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THE IMPACT OF BIOTECHNOLOGY ON DEVELOPING COUNTRIES

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BRIEFING

THE IMPACT OF BIOTECHNOLOGY ON DEVELOPING COUNTRIES

Abstract

Modified (GM) crops are increasingly grown in developing countries and can lead to socioeconomic benefits and costs depending on where and how they are adopted. After examining conventional assessments of farm-level indicators such as: yield increase, pesticide costs, farmers' incomes from GM crops, the paper goes on to argue that a variety of structural issues at the national and international level have to be considered in order to obtain a comprehensive picture on the potential which GM crops have to enhance food security in developing countries. Hence, the paper further explores the relationship between GM crops and biodiversity against the backdrop of agro-ecology as a potentially beneficial concept for smallholders in developing countries.

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EXECUTIVE SUMMARY

After the food crisis in 2008 the number of hungry people increased to over one billion with food prices remaining high in subsequent years. Strategies to curb global hunger in developing countries have had limited success. Agricultural production in developing countries has lagged behind and is increasingly affected by climate change and extreme weather events. Many developing countries, therefore, are far behind schedule to meet the Millennium Development Goal of halving the number of hungry people by 2015.

After decades of neglecting the agricultural sector in developing countries, a growing consensus is emerging among international institutions that increased investment in agriculture targeted to benefit small farmers is central to socio-economic development and food security. Development cooperation funds and national support to agriculture in the next years and decades will have a significant influence on the direction agriculture in developing countries will take. Priorities in funding and market regulation will either push for the production of commodity crops for export or for smallholder production for sustenance, local food supply chains and regional markets. One of the most controversial debates arises between the advocates of the application of biotechnology and the promotion of genetically modified organisms (GMO) to foster food security in developing countries and alternatively, those that emphasize the productive potential of agro-ecology as a more egalitarian and environmentally sound strategy for sustainable agricultural production. The increasing polarity of the debate is perhaps the greatest challenge to understanding where and when benefits of GM crops exist and for whom as well as assessing situations where GM commercial seed varieties may be less suited to institutional contexts or specific agro-ecological environments.

In the last decade, the uptake of GM crops in developing countries has increased and thus potentially provides important insights on their value and usefulness for food security. This paper finds the socio-economic impacts of growing GM crops in developing countries to be highly variable, producing yield increases and economic benefits in some rather short-term studies, but far less in studies taking a long-term perspective (over more than ten years). It becomes clear that the socioeconomic impact of GM crops must be evaluated on a case-by-case basis and that the performance of GM technology to increase incomes is dependent on multiple regional but also external variables.

Using several case studies from Argentina, China, South Africa and Mexico, this paper finds the accrued benefits and/or disadvantages to be highly dependent on the context of the country where they are grown (environmental, social, political and economic). Countries with functional and effective regulatory institutions (public and/or private) were found to experience more equitable distribution of benefits and improved incomes, while those lacking institutional support experienced negative outcomes, such as increased inequality between farmers and other rural actors. The international context and specifically trade relationships between countries were identified as influential in determining socio-economic outcomes with important implications for economic benefits but also for socio-cultural traditions and livelihoods.

In a second section, the potential risks of GM crop expansion for biodiversity are explored. It is argued that biodiversity is crucial for sustainable food production and future food security, since agricultural diversity can help mitigating the effects of climate change and extreme weather events. Food production for food security, therefore, depends on agricultural production systems that are resilient, sustainable and which produce benefits that are equitably shared. In this respect, the final section evaluates the role of agro-ecology to meet the production needs of a growing population, the sustainability needs of the environment, and the livelihood needs of smallholder farmers. Since the adoption of GM crops contradicts some of the core principles of agro-ecology, the study concludes that

the agricultural production model associated with GM crops should not be promoted as enhancing food security and that the approach of agro-ecology is better suited to the economic, social and environmental realities of farmers in developing countries.

1. INTRODUCTION

A growing number of developing countries, aid organizations and international lending institutions are considering GM crops as an essential tool in addressing global poverty and food insecurity, which are two priorities identified by the Millennium Development Goals.

Food security dominates the international development agenda, but strategies to curb chronic hunger in developing countries have had limited success so far. Over the past several decades, world aggregate grain supply has achieved unprecedented production levels, with cereal production consistently outpacing demographic growth (Shattuck, et. al., 2010).[1] At the same time, the number of food insecure people has steadily risen to over one billion. A situation has emerged where, despite adequate supply, food remains unaffordable and inaccessible to the poorest and most vulnerable, the vast majority of whom live in rural areas in developing countries working on small plots of land. The challenge, therefore, is not simply to produce more food, but to empower the poorest producers, particularly smallholders in developing countries. To sustain their incomes, smallholders need consistent access to land, water and financial resources and more stable and productive yields (de Schutter, 2011a). Farming methods must also match the realities of smallholder farmers in developing countries that work in regions characterized by poor soils and climatically harsh conditions bearing, for example, a high risk of droughts. Food production that achieves food security depends on an agricultural that is resilient, sustainable and from which the benefits are equitably shared.

A general consensus exists that increased investment in agriculture targeted to benefit small farmers is central to socio-economic development and food security (IFAD, 2012). Development cooperation funds and national support to agriculture in the next years and decades will have a significant influence on the direction agriculture will take in developing countries. Priorities in funding and market regulation will either push for the production of commodity crops for export or on smallholder production for sustenance, local food supply chains and regional markets. One of the main controversial debates arises between the advocates of the application of biotechnology and the promotion of genetically modified organisms (GMO) to foster food security and alternatively, those that emphasize the productive potential of agro-ecology as a more egalitarian and environmentally friendly strategy for sustainable food production and security in developing countries. The increasing polarity of the debate is perhaps the greatest challenge to understanding where and when benefits of GM crops exist and for whom, as well as, assessing situations where GM commercial seed varieties may be less suited to institutional contexts or specific agro-ecological environments.

The potential benefits of GM crops include increased yields, enhanced nutrition, improved resistance of crops to pests and disease, and tolerance to environmental stresses such as saline soils and droughts. On the other hand, GM crops can pose risks for biodiversity (Hawes et al., 2003), and could undermine the economic and social structures that provide the livelihoods to rural smallholder farmers (Fransen et al, 2005). Providing a clear picture on the overall impact of GM crop adoption in developing countries is made difficult by the fact that long-term studies on farm incomes are still scarce, which take price dynamics, resistances of weeds or pests against the GM trait and differences in factor inputs (such as

[1] Over the last twenty years, food production has risen steadily at over 2% a year. Meanwhile, over the same period, population growth has slowed to 1.09% per year, with an average growth rate of 1.2%

pesticide applications) into account. Moreover, due to high commercial interests, it is often unclear whether studies paid by GM industry are biased in their outcomes. The same, however, is true for the wide community of opponents against GM adoption, making it difficult to generate a "based-on-facts" view on this highly polarised issue.

The aim of the standard briefing is to present balanced information on the potential impact of GM crops in developing countries focussing on studies that take a long-term perspective. The briefing critically discusses the potential role GM crops could have in the quest of sustainable economic development and food security in the developing world. In this context, it touches upon the socio-economic effects of GM adoption for farmers, some implications of the expansion of GM crops in developing countries and the current state of knowledge on the risks GM crops and their cultivation might pose for biodiversity and the environment.

2. ECONOMIC AND SOCIAL BENEFITS/DRAWBACKS OF GMO ADOPTION FOR FARMERS IN DEVELOPING COUNTRIES

2.1 General overview

Using GM crops in agriculture and in particular in developing country economies is associated with a wide array of potential benefits and costs that impact farmers' livelihoods. This paper identifies three levels of influence that can impact the social and economic outcomes of GM crop adoption. One level being the individual farmer or farm-level, then the national government structures, and the level of international relations between developed and developing countries.

As of 2011, GM crops were grown on 160 million hectares in 29 countries, with developing countries accounting for around half of the total land used to grow GM crops worldwide (See Figure 1 (ISAAA, 2011)). Despite their widespread cultivation, only four commercial GM crops—soy, maize, cotton and canola—dominate the global market. The two dominant agronomic traits are GM crops modified to express the *Bacillus thuringiensis* (Bt) toxin, a natural insecticide, and crops modified to herbicide tolerance (HT). For HT crops, the plant is genetically modified to tolerate an application of a specific herbicide, which can simplify weed management systems for farmers and reduce the overall use of herbicides on the crop (Qaim, 2009). Herbicide tolerance is the prevailing trait that is deployed in all four dominant crops, while maize and cotton are the only two insect resistant GM crops currently available at commercial scale (Sanvido et al., 2007).

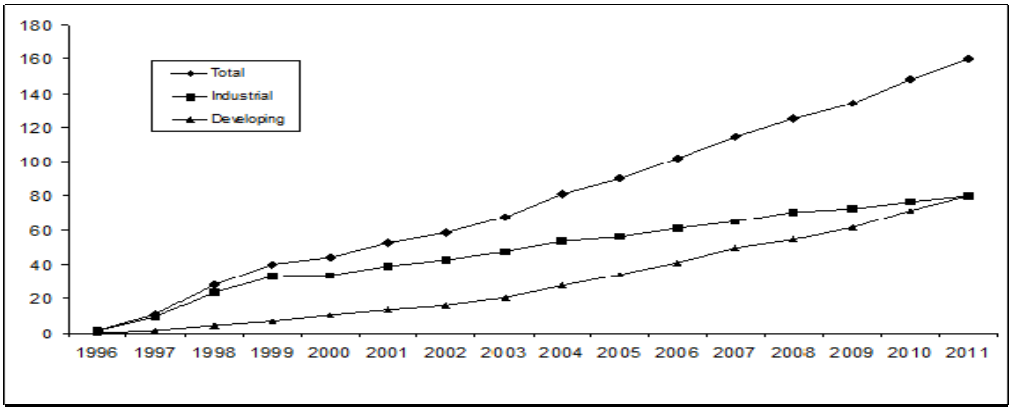

Figure 1. Global area of GM Crops, 1996-2011: Industrial and Developing Countries (Million Hectares) (James, 2011)

2.2 Socio-economic assessments of GM crops at the Farm Level

In a recent study, Carpenter (2010) covers 12 countries worldwide (among which are the Philippines, India, South Africa and Mexico) and summarises results from 49 peer-reviewed publications that report on farmer surveys comparing yields and other indicators of economic performance for adopters and non-adopters of GM crops. According to Carpenter, financial benefits from growing GM crops derive from increased yields, and can also be attributed to lower production costs by reducing pesticide use, as well as labour and fuel costs. The economic impact at farm-level, therefore, depends on the costs and returns of growing GM crops compared to non-GM crops. Some factors identified by Gómez-Barbero and Rodriguez-Cereozo (2006) that influence financial gains at farm level are:

1. Differences in yield (Bt crops are expected to **reduce yield losses** attributed to pests);
2. Reductions in insecticide costs (some Bt crops are expected to **reduce insecticide use**);
3. Reductions in weed management costs (HT crops are expected to save costs through **simpler and more flexible weed management regimes** based on a specific herbicide);
4. Differences in **seed prices** (GM seeds are usually more expensive than conventional counterparts);
5. Differences in price received by the farmer between GM crop and its conventional counterpart with GM crops often obtaining a **price premium**.

HT crops do not generally improve yields but often reduce expenditures on herbicides and thus improve farm incomes. In some developing countries where herbicides had not previously been used or where weed species had been particularly pervasive (common in tropical climates), yield increases were observed when GM crops were adopted (Qaim, 2009). For example, HT corn in Argentina increased yield by 9 percent, and HT corn in the Philippines improved yield by 15 percent (Brooks & Barfoot, 2010). Simplified weed management systems provided by GM crop adoption over the short term, however, are not always sustained. In the US, weeds have become resistant towards the herbicide applied only recently, 16 years since the adoption of HT soybeans. Such resistances have pushed American farmers to apply increased quantities of more toxic chemicals in order to sustain reasonable yields.

Bt cotton is the most extensively studied crop in relation to socio-economic impacts in developing countries, because it is a common crop grown by small farmers in developing countries (Raney, 2006). In contrast to HT crops, Bt crops generally improve yields and in this way improve farm-level incomes. The average yield increases for Bt cotton and Bt corn vary depending on the extent of the pest problem prior to adoption of GM crops and local climatic conditions. For instance, 54.8 percent yield increase for Bt cotton has been observed in India since its introduction in 2002, a 28.6 percent yield increase for Bt cotton in Argentina since its introduction in 1998, a 24.1 percent increase in the Philippines since its introduction in 2003, and 24.3 percent for Bt cotton and 15.3 percent for Bt corn in South Africa since their introduction in 1998 and 2000 respectfully (Popp et al. 2012). In addition to improved yields, Bt crops have also reduced costs on pesticides, which have had positive health impacts, particularly in developing countries where small farmers tend to experience high exposure to poisoning because of faulty equipment (e.g. leaky backpack sprayers) (Antle, 1994).

The price of GM seeds compared to conventional seeds is a key determinant of incomes at the farm level after GM adoption. GM seeds tend to be more expensive than conventional seeds because they are designed by biotech businesses that require a "technology fee"[2] often secured through patents or

[2] See review in Kaphengst et al., 2011 and especially for Bt Cotton: Qaim and de Janvry, 2003

breeders' rights. Most developing countries do not have strict Intellectual Property Rights (IPR) systems in place, and for this reason seeds remain affordable (see Argentine case study on next page). In fact, most developing countries as of today either recognize the rights of small farmers to save and exchange seed, or there is no relevant IP legislation forbidding such practices (see Oberthür et al. 2011). However, developing countries are under increasing pressure from GM business and governments in developed countries to strengthen their IPR systems, which would restrict the traditional practices of farmers to save, sell and exchange seeds, which in turn could lead to higher costs of patented seeds and to an overall loss in farmers' incomes (Louwaars et al. 2005).

A second issue associated with strengthening IPR systems is the fact that patents increase the risk of farmers' liability for accidentally growing patented GM crops. In the US, biotechnology companies have brought patent infringement lawsuits against farmers, whose fields were accidentally contaminated by an adjacent farmer's patented GM seeds, effectively putting the non-adopter of the GM crop out of business.[3]

Argentina: 100% adoption of GM soy due to affordable seed prices

Argentina is one of the major adopting countries of GM crops, and HT soybeans have been readily adopted accounting for 100% of the total area under soybean production.

An important determinant of rapid and wholesale adoption in Argentina was the fact that national law prohibits the patenting of plants. As a result, farmers that buy and grow HT soybeans are still able to save and exchange seeds for future plantings. Crops from saved seeds account for approximately 30% of soybeans planted. Weak IPR rights have also had an important impact on seed prices, effectively driving down the price difference to less than €3 per hectare. Affordable seed prices are attributed by several authors (Barfoot, 2006; Qaim, 2005; Trigo, 2003) as the main factor leading to the 100% adoption rate in Argentina.

In contrast to trends elsewhere in the world, herbicide applications have increased dramatically since HT crop adoption. The reason behind increased insecticide applications is the tendency of Argentine farmers to apply additional herbicide in place of tillage, thereby reducing labor (Qaim, 2005). Despite significantly increased costs on extra herbicides, Argentine farmers benefited economically on average by an increase of €19 per hectare, representing an increase of 8.5% over the gross margin obtained by conventional soy farmers (Barfoot, 2006)

Farmers in Argentina were able to incur higher input costs and still make a profit because of the affordability of seeds, the ability to save and exchange seed, and the fact that they farmed on generally larger pieces of land, with "small farmers" operating on 100 hectares or less. Economic benefits, therefore, were obtained despite no change in yields over conventional crops and increased costs in chemical inputs.

It is clear that analyzing yield and cost dynamics at the farm level is important for gauging the socio-economic benefits of introducing GM crops in developing countries. However, the Argentine case study illustrates that the positive effect on farmers' incomes cannot be automatically transferred to other countries. Moreover, a wide range of factors influencing the actual economic performance of GM crops in comparison to conventional counterparts can be found in the literature, e.g. the suitability of the

[3] See id. At 4; Keith Aoki, Weeds, Seeds & Deeds: Recent Skirmishes in the Seed Wars, 11 Cardozo J. Int'l and Comp. L. 247, 286-304 (2003) One of the main concerns about patent protection of seed technology is the possibility that an innocent farmer whose crops are contaminated with GM seeds from a neighbor's field may be liable for patent infringement. This has happened to several farmers in the US and Canada.

variety to local climatic and soil conditions, infestation rates experienced before the adoption of the GM variety and the level of education and knowledge of adopting farmers (Kaphengst et al., 2011).

Of particular importance, however, is the relatively limited number of long-term studies (more than ten years) on the economic impacts of GM crops especially in developing countries, resulting from their relatively recent adoption. Long-term studies on farmer incomes post-GM adoption in developing countries should be a priority of future research, as the usefulness of GM technology is only relevant if the benefits can be sustained over time. Judging from long-term studies in the US, this is a point of concern. Only in recent years (16 years post GM adoption) have issues with "resistant" pests and plants and secondary pests become a economic and environmental problem for farmers. Resistance in the US has posed new financial costs on farmers with the need for increased applications of more toxic chemicals (Benbrooke, 2012). Problems with secondary pests and Bt cotton have already been observed in China (Wang et al., 2009), however, it remains unclear how the issue is being dealt with other than additional applications of chemical inputs.

Much of existing literature focuses exclusively on income influenced by yield and cost variables at farm-level and aggregate national level, and, for this reason, overlooks other factors determining the overall social and economic impacts of GM crops. Other criteria could, for instance, include the national specifics like public acceptance of GMs, institutional frameworks in which GMs are introduced, or international relations between one country and another that determine trade and development cooperation relationships. For this reason, it is necessary to analyze the economic patterns of farm-level incomes after GM adoption with these aforementioned "other" variables on a case-by-case basis. The next two chapters (2.3 and 2.4) will stress some of these issues.

2.3 Socio-Economic impacts at the national Level

An analysis of different case studies unveils that the institutional environment in the adopting country is an important factor determining whether social and economic benefits are achieved and if so, whether the benefits are distributed equitably among different farmers with different financial capabilities. Raney (2006) argues that institutional factors such as national research capacity, food and safety regulations, intellectual property legislation and agricultural input markets, are as much a determinant of social and economic benefits as the GM technology itself. Focusing on the context of institutional capacity in countries where GM crops have been introduced can help explain the high level of variability in case study results and provide insights into when GM crops should actually be used in developing countries. They might, from an economic point of view, be more suited for some developing countries with capable institutions and strong government regulatory oversight than others with weak or absent institutions and governance.

China: Successful Adoption of GM crops with Institutional Support

Bt cotton is grown by 7.5 million small-holder farmers in China (Pray et al. 2002 cited in Raney 2006). The success of Bt cotton in China can be attributed to the strong role the public agricultural research branch takes in developing and distributing different varieties of Bt cotton. The public agricultural research system has produced two transgenic constructs that have been incorporated into a number of locally adapted cotton varieties that compete with Monsanto directly and effectively push down the price premium of seeds. In China, the price of GM seeds is significantly lower than in other developing countries. Lower seed prices coupled with increased yields and lower costs in pesticide applications bring about more significant net gains for small farmers and larger increases in incomes. Interestingly, it was the smallest land holders that benefited the most from the technology with farms

of less than 0.47 hectares experiencing the largest yield gains and mid-sized farmers (0.47 to 1.0 ha) experiencing the largest reductions in total costs owing to less pesticide use (Raney 2006).

In many developing countries, particularly in sub-Saharan Africa, state institutions are weak and many farmers are already in a precarious financial situation—one of either extreme poverty or already indebted (Cohen, 2005). When farmers adopt GM technology they are likely to become dependent on external inputs, because contrary to the varieties traditionally used by farmers, GM crops cannot be saved, bred and used year after year by farmers themselves. Moreover, GM crops are often sold together with specific pesticides to be applied with the trait. Even if seed inputs are free in the initial years they are introduced (as was illustrated in the South African case study), the use of GM crops can lead to adverse effects if the GM crop requires additional inputs at a later point in order to grow. Since small farmers are often in a situation where they have debts from previous years, or are so poor that even small credits threaten their liquidity, taking out additional loans to buy inputs for the GM crops can lead to bankruptcy. Moreover, if small farmers are operating in a country where IPRs are enforced and saving and exchanging seed is prohibited, one failed harvest can lead to irrecoverable debt and, in some cases, loss of land. In South Africa, growing GM cotton increased the dependency and vulnerability of the poorest farmers that were unable to grow other crops due to a severe lack of choice in seed inputs. When the harvest of cotton failed no safety net of other crops to maintain sustenance could compensate for the losses (see South African case study).

South Africa: Poor farmers excluded from beneficial cultivation of Bt cotton

In the Makhalathini Flats in South Africa, the 100% rate of adoption for Bt cotton has been attributed to its success in bringing financial benefits to smallholder farmers. Bt crops were introduced in 1998/1999 and subsequently yields increased for farmers working on irrigated land but did not change for farmers operating on dryland pastures without access to water inputs. In the year 1997/1998 (when GM were at 0 per cent) dryland farmers' yields were at 600kg seed cotton per hectare. In 2004/2005 with close to 100% GM cotton adoption, yields were again 600kg/seed cotton per hectare (Cotton South Africa (Cotton SA), 2005).

According to the analysis by Witt et al. (2006) farmers in Makhathini are found to have taken up Bt cotton mainly because alternatives such as growing conventional cotton or crops for sustenance were limited or not affordable. In the first years of Bt cotton introduction, the seeds were provided for free by Monsanto, and were thus economically attractive to poor farmers and resulted in an overall high adoption rate both on irrigated and dryland.

The long-term benefits of Bt cotton technology, however, were not equitable and favoured larger farmers with access to irrigation. For instance, the Makhathini Cotton Company (MCC) operated the only local ginning facility and also engaged in cotton production encouraging joint-company ventures with small and medium sized farmers. These joint-company ventures, however, were only accessible to individuals that could afford to be included in the irrigation system, which required a land size threshold for which the plots had to be adjacent (Witt et al. 2006). As a result, poor farmers who could not afford to buy into the irrigation system but who were in the territory of the proposed irrigation expansion, were evicted.

Another interesting fact in the Makhathini case study is the high levels of debt among all farmers. Precarious credit schemes prior to GM adoption meant that farmers were already indebted when GM technology was introduced. Buoyed by the hype of GMs to deliver, the only lending institution in the region, the Land Bank provided additional credit to already indebted small-scale farmers of R8 million (approx. 700.000 Euro) for the adoption of GM crops. In 2004 the Land Bank stopped lending with R22.7 million (about 2 million Euro) in outstanding defaulted loans. Successive years of drought have pushed

dryland farmers and those not in the irrigation plan, further into debt, since they were unable to even plant their seeds—as cotton requires water to be plantedThe case of Makhathini thereby shows, that the adoption of GM technology did not free the farmers from poverty but even aggravated the economic situation of the poorest smallholders. The policies in place were not appropriate for the ecological conditions of the region, and the institutions, despite credit and lending schemes, were not able to maintain reliable support services to poor farmers, and inadvertently favoured wealthier farmers (Witt et al, 2006).

In the case study on China where GM crops reportedly brought economic benefits, technology was distributed and heavily monitored by the national Centre for Chinese Agricultural Policy (CCAP). The CCAP has been conducting household surveys every year since GM technology was introduced and also produces its own transgenic varieties that compete with those produced by biotechnology companies from developed countries. In the Makhalathini Flats in South Africa, farmers were limited in the choice to grow an alternative crop to cotton, and even limited choice to grow GM or not. There was no government oversight or public research undertaken to monitor the introduction of GM seeds that were at first provided for free by Monsanto. Compounded by poor lending practices of the local Land Bank and the local cooperative (MCC) that provided joint-venture agreements to wealthier farmers, the introduction of GM crops contributed to increased socio-economic inequality. Several years after first adoption of GM cotton, the MCC started to charge for seeds and adoption rates fell because no moderating institution was able to provide seed to affordable prices for poorer farmers. Additional case studies support the argument that institutional context matters (Evenson, 2004; Byerlee, 2002; Anderson, 2005; Qaim, 2005) and in the case of introducing biotechnology, positive results were better achieved when accompanied by public sector research and the oversight of functioning national institutions.

From these case studies it is evident that well-functioning institutions that can provide long-term support services as well as oversight and regulation on GM crop adoption can improve the possibility of GM crops to deliver social and economic benefits to the poor.

2.4 Relations between developing and developed countries and the socio-economic impact of GM crops on the rural poor

International relationships, particularly trade relations have further implications for whether GM crops will bring benefits to the rural poor. Importantly, the introduction of GM crops questions whether different indigenous and other rural communities have a right to maintain their traditions and cultures, and whether those rights can be protected and can continue to operate in harmony with the introduction of GM crops.

Trade relationships are a major determinant of whether a developing country and its domestic farmer population will benefit or lose economically as a result of adopting GMOs (Jackson, 2005). Developing countries that adopt GM crops could be hurt if their trade partners impose import bans or restrictions on GM crops because of consumer preferences. The EU, for instance, in 2003 replaced the *de facto* moratorium on GM imports with strict labeling regulations. The costs of conforming to the strict regulatory standards may be prohibitive for many developing countries that lack the institutional capacity and financial ability to set up such systems. GM crops are currently being promoted through development cooperation and trade agreements with African countries, with for instance, the *Alliance for a Green Revolution* in Africa initiated by the Bill and Melinda Gates Foundation and supported by the UK Department for International Development, among others. Given that the EU imports 40% of Africa's

agricultural exports (European Commission, 2012), it is of particular concern that some international actors are pushing for the adoption of GM crops for export. The widely divergent perspectives on importing and growing GM crops among nations raises the question of whether promoting this technology in developing countries whose economies depend predominantly on agricultural exports for food is the right strategy (Ng and Aksoy, 2008; Tothova & Oehmke, 2004). For example, in December 2012 Peru banned the import, production and use of genetically modified foods, Russia has suspended imports of Monsanto's GMO corn, since 2009 Ireland banned growing GMO and Japan and Egypt also have banned the cultivation of GMO crops.

In addition to economic impacts, the introduction of GM crops in developing countries has social and cultural ramifications, particularly in developing countries where farming practices are embedded in longstanding cultures and traditions. The import of GM corn from the US to Mexico illustrates the interconnectivity of the food system and both the social and economic impacts that GM crops can have on a developing country. In this case, the trade dynamics between the US and Mexico favor large producers of GM crops in the US over smallholder producers of alternative varieties in Mexico. Indirectly, these trade dynamics coupled with issues of GM contamination threaten the socio-cultural practices and livelihoods of rural Mexican farmers, a significant number of whom have voiced their desire to maintain the ability to plant alternative varieties and protect genetic diversity through seed saving and breeding.

Mexico: Opposition from peasant organization against imports of GM crops and their adoption

Oaxaca, Mexico is a remote mountainous region in Mesoamerica and it is the centre of origin and diversification of maize. In this region, farmers began to select and breed wild grasses 8,000 years ago. Today, rural Mexicans in Oaxaca, the descendents of those first farmers, continue ancient practices of saving and sowing native varieties of maize adapted to the difficult climatic conditions of the area. In 2001, two professors from University of Berkeley conducted field tests that confirmed the unintentional contamination of native maize varieties by transgenic maize 1,400 km south of the US border (Quist & Chappella, 2001). A GM corn, Starklink, approved solely for animal feed was also found in Taco Shells manufactured in Mexico in 2000 (Taylor, 2001).

Since the liberalization of trade and opening of trade borders in 1994 with NAFTA, rural Mexicans and particularly smallholder farmers have not fared well economically (Lopez, 2004) a result of NAFTA, cheap subsidized corn from the US—approximately 50% of which is GM—flooded Mexico's markets and effectively priced Mexican smallholders out of local markets as they were unable to compete with the artificially low prices (Wise, 2004). Weakened domestic markets and cheap imports have transformed Mexico into a net-food importing nation and in 2000 Mexico become the second largest importer of US corn, at 6.2 million tons annually. Fifty percent of corn grown in the US is genetically modified and the Mexican government does not require segregation or labeling of GM, which has mysteriously been found both in the fields of farmers and the food shelves of consumers.

The most outspoken opponents to GM maize in Mexico are the small farmers themselves. Organized in peasant organizations with local chapters of the International peasant movement, La Via Campesina, along with the national organisations Unión Nacional de Organizaciones Regionales Campesinas Autónomas (UNORCA), and El Campo No Aguanta Más (Countryside Can't Take it Anymore), these organized groups of rural Mexican farmers have launched an effective resistance movement against liberalized trade in agriculture and GM imports. In 2004 Mexico's peasant organizations successfully lobbied a subsidiary body of NAFTA for more research on GMs and improved import regulations. Most recently, in November 2012, peasant organizations are opposing a request by Monsanto, Dow and

Dupont proposed to the Mexican government to plant 2.5 million hectares (a landmass the size of El Salvador) with GM maize (La Via Campesina, 2012).

3. POTENTIAL RISKS OF GM CROPS ADOPTION ON BIODIVERSITY AND THE ENVIRONMENT

Similar to the debate on the socio-economic impacts of GM crops adoption, there are different opinions about the potential risks of the cultivation of GM crops for the environment and, in particular, biodiversity. While some judge the environmental risks of GM adoption as severe, others argue that the benefits of GM crops compared to conventional crops prevail and the risks are rather limited.

An often quoted and more recent study based on a literature review on the environmental impacts of GM crops with particular emphasis on biodiversity came to the conclusion that "by increasing yields, decreasing insecticide use, increasing the use of more environmentally friendly herbicides and facilitating the adoption of conservation tillage, GM crops have already contributed to increasing agricultural sustainability" (Carpenter, 2011).

A key variable for the environmental performance of GM crops is the amount of pesticides needed compared to the conventional counterparts. Carpenter (2011) quotes one particular survey among farmers, which has shown decreases of up to 75% in the amount of insecticide and/or number of insecticide applications used on Bt crops compared to conventional crops in Argentina, Australia, China, India and the US. In HT crops, the amount of herbicides sprayed often does not change significantly but the advantage for the environment arises from fewer varieties of herbicides that have to be applied.

However, a closer look at the selection of literature in this study unveils that conclusions were mostly drawn from studies on developed countries and do not take into account the long-term effects already discussed above, which could, for example, lead to an overall increase of pesticide use with growing resistance of pests and herbs to the GM trait.

Another more comprehensive study, which focused on long-term effects of GM crops on the environment and health, indentified different potential environmental risks of GM adoption from the literature (Bartsch et al. 2007). Although the study points out that it is not yet possible to quantify long-term risks of GM crops adoption as "experience is lacking" (Bartsch et al. 2007) it warns over potential future environmental risks, which are differentiated in four major priorities:

- Potential adverse effects due to **changes in cultivation and agricultural management** of HT crops, mainly by the use of complementary herbicides.
- **Resistance development** in pests targeted mainly by Bt crops followed by an even higher use of pesticides
- Potential **gene flow to wild relatives** with consequences for species conservation and biodiversity
- Potential **impacts on soil and soil organisms** with a high degree of uncertainty due to a limited number of studies available

While the study points out that there is still insufficient evidence for clear conclusions and that regional differences have to be taken into account, some of these risks have meanwhile become harsh reality in certain regions. For example, a recent assessment of the impacts of genetically engineered crops on pesticide use in the U.S. in the last 16 years (Benbrooke 2012) has shown that the overall pesticide use has increased by an estimated 183 million kg or about 7% since the GM adoption. The use of HR crops

and the emergence and spread of glyphosate-resistant weeds are the most important factors driving up herbicide use on land planted with herbicide-resistant varieties (Benbrooke 2012). Glyphosate-resistant weeds are forcing farmers to respond by increasing herbicide application rates, making multiple applications of herbicides, applying additional herbicide active ingredients, deep tillage to bury weed seeds, and manual weeding all of which can have negative impacts on biodiversity.

For Bt crops Benbrooke (2012) and other studies from different regions have shown that the application of insecticides can be significantly reduced, at least in short-terms. Moreover, the narrow toxicity of the Bt trait in cotton allows more beneficial insects to survive (see e.g. Wu and Guo 2005). However, this advantage can also pose a threat to growers of Bt crops. The use of Bt cotton and the associated lower levels of conventional insecticide spraying create a safer environment for other, non-bollworm insects (Wang et al. 2009), which are not targeted by the Bt trait. That in turn can lead to yet another compensating increase of pesticide use for combating "secondary insect infestations"[4] as happened for example in China (Wang et al. 2009). However, the relationships between the Bt trait, secondary infestation and pesticide use are more complex than with the HT trait, as climatic conditions have a strong influence on the general fitness of the plants and, respectively, with the infestation rate of pests.

Many concerns have also been raised in terms of the gene flow of GM crops to wild relatives. A respective study for the HR transgene concluded that there is no evidence that its presence in wild plants is inherently problematic (Warwick et al. 2008). The study suggests that wild hybrids containing the transgene are only likely to be present in large numbers in agricultural areas where herbicides are applied frequently as they can outcompete plants with no resistance against the herbicide. As in many developing countries a frequent use of herbicides is rather exceptional, it can be tentatively concluded, that gene flow is of rather minor significance in these areas. However, it is important to note, that the potential danger of living modified organisms (LMOs) on global biodiversity was the greatest concern and underlying mandate for adopting the Cartagena Protocol on Biosafety under the Convention of Biological Diversity (CBD) in 2000. In order to reduce (potentially unknown) risks from GM seeds and other organisms, the Protocol requires exporters to seek consent from importing countries before the initial introduction of an LMO into the environment and provides guidance for a risk assessment.

A key issue that needs further consideration in the context of this briefing is the model of agricultural production, which is related to the promotion of GM crops. Many argue that the GM crops available so far generally encourage agricultural intensification associated with high-input farming practices, monocultures and an overall reduction in (agro-) biodiversity (see e.g. Garcia and Altieri, 2005). Moreover, they potentially discourage farmers from using other, more ecological pest management methods, such as "biodiversity islands", field margins, or corridors. This is particularly true in developing countries when farmers, who have previously grown a wide variety of crops and applied traditional low-input farming practices, do shift to mono- cropping and application of pesticides and artificial fertilisers. Such changes do not only have a significant impact on the biodiversity in the surrounding area, but also increase the vulnerability of farmers relying mostly on GM crop rather than dividing risks of crop failure between a greater variety of products (see also the South African case study). These effects are not exclusively related to GM crops as they might also occur when shifting from traditional crops to conventional crops grown in monocultures. However, the general promotion of GM crops as the solution for increasing yields and for higher incomes for farmers brings GM crops in a special focus when discussing changes in agricultural practices in developing countries.

[4] Secondary insect infestation refers to pests not targeted by the Bt trait gaining higher occurrence with the absence of pests targeted by the Bt trait

4. THE ROLE OF AGRO-ECOLOGY FOR FOOD SECURITY IN DEVELOPING COUNTRIES

In 2008, 400 scientists and experts from 80 countries and endorsed by 62 governments compiled a report on the future of agriculture commissioned by the World Bank and four UN agencies, titled the International Assessment of Agricultural Knowledge, Science and Technology (IAASTD). It identified the dominant agricultural production system as one that has exhausted resources unsustainably and led to soil loss and degradation, over-utilization of water, water pollution, habitat and biodiversity loss, global warming and climate change (IAASTD, Global Report 2008). It acknowledged GM technology and its productive potential in terms of yields as "highly variable" and went so far as to state that GM technology was potentially counterproductive to food security and rural poverty alleviation. The report instead identified agro-ecological farming as the key to future food security and equitable development among rural smallholder farmers.

Agro-ecology is a natural science approach to agricultural production that aims to maintain productive agricultural yields over the long term through the optimization of resources with an emphasis on minimizing environmental stresses (de Schutter, 2011b). The IAASTD identified agro-ecology as encompassing a broad range of organic management practices such as crop rotations, supporting low external input agriculture, applying water-conserving practices, promoting agro-bio-diversity for increased resilience of agricultural systems and the diversification of agriculture. Inherent to the approach is a focus on indigenous knowledge and farming practices and through this emphasis widespread participation and dissemination of technologies developed by and for smallholders is promoted (Altieri & Nicholls, 2000). Some aspects of agro-ecology identified by IAASTD (Global Report, 2008) and other sources include:

- **Low input, energy-saving practices** that preserve and build soil, conserve water, and enhance natural pest resistance and resilience in crops
- Innovative farming methods that **minimize** or eliminate costly c**hemical pesticides and fertilizers**
- Use of **agro-biodiversity, traditional varieties and land races** which are naturally adapted to stresses such as drought, heat, harsh weather conditions, flooding, salinity, poor soil, and pests and diseases
- Promote programs that encourage farmers to **save seeds and thus genetic biodiversity**, use and maintain seed banks and agricultural cooperatives
- Use of existing crops and their wild relatives in science based and traditional breeding programmes to develop varieties with useful traits (Collard & Mackill, 2008).

Sustainable agricultural projects with agro-ecological approaches have been successful in providing yield increases and improved food security in Africa, Asia and Latin America (Hine et al., 2008). In Africa, a 2008 UNEP-UNCTAD report evaluated 114 farming projects in 24 African countries and found organic or near organic methods resulting in yield increases of over 100% (Hine et al., 2008).

An example of successful agro-ecological philosophy is the "integrated rice-duck strategy" used to grow rice in several Asian countries. The "integrated rice-duck" strategy uses ducks and fish to control pests in rice fields reducing labour costs in weeds, and chemical costs in pesticides. In Japan, China, India, the Philippines and Bangladesh, yields have increased by an average of 20% and farm incomes by up to 80% (Khan MA, 2005). Much of agro-ecology draws on traditional farming knowledge and genetic diversity to deal with environmental stresses both biotic and abiotic. Agro-ecology can effectively

increase the incomes of the poorest producers, because it depends less on chemical inputs and more on long-term sustainability. Agro-ecology emphasises species diversity to achieve resilience to risks of extreme weather events, and the invasion of pests, weeds, and diseases that result from global warming (de Schutter, 2011b).

Importantly, agro-ecology is not opposed to agricultural innovation. It encourages incorporating technology development and dissemination to rural smallholders but insists on engaging them in the process of research and development. For example, participatory plant breeding (PPB) is a program where farmers work in partnership with researchers to combine traditional seeds with modern varieties. Research is undertaken in the community for which the technology is designed to benefit, with most scientists conducting research at the farm. Rather than imported non-traditional crops, local varieties are used which are often better suited to the local environment (de Schutter, 2011a). PPB has been particularly important for women farmers, since it is women who traditionally save seeds for replanting and thus serve as an important source of knowledge in managing genetic resources. PPB programs currently exist in Syria, Egypt, Eritrea, Mali, Nepal, Yemen, Nicaragua and Honduras.[5]

5. CONCLUSION

The discussion provided in this briefing supports the general conclusion that food security and poverty alleviation cannot be solved through maximizing agricultural production alone and that GM crops are not a foolproof solution to empowering small farmers in developing countries. Increasingly the international community and proponents of GM oriented agriculture recognize the importance of improving the incomes of smallholders and enabling them to be productive members of society capable of fulfilling their most basic needs.

This paper aimed to assess if, and to which extent, the adoption of GM crops can contribute to food security in developing countries. Drawing from the case studies, it becomes clear that the benefits and drawbacks of GM crops are more polarized in the intellectual debate than they need to be. GM crops have brought both social and economic benefits to smallholders in some developing countries. At the same time, they have seriously exacerbated inequality and threatened cultures and communities imposing novel technologies without the participation of those they claim to help. In order to maximize the benefits and minimize the damage of GM crop introduction it is important to identify the local, regional, national and international circumstances of farmers in each developing country. As a matter of principle, farmers should have the choice of whether to adopt or not adopt GM crops without the risk of being excluded from support schemes and markets if conventional crops are chosen. In order to maximize the benefits and minimize the risks for farmers that choose GM crops, the presence of regulatory institutions is important, both to regulate patents and prices, but also to offer some level of social security or safety net in case of a bad harvest season that would otherwise push the poorest farmers further into chronic poverty and exacerbate socio-economic inequality. These considerations provide farmers with choices and protection against cycles of dependency, also but not exclusively caused by unguided adoption of GM crops. Importantly, such cycles of dependency are not limited to farmers but can also occur at the country level, as developing countries get stuck in a dependent situation as users of technology from Western biotechnology companies that produce the technology.

At a more fundamental level, the promotion of export-oriented agriculture which the current growth of GM commercial crops is aligned to, does not match up to the most pressing needs of the food insecure

[5] For further information in PPB see website of "The Program on Participatory Research and Gender Analysis: http://www.prgaprogram.org/index.php/plant-breeding

and the rural poor (de Schutter, 2011b). GM-seed is supplied by an increasingly concentrated number of actors from the private sector, encouraged to invest in IP rights, and thus far have directed research towards high-value markets, explaining the commercial availability of four commercially grown and traded crops: soy, maize, cotton and canola. 97% of developing countries are net-food importers (Ng and Aksoy, 2008), and export oriented agriculture increases developing countries' vulnerability to food price hikes as experienced in 2007/2008 and thereafter (Nixon, 2012). For technology to benefit small farmers, the focus would better be suited on improved yields in staple/sustenance crops (sorghum, cassava, cowpeas, legumes etc) or products with improved nutritional value that could be produced for sustenance and which could grow in saline soils and drought conditions.

At the crux of the debate on GM production is the fact that two parallel agricultural development systems are being promoted in international spheres and these two systems are essentially at odds with one another. The promotion of GM crops contradicts some of the core principles of agro-ecology, most importantly the promotion of agro-biodiversity and traditional crop varieties. Agro-ecology also favors practices that seek soil and water conservation and that find natural solutions to pest problems rather than using chemical inputs on which GM crops currently depend. Thus, if the approach of agro-ecology is regarded as a better model for ensuring food security in developing countries, while at the same time protecting biodiversity and natural resources, such as the IAASTD and others have claimed, GM crops should not be further promoted in development policies.

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