetically modified organisms (GMOs) to explore the challenges that are likely to be encountered when implementing some of the suggested adaptation mechanisms.

Impacts of Climate Change on Agriculture

Agriculture in many regions of the world is extremely vulnerable to climate change. Changes in temperatures and precipitation patterns are predicted to result in positive and negative effects on agriculture globally (Table 1). Climate change is expected to contribute to loss of habitat for wild relatives of crops, which are a vital source of genetic diversity for crop improvement (FAO, 2008). It is projected that continued climate change will affect wild relatives of three major food security crops: groundnuts, cowpea and potato causing of extinction of 16 to 22 percent of wild species by 2050 (FAO, 2008). Climate change is also likely to cause increased manifestation of human diseases. Increases in temperature and humidity will create ideal conditions for vector-borne diseases such as malaria, sleeping sickness and other infectious diseases that will directly affect the availability of human resources for the agriculture sector. While some parts of the world are expected to have agricultural benefits from climate change at least in the short-term, many African countries are likely to experience more negative impacts (IPCC, 2007b) that will threaten national economies and food security.

Table 1: Climate change impacts on agriculture

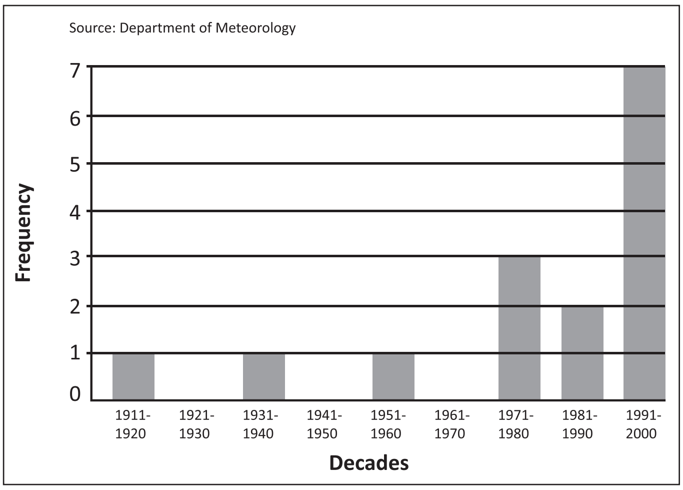
Climate event	Possible impact on agriculture
Warmer and fewer cold days and nights; warmer and more frequent hot days and nights over most land areas (virtually certain)	Increased yields in colder environments; decreased yields in warmer environments; increased insect pest outbreaks
Warm spells and heat waves increasing in frequency over most land areas (very likely)	Reduced yields in warmer regions due to heat stress; increased crop damage due to wildfire
Heavy precipitation events increasing in frequency over most areas (very likely)	Damage to crops; soil erosion; inability to cultivate land due to water-logging of soils
Drought-affected area increases (likely)	Increase in land degradation and soil erosion; lower yields from crop damage and failure; increased risk of wildfire; loss of arable land
Intense tropical cyclone activity increases(likely)	Damage to crops
Extremely high sea levels increase in incidence (excludes tsunamis) (likely)	Salinization of irrigation water; loss of arable land and increase in migration

Source: FAO, 2008

In Africa, 220 million people are affected by drought each year (UNFCCC, 2007) and this number is projected to rise to 350-600 million by 2050 (IPCC, 2007b) as a result of both population growth and increased drought frequency. For example, in Uganda there is already evidence of increased drought events (Figure 1). An estimate 25–42 percent of crop species habitats is expected to be lost across Africa due to drought leading to species range shifts and extinction of some species including wild indigenous foods and plant-based medicines (FAO, 2008). Between 9 and 20 percent of SSA's arable land is expected to become much less suitable for agriculture by 2080 (Fischer *et al.*, 2002; WDR, 2008).

Sub-Saharan Africa's agriculture is extremely vulnerable to climate change because it is largely rain-fed (97 percent) (Alvaro *et al*. 2009), and is therefore greatly affected by precipitation pattern variability. Crop yields from rain-fed agriculture are expected to be halved by 2020 (Boko *et al*. 2007; FAO, 2008). According to a crop model by International Food Policy Research Institute (Nelson *et al.*, 2009), cereal production in sub-Saharan Africa will decline by 22 percent for wheat, 14 percent for rice and 5 percent for maize by 2050 due to climate change. Similar maize yield losses were predicted for East Africa by Thornton *et al.*, (2009). Some vulnerability mapping for the continent has identified hotspots including arid–semiarid systems in the Sahel, arid–semiarid rangeland systems in parts of eastern Africa, the coastal regions of eastern Africa, and dry-lands in southern Africa. These are areas where agricultural populations are already vulnerable, and the situation is expected to get worse in the future (Thornton *et al.*, 2009).

Fig 1: Occurrence of drought in Uganda. Source: Department of Meteorology, Ministry of Water and Environment 2007



Floods are also a major cause of vulnerability in SSA. For example floods in 2007 affected 22 districts in northern and eastern parts of Uganda, affecting more than 200,000 people who lost 90 percent of their crops, which created food insecurity that will last throughout 2008 (FEW NET, 2008). This crop loss resulted in food shortages causing increased food prices with a 20 to 65 percent rise for cereals, and a 60 percent increase for beans during that time period. Floods also cause infrastructure damage, displacement, destruction of livelihood assets and disease epidemics, which increases peoples' vulnerability (McGrath, 2008).

Future predictions indicate that if global GHG emissions continue to remain high then Africa temperatures will rise by more than 2°C above the current temperature (IPCC, 2007b). This temperature rise will have a great negative impact on many crops that are important for Africa for example a 2°C temperature rise is expected to significantly affect Uganda's coffee production potentially causing a US $ 265.8 million income loss that is 40% of export earnings (Hepworth and Goulden, 2008). With these crop productivity reductions, and expected increase in population (UN, 2009), SSA needs to have in place an adaptation system to assuage the devastating consequences expected due to climate change.

Climate adaptation strategies for SSA's agriculture

Many SSA countries have adopted a national adaptation programme of action (NAPA) in compliance with international policies such as United Nations Framework Convention on Climate Change (UNFCCC, 2007). Some countries have developed a number of national policies related to adaptation and mitigation impacts of climate change (WDR, 2010). In relation to agriculture, such policies advocate for adaptation to climate change through adoption of stress resistant crop varieties, improved water and soil management, land management systems, and market and extension services as well as enhance communication (Nelson *et al.*, 2009). All the above-mentioned strategies are important but this paper will focus on adoption of stress resistant crop varieties.

GMOs and Agriculture

Ongoing studies of climate change and agriculture have recommended adoption of stress-resistant crop varieties as a feasible strategy (FAO, 2009a). These crop varieties will have to be resistant to pest and diseases, and tolerant to drought and increased soil salinity. These varieties can be developed by crossing, irradiation or chemical treatment, marker assisted breeding or genetic engineering. Genetic engineering (GE) provides breeders the tool to transfer characteristics within species, and between species that cannot naturally cross. For example through GE plant breeders have transferred a disease-resistant characteristic from rice to banana (Arinaitwe, 2008). This tool broadens potential sources of characteristics for crop improvement for both productivity and nutrient enhancement especially in situations where conventional breeding may not be possible. Products developed by GE are known as genetically modified organisms (GMOs). Genetically modified (GM) crops have been grown in various parts of the world for the last fifteen years (James, 2010). Currently, a few crops species have commercially grown GE varieties including soybean, maize, and cotton, and the common traits are herbicide tolerance, insect resistance, and a combination of the two traits. "Since their introduction in 1996, the cultivation of GM crops has grown rapidly and accounted for over 80 percent of soybean, maize, and cotton acreage in the United States in 2009" (NAS, 2010). Globally, there has been an increasing adoption rate of GM crops starting with 1.7 million hectares of biotech crops in 1996 in USA to 148 million hectares in 2010 in 29 countries (James, 2010). GM crops can affect all the three pillars of sustainable agriculture: environmental protection, economic and social development. However, this adoption rate is much lower than expected, especially in developing countries (Paarlberg, 2008).

Benefits and Concerns with GMOs as an adaptation strategy for climate change

In relation to crop agriculture, GMOs can be considered a climate change adaptation strategy because it can contribute to sustainable agriculture by reducing cost of production incurred by farmers or increasing crop productivity thus increasing the net income per land unit. Genetic engineering technology can facilitate speeding up of breeding and introduction of new desired trait in crops, for example resistance to high mineral content, drought tolerance or pest and disease resistance that reduce the requirement for expensive and hazardous chemicals, increase productivity per unit area on the current 1.5 billion hectares of arable land, and enable expansion of agriculture to accessible marginal land, which could probably reduce the driving forces for deforestation thus enabling preservation of the forest biodiversity (Ferry and Gatehouse, 2008; James, 2010). Additionally, the technology may provide crop varieties tolerant to abiotic stresses such as drought and salinity, which would expand agricultural production to less arable land such as saline soils and areas with extended dry seasons.

However there are potential risks associated with GMOs including invasion and persistence of GMOs or their genes which could cause loss of plant biodiversity (Pimentel, 2005). For example if a herbicide resistant GM crop such as rice was introduced in an environment with its weedy relatives then the off-springs could persist in the environment and compete with other plant diversity for the limited arable land. Some GM crops require increased application of chemicals, which increases the cost of production for the resource poor farmers. This may increase rather than reduce the vulnerability of resource-poor farmers to climate change. All GMOs, currently on the market, have been tested to alleviate these concerns (Paoletti *et al.*, 2008). Another concern associated with GMOs is the fact that most of the products currently on the market are owned by multinational companies, thus farmers will have to depend on these companies as the source of seed.

Trade issues are another concern because the European Union, which is the biggest customer of global agricultural commodities, has adopted a precautionary approach to the use of GM crops (Paarlberg, 2008). This caused a mechanism known as "trading up" (Vogel, 1995) where producers interested in selling their commodities to a particular market have to produce what the customer wants, at the quality level and using production process demanded by these customers thus following the quality and regulatory standards in the import countries. Even the United States of America is strongly affected by European standards, as Mitchner (2003) stated, "Americans may not realize it, but rules governing the food they eat, the software they use and the cars they drive increasingly are being set in Brussels". This has contributed to low adoption of GMOs and implementation of very stringent regulatory procedures in countries interested in selling their agricultural commodities to Europe.

Solutions to some of the concerns related to GMOs

To address the issue of the environmental and human health concerns associated with GMOs, there is a need for thorough risk assessment on a case-by-case basis for each GM crop before it is introduced into the environment. All countries that have adopted GMOs set up or modified existing formal risk assessment systems to screen all new GMOs before they are introduced in the environment (Paarlberg, 2008).

Concern about multinationals can be addressed by developing GM crop varieties from locally adapted plant materials (Cohen, 2005) addressing native production constraints. Such products may not be of interest to the multinational companies, therefore public research and development is most likely to take into consideration the local farmers' need and local conditions. As Kofi Annan, then UN Secretary General, said in a 2004 speech "there is need to generate a uniquely African green revolution focusing around ensuring food security and agricultural development because this will go a long way to help foster dignity and peace" (Paarlberg, 2008).

An example of a successful story of adopting new crop varieties is the New Rice for Africa (NERICA) rice scheme (Africa Rice Center, 2008). The rice was developed using conventional methods by crossing high yielding Asian rice with poor yielding but better adapted African rice. The new varieties have high yields, have shorter growing seasons and are tolerant to the local conditions. The NERICA is not restricted to working on rice growing in paddies; thus it may enable farmers to grow rice in environments not previously thought possible. Uganda as an example launched an Upland Rice Project in 2004 and NERICA is a major component. In 2007, 35,000 farmers were involved in rice production compared to 4,000 in 2005 (Karembu *et al.*, 2009). Over the same period, the country reduced its rice imports from 60,000 to 35,000 tonnes, which saved approximately US$ 30 million. Plans are under way to enhance the nutrient content of this rice using biotechnology tools so as to alleviate malnutrition (Karembu *et al*., 2009).

An example of a GMO currently undergoing regulatory assessment that will be important for enhancing SSA's agricultural resilience to climate change, if successful, is drought tolerant maize commonly known as water efficient maize for Africa– WEMA (AATF, 2009). Drought tolerant crops are going to became increasingly essential because projected climate change effects include 10-20 percent reduction in rain in eastern Africa by 2050 (Kigotho, 2005), increased soil moisture loss and reduction in arable land (WDR, 2008). Certain characteristics may be necessary to facilitate GMOs adoption by a social system including: the ability to try them on a limited basis without a commitment, superiority to the traditional varieties, ease of use, compatibility with existing practices, the ability to observe others utilizing them and affordability (Rogers, 1995).

Trade issues can be mitigated by encouraging more internal and regional marketing of the agricultural products. While Europe is still an important importer of SSA's agricultural commodities, the trade trends have changed. Currently there are many regional markets in SSA for example Kenya, Sudan, Rwanda and Democratic Republic of Congo are major importers of Uganda's agricultural commodities with a share of 39 percent, which is higher than the European share of 25 percent (CIA, 2008). According to a study carried out by the Regional Approach to Biotechnology and Biosafety Policy in Eastern and Southern Africa (RABESA) in 2006, although Africa's total agricultural export value to Europe was US $ 6.1 billion, only 6.64 percent of that value represented crops that have commercially available GM varieties grown in different parts of the world including South Africa (Minde and Kizito, 2007). Maize and cotton are the only export commodities with GM varieties currently on the market, and most of the crops necessary for food security in SSA for example beans, cowpea, cassava and sweet potato are not exported to Europe. Regional and internal markets need to be encouraged so that the country has flexibility to adopt technologies to improve productivity and quality of crops required for local and regional utilization, while respecting the requirement for products imported to Europe. A similar approach was adopted by the United States when they decided not to produce GM varieties for crops like rice and wheat to avoid losing their export markets in Europe, but they continue to grow GM crops that are utilized locally or exported to parts of the world that do not restrict GMO imports.

Challenges to adoption of GMOs in SSA's agriculture

Adoption of GMOs presents a number of challenges including issues related to ownership of the technology (intellectual property rights), trade related issues, the need for investment in research and development, and capacity for regulation and effective governance of the technology. The major challenge facing SSA will be the cost of building human and infrastructural capacity required for adoption of this technology.

Most GMO technologies and seeds are protected by utility patents and not plant variety protection therefore the intellectual property rights (IPR) issues are much more complex. Public institutions must take care when developing GM crops so that they do not use patented genes or germplasm without the authorization of the patent owners. This is essential because before releasing a product, the developer will need to gain the freedom to operate for most of the patented technologies (Byerlee and Fischer, 2002). Currently, the African Agricultural Technology Foundation (AATF) an Africa not-for-profit organization assists public research institutions to develop partnerships with other private/public institutions so that they can access proprietary technologies that maybe relevant for small-scale farmers (AATF, 2009). Nevertheless, countries and the institutions involved in biotechnology research need to develop their own capacity in IPR so that they can actively participate in negotiations for access and benefit sharing of genetic resources. Effective IPR systems may be necessary both at national and institutional level to attract external technologies and generation of local innovations that address national priorities. Critics of IPRs indicate that control over seed and other farm inputs are in the hands of a few multinationals (IAASTD, 2008a), however, not all IPRs are in these companies. Plant variety protection is necessary to promote plant breeding in both private and public research institutions, and it encourages importation of foreign varieties, plus it also provides breeders with bargaining power for genetic resource access and benefits sharing, thus should be implemented.

A trade-related challenge is the vulnerability of farmers to fluctuating international market prices, where their products sometimes receive prices below the cost of production (IAASTD, 2008a). If GMOs are adopted as an adaptation strategy for climate change, there is likely to be an increase in productivity and thus enhance need to reach new markets. There is need to improve competitiveness of the SSA agricultural commodities on international markets. This can be achieved by encouraging local value-addition through providing credit and markets to small-scale processors, and reducing tariffs on these commodities. Farmer collective action should be facilitated to encourage more value-addition and bulking, improve negotiation power, and to identify alternative markets. At the same time the Governments needs to negotiate removal of trade barriers on SSA products that have a comparative advantage at international markets. All these efforts will contribute to reducing the vulnerability of SSA's agriculture to fluctuating international market prices which are expected to increase due to climate change (IAASTD, 2008b).

Sub-Saharan African countries experienced a reduction in foreign investment in agriculture in the 1980s and this caused a decline in funding of research and development of technologies relevant to local priorities (IAASTD, 2008a). International donors especially from US and Japan have been reducing support to agricultural research particularly for the CGIAR system, leaving European nations as the major donors (Paarlberg, 2008). This may hamper research on GMOs, since many European nations oppose the application of this technology.

Many donors are currently advocating for organic farming. Organic agriculture contributes to crop production with minimum inputs, decreases environmental and human health hazards due to chemical application, and provides farmers with comparative advantage over conventional agriculture in European markets (Vaast *et al*, 2009), however it is not certain whether or not organic farming will produce enough food to meet current and future needs in response to continued population growth (Scialabba, 2007; UNCTAD, 2008). FAO Director-General Jacques Diouf indicated that "while organic agriculture contributes to poverty reduction and should be promoted, it cannot feed 6.8 billion today and 9.1 billion in 2050" (FAO, 2009b).

For example, in 1960s and 1970s Asian countries including China, India and Philippines underwent a "Green Revolution" by adopting new improved crop varieties especially hybrids of wheat and rice, and increasing application of irrigation, fertilizer and pesticide (Paarlberg, 2008). The Green Revolution is widely criticized for causing environmental damage, however, the positive impacts were that this move helped Asia to feed its rapidly growing population, reduce its permanent dependence on foreign food aid, and increase farmers' income and the country GDP making them more affluent (IFPRI, 2002). Currently these countries are also utilizing GM technology to further improve their crop varieties so as to reduce their dependence on inputs like pesticides, and to increase resilience of their crops to climate change. Asian countries have ensured substantial continued investment in research and development and human and infrastructural capacity building even after the initial donors such as the Rockefeller and Ford Foundation ceased their funding. Given the Europeans dominance of funding and their reluctance regarding GMOs, use of GMOs as a strategy to adapt to climate change will require finding alternative source of funding. This can be achieved by providing an enabling environment through legislation, and having clear national priorities. Governments should also put in place mechanisms to ensure continued sustainable investment in agriculture even after donors withdraw.

To provide an enabling environment for investment in research and development, and application of GMOs, SSA countries need to have in place updated laws related to GMOs. Many SSA countries are signatory to international treaty responsible for transboundary movement of GMOs known as the Cartagena Protocol on Biosafety, which advocates for a "precautionary approach" to GMO adoption (CBD and UNEP, 2003). While there are benefits to the precautionary approach, the stringent regulatory system adopted from the EU by many African countries may hinder utilization of the technology. This may especially disadvantage technologies that could benefit of the small-scale farmers because only wealthy seed companies interested in export crops will be able to afford the regulatory approval requirements. No comparable source of funding exists to support regulatory approval for technologies developed for poor producers. Also such a system may create a difficult environment for external investment and partnerships in GM technology. Therefore, SSA countries need to develop national legislation that allow for flexibility in governance so that technologies that are likely to address the food security situation and enhance the livelihood of resource-poor farmers are given greater consideration. The legislation needs to clearly state the national priorities for utilisation of GM technology for development but should also allow for flexibility taking into consideration changes in knowledge and local needs.

As SSA countries prepare to adopt GMOs, regulatory authorities need to institute a system for a thorough case-by-case risk assessment of GM crops to enable the country to utilize the benefits of the technology while controlling for any potential risks. Countries should have in place national biosafety committees responsible for reviewing all applications related to GMOs including assessing potential risks for introducing them to the local environment. These committees need to comprise members from various relevant sectors such as scientists, health workers, policy makers, consumers and farmers' representatives. Thus risk assessment should be a multidisciplinary approach with stakeholder engagement.

The multidisciplinary approach for risk assessment is necessary for effective governance of GMOs as the decision takes into consideration a diverse scope of the local concerns and values. However, this approach may result in a delayed or erroneous decision. This outcome can be prevented by conforming to the requirements for effective governance (Dietz *et al*. 2003; Ortwin, 2008) described in the subsequent paragraphs.

First, timely distribution of accurate information to stakeholders is necessary to develop trust and enhance confidence in the processes. Information provided should be comprehensive and relevant so that the decision-making process is focused and considers all pertinent concerns. Oversimplifying the science or skewing the results may cause inaccurate risk management decision, while providing too much detail that does not address key concerns can undermine the audience's trust in the system (Stern and Fineberg, 1996). The information provided should include uncertainties and tradeoffs to be considered in the decision (Ortwin, 2008). To achieve this, clear policies are needed on what is nationally considered valuable and risky, as well as standards for information sharing.

Second, involvement of a wide range stakeholders' in the decision-making process is likely to result in conflict due to the diverse interests and concerns of the different sectors. Addressing such conflicts is another requirement for effective governance (Dietz *et al.*, 2003; Ortwin, 2008). Various approaches can be used to achieve conflict resolution including voting by ballot, intense deliberations, or legal redress. Deliberations allow for a negotiated and comprehensive decision-making process, however sometimes this approach can also be costly and cause prolonged.

Third, effective governance requires that standards must be developed and complied with by all stakeholders to ensure safe application of the technology. The countries and institutions need to establish mechanisms to ensure homogeneous compliance of these standards. This can be achieved through "command and control" where violation results in sanctions such as fines or jail terms. The severity of the sanction should increase with number of violations (Ostrom *et al.*, 1994). This approach requires funding to monitor compliance and ensure enforcement of these standards. An alternative approach is to encourage "voluntary compliance" through incentives (Dietz *et al.*, 2003). Incentives may include research grants, tax reductions and compliance recognition through awards.

Fourth, effective governance also requires human and infrastructural capacity to regulate introduction of technologies (Dietz *et al.*, 2003; Ortwin, 2008). As discussed earlier, SSA countries need to build a substantial and competent human resource as well as well-equipped testing facilities for environmental and food safety assessment of GMOs. Other infrastructures such as communication and transportation systems are also necessary for effective governance. Finally, effective governance requires flexibility so that the regulatory system evolves with changes in knowledge, social values, and local and international situations.

Conclusion

With growing evidence that the threats of climate change are real and already happening, SSA countries need to start implementing a plan for adaptation, including ensuring food security and increased income for majority of the citizens who depend on agriculture. Increasing resilience to climate change is going to require utilizing "all the innovations and ingenuity that the human race is capable of" (WDR, 2010).

If safely used, GMOs can contribute to overcoming the challenge from climate change by speeding up breeding, and developing stress-resistant crop varieties when conventional breeding is not effective. However, for effective utilization of GMOs as an adaptation strategy, the country will need to: develop capacity in IPR management at national and institutional level; have in place appropriate legislation that clearly states the national objectives and concerns; and increase investments in agricultural research and regulation to facilitate introduction of GMOs that address local needs. It may also be necessary to encourage regional and internal markets, while respecting the quality requirements for the international markets so as to reduce farmers' vulnerability to fluctuating international prices. Setting up these systems requires substantial funding and most SSA countries will require external assistance so that it safely and effectively integrates GMOs with other improved technologies to meet the growing demand for food, and increase the adaptation capacity to climate change for SSA's agriculture.

Acknowledgement

Special thanks to Prof. Jim Hancock, Department of Horticulture for the Graduate assistantship, and to the Environmental Science and Policy Program, Michigan State University for the technical support.

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