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Implications of GM crops in subsistence-based agricultural systems in Africa

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Abstract

Africa has deep contentions on the use of GM crops in agriculture, similar to those found in Europe and elsewhere. However, it is apparent that the debate is most protracted on the continent with two entrenched viewpoints i.e. the pro-GMO and anti-GMO groups. The challenge for an acceptable consensus is attributable to a complexity of issues relative to the introduction of GM maize into small-scale farming systems that fundamentally relies on open pollinated varieties (OPVs) with broad genetic backgrounds and tolerance to diverse biotic stresses, and which is usually produced for the informal seed market. Other factors relate to the generally low capacity of African states and weak mechanisms for assessing the potential risks posed by GM crops. The lack of public awareness, participation and information sharing are additional limiting factors.

These issues have weakened government and policy responses to the potential deployment of GM crops on the continent. This review draws on research-based evidence as a basis to comment on some key issues to inform the development of biosafety standards in African countries. We conclude that the potential introduction of GM crops into small-scale farming would lead to huge consequences from emerging ecological, economic and trade impacts if these issues raised are not taken into account in decision-making processes.

Introduction

The objective of this review is to draw attention to some key issues within the African context relevant for improving biosafety implementation efforts on the continent. The task of predicting how the presence of transgenes in agricultural crops is likely to influence the ecology and development of a recipient environment and society is highly demanding and requires best available knowledge from a number of different disciplines (Myhr & Traavik 2007). Moreover, socially responsible actions must also be based on knowledge about the cultural context and agricultural practices, and the level and demands of farmers and the seed industry (Mugo et al. 2005). The arguments in favour of genetically modified (GM) crops for small-scale farmers center on selective advantage in the form of insect pest resistance or herbicide tolerance with the promise of higher productivity. However, both insecticidal traits (Bt) and herbicide tolerance traits (HT) raise concern for long-term reliability against resistance development, biodiversity conservation, food security and environmental sustainability in African agriculture and related ecosystems. The perceived benefits of growing GM crops for poverty alleviation in Africa must be evaluated together with possible conflicts posed to the environment as well as with the bigger picture of food insecurity on the continent (deGrassi 2003).

Environmental uncertainties related to GM crops, and in particular for Bt maize include potential development of resistance among target insects, non-target adverse effects on beneficial organisms and cross hybridization with non-GM varieties, with subsequent loss of biological and genetic diversity (Andow & Zwahlen 2006). The contention on the use of GM crops in small-scale farming has been on this basis. Presently, the debate has assumed another dimension. The argument stands to reason that whether GM crops are grown or not within small-scale systems, one must take into account that the African context has a low level of control, testing, monitoring and possible response measures. Furthermore, whether modern biotechnology will meet the needs of poor producers and whether the capability exists in current input markets to deliver the seed and information that embodies GM technology have long been debated (Tripp 2001). This makes Africa at large particularly vulnerable to potential unintended and undesirable spread of GMOs due to a consecutive mixing with non-GM material. Maize seed is easy to store and transport and through pollen flow, characteristics can easily be transferred between varieties (Smale & De Groote 2003). Chances are high that GM crops, as well as their associated food and feed products traded on the world market could still find their way into countries and places where they were originally not anticipated or accepted. Transgenes could spread across national borders regardless of whatever policy exists. However, it has been indicated that Africa needs to strengthen its capacity both with regards to research and development as well as with regard to legal and policy aspects of biosafety (Eicher et al. 2006). This review aims at discussing implications of GM crop introductions in African food systems in particular maize based on science-based evidence. Possible impacts are discussed and we suggest ways forward for how the challenges could be mitigated or resolved, with the intention to improve the African biosafety situation.

Agricultural structure

The agricultural structure in most of sub-Saharan Africa is not only small-scale but typically dense. Dominance of small fields with relatively few larger fields in the neighbourhood is common. This type of agricultural setup would facilitate the possibility of transgene flow through higher cross-pollination among small field neighbours

(Aheto et al. 2011). Maize has a high risk of gene flow through cross-pollination, particularly when landholdings are fragmented, varieties are planted contiguously, and farmers recycle, exchange, or mix maize seeds (Smale & De Groote 2003). This is of special interest to estimate impacts not only on smallholders but also on a wider number of smaller fields with potentially diverse locally-grown seeds. GMOs if introduced would clearly spread and diffuse transgenes due to high rates of cross-pollination among neighbouring fields (Aheto 2009; Bøhn et al., this issue). This would pose a major obstacle in maintaining GMO-free zones as proposed in the African Model Law on Safety in Biotechnology. GM crops, if introduced, would pose a major challenge to maintain GMO-free zones also due to the prevailing systems of seed acquisition and local exchange which would pose a further complexity. High density of fields poses a major difficulty to practice any legal isolation distance requirements within the small-scale setting. In this context, the presence of feral maize on the landscape would contribute to the unintended persistence of transgenes in the local maize gene pool.

Farming within the African context is mostly operated on small plots of land mostly in a size range of below two hectares (Fig. 1). Seed saving guarantees multi-year seed supply among farmers as an important cultural practice that enhances local seed diversity, crop improvement and secures household food security (deGrassi 2003). For example, in smallholder agriculture in Kenya, open pollinated varieties and seed-saving and exchange are common (Mwangi & Ely 2001). Similar practices are implemented throughout Africa (Smale & Phiri 1998; Smale & DeGroote 2003) and also in South Africa where there is a strong and regulated private seed sector, seed production and marketing system (Mphinyane & Terblanché 2005). The use of genetically modified varieties would limit options for these traditional practices and put farmers and their households at risk. The geometry of fields, mostly small, dense and often close to each other renders gene flow highly likely (Tab. 1). These issues have adverse implications for organic and conventional food production but also for the purity of non-GM seed production.

Table 1: Features of small-scale maize farming within the African context.

Feature	**Ghana**	**Zambia**
Settlement description	Urban periphery (Accra, 2006)	Rural area (Chongwe, 2012)
Area of investigation	1 km^2	1 km^2
Number of fields per km^2	58	97
Average field acreage from GIS records (ha) (minimum – maximum acreage in m^2)	0.81 (1.0 – 35000.0)	0.49 (13.0 - 43609.0)
Fractional maize area as a % of total maize acreage	4.5	48.0
Range of distances to next field (m)	5 – 10	2 – 10

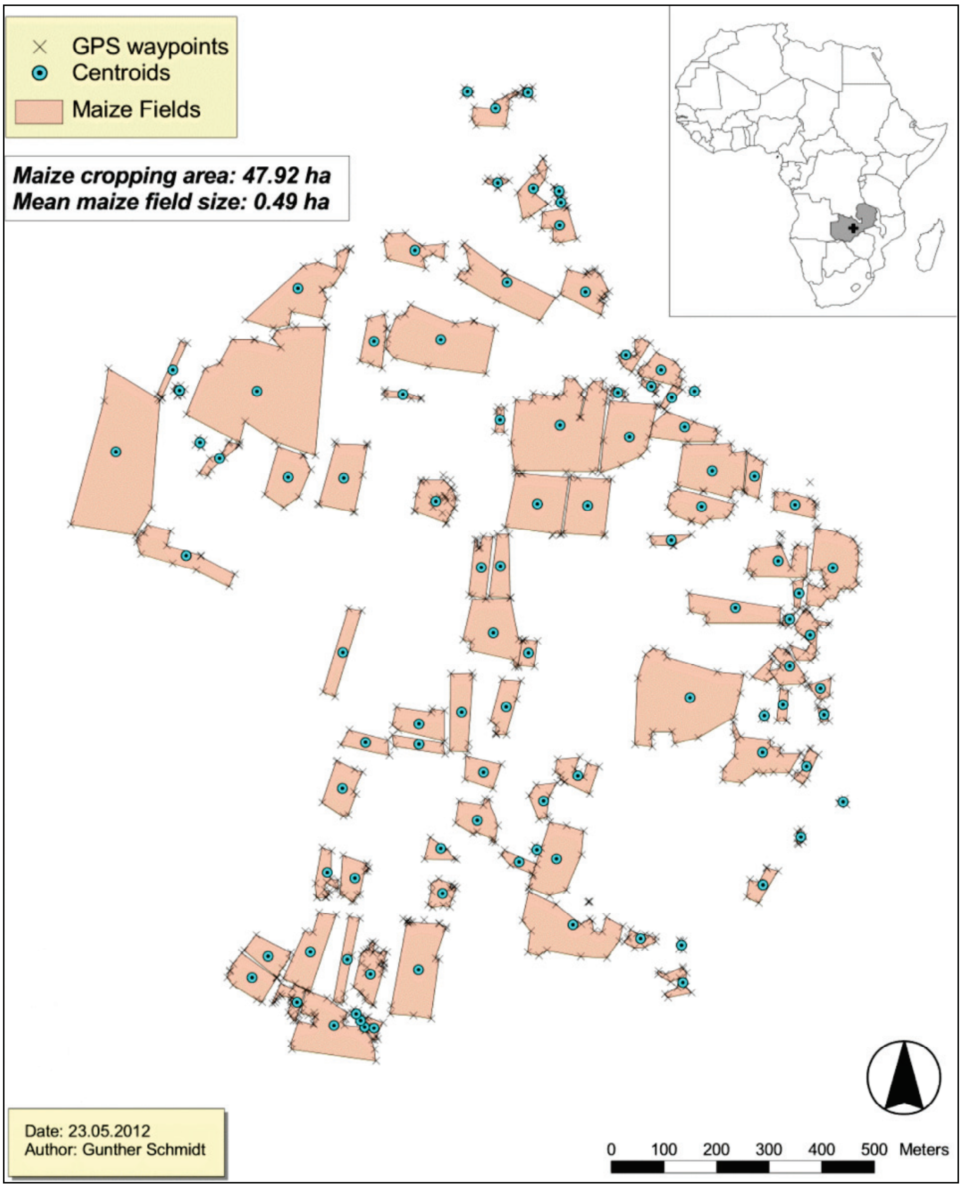

Figure 1: Example of a typical small-scale maize agriculture in Africa encompassing a large sector of smallholder farming crucial for food security (Chongwe Province in Zambia, March 2012).

Administrative and regulatory competencies

Establishing the capacities to monitor the fate of transgenic DNA ("transgenes") in the environment is an essential element in any biosafety effort. Any regulation of genetically modified organisms (GMOs), including market-driven differentiation and governmental regulation of transgene-containing products must include some measure of detection and monitoring of transgenes. On the other hand, transgenes also offer unique markers with which to trace the flow of genetic materials in general through complex ecological situations. Genetically modified crops are traded on the world market and therefore require countries to set up regulations for transboundary movements. The

Cartagena Protocol on Biosafety (2000) is the only international treaty specifically regulating GMOs and all parties have to take legal, administrative and other measures to implement the protocol, which often includes the development of national biosafety regulations. In the African context, regulations as well as enforcement on biosafety are still largely limited. The UNEP-GEF and the African Union operated framework Projects and now NEPAD have made modest gains in assigning some administrative competencies. Unfortunately independent risk assessment data that draws on regionally acquired environmental data is still widely lacking (Aheto et al. 2011). For biosafety, this is problematic since GM varieties on the world market are continuously being developed and notified for conditions in Africa that differ in climate, agricultural structure, interacting organisms (both pests and beneficial organisms) and differ in consumer preferences. There are therefore highly relevant gaps in this field required to be filled.

Seed use and seed exchange practices

A majority of traditional farmers acquire seeds for planting from a wide variety of sources within the informal sector. Acquisition of seeds as gifts from neighbours or home-saved from previous harvests are relevant sources. Commercial procurement of seeds does not rely upon a need for insect resistant varieties but rather on more stable high yielding varieties that may be shared among farmers in subsequent seasons (Fig. 2). Farmers would like to grow different crop varieties, i.e. land races. Also, seed exchange among farmers limits the possibility of co-existence of farming systems involving conventional and GM crop farming, possibly lowering the economic value for conventional and organic food producers and causing a decline in crop genetic purity.

A crucial factor relates to the non-distinction between food grain and seed grain by small farmers. Therefore any GM food import or aid would eventually end up in the cultivation systems of farmers. Another critical issue also relates to the fact that commercially-oriented subsistence farmers, in many cases, procure seeds from formal seed stores with a notion to benefit from high-yielding and early maturing varieties. The trait of insect-resistance is not among the most important options when it comes to choice of seeds for planting, especially if the target pest is a minor problem and farmers cannot physically observe the protection provided by the Bt trait (Assefa & van den Berg 2010). Most often, agronomic factors such as yield potential, drought tolerance, husk cover of ears, as well as resistance to storage pests and rain damage may be overriding factors in hybrid preference amongst farmers (Assefa & van den Berg 2010; Grouse et al. in review). Farmers may not discern the benefits from the inserted trait, or may view these as less important than some other disadvantageous traits of the new variety relative to those they currently grow (Smale & De Groote 2003).

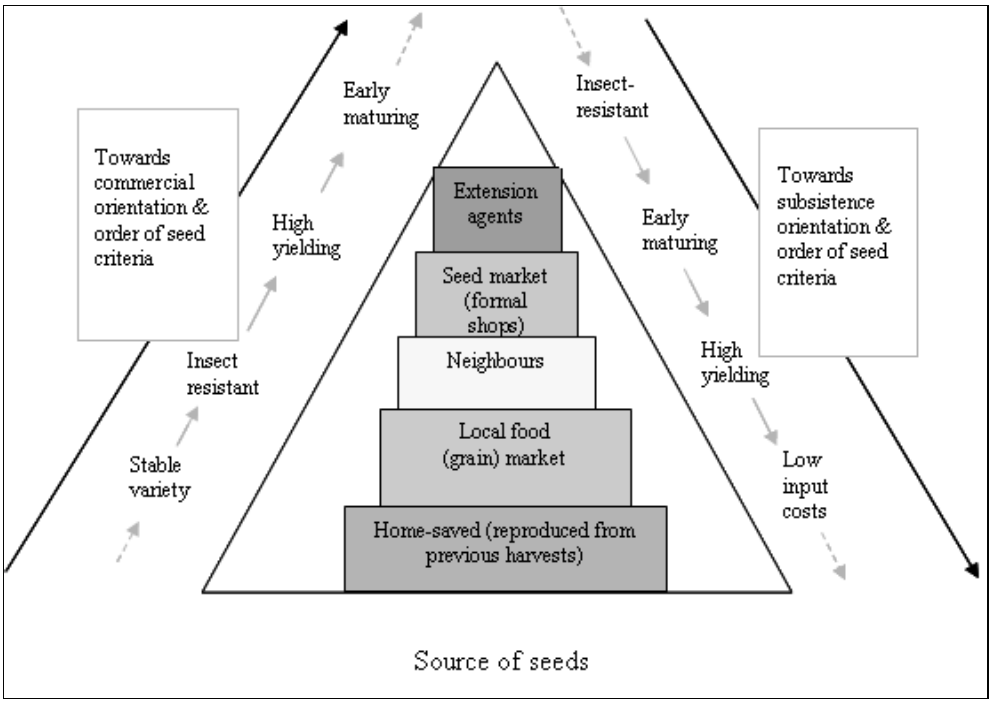

Figure 2: Conceptual model of farmer seed selection criteria (modified from Aheto 2009).

Coexistence and trait segregation

Systems of seed use and exchange will impose further complexity to coexistence between GM and non-GM since distinction is hardly made between food grain and seed grain with respect to seed sown, as smallholders cultivate various landrace open-pollinated varieties alongside available commercial hybrids. This makes trait segregation difficult if not impossible. Therefore, coexistence of GM and local non-GM systems as being tested under the European conditions would be impractical for the African situation. In theory, different planting times among neighbouring farmers seem not practically implementable because most small-scale farmers do first plantings to take advantage of the rains when it comes, i.e. not under their control. Thus, co-existence of GM and non-GM crops would be an impractical scenario under the small-scale context.

Food security, genetic resources conservation and trade

A high number of African households are supported per acre of farm with women constituting the majority. Therefore, should GM crops / foods be adopted, these should be under conditions that avoid potential risks. Time and effort must be devoted to on-farm trials before any interventions in this regard. Policy makers and researchers in developing countries should carefully assess environmental and socioeconomic risks (such as the major risks to biodiversity, the prospects of insufficient out-crossing distances, the relative absence of clear labeling and other threats to seed purity from adjacent traditional food production) before farmers change their conventional farming methods to GM (Azadi & Ho 2010). Introduction of GMOs could lead to transgenic contamination of local seeds, with a high probability of impacting areas where organic food farming is likely practiced. This could potentially lead to economic and social impacts. Consequences on native biodiversity cannot be ruled out. Such infringement of natural borders has been described as a crucial ethical concern. Also, options for improving conventional or organic export trade and foreign income will be closed under an agricultural system where GM and non-GM crops are mixed up. The documentation of crop purity is a must for premium price products in the organic trade, a niche in growth and in developed and developing countries (Hewlett & Azeez 2007). Crop management traditions, including local adaptation to food security through seed saving cultures of landraces must therefore be upheld and protected.

Consumer choice, liability and patent infringement

The possibility to allow for consumer choice and trait segregation is largely minimal. Containment of GM products, including potential mitigation or removal from the environment if undesirable results should become apparent would require serious and realistic provisions to enforce within the African context. Central planning of production and regulation of agricultural products marketing would be difficult to implement. To orient producers to meet the needs of consumers would constitute a daunting task since the producers are mostly the consumers and vice versa. Since transgenes are protected by national and international laws as intellectual property (IP) (Heinemann 2007), small farmers who unintentionally grow GM crops in their farms may face legal actions. Patent infringement is considered a very serious issue and even the use of certain transgenes and locally adapted GM crop varieties may be problematic (Mugo et al. 2005). The case of Percy Schmeiser versus Monsanto provides clear indications that infringement of IP may be followed up even in a situation where the farmer does not know or does not want the transgenic trait. This could be a serious issue for example in organic production. Patent infringement under the provisions of the Canadian Patent Act for example was seen as illegal even when farmers were inadvertently contaminated by neighbours who cultivated GM crops (Heinemann 2007). Should a similar case occur in the African context, it might negate small farmers' rights to save and replant their own seeds and thus break down long histories of traditional culture.

Monitoring implementation

Biosafety measures are comparatively more difficult to implement within the African context, in relation to the developed countries, since the resources that can be invested in the establishment of anticipatory regulatory efforts – including monitoring and enforcement – are substantially less. On a policy level, some gains have been achieved through the established National Biosafety Frameworks (Mclean et al. 2002), which provide basic regulatory guidance regimes, as a basis to move forward. As indicated by Eicher et al. (2006) African governments need to develop a national biotechnology strategy that defines how biotechnology fits into the overall national agricultural research strategy, agricultural development strategy and target farmers and sectors where biotechnology tools will be applied based on needs and priorities identified by various stakeholders. A key measure would be to effectively regulate GM food and feed products imported into the country since once they are admitted; it is not feasible to control their further spread and diffusion into on-farm seed stocks and into the environment.

Public participation

Maize has a critical role for nutrition across the African continent. It is the most important staple food crop. Therefore, public awareness on GMO issues and discussion on implications must be enhanced (Egziabher 2007). People have the right to participate and contribute to decision-making when it is about their staple crop, grown in gardens and fields, guided by their own traditional knowledge and culture. Coherence in the administrative and regulatory structures is limited, as could be seen in the operation of extension services in urban areas. Dealing with uncertainties and contradictions are among key areas that need to be addressed. Efficient programmes should be developed to support farmers to improve their responses towards effective seed saving and cropping management. It should however be acknowledged that to orient smallholder producers to meet the demands of consumers will be difficult to achieve in Africa (Mugo et al. 2005) because producers are also the consumers. The most important freedom of choice for farmers in Africa seems to be the ability and right to save and share seeds without risk of contamination by transgenes and to maintain seed availability and exchange as an open system.

Research financing on risk assessment

A major setback is the limitation in the capacity and financing of biosafety initiatives. This affects biosafety implementation efforts and limits the effectiveness of risk assessment procedures. Independent risk assessment research that is not influenced by external business interests is a requirement for a credible regulation and administration acting in the interest of the general public. Risk assessment is the identification and evaluation of potential adverse effects of genetically modified organisms on the conservation and sustainable use of biological diversity in the potential receiving environment, taking into account also risks to human health (Cartagena Protocol 2000).

African countries generally have limited scientific competence to monitor, research and conduct risk assessments that examine the full health, environmental and socio-economic implications of genetic engineering and GMOs. For African countries, the entering into force of the Cartagena Protocol on Biosafety in 2000 provided an important benchmark for addressing risk-related issues of GMOs. The Protocol stipulates that the national approval of a GMO should be based on prior informed consent. For approval, a complete risk analysis is required. If the variety was developed in an African country, the effort has to be made completely in that country. If it is a foreign variety for which an applicant seeks consent, the risk evaluation should take into account previous risk studies but also complement it with additional information that covers specific conditions of the country for which consent is being sought (Aheto 2009).

Risk assessment therefore is expected to cover the full spectrum of relevant effects i.e. direct or indirect, immediate or delayed, cumulative and detrimental effects of GMO on biodiversity, environment and human health (Reuter et al. 2008). In the event of an irreversible or detrimental effect, decisions should be based on the precautionary principle. If the effects are assumed to be negligible, they will be considered irrelevant and ignored. If effects are found to be relevant or significant, then the assessment of risk should be extended and broadened. However, it is important to note that risks that are irrelevant in one environment may not be irrelevant in another. Thus, in risk analysis of GMO, a combined knowledge on scientific and technical procedures is necessary. Capacity building is crucial for the implementation of effective biosafety standards on the African continent. The majority of African countries lack capacity to execute effective biosafety investigations including laboratory testing according to the requirements of their own environmental and social situation.

Conclusions

Large-scale consequences of small-scale farming with GM crops are implied in this analysis. The introduction of new technologies that do not take into account the contextual factors in Africa will cause problems and ultimately fail. From an ecological perspective, introduction of GM crops would lead to uncontrolled large-scale spread and persistence of transgenes within the small-scale agricultural systems in Africa with unpredictable recombination and evolution in crop meta-population. The socio-cultural implications relate to intellectual property rights, which threaten traditional seed use patterns. Impurities in harvest would prevent development and export-options. Major challenges in regulatory decision-making are envisaged since traceability, administrative regulation and resistance management regimes are difficult to impossible. Furthermore, huge increases in administrative costs are expected owing to laboratory analysis, monitoring and assuring quality control in testing.

This paper therefore makes a strong call for a precautionary approach to biosafety in the face of uncertainty. Independent research and biosafety capacity building across Africa are top-ranked priorities in food security. The question of transgene flow in crop plants must be addressed as a meta-population problem, since transgenic plants will be exchanged between local (and over time more remote) seed pools due to human agency, triggered by individual farmer decision-making, commercial forces, governmental regulation, etc. The convergence of ecological, commercial, cultural and regulatory interests in understanding flows of transgenes is perhaps most noticeable in the agricultural environment of major crops.

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