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Engineering yields and inequality? How institutions and agro-ecology shape Bt cotton outcomes in Burkina Faso

Brian Dowd-Uribe *

Department of Environment, Peace and Security, University for Peace, Costa Rica

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ABSTRACT

The research presented in this paper assesses how four social and agro-ecological factors – credit, governance, seed price and pest dynamics – mediate Bt cotton outcomes for producers in Burkina Faso. It finds that the cotton sector's integrated credit provisioning scheme provides a mechanism for all socio-economic groups to adopt Bt cotton. High seed prices, however, are likely to dissuade resource-poor farmers from Bt cotton adoption, despite the presence of secure credit institutions. Governance issues, including corruption and late payments, demand greater attention since they are driving large numbers of producers to abandon all forms of cotton production. Bt cotton will control target pests, but secondary pests are likely to emerge shortening the benefits of the technology. These findings suggest that many issues with Bt cotton adoption in Burkina Faso lie in the social and agro-ecological context of adoption, which traditionally is not examined in farm-gate analyses of transgenic crop outcomes. An examination of relevant social and agro-ecological factors improves assessments of the likely outcomes of transgenic crops for producers, and allows for greater understanding of their differential impacts.

1. Introduction

Transgenic crops are one of the most controversial contemporary tools to alleviate poverty in sub-Saharan Africa (SSA). This controversy centers on whether or not they can achieve improved nutrition, yields, risk-reduction and profits for the millions of smallholder producers in SSA who face enduring poverty and low comparative agricultural productivity. The performance of one transgenic crop in particular drives this debate – an insect resistant variety of cotton, Bt cotton.[1] As of 2013 it is the primary transgenic crop adopted by smallholders on the continent.[2] South Africa was first to introduce Bt cotton to smallholders in 1998. But the 2008 introduction of Bt cotton in Burkina Faso is much more significant since it reaches tens of thousands more smallholder producers, and it is the only adopting country in Africa where smallholders dominate the agricultural sector.[3] For the 2010/2011 growing season it is estimated that over 80,000 producers in Burkina Faso grew Bt cotton on 275,000 ha, or roughly 66% of the total area devoted to cotton production (Dabire, 2010; ISAAA, 2011).

The rapid emergence of large-scale, smallholder-driven Bt cotton production in Burkina Faso comes at a pivotal time in our understanding of Bt cotton outcomes for smallholders in the global South. Many peer-reviewed articles have pointed to the success of Bt cotton at reducing pesticide use, boosting yields, and increasing profits for millions of smallholder producers in China, India and South Africa (Morse et al., 2004; Pray et al., 2002; Qaim and Zilberman, 2003). An emerging literature, however, questions this unmitigated success. Recent reviews demonstrate that though in many cases smallholder producers in the global South benefit from Bt cotton adoption, outcomes can be highly variable, and success depends on a mix of institutional, socio-economic, and agro-ecological factors (Glover, 2010a, 2010b; Smale et al., 2006; Tripp, 2009).

One key reason for these divergent views on the success of Bt cotton is methodology. Most evaluations of transgenic crops are grounded in the field of agricultural economics, focus at the farm-level, and fail to examine how the larger institutional, social and agro-ecological factors mediate the performance of transgenic crops for producers. These studies tend to aggregate data into averages drawn from a narrow set of metrics, primarily yields and profits, obscuring the longer term and differential impacts of the technology. Yet it is precisely the longer term and differential

* Address: P.O. Box 138-6100, San José, Costa Rica.
E-mail address: bdowd-uribe@upeace.org

[1] Bt, or *Bacillus thuringiensis* cotton produces a protein, or a series of proteins, fatal to many cotton pests, most notably the bollworm.

[2] South Africa smallholders have also adopted Bt and herbicide-tolerant maize with mixed results. See Gouse et al. (2009).

[3] According to the UN FAO (2010) at least five other African countries, Ghana, Kenya, Malawi, Uganda, and Zimbabwe are currently experimenting with transgenic crops in the field trial stage.

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impacts that are important to assess when considering whether and how Bt cotton may contribute to poverty alleviation.

The case of South Africa is illustrative. Initially researchers hailed the adoption of Bt cotton by smallholders in the Makhathini Flats area as a great success; farm gate surveys of Bt and non-Bt cotton farmers demonstrated that Bt cotton boosted yields and profits, particularly for smaller producers (Bennett et al., 2006; Ismael et al., 2002; Thirtle et al., 2003). Two key institutional components drove the initial success of Bt cotton: (1) comparatively good extension services, and (2) the availability of credit, which gave smallholders the ability to afford both the expensive transgenic seeds and the fertilizer and pesticide inputs needed to secure a good harvest (Ismael et al., 2002; Thirtle et al., 2003). But the institutional factors that drove the success of Bt cotton suddenly came to a halt when the cotton company that provided extension services and credit to producers, VUNISA, shut its doors in 2003. A rival gin had opened breaking VUNISA's monopsony on the purchase of cotton and effectively ending its ability to provide credit and stay in business (Witt et al., 2006; Schnurr, 2012) As a result, Bt and conventional cotton production collapsed and have never completely recovered (Glover, 2010b). Now only wealthy smallholder producers and/or those with substantial non-farm incomes continue to grow Bt cotton, with variable success (Morse and Mannion, 2009). The number of independent smallholder farmers growing Bt cotton dropped from 2260 in 2007/2008 to 210 in 2009/2010 (Schnurr, 2012). Nonetheless, as Schnurr (2012) notes, the Makathini case continues to be regarded as largely positive, and is used as a marketing tool to advance the adoption of Bt cotton in other African countries.

This brief review demonstrates how initial farm-gate surveys often underexplore the critical determinants of Bt cotton outcomes for producers, while failing to examine the longer term community and ecological dimensions of these introductions, including, for example, their potential contribution to rising inequality. To address these analytical shortcomings, what is needed are analyses that examine the broader historical, institutional and agro-ecological context of transgenic cotton adoption (Stone, 2011).

This research takes a methodological approach grounded in the fields of political ecology and agro-ecology. It views outcomes at the farm-level as embedded in social and agro-ecological processes that reach far beyond the farm-gate. Broadening transgenic crop evaluations to include this context draws attention to a different set of drivers of outcomes. Rather than focusing on the "average" individual farmer, this methodological approach emphasizes how institutions, as the social systems of production and delivery of transgenics, and agro-ecology, as the biological system of interactions in which transgenics are introduced, shape outcomes at the farm-level. This context is not to be controlled for, but rather is a site for study in order to understand the mechanisms that produce farm-level outcomes. Such analyses can, in principle, avoid some of the shortcomings associated with earlier farm-gate analyses. Moreover, such analyses draw attention to the distributional impacts of the technology, which are otherwise masked in the reporting of average profits in farm-gate surveys. Drawing attention to distributional impacts is important in order to assess claims about the technology's potential to alleviate poverty.

The research presented in this paper critically analyzes four social and agro-ecological factors – credit, governance, seed price and pest dynamics – that mediate Bt cotton outcomes in Burkina Faso. These four factors were chosen based on a literature review of transgenic crop evaluations in the global South and a careful analysis of key areas of concern in the Burkinabè cotton sector. This research draws principally from (1) over 100 interviews of key actors involved in the introduction of Bt cotton in Burkina Faso from 2007–2012,[4] and (2) a survey of seventy heads of household in three villages in the cotton growing region of southwestern Burkina Faso conducted in 2009.[5]

The paper is organized as follows. The next section examines the historical and political foundations of the institutional structure governing Burkina Faso's cotton sector, with a specific focus on how the introduction of Bt cotton shapes this structure. This provides a framework for Section 3, which explores in detail how four key factors mediate the success and evenness of Bt cotton outcomes for producers – credit, governance, seed price and pest dynamics. The last section offers some concluding remarks.

2. An institutional history of cotton production in Burkina Faso

A key component missing from many transgenic crop assessments is a critical analysis of the institutional structures, which steward producers' adoption of the technology. Particular institutional features aid, while others impede, the successful adoption and performance of Bt cotton. Some features may also increase or attenuate the differential impacts of the technology. How Burkina Faso's cotton sector institutions affect Bt cotton adoption and performance depend to an extent on their historical configuration and commitments. This section traces that history from the emergence of the Burkinabè cotton sector in the colonial era, through World Bank restructuring, to the 2004–2007 cotton crisis. This critical institutional history provides a framework for the social and agro-ecological analysis in Section 3.

2.1. Burkina Faso's vertically integrated cotton sector

Two main interventions have shaped Burkina Faso's cotton sector, (1) French colonial efforts to set up a vertically integrated export-oriented cotton sector beginning in the 1950s and (2) World Bank-led efforts to reduce the degree of state control and power in the sector beginning in the 1990s. After World War II the French colonial government sought ways to boost cotton exports from its colonies. But efforts were slow given the diversity and poor performance of cotton varietals, the existence of a regional (domestic) cotton market and a lack of modern growing practices. To address these concerns the French formed a research centre charged with the production of modern cotton cultivars and founded the French government-owned *Compagnie Française pour le Développement des Fibres et Textiles* (CFDT), or the French company for the development of textiles and fibers (Isaacman and Roberts, 1995).

The CFDT colluded with gins to destroy locally grown traditional varieties of cottonseed. After successfully eradicating these traditional varieties, and gaining a legal monopoly over cotton manufacturing, marketing and credit supply from the newly inde-

[4] All interviews were semi-structured and were conducted by the author in French. Interviewees included: representatives from the three Burkinabè cotton societies, SOFITEX, FASO COTON, and SOCOMA; the French cotton company and majority owner of SOCOMA, Geocoton; the Burkinabè cotton growers union UNPCB; the two main firms involved in the introduction of genetically engineered crops in Burkina Faso, Monsanto and Syngenta; the Burkinabè state-level office that manages the cotton sector – *Le Secrétariat Permanent de Suivi de la Filière Coton Libéralisée* (SP/SFCL); the regional anti-GE organization – *La Coalition des Organisations pour la Protection du Patrimoine Génétique Africain* (COPAGEN); the Burkinabè Ministry of Agriculture; the Burkinabè National Research Institute, INERA; the French Development Agency, AFD; the World Bank; the French academic research institute, CIRAD; the Dutch development organization, SNV, and a host of non-governmental organizations that work in the Burkinabè cotton sector.

[5] This survey is part of a broader collaborative project analyzing the dynamics of agrarian change in southwestern Burkina Faso. The surveys referenced in this research were conducted in February and August of 2009, and we conducted with a team of local research assistants in four different languages, French, More, Dioula and Bwaba. Households were chosen based on their prior inclusion in previous surveys conducted in 1996 and 2004.

pendent African states, the CFDT was able to expand production of cotton cultivars that produced lint with consistent quality and length. Both were traits important to the textile industry. The CFDT pioneered a vertically integrated supply chain called the *filière* to promote production in areas without credit or improved farm equipment. In the 1970s the CFDT ceded majority control of Francophone African cotton sectors to state-run cotton companies. The vertically integrated system they formed still persists in some modified form today in most cotton producing nations in Francophone Africa, including Burkina Faso[6] (Bassett, 2001).

The *filière* model integrates all aspects of production including credit supply, seed production and dissemination, extensions services, transportation, ginning, and marketing under the control of one parastatal cotton company. The cotton company fixes the cotton price before the planting season, giving producers a secure market for their production. This supportive institutional framework is credited by many analysts as the driving force modernizing agriculture across large parts of Francophone Africa and boosting both cotton and grain production (Gabre-Madhin and Haggblade, 2004; Lele et al., 1989). From 1974 to 1999 total cotton production increased 6-fold in Francophone Africa. Over that same period of time Francophone Africa increased its percentage of total world cotton exports to 15.4% (Levin, 1999).

Despite this apparent success, the World Bank pushed heavily to liberalize Francophone African cotton sectors. The World Bank argued that state-directed cotton sectors excessively taxed producers, limiting incentives to increase production. In Burkina Faso the push to liberalize resulted in three major reforms, (1) the 1996 restructuring of village-level cooperatives in charge of administering credit to cotton producers, (2) the 1999 inclusion of the cotton producers union as a shareholder in the state-owned cotton company *la Société Burkinabè des Fibres Textiles* (SOFITEX), and (3) the 2004 creation of two private cotton companies to operate regional monopolies within parts of the country, parallel to SOFITEX.

Burkina Faso's liberalization reforms altered the formal governance of the cotton sector, but did not significantly change its vertically integrated structure. Cotton companies still control all managerial and logistical aspects of cotton production in their regional monopolies. The inclusion of the Burkinabè cotton growers union – *L'Union Nationale des Producteurs de Coton Burkinabè* (UNPCB) and two private cotton companies propelled the creation of an inter-professional umbrella institution comprising all actors in the cotton sector – the AICB, or *Association Interprofessionnelle du Coton du Burkina Faso*. A board at the AICB now officially governs the sector. The UNPCB names seven of the board's twelve members, and is the only entity in the cotton sector to own shares in each of the three cotton companies (Burkina Faso, 2007). The AICB fixes the purchase price for both cotton and agricultural inputs, and sets research priorities[7] (Burkina Faso, 2007).

Since the onset of liberalization reforms the Burkinabè state has paradoxically retained and even consolidated its power over the cotton sector. The state-run cotton parastatal SOFITEX still retains a monopoly of more than 80% of total national cotton production and the state is still its majority shareholder. In 2007 SOFITEX recapitalized, and the state increased its total percentage of shares from 30% to 65%. The two private companies, SOCOMA and FASO COTON, operate in relatively new and less agriculturally developed areas, and consequently account for less than 20% of total national cotton production.

The persistence of a vertically integrated and state-controlled cotton sector was a key selling point for Monsanto officials when they approached Burkina Faso in 2003 regarding Bt cotton adoption. Previously Monsanto had difficulty entering the highly competitive seed markets in India arising from the multitude of non-Monsanto Bt cotton varieties already available there. Burkina Faso's cotton companies have a monopoly on cottonseed production, meaning there would be no competition from private sellers, and a reduced likelihood of pirated seeds entering the market. Moreover, state-control of the sector streamlined decision-making and approval of Bt cotton.

2.2. A political economy of Bt cotton adoption

The introduction of Bt cotton in Burkina Faso corresponded with a severe crisis in the cotton sector. In the mid-2000s, a sagging US dollar, high input costs, substantial cotton subsidies in the developed world and a declining world cotton market price all contributed to severe problems in West African cotton sectors. From 2004 to 2007 alone cotton companies in Burkina Faso accumulated a deficit of 68 billion FCFA, or roughly US$ 146 million (Schwartz, 2008).[8] This crisis also meant tumbling cotton prices for producers. Cotton prices peaked in 2004/2005 at 215 FCFA per kilogram of cotton produced, but declined to 165 FCFA in 2006/2007. Many in the cotton sector link falling prices with declining productivity. Total production dropped 51% from an all-time high of 760,000 tons in 2006/2007 to 377,000 tons in 2007/2008 (FAOSTAT, 2013).[9] Cotton prices surged in 201 l. Though this surge may have improved cotton company balance sheets, it has yet to translate into an increase in cotton productivity; total cotton production remained relatively low at 441,000 tons in 2011/2012 (FAOSTAT, 2013).

The adoption of Bt cotton in Burkina Faso also took place in the context of a severely underfunded public agricultural research sector. Publicly funded agricultural research in SSA has declined rapidly across the continent (Akroyd and Smith, 2007), and Burkina Faso's main research centre INERA, has been severely affected by cuts. INERA is largely reliant on funds from the cotton sector to perform cotton research activities including seed propagation and cultivar selection. Cotton companies contributed roughly US $4.5 million over the last 10 years to fund its cotton-related research programs (AICB, 2008). During the current cotton crisis, however, cotton sector payments to INERA arrived months behind schedule. This often left researchers at INERA's cotton program in the precarious position of being several months behind in receiving their salary. Interviews with researchers at INERA confirm that they often have to look for additional income via side ventures and/or conference per-diems.

It is within this context that Bt cotton represents a potential boon for the struggling Burkinabè cotton sector. A series of farm-gate studies performed by Vitale et al. (2008, 2010, 2011) assessed the average yield and profit gains of Bt cotton in Burkina Faso. They demonstrate an average yield gain of 18% and average profit gain of US$ 62 per hectare. If these yield and profit gains turn out to be true for most farmers, this would be good for both the farmers and the cotton companies.[10] Higher yields mean more fiber to commercialize, leading to greater returns for cotton companies. The introduction of Bt cotton also offers INERA researchers a chance to conduct Monsanto-funded research on the impacts of novel technol-

[6] The CFDT is now a private company, GeoCoton, with modest holdings in Francophone African cotton sectors.

[7] Since the institutions of a new price mechanism protocol in 2006, the cotton purchase price, often the most controversial decision, is now largely out of the hands of this committee. The protocol uses a mathematical formula designed to be free of political influence.

[8] This is based on an exchange rate on 21 January 2010 of US$ 1 = 465 FCFA.

[9] In response, a World Bank report argued that the adoption of transgenic cotton represented one way to blunt the effects of the cotton crisis in West Africa (World Bank, 2007, p. xiv).

[10] There is sufficient reason to believe that yield gains main not be realized. As Stone (2012) explains, yield gains in the cited studies were based on comparing Bt cotton yields with those from adjacent refuge areas.

ogies and the chance to author, publish and present work domestically, regionally and at international conferences (Bingen, 2008).

Monsanto and Burkinabè authorities created a unique partnership beginning in 2003, which improved the viability of Bt cotton and offers significant incentives for Burkina Faso's struggling cotton sector. A key feature of this agreement allowed Monsanto's Bollgard II Bt cotton to be crossed onto two locally used cultivars, FK-37 and STAM-59A (Traoré et al., 2008; Vitale et al., 2008). This allowed for the domestic production of Bt cottonseed and improved the adaptability of Bt cotton to local growing conditions.[11]

This agreement also allowed for Burkinabè cotton sector institutions to become partners with Monsanto in the sharing of royalties accrued via the sale of cottonseed to producers. According to this agreement 28% of the royalties from the sale of seeds to producers will go to Monsanto. Monsanto also agreed to build a new research facility. The remaining 72% will be split among the cotton companies, the UNPCB and INERA. It is unclear how exactly the derivative sum is divided.

The royalties could be substantial for domestic production but are dwarfed by the potential of gaining royalties via the export of Bt or other transgenic cotton varieties to neighboring West African countries. Interviews with Burkinabè cotton sector officials confirm a desire to export transgenic seeds provided that regional seed markets are liberalized. Mali, Ivory Coast, Ghana and Togo all use similar cotton cultivars, and all have significantly sized cotton sectors. Though none of these countries have approved Bt cotton research trials, Mali and Ghana are poised to begin field trials soon, and all countries have signed onto efforts to harmonize bio-security legislation (World Bank, 2007). With the Burkinabè cotton sector in serious financial difficulties, the prospect of a potential new market for seed export constitutes a significant economic incentive to promote a quick and successful adoption of Bt cotton.[12]

3. Social and agro-ecological factors mediating Bt cotton outcomes in Burkina Faso

Burkina Faso's vertically integrated and state controlled cotton sector provided a number of advantages for the introduction of Bt cotton. Monsanto was attracted to the Burkinabè cotton companies' monopoly on seed production and distribution, since there would be no competition with other private seed companies, and a reduced likelihood of pirated seeds. Moreover, the consolidated control of the sector facilitated policy decisions supporting Bt cotton adoption. Their Burkinabe counterparts also had a suite of incentives supporting adoption. For INERA employees Bt cotton brought new funded research opportunities. For cotton companies Bt cotton could bring increased fiber production and open new export markets for Bt seed. This mutually supportive set of incentives led to Africa's largest introduction of Bt cotton for smallholder producers in 2008 in Burkina Faso.

This next section builds on this context to examine how the social, institutional and agro-ecological dimensions of the introduction of Bt cotton in Burkina Faso affect outcomes for producers. I examine in detail four factors – credit, governance, seed price, and pest dynamics – that help to determine the performance of Bt cotton for producers. I pay particular attention to how these factors affect the evenness of outcomes.

3.1. Credit provisioning

The secure availability of credit is one of the most important factors assuring the successful and wide-scale adoption of Bt cotton in Burkina Faso. Credit is offered to all male members of local cotton grower cooperatives – GPCs – *Groupements des Producteurs du Coton* for the purchase of fertilizer, pesticides, and seeds.[13] The cotton companies provide the inputs and then subtract debts when they collect the harvest later in the year. This means that every male producer who is a member of a GPC, and who has had good credit in previous seasons, will have the option to purchase the more expensive Bt cottonseeds on credit.

The key aspect ensuring the stability of producer credit in Burkina Faso is the cotton company's monopsony on the purchase of cotton. Without such an arrangement, the cotton company would not be able to recover its input credits. There are no plans to erode this monopsony arrangement, meaning that credit provisioning is likely to remain secure. As noted earlier, secure credit provided by a similar cotton company monopsony sustained the successful initial adoption of Bt cotton in South Africa.[14] In this regard, Burkina Faso is well suited for a rapid and equitable adoption of Bt cotton.

In addition to a reliable monopsony, secure credit markets also require an ability to recover bad credits. In this regard too, the history of credit recovery in Burkina Faso's cotton sector further demonstrates that producers are likely to have access to Bt cottonseeds on credit well into the future.

Like many of its Francophone neighbors, Burkina Faso's cotton companies recover credit via a system of shared liability or *caution solidaire*. Village-level cotton cooperatives, or GPCs, distribute inputs and seeds to members. If one member is not able to pay back his credits, other members are required to cover the debt. Problems with this system arose in the early 1990s leading to large debts being accrued by cotton cooperatives. However, liberalization reforms reconfigured the composition of cotton cooperatives; one single cooperative per village was broken into multiple cooperatives comprised of members of the same ethnic group. It was argued that these smaller, reconfigured cooperatives would increase the social ties between members leading to improved debt repayment (Schwartz, 1996).[15]

The restructuring of village-level cooperatives has helped to shore up input credit markets and spur cotton productivity, but problems still remain. Since the first year that GPC reforms were instituted in 1996, cotton production soared from 200,000 tons of seed cotton to a height of 760,000 tons in 2006. To what extent this can be attributed to GPC restructuring is unclear. Evidence from interviews and survey results indicate that significant problems still plague the internal management of GPCs. The most commonly reported problems were (1) members taking more inputs than needed for their cotton production, and (2) the mismanagement

[11] This also blunted criticism by domestic and international NGOs that condemned Burkina Faso's decision to adopt Bt cotton as one that put Burkinabè cotton companies and producers at the mercy of foreign multinationals for their seed production.

[12] The intellectual property rights of these cultivars remain unclear. The Togolese cotton company developed one of the two original cultivars used – STAM-59A – at their Anie-Mono research station. It is unclear whether SOFITEX or Monsanto have signed an agreement with their Togolese counterparts to modify and sell these cultivars. Burkinabè cotton companies have renamed the STAM-59A cultivar with the Bt toxin to FK-96 BGII.

[13] In Burkina Faso, cotton is grown almost exclusively on fields operated by men, though women participate in all aspects of its production. In the rare event that cotton is grown on a field operated by a woman, the seeds and inputs are unofficially obtained via a male GPC member. See Zambrano et al. in this volume for a detailed discussion of the gender dynamics of cotton production in Burkina Faso.

[14] The lack of a monopsony on the purchase of cotton, and the resulting inability to recover input credits, was also the primary factor leading to the collapse of cotton production in some African countries in the 1980s and 1990s, as a by-product of radical privatizations of their state-run cotton sectors (Fok and Tazi, 2003). Many of these countries that instituted such reforms, including Ghana, Tanzania, and Uganda, are also currently conducting Bt cotton field trials. On-going efforts to reinstate secure input credit markets will likely be important to the success of any future transgenic crop introductions in these countries.

[15] See Schwartz (1996) for a compelling history of cotton cooperative restructuring in Burkina Faso.

of the money remitted to the GPC to administer the cotton selling market. Nonetheless, a secure shared liability framework suggests that most cotton producers will continue to have access to Bt cottonseeds on credit, thereby bolstering its even adoption.

3.1.1. Credit inflating cotton production?

Integrated credit provisioning boosts productivity and allows for all social classes of farmers to produce cotton. But since the cotton sector is the only reliable channel to acquire inputs on credit, producers often inflate the total area devoted to cotton in order to obtain fertilizers for their grain crops. If a different input credit mechanism for grain crops were established, survey data suggests that all cotton production – conventional and Bt – would likely decline.

It is well established that cotton production benefits grain production. Since the 1960s the cotton sector has been the driving force modernizing agricultural production throughout West Africa. A primary way the cotton sector boosts grain production is by facilitating access to inputs on credit.[16] It is well understood, and other commentators have noted (Gray, 2005, p. 75) that a sizable portion of the inputs that are given to cotton producers on credit by the cotton companies goes towards grain production.[17] The only other means for producers to obtain fertilizers for their grain crops would be to pay in cash. Since many producers do not have this ability, they depend heavily on inputs obtained on credit from the cotton company.

Since cotton companies are the only source of reliable credit, many producers use that credit to divert inputs from cotton production towards grain production. Many producers report that they would reduce the total area devoted to cotton production if they could gain credit for inputs from a different entity than the cotton company. Of the 69 heads of household surveyed, 43 said that they would either leave cotton production altogether or reduce their total area devoted to cotton if they could receive inputs on credit via a different reliable mechanism.[18] Though prospective actions are not necessarily the best predictor of actual performance, and this is a relatively small sample, these numbers do demonstrate a strong likelihood that total cotton production is inflated due to the current organization of input credit markets.

The solidity of Burkina Faso's cotton credit provisioning system is likely to boost the adoption of Bt cotton among all social classes of producers. Access to secure credit gives producers the ability to purchase expensive Bt cottonseed. Access to credit also means that producers will have the ability to afford the inputs necessary to secure high yields. Nevertheless, if alternative sources of credit became available for producers, total area devoted to cotton production – both conventional and Bt – may decline. Producers would no longer have to inflate their cotton production in order to gain enough inputs for their grain crops.

Many researchers tend to focus on how the prospect of higher profits is what drives adoption of Bt cotton. In many cases this is true. But the larger suite of incentives in which Bt cotton is embedded is also a significant incentive for adoption. In other words, without secure credit, access to agricultural inputs, and a guaranteed purchase, Bt cotton would not be as attractive to Burkinabè producers. Similar to the Burkinabè case, Schnurr (2012) notes that in South Africa, access to credit and access to a secure market with guaranteed purchase were the primary reasons producers were drawn to Bt cotton. These two cases demonstrate that Bt cotton cannot be separated from the key role that these institutional incentives play in driving adoption, and, in the case of credit for inputs, driving success.

3.2. Governance

Though the structure of credit provisioning boosts overall cotton production, other aspects of the institutional structure governing the cotton sector may limit it. An overlooked area is the reduction in the total number of cotton producers due to perceived corruption in the cotton sector and late cotton payments. As mentioned in the previous section, total cotton production in Burkina Faso plummeted from a high of 760,000 tons in 2006 to a low of 377,000 in 2007, and has only marginally recovered since to 441,000 in 2011. Elite cotton sector actors, including cotton company executives, government officials and many union representatives, attribute this decline to low global cotton prices and US cotton subsidies. A close examination of cotton producer sentiment, however, reveals that strong distrust and charges of corruption limit producer desire to grow cotton, whether conventional or Bt.

A 2008 Master's Thesis by a University of Ouagadougou graduate student, Hamadou Diallo, explored reasons for apparent discouragement of producers to grow cotton. In 2007 Diallo (2008) surveyed 140 producers in eight villages in the Cascades region of Burkina Faso. Eighty-six percent of those surveyed had either completely given up on cotton production or had reduced the size of their cotton fields. Rather than low cotton prices being the main factor reducing overall cotton production in the region, Diallo's research showed a series of local factors had persuaded cotton producers to exit cotton production or reduce the size of their cotton fields. The local concerns raised by producers included corruption by cotton grade inspectors, late payouts for their cotton, and a general lack of trust of cotton sector organizations.

3.2.1. Corruption by cotton graders

Surveys and interviews of producers demonstrate longstanding corruption in cotton classification (Gray, 2008). Each year a cotton conditioner employed by the cotton company arrives to the village to designate cotton as either first or second grade. In principal this designation is designed to provide incentives for better production methods and more care during harvest and storage. Cotton that is free of cotton leaves and other debris generally receives a better grade classification and a price premium. Most producers effectively assume they will receive first grade status for their cotton, since, by most accounts, the handpicked Burkinabè cotton is of high quality. Depending on the size of the cotton harvest, the designation between cotton grades can often lead to a difference in hundreds of dollars for growers.

However a perverse set of incentives permits cotton conditioners to demand payment for favorable classification. Producers often have to "wash" their cotton by giving a remittance of cash or livestock to the conditioner in order to ensure their cotton is classed as first grade. For the producer it makes much more sense to give a bribe than risk their cotton be given a lower grade. In our survey of 69 heads of household, 37% reported remitting either cash or livestock to a cotton conditioner in the past 4 years. In all likelihood these numbers are underestimated, given that growers are reluctant to admit bribes. Perhaps most disturbing is the longevity of this corruption problem. Gray's (2008) survey work dating back to 1995 demonstrates the same problems with cotton conditioning corruption. This signals that the increased power of the cotton union has not been able to stamp out corruption involved in cotton classification.

[16] Cotton production also facilitates grain production via a maize–cotton crop rotation whereby an early maize crop benefits from the fertilizers that remain in the soil from the prior year's cotton fields.

[17] Attempts have been made by the cotton companies to verify reported and actual area devoted to cotton production. But if the producer can pay back the input credit, there is no clear incentive for the cotton company to regulate this activity.

[18] Twenty-two respondents indicated that they would leave cotton production. Twenty-one indicated that they would reduce their total area.

3.2.2. Late payments

In addition to corruption, late cotton payments also dissuade producers from growing cotton. The cotton harvest takes place from November to January. After harvest producers set up a cotton market – normally on a denuded piece of land – where they amass their cotton in piles awaiting its classification, weighing and transport to the gin. Often months can go by between harvest and classification.[19] Classification and transport to the gin often happens in January and February, but producers must often wait until April, May, or even June before they receive payment for their cotton harvest.

The difficulty with late cotton payments is compounded by the agricultural calendar. At harvest in November, grain prices are low and producers are in most need of cash in order to pay their expenses. Since their cotton payment is still 5–6 months away, producers often must sell their grain crops in order to obtain cash. By May often their grain reserves are not sufficient to feed their families. Producers are then obliged to purchase grain crops at twice or three times the November price. To avoid this situation many producers reduce the size of their cotton fields in order to grow more grains. Doing so allows producers to sell some grains in order to immediately obtain cash to pay their expenses without compromising their grain reserves for the year.[20]

3.2.3. Producer distrust of cotton sector institutions

Both late payments and corruption by cotton graders are parts of a general mistrust by producers of the cotton sector. The general perception by many producers of corruption and mistrust is rooted in their complex and at times adversarial relationship with both the cotton companies and their union.

Researchers continue to relate the inclusion of the cotton growers union into the formal governance of the cotton sector as an unmitigated success and the by-product of the World Bank-inspired liberalization process (Araujo Bonjean et al., 2003). This story, however, overlooks the political history of its creation and inclusion as a cotton sector partner. SOFITEX was heavily involved with the creation of the cotton producers union, the UNPCB, and effectively chose a moderate group of leaders to run the UNPCB (Dowd-Uribe, 2011).[21] This had a twin effect for producers. In the short term it blunted a more radical and broad-based producers movement, but in the long term it fostered a level of discontent for many producers. Almost three quarters of surveyed producers reported a negative opinion of their union. The union's inability to address issues of low-level corruption in cotton classification has contributed to this negative view.

In 2011 this general producer distrust of the cotton companies and the producers union sparked significant protests. Splinter producer groups formed to demand higher cotton prices and lower input prices. These demands came after the cotton sector had announced the highest cotton price in the history of cotton production in Burkina Faso – 245 FCFA/kg. Despite this unprecedented price, protesters argued that they deserved an even higher price, since cotton lint at its peak price in March was trading internationally at close to 490 FCFA/kg[22] (Gongo, 2011a, 2011b). By the beginning of the growing season, however, their demands were largely unmet. According to interviews with cotton farmers, this drove roving bands of protesters to uproot planted cotton in sporadic protests across the country. Many producers refused to grow cotton altogether. Because of these protests cotton production is not projected to significantly improve in the 2011/2012 growing season despite record high prices for producers.

Governance issues in Burkina Faso's cotton sector constitute a serious and underexplored factor that limits all cotton production – whether conventional or Bt. Perennially late cotton payments and persistent corruption in the classification of cotton erode enthusiasm for cotton production, and in some cases cause producers to abandon cotton altogether. These issues are likely to affect poor producers more, since they are less able to shoulder the burdens of delayed cotton payment, or the increased costs to achieve favorable cotton classification. The introduction of the cotton growers union into the formal governance of the cotton sector was designed to address some of these issues, but the union has been co-opted by state interests. Producers remain skeptical about union leadership since they have yet to see tangible benefits from their involvement. Without improved payment schedules and transparency, and persistent corruption being addressed, all cotton production is likely to remain stagnant.

3.3. Seed price and risk

The increased risk due to the high seed price of Bt cotton may limit its success and even adoption. Some analysts claim that Bt cotton reduces risk for producers since it generates greater and more consistent yields than conventional cultivars. As Zilberman et al. (2007: 74) explain, the randomness at which pest infestations occur means that insect-resistant cultivars act as a form of 'financial insurance for farmers' moderating the disastrous effects such infestations have over time. Moreover, since in their view risk-averse smallholder producers 'are ready to pay a premium to reduce the risk they face,' they would be more inclined to adopt transgenic crops (Zilberman et al., 2007: 69).

This conception of risk is problematic in at least two regards. First, as Glover (2010b) explains, transgenic cotton does not so much reduce risk as spread it across seasons, since pest pressure differs between growing seasons. Moreover it only protects against one type of risk – target pest infestations – and does not control for the multiple other risks confronted by farmers, most notably agro-climatic variability. Thus in years of no target pest infestations, Bt cotton adopters would essentially be paying extra in the form of increased seed prices for unneeded protection.

Another significant reason this is problematic is that the high cost of Bt cottonseed, and the debt producers must incur to purchase it, constitutes a significant risk for poor producers. Research shows that Bt cotton yields are highly dependent on a suite of agro-ecological, institutional, and socio-economic factors. The specter of counting on an increased yield to satisfy a higher than normal debt may keep many resource-poor producers away from Bt cotton altogether. This means that the price at which Bt cottonseed is made available to producers is vitally important towards its wide-scale adoption.

Those holding the royalties – Monsanto and Burkinabè cotton sector institutions – set the producer price for Bt cottonseed. The high Bt cottonseed price in Burkina Faso demonstrates that the institutional interests of Burkinabè cotton companies and Monsanto were favored over producers' interests, potentially affecting the ability of poorer producers to benefit from the technology. A 2007 study by Vitale and colleagues used mathematical models to predict the socially optimal price for Bt cottonseed in Mali.[23] They

[19] This works against the producer in two ways. First the producer must store their cotton in a way that avoids excessive debris and dust, or risk receiving an inferior cotton grade classification. Second, the storing of cotton in dry weather reduces its overall weight. Since weight is what determines the cotton price, this can reduce producer profits.

[20] But late cotton payment was not always the norm. As late as the mid-1990s producers report receiving payment for their cotton at the time of weighing and transport.

[21] Also see Bonnassieux (2002).

[22] This is based on the exchange rate on 1 March 2011 of US$ 1 = 474.9 FCFA. The cotton price was US$ 2.27/lb.

[23] Though Vitale et al. (2007)'s analysis was for Mali, it is reasonable to assume a similar socially optimal pricing structure in Burkina Faso given the similar production strategies and institutional structures of the two countries.

found that the Bt cottonseed price will have an upper boundary where a higher seed price will lead to diminished adoption and profitability. Their research showed that the producer seed price that garnered the highest returns for the technology royalty holders was US$ 60 per hectare. Lower seed prices would lead to higher adoption rates, and a higher percentage of the overall social welfare benefits being accrued by the producer. However, instead of adjusting the seed price to produce incentives for a more wide-scale adoption, in Burkina Faso the Bt cottonseed price was ultimately set at US$ 60 per hectare. This could signal the continued strength of the cotton companies, despite a voting majority held by the cotton growers union in the governing AICB.

In Burkina Faso Bt cottonseed price of US$ 60 per hectare far exceeds the conventional seed cost of US$ 2 per hectare.[24] If the technology works as expected, and there are no heavy infestations of secondary pests requiring supplemental pesticide applications, the US$ 60 charge per hectare is still substantially more expensive than the four pesticide treatments the Bt technology is meant to replace. These four treatments cost approximately US$ 40.[25] Since both systems use the same amount of fertilizer and other insecticide applications, the total cost differential between the two systems is US$ 18. The extra cost for the Bt production system is meant to be justified by a yield increase, and a reduction in labor allowing producing families to re-allocate scant labor resources to other crops and activities. For many growers, under average rainfall and pest conditions, this price structure is likely to be sufficient to gain a profit from Bt cotton (Vitale et al., 2010) .

One key element of this price structure works towards a successful and more even adoption of Bt cotton – setting the seed price to the hectare as opposed to the seed sack. This innovative price structure allows producers to use as much seed as necessary to completely seed a hectare of cotton and be assured that seed costs will not exceed US$ 60. Fixing the seed price to the hectare as opposed to the seed sack is critical to the success of Bt cotton in Burkina Faso. Due to highly erratic rainfall, particularly early in the growing season, producers often have to plant cottonseed multiple times in order to ensure full germination (Dowd-Uribe and Bingen, 2011). How much seed producers sow per hectare depends largely on agro-climatic conditions and seed germination rates, and can vary from 6 kg in moist conditions with consistent rainfall to 30 kg or more in dry areas with erratic rainfall.[26] Without this seed pricing structure, early periods of drought would surely lead to a large number of producers falling into debt, and severely limit the adoption of the technology.

Producers who adopt Bt cotton are initially given a 10-kg seed sack per hectare of cotton. Producers can appeal to the cotton company extension agent for more Bt seed if one 10-kg bag is not sufficient to completely seed one hectare. The extension agent verifies the un-seeded area, and remits a 2 kg supplemental seed pack to complete the planting. According to interviews with cotton sector officials, producers demanded extra seed during the 2008/2009 growing season primarily because highly variable rainfall in many areas throughout the country resulted in low seed germination.[27] This was further exacerbated in some areas due to the common producer practice called "*semer à sec*" – or planting when the ground is dry in the hopes that rain will come soon. In some extreme cases where 12 kg of seed was not sufficient for an entire hectare, more seed was made available.[28]

Despite these advances in the seed pricing mechanism, the high price of seed, and likely corruption with its distribution, are significant hurdles to wide-scale adoption. As noted earlier, cotton production is rainfed, and any variability during the cotton-growing season could result in reduced yields thereby limiting the ability to pay back Bt cottonseed debts. The primary way in which Burkinabè officials mitigated the risk associated with Bt cotton was to provide supplemental seed at the time of seed sowing to those producers who struggled to germinate their crop. Climatic variability later in the season, however, remains a significant risk factor. Evidence from South Africa demonstrates that climatic variability can lead to a wide fluctuation in Bt cotton yields. Hofs et al. (2006) found that heterogeneous grower management practices and variable growing conditions created high yield disparities among Bt cotton smallholder adopters, even more than those for conventional cotton. Moreover, among the Bt cotton growers, the highly uneven yields generated significant differences in profits; some even lost money. This is particularly worrisome in Burkina Faso since all cotton is rain-fed and the weather is highly variable. A case where the rainy season ends too early, for example, could substantially reduce the yields of cotton growers, limiting their ability to pay back their cottonseed debt. Low rainfall levels in the early life of the Bt cotton plant could also limit its performance. Since increased yields associated with Bt cotton have been attributed to increased early boll development, a reduction in rainfall early in the life of the cotton plant may reduce this boll development, and any improved yield potential (Hebbar et al., 2007).

During the first year of widespread availability (2008/2009) of Bt cotton, producers staged significant protests over its high price. The cotton companies made Bt cottonseed available to only a select number of GPC's and producers, presumably since there was not enough seed for the entire country. In a survey of producers in three villages in southwestern Burkina Faso, SOFITEX gave GPCs in only two of the three villages the opportunity to adopt Bt cotton. Of the sixteen GPCs located in these two villages, five refused to adopt Bt cotton because of its high price.[29] Interviews with cotton sector actors confirm that many other GPCs throughout Burkina Faso also refused to grow Bt cotton because of its high cost. The extent of GPC refusals of Bt cotton, and whether they will continue to refuse to grow Bt cotton, remains unclear.

In addition to a high seed price, the local governance of seed distribution represents a further hurdle to a more even adoption of Bt cotton. Under the current seed price policy tied to the hectare, cotton extension agents wield considerable power. They survey fields to determine whether producers require supplementary seed, and have access to substantial seed stock for remittance. Cotton extension agents could conceivably ask producers to pay a commission for additional seed. There is good reason to anticipate such corruption, given the similar set of incentives and lack of accountability in the classing of cotton by the cotton companies.[30]

[24] 27,500 FCFA and 900 FCFA, respectively; based on prices during the 2008/2009 growing season.

[25] Pesticide treatments cost 4345 FCFA for each 1/2 l bottle, of which four are used totaling 17,380 FCFA.

[26] This range of seeds per hectare comes from interviews with cotton sectors officials. Historically, Francophone African cotton societies managed this problem by providing ample amounts of low cost conventional seeds to producers. Left over seed was then used as feed for cattle, prepared for human consumption or sold on an increasingly thriving black market for oil production.

[27] Another reason producers demanded more seed was the inferior quality of the Bt cottonseed sacks, which allowed seeds to be lost in transportation to the producer.

[28] Interviews with cotton sector officials reveal that the unloading of seed sacks at regional and village warehouses caused widespread illness among laborers leading some to lose consciousness. This was due to the chemical used to de-lint the Bt-seed being released from the poor-quality seed sacks. Illness and loss of consciousness of laborers were reported in all regions where Bt cotton was grown.

[29] In the third village only larger growers independent of GPC affiliation were given the ability to grow Bt cotton. It should be noted that the GPCs that refused to adopt Bt cotton were largely comprised of Mossi immigrants to the region.

[30] Given the existing seed distribution polices, one can think of a series of possible avenues of corruption that could sour relations between Monsanto and the cotton companies, including cotton extension agents selling surplus seed to producers at a reduced rate, or producers demanding extra seed and selling it via illicit markets.

Bt cotton represents a potential boon for growers, but also a significant risk. The high price of Bt cottonseed keeps many growers from adopting the technology. Those that do adopt run the increased risk of carrying a higher than normal debt with the cotton company. If rains are not sufficient early in the season, or do not last throughout the growing season, Bt cotton adopters could end up with lower yields and significant debts. High Bt cottonseed prices and the higher risk they engender could lead to Bt cotton becoming a crop of the relatively wealthy, disenfranchising poorer producers from the most significant recent effort by development institutions to alleviate rural poverty in Burkina Faso. Evidence from the only other Bt cotton introduction in SSA among smallholder producers in Makhatini Flats, South Africa suggests that wealthier farmers were the first to adopt Bt cotton and continue to constitute the bulk of producers (Morse and Mannion, 2009). Morse and Mannion (2009) attribute the predominance and persistence of relatively wealthy farmers in the production of Bt, however, to the collapse of credit institutions in the region. What remains unclear is whether, under conditions where credit is reliably available through cotton societies, as in Burkina Faso, high prices and high risk will cause a similar differentiation among social groups. If it does, it would have important ramifications for Bt cotton as a poverty alleviation strategy.

3.4. Pest dynamics

Bt cotton production significantly affects pest ecology. Its primary impact, the targeted control of particular cotton pests, will undoubtedly aid many producers, but its focused control of a small number of pests will also promote target pest resistance to the Bt toxin, and potentially the emergence of secondary pests not repelled by the toxin. These two impacts on pest ecology could reduce both the long-term effectiveness and overall profitability of the technology.

Since the commercialization of Bt crops, researchers have recommended, and many governments have required, the planting of refugia to forestall the emergence of target pest resistance. Refugia are spaces where conventional cotton is intercropped or planted adjacent to Bt cotton. This allows for sufficient interbreeding between insects exposed and not exposed to the Bt toxin, effectively limiting the passing down of resistance. Despite this insistence, many growers around the world have not planted refugia. In some cases this has led to the advanced emergence of target pest resistance.

Researchers report at least five cases of field-evolved target pest resistance to the Bt toxin (Carrière et al., 2010). Some of these cases are in countries where the government has required the planting of refugia and presumably had the institutional capacity to enforce it. Yet the lack of refuge planting has contributed to the emergence of target pest resistance. For example, in South Africa, most Bt corn growers did not plant refugia even though the law requires it. Subsequently, researchers found that the relatively small space devoted to refugia contributed to the emergence of target pest resistance to the Bt toxin (Kruger et al., 2009). Similarly, in the United States, where refugia are also required by law, resistance to the Bt toxin evolved quicker in areas with less space devoted to refugia (Tabashnik et al., 2008).

Recently target pest resistance has been documented in areas of both India and China where smallholders grow Bt cotton. Chinese researchers found a high incidence of resistance to the Bt toxin among bollworms in Bt cotton fields in Qiuxian County, Hebei, China (Liu et al., 2008). Similarly, in 2010, Monsanto researchers documented resistance to Bt cotton in Gujarat state India (Monsanto, 2010). In both cases the lack of refugia planting and the prevalence of pirated Bt cotton cultivars and hybrids with limited expression of the Bt toxin were primarily to blame for the emergence of target pest resistance. Chinese law does not require the planting of refugia.[31]

In all cases, target pest resistance evolved in response to first generation Bt crops that produced only one Bt toxin. Next generation Bt crops, including Burkina Faso's Bt cotton cultivars, produce two Bt toxins, presumably decreasing the speed in which target pest resistance emerges. Nonetheless, recent research suggests that resistance to Bt cotton containing two toxins will still occur (Tabashnik et al., 2009). In the words of the lead researcher of these experiments, "[Regardless of the number of Bt toxins present] evolution by insects is not something that scientists are going to stop" (Ledford, 2009).

As with first generation Bt crops, those that express two toxins still require the planting of refugia to forestall the emergence of target pest resistance. In Burkina Faso officials are not currently enforcing the planting of refugia. None of the surveyed Bt cotton growers reported planting refugia. Apparently Burkina Faso is experimenting with a novel and scientifically unproven refugia method that does not require the planting of conventional cotton adjacent to or intercropped within Bt cotton fields. Burkinabè cotton sector officials assert that the diversity of crops in which cotton is grown can serve as alternative sinks for cotton pests, effectively serving as a type of refugia.[32]

Even if Burkinabè officials insisted on the planting of proper refugia, it is likely they would not have the institutional capacity to enforce it, and producers would have little incentive to comply. The planting of refugia effectively entails sacrificing a portion of cultivatable land solely for the purposes of pest interbreeding. Though producers would still harvest cotton from refugia areas, yields will likely be much lower than adjacent Bt cotton fields. In a producer's eyes, this would be an unnecessary economic sacrifice. Under such circumstances the enforcement of refugia may not be possible.

3.4.1. Secondary pests

Beyond target pest resistance, Bt cotton production will also have landscape-level effects on pest dynamics. Some of these impacts will be beneficial to producers, while others could limit the profitability of the technology.

When Bt cotton is grown on a wide-scale, research shows that it can promote a general landscape-level reduction of target pests. Research in China shows that the wide-scale planting of Bt cotton reduced target pest outbreaks in other crops (Wu et al., 2008). Similarly the wide-scale planting of Bt maize in the United States has been shown to reduce overall levels of the principal maize pest, the European corn borer (Hutchinson et al., 2010). In both cases the primary beneficiaries of a broad-scale reduction in target pests are non-Bt crop producers; they can reduce the amount of pesticides used to control these pests.

But research shows that as it promotes a landscape-level reduction of target pests, the reduction in insecticide use associated with wide-scale Bt cotton production also promotes an increase in non-target pests. It is well documented that the Bt toxin does not repel many secondary cotton pests and may lead to their increase on Bt cotton plots (Men et al., 2005). Recent research from China demonstrates that the wide-scale planting of Bt cotton increased populations of a non-target pest, mirids, on Bt cotton and other adjacent crops (Lu et al., 2010). The control of these non-target pests made

[31] Liu et al. (2008) note the presence of the resistant allele before Bt cotton adoption due to Bt spraying since 1991. This likely contributed to the current levels of resistance.

[32] According to interviews with cotton sector officials, this alternative style of refugia was not legally agreed to in the Bt cotton commercialization contract. Monsanto still expects and insists that proper scientifically validated refugia be planted.

Bt cotton less profitable than conventional cotton production, just 7 years after its initial commercialization (Wang et al., 2008). Similar increases in secondary pests have also been reported in South Africa (Schnurr, 2012) and India (Stone, 2011).

In Burkina Faso the emergence of secondary pests or pest resistance could be problematic. Pesticides are purchased on credit and distributed early in the season depending on a producer's proposed cotton production. If secondary pests or pest resistance were to emerge during the growing season requiring the use of pesticides to limit the outbreak, it is unclear whether there would be sufficient quantities or access to such pesticides. Contingency plans would likely require stocking pesticides in rural locations in the event of such an outbreak. Currently there are no known plans for such pesticide stockpiles.

Interviews with cotton sector officials demonstrate a nascent concern with one pest that may not be controlled by the Bt toxin, the cotton leafworm (*Spodoptera littoralis*). In Burkina Faso cotton extension agents advise six applications of pesticides in order to control cotton pests. But Bt cotton producers only have to spray twice in order to control sucking bugs that are not repelled by the Bt toxin. These two pesticide applications, however, do not repel the cotton leafworm. Though the Bt toxin is thought to moderately repel the cotton leafworm, Burkinabè researchers have yet to test its effectiveness (Hema et al., 2009). Interviews with Burkinabè actors involved in the introduction of Bt cotton confirm that they have observed increased levels of the cotton leafworm on Bt cotton fields. If the cotton leafworm emerges as a significant pest of Bt cotton this would require additional pesticide applications and thereby likely erode any potential profit gains from the adoption of Bt cotton.

The introduction of Bt cotton has large and complex effects on pest ecology. Some will benefit cotton growers, including the targeted control of cotton pests across the landscape. But many of these effects, including the likely development of pest resistance and emergence of secondary pests limit the medium to long-term profitability and viability of Bt technologies. Moreover, the techniques to forestall pest resistance and secondary pest emergence, like refugia, are currently not practiced or enforced in Burkina Faso.

4. Towards a social and agro-ecological assessment of transgenic crops

Most contemporary assessments of transgenic crops are limited. They are primarily confined to the farm and use a small set of technical criteria, chiefly yield and profit data, to judge success. These analyses often overlook the contextual elements that drive Bt cotton adoption and mediate its yield and profit outcomes through time. Moreover, by not sufficiently exploring the institutional dimensions of adoption, and reporting yield and profit data in averages, they overlook what could be potentially large differential impacts associated with the technology. As Smale et al. (2006: 209) note in their review of Bt cotton performance in the global South, though a crop may perform technically as designed, "institutional and marketing arrangements ... may be the single most important determinant of Bt impact at the farm-level ..." In other words, no matter what evidence from field and farm trials may suggest, transgenic crop outcomes for producers will depend to a large extent on the social context of production.

The research presented in this paper takes a broader view. It draws attention to what Schnurr (2012) calls the "socio-spatial" context of adoption via a critical analysis of four social and agro-ecological factors that mediate the success of Bt cotton outcomes in Burkina Faso. A key element of this context is Burkina Faso's credit provisioning system, which allows producers to purchase Bt cottonseed, fertilizers and pesticides on credit facilitating the adoption of Bt cotton and its successful cultivation. This sets the introduction of transgenic crops in Burkina Faso apart from other areas, like South Africa, where credit-provisioning institutions were not secure. Another key element is Burkina Faso's unique seed-pricing mechanism, which pegs the seed-price to the surface area planted, as opposed to the seed sack, facilitating the adoption and profitability of the technology for producers. This also reduces the risk involved in growing Bt cotton should rainfall at the time of planting be inconsistent.

Many of these socio-spatial attributes, however, impede the successful adoption and performance of Bt cotton in Burkina Faso. Late cotton payment and corruption by state officials in cotton classification contribute to a mistrust of the cotton sector. As producer protests in 2011 attest, these lingering issues impede the successful adoption of Bt cotton since they discourage producers from growing cotton altogether. Persistent state power in the Burkinabè cotton sector likely facilitated the introduction of Bt cotton to Burkina Faso. However it also resulted in the relatively high Bt cottonseed price, potentially limiting its overall adoption. High Bt cottonseed prices combine with the inherent agro-climatic variability of the region to increase the financial risk associated with cotton production. Since Bt cotton is associated with higher risk, many producers elect to forgo Bt cotton adoption, even though field trials shows the Bt cotton increases yields and profits. Moreover, modifications to pest ecology activated by Bt cotton's introduction likely reduces the time frame in which Bt cotton will be profitable, particularly with the lack of refugia planting in Burkina Faso.

The potential risks associated with Bt cotton are likely to disproportionately fall on resource poor farmers. In the first year of adoption, many farmers refused Bt cottonseeds out of concern for its high cost. Relatively wealthy farmers can more easily shoulder the risk associated with agro-climatic variability and afford the inputs necessary to garner a successful harvest. Moreover, corruption in seed classification and late cotton payments disproportionally affect resource poor farmers, since they do not have the means to shoulder these extra costs. Though Burkina Faso's secure credit and unique seed pricing policies help to even the prospects for adoption and success, it remains to be seen whether or not these advances are sufficient to forestall Bt cotton becoming a crop for the relatively wealthy in future years. If Bt cotton indeed primarily benefits relatively wealthy farmers, this would have important ramifications for its promotion as a poverty alleviation strategy.

By drawing attention to institutions, agro-ecology and the prospects of differential outcomes, this analysis points towards potential interventions that can even out the adoption, and improve the overall performance of Bt cotton. Immediate attention to quicker cotton payments and reduced corruption could boost adoption rates, particularly for resource poor farmers. The implementation of integrated pest management techniques and farmer education programs could improve the profitability of the technology while forestalling longer-term pest issues. Reducing the cost of Bt cottonseed to the socially optimal seed price of US$ 40 per hectare could further spur adoption levels and profits for producers by return a greater percentage of the overall benefits of the technology to producers.

More broadly, this analysis underscores that transgenic seed adoption and performance must be thought of as contingent upon a suite of social, institutional and agro-ecological factors. Traditional farm-gate analyses divorce transgenics from the sociological and agro-ecological context of its adoption. In so doing they perpetuate an agricultural development paradigm that favors technological introduction over farmer-centered development approaches; they perpetuate a myth that by engineering better seeds alone, scientists can simultaneously solve agricultural and social problems. But, one way to break out of that paradigm is to devote greater attention to evaluative analyses that focus on how these technologies are embedded in a social and agro-ecological context. Greater awareness of this reality can lead to a more nuanced understanding of the suite of impacts of transgenic crops interventions. It can also open the door to different, more socially embedded development processes, like farmer fields schools, which rely on knowledge as the key to addressing agricultural and social problems.

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