



Knowledge politics and the Bt cotton success narrative in Burkina Faso

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ABSTRACT

Burkina Faso's 2008 Bt cotton adoption was Africa's largest genetically modified (GM) crop introduction principally for small farmers, and became its most celebrated success story. In 2016, however, Burkina Faso announced an abrupt phase-out of Bt cotton, citing millions of dollars of losses due to inferior lint quality. In hindsight, quality issues were conspicuously absent from the success narrative, particularly given that cotton sector actors were aware of problems for a decade. Recent data also reveal significantly lower yield gains and substantial inequalities between farmers, further questioning the success story and the evaluation literature it relied upon. Why and how was such a faulty and incomplete success narrative produced and promoted? To answer this, we draw on extended fieldwork conducted over ten years in Burkina Faso to critically examine how the knowledge used to build this success narrative was produced. We first scrutinize the evaluation literature, pointing out flaws and blindspots in the methodologies and reporting of findings. We then extend our analysis, drawing on political ecology and critical science studies, to focus on the power relations of knowledge production. We focus on three themes and show how (1) the political economic context favored the production of positive results, with Monsanto holding substantial power over the evaluation process, (2) the narrow epistemologies of agronomic evaluation produced "apolitical" knowledge that overlooked how local-level power dynamics shaped data collection, and – in at least two cases (fertilizer application rates and seed costs) – the returns accrued by smaller-scale Bt cotton farmers, (3) the knowledge produced via these processes was used to accrue material benefits to Monsanto and helped to promote GM crops across the continent. We conclude that future GM crop evaluations should be more self-reflexive, critical, and transparent in how power shapes the evaluation process and agricultural outcomes for differentiated farmers.

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In 2008, Burkina Faso became the first African nation to commercially introduce a genetically modified (GM) crop to a significant number of smallholder farmers. Bt cotton, which provides insect resistance, was widely embraced by the Burkinabè cotton sector under the promise that it would increase yields and incomes, and boost overall cotton sector profitability and "competitiveness." Quite rapidly, Bt cotton was framed as a success story. Proponents of a "Gene Revolution" for Africa extolled Burkina Faso's rapid entry into the ranks of "biotech mega-countries" (James, 2009). With glowing reports of widespread Bt cotton adoption, rising yields, increased farmer incomes, and efficient pest control (James, 2010; Pertry et al., 2016), Burkina Faso was held up as an example for other African countries to emulate, and as evidence

of the unequivocal benefits of GM crops for African smallholder farmers (ISAAA, 2010).

It thus came as an abrupt surprise to many when Burkina Faso's cotton sector announced in early April 2016 that it would end Bt cotton production and return to "100% conventional" cotton (L'Economiste du Faso, 2016). The Inter-Professional Cotton Association of Burkina Faso (AICB, 2015), an umbrella group that consists of Burkinabè cotton companies and the cotton producers' union, explained that Bt cotton had inferior quality characteristics which had resulted in major economic losses for the cotton companies. They reported a lower ginning ratio and a shorter fiber length than conventional Burkinabè cotton varieties. Whereas long-fiber conventional cotton had previously attracted a price premium and eager buyers on the international market, Burkinabè cotton companies were struggling to sell their shorter fiber Bt cotton. They reported economic losses of 48 billion CFA francs (roughly US\$76 million), and sought compensation from Monsanto, the U.S. company that had provided the Bt technology (Bavier, 2017).

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Burkina Faso's abrupt reversal on Bt cotton was surprising to many, given the widely promoted success narrative. Problems and discrepancies with Bt cotton, however, were apparent to those inside the cotton sector well before 2016. Burkinabè cotton sector officials and Monsanto executives were concerned about lint quality and fiber length issues since 2006. Furthermore, aggregate cotton sector data revealed significantly lower average yield improvements (13%) associated with Bt cotton than the numbers cited in the peer-reviewed scientific literature and used in calculating royalty payments for Monsanto (30%) (AICB, 2015). This large discrepancy in yield gains – and recent findings of major inequalities between poorer and wealthier farmers in how they benefited from Bt cotton (Sanou et al., 2018; Vognan & Fok, 2019) – raise important questions about how yield data were generated, analyzed, and reported in the Bt cotton evaluation literature. While lint quality issues led Burkina Faso to end Bt cotton production, both quality and yield issues indicate problems with the broader success narrative, which was either silent despite existing knowledge (on quality issues) or later found to be inaccurate (on yields and the distribution of benefits). We find it particularly puzzling that many problems were known about or suspected for many years yet were absent from the evaluation literature that proclaimed Bt cotton in Burkina Faso as a success. How and why was such a faulty and incomplete narrative produced and promoted?

The research presented in this article focuses on the power relations of knowledge production as a way to understand the creation and endurance of Burkina Faso's Bt cotton success narrative. The case of Bt cotton in Burkina Faso is particularly significant, as it was not only a highly visible pioneer of GM crop commercialization in Africa, but also one of the only cases worldwide of a major reversal in GM crop production. Examining the production, and the surprising persistence, of the success narrative surrounding this case holds lessons for how to understand and assess GM crop development in Africa.

We begin by situating our work in a broader political ecology literature which explores the relationship between different forms of power and knowledge production in relation to GM crops. We then examine methodological and conceptual issues in the Bt cotton evaluation literature in Burkina Faso, pointing to the need for a deeper analysis of how material interests and unequal relationships between actors shaped, or were overlooked in, the production of knowledge. We examine the power / knowledge production nexus in three parts. First, we analyze the political economy of knowledge production, exposing important conflicts of interest, which help to explain key silences in the reporting of problems. Second, we examine how the resulting evaluation literature was “apolitical,” meaning that it ignored how local-level power relations shaped both data collection and Bt cotton outcomes for cotton producers. Many of the glaring oversights in the success narrative resulted from a failure to recognize how relationships between farmers and cotton company employees can dramatically affect farmers' seed costs, fertilizer use, and consequent farm outcomes. Third, we examine how this apolitical knowledge production process served to reproduce uneven material benefits in favor of the biotech industry in Africa. Finally, we discuss the implications of this work for ongoing GM crop debates in Africa and beyond.

1. Knowledge politics, success narratives, and GM crops

In the contemporary moment of “post-truth” politics, in which deconstructionist logics have been deployed to question all kinds of truth claims, many scientists – including those who study GM crops – have sought to defend the idea of neutral, disinterested,

and apolitical science. Yet part of the practice of science is continuous scrutiny of scientific knowledge. Neimark et al. (2019) argue for the renewed importance of careful social scientific study of the relationships between power and the production of knowledge. They note that “foregrounding (once again) these relationships between political power and truth claims makes it possible to clarify mechanisms of knowledge production and exclusion” (p. 3), allowing us to understand how “power constitutes, moves within, and reproduces socio-material relations to shape which knowledges, social relations, and practices (and corresponding ecologies) are hegemonic” (p. 4). In other words, despite impulses to circle the wagons in defense of apolitical science, critical social scientists must continue to illuminate and critically analyze the power-laden processes of knowledge production.

Since the post-structural turn in the 1990s, the field of political ecology has broadly examined linkages between power, discourse, and knowledge claims (Forsyth, 2013; Peet & Watts, 2002; Robbins, 2012). Political ecologists and other critical social scientists have drawn from Foucault and poststructuralism to examine how the linkages of discourse and power shape our very parameters of thought and action. As in Bourdieu's concepts of doxa and domination or Gramsci's theory of hegemony (Burawoy & Von Holdt, 2012), discourses or knowledge structures shape peoples' assumptions, the models they use, and what comes to be considered “truth.” Many scholars have interrogated how the production of certain kinds of apolitical and ostensibly neutral scientific knowledge is actually deeply intertwined with the re-production of material power (Ferguson, 1994; Leach & Mearns, 1996; Mitchell, 2002; Robbins, 2012). For example, “scientific forestry” was used in India to advance timber extraction while significantly transforming livelihoods and disenfranchising local communities (Bryant, 1997; Guha, 2000). Goldman examined how the World Bank funds the production of expert knowledge, which it then uses to “underwrite a particular ideology of development” (2005, p. 174). Forsyth and Walker (2008) have argued that environmental discourses about forest loss in Thailand rely on selective forms of knowledge that reinforce social structures, particularly ethnic divisions.

Sociologists and historians of science have also examined the growing links between industry and scientific research, asking critical questions about how the scientific knowledge produced through such partnerships – and what the public hears about this science – gets shaped by commercial interests (Frickel & Hess, 2014; Mirowski, 2011; Moore et al., 2011; Oreskes & Conway, 2011). In the case of biotechnology, research by Glenna et al. (2015) shows how “the intellectual property protections in GE (genetically engineered) crops are hindering some types of agricultural and environmental research,” (p. 166) despite concerted efforts to allow for such public research to occur (also see Kloppenburg, 2004; Tansey & Rajotte, 2008). Of particular interest is the question of silences, including how Material Transfer Agreements and confidentiality or non-disclosure agreements shape scientific research, and the question of “undone science” – the fact that many important questions are simply not researched (Frickel et al., 2010).

Critical social scientists examining GM crops in the Global South have focused on power and knowledge production but have seldom examined both in tandem. One strand of research examines the networks and actors promoting GM crops globally, and in Africa in particular. Recent scholarship examines the broader political-economic landscape in which coalitions of actors have sought to promote and build consensus around GM crops (Harsh, 2014; Ignatova, 2017; Schurman, 2017). Donor dependence (including the funding and training of African scientists) and the economic interests of corporations strongly shape these coalitions (Rock, 2019; Rock & Schurman, 2020; Schnurr, 2013; Schurman,

2017). Several scholars have built on Gramsci's notion of hegemony (Andrée, 2007; Newell, 2009; Schnurr, 2013). Newell (2009) introduced the term "biohegemony" to examine how powerful groups produce consent to GM crops through the use of material, institutional, and discursive power. Discursive power, he argues, "derives from and expresses itself in the ability to construct and reinforce dominant framings of issues" (p. 52). Drawing on Newell, Schnurr (2013) examines the "constellations of power" – networks of organizations, corporations, and institutions – that create consent for the narrative that GM crops are the only solution to African agriculture. Other parallel scholarship has emphasized how these powerful dominant (productivist and techno-centric) perspectives emphasize particular expectations and narrowly frame debates around GM crops (Dowd-Urbe, 2017; Glover, 2010b; Jansen & Gupta, 2009; Moseley et al., 2015; Scoones & Thompson, 2011).

A second strand of research analyzes shortcomings in the evaluation literature undergirding GM crop success narratives in the Global South. Scholars have found persistent methodological problems in the GM crop evaluation literature in India and South Africa: narrow evaluation criteria, selective interpretation of evidence and data (Glover, 2010a), methodological problems in comparison known as selection and cultivation bias (Stone, 2011, 2012), and a downplaying of significant variability by reporting findings in averages (Glover, 2010a; Stone, 2011; Thompson & Scoones, 2009). These concerns about problematic evaluation methodologies contribute to a broader literature critical of how pro-GM success narratives rely on epistemologically narrow economic analyses that are disembodied from broader social, institutional, and historical contexts (Dowd-Urbe, 2014a, 2017; Flachs, 2019; Glover, 2010a; Jansen & Gupta, 2009; Schnurr, 2012, 2019; Smale et al., 2006; Stone, 2011, 2012; Thompson & Scoones, 2009).

We draw from both strands of research to examine the power dimensions of GM crop knowledge production in Burkina Faso. Our analysis employs a broad political ecology approach to power, paying attention to who has the ability to exercise influence, shape discourses, gain access to resources, and who (or what knowledge) is marginalized in relation to these abilities (Robbins, 2012). We thus examine how dominant epistemologies of agronomy and economics are intertwined with the economic interests of agribusinesses that often fund those research programs. In a classic political ecology vein, we are interested in how "apolitical narratives" that appear neutral, in fact, work to render invisible the material interests at stake (Ferguson, 1994), particularly relations of inequality and marginalization. Finally, we pay attention to how this process of knowledge production served to reproduce material benefits and the favorable position of the biotech industry in Africa.

2. Data and methods

This paper draws on multiple datasets, including an extensive review and content analysis of existing literature on Bt cotton in Burkina Faso. We also draw on two sets of long-term, qualitative data collected by the authors in Burkina Faso, indicating, where appropriate, upon which data we are drawing.¹

The first author conducted eight months of ethnographic fieldwork in 2016, during Bt cotton phase-out negotiations and the return to conventional cotton. This author conducted 125 interviews with cotton sector actors, including employees of the state-owned cotton company *Société Burkinabè des Fibres Textiles* (SOFITEX), government employees and research scientists, Mon-

santo employees, non-governmental actors, and 80 interviews with male and female cotton farmers. Fieldwork also included one month of participant observation with SOFITEX, attendance at a regional cotton conference and anti-GMO activist events, and five months of participant observation in a farming community in the Houndé region near Koumbia. The author conducted research in French and Dioula, languages the author speaks fluently. This enabled data collection not just from interviews but from the conversations and interactions of daily life, including extended farm visits, observations of conflicts and disputes, and long evenings of conversation with diverse groups of people.

The second author conducted eleven months of ethnographic field work between 2007 and 2009, during the final farmer field trials and first commercial growing season of Bt cotton. The author conducted over 100 interviews of actors implicated in the introduction of Bt cotton, including cotton sector officials in all three Burkinabè cotton companies, the Burkinabè Ministry of Agriculture, Burkina Faso's Agricultural Research Institute – the *Institut de l'Environnement et des Recherches Agricoles* (INERA) (where he held a research affiliation), Monsanto, Syngenta, the World Bank, the French Development Agency, anti-GM groups and activists, and implicated local NGOs. This author also attended farmer field trials, two regional conferences on GM crops held in September 2007 and October 2008, and a November 2008 training on refugia sponsored by Monsanto. Additionally, this author conducted a survey of 70 heads of household in one of the most productive cotton growing areas in Burkina Faso (Tuy Province) in February of 2009. This paper also draws from further trips to cotton growing communities and interviews with cotton sector officials and cotton growers in Burkina Faso totaling ten weeks in 2012, 2013, and 2018.

3. Portrait of a young success story

To briefly review, Burkina Faso conducted its first confined field trials of Bt cotton from 2003 to 2005. These trials were of two imported American Bt cotton cultivars (Coker 312 and DP50), which included the patented host material of their international partner, Monsanto. These original field trials reported an average yield increase of 14.7% (Vitale et al., 2008). Burkinabè cotton sector officials, however, wanted to use a Bt cotton cultivar that retained the agro-climatic adaptation and quality characteristics resulting from decades of local breeding efforts. At their request, the Bt trait was backcrossed onto three local cultivars – FK 290, FK 37, and STAM 59A – and reproduced for three generations with the aim of retaining desired characteristics (Dowd-Urbe & Schnurr, 2016). Two of these new cultivars (FK95 BG II and FK96 BG II) were tested in a small field trial in Boni in 2006, and then on 20 farmer-led field trial sites in 2007. The peer reviewed literature on these field trials reported an average yield gain of 34% (Vitale et al., 2011). These field trials were the subject of great attention, receiving visits from an international delegation in October 2007 of multiple African countries, sponsored by USAID. Subsequent Bt evaluation publications were based on field surveys conducted by INERA (Burkina Faso's Agricultural Research Institute) in 2009 of 160 cotton producers (Vitale et al., 2010), and then similar surveys from 2009 to 2014 (Vitale et al., 2016).

Just as in other GM crop-adopting countries in the Global South, pro-GM organizations portrayed Bt cotton in Burkina Faso as an unmitigated success. There were also, as elsewhere, pockets of anti-GM resistance and counter-narratives coming from both within and outside Burkina Faso, but these voices were generally disregarded by Burkinabè cotton sector officials and partners (Luna, 2020a). The dominance of GM advocacy organizations in constructing a success narrative was clear. They published reports with celebratory titles such as "Six Years of Successful Bt Cotton

¹ We often leave interviewees' positions vague in order to protect anonymity, particularly given the small community of implicated scientists in Burkina Faso.

Cultivation in Burkina Faso" (Karembu et al., 2014) or, "The success story of Bt cotton in Burkina Faso" (Pertry et al., 2016). Even after Burkina Faso's phase out of Bt cotton, the narrative of success continued. One organization in particular, Cornell's Alliance for Science, published articles claiming that "GM cotton in Burkina Faso has in reality been a runaway success" (Conrow, 2016), and that the withdrawal of Bt cotton was "reversing the tide of progress" (Gakpo, 2017). The post-withdrawal success narrative often framed Burkina Faso's reversal as based on a simple "technical problem" (See Luna, 2020a). Importantly, Monsanto and other international organizations known for promoting biotechnology (e.g. the International Service for the Acquisition of Agri-Biotech Applications, or ISAAA, and Cornell's Alliance for Science) played a disproportionate role in creating and propagating this success narrative.

What is striking about this success narrative is that nearly all of these articles and reports relied on and reproduced the same set of numbers and basic claims: that Bt cotton offered farmers 20% or even 30% yield improvements and increased "smallholder farmer profits by an average of 51 percent" (Gakpo, 2019). These and related numbers were consistently repeated and assumed to be proven. ISAAA used these numbers. Academic articles used these numbers, as in an article titled "Africa's inevitable walk to genetically modified (GM) crops" (Okeno et al., 2013). Monsanto's internal advice to employees regarding how to respond to questions about Bt cotton in Burkina Faso included the following line: "It has been proven that farmer income on average has increased up to 50%" (FleishmanHillard, 2015).

Significantly, these claims were drawn from a small number of studies from a narrow evaluation epistemology with significant methodological issues. We contend that these studies provided a thin and faulty basis on which to make grand claims about the success of Bt cotton in Burkina Faso. As Thompson and Scoones (2009, p. 391) remind us: "models are of course only as good as the assumptions and the data on which they are built." In analyzing these studies, we find many of the same fundamental problems that have been found in the GM evaluation literature on Bt cotton in India and South Africa (Glover, 2010a; Schnurr, 2012; Stone, 2011, 2012). Here, we outline some of these central empirical concerns, before turning our analysis to how the production of this apolitical success narrative was itself a product of and productive of unequal power relations.

Finally, although we are critical of the unmitigated success narrative, we also want to be clear that we witnessed several bracketed benefits from Bt cotton in Burkina Faso, most notably pesticide use reduction (a significant benefit for farm families exposed to toxic insecticides) and yield and labor productivity improvements for some farmers. These benefits were often ignored or denied by anti-GM activists. Our analysis seeks to carve out space for a more nuanced assessment.

3.1. Critical omissions and spurious claims

The critical literature on GM crops has well established that crop evaluation studies downplay or omit issues that operate at longer time scales,² and obscure differential outcomes via a focus on average results (Glover, 2010a). These criticisms hold true for the Burkina Faso case as well. Curiously, the very same literature that establishes the "average" claims used to push a success narrative also documents significant differences in outcomes for farmers.

² Concerns have been raised about the emergence of pest resistance and secondary pests in areas of intensive Bt cultivation. The dominant narrative in Burkina Faso either assumed refugia were planted or ignored the issue entirely. Yet our evidence indicates that refugia were rarely – if at all – planted (see below).

These findings are minimized, however, through linguistic framing and a general neglect of these findings.

Evaluation studies of Bt cotton in Burkina Faso regularly used "averages" in abstracts, introductions, and conclusions to assert the benefits of Bt cotton. These reported averages were widely circulated in news coverage and used to build the success narrative of Bt cotton. These averages, however, obscured substantial variability and differences in outcomes for farmers, which can be found buried in these same analyses. For example, one early paper claims that "the results found that across all years and both sites, that Bollgard II cotton provided a significant yield advantage of 14.7% over conventional cotton" (Vitale et al., 2008, p. 1964). Yet this claim obscures their own finding of a significant yield advantage in only two out of three years of research trials. Another paper claims that "Bt cotton producers earned a profit of \$39.00 per ha, a \$61.88 per ha increase in cotton income over conventional cotton, and also shifted producers' bottom line from a negative position to a positive one" (Vitale et al., 2010, p. 320). This claim was based on a partial budget analysis, and the calculated profit gain was primarily a function of an estimated (average) 18.2% yield gain. However, the data in this paper (which suffer from major limitations which we discuss below) reveal significant variability. In one data table (p. 326), of 24 different combinations of farm size, region, and number of pesticide sprays, ten of these categories of farmers had *negative* revenue farming Bt cotton.³ Nonetheless, the paper glosses over this variability and instead gives the impression of uniform or reliable gains via the reporting of averages, as in the quote above.

Beyond issues of selective reporting and placement of findings, at times the evaluation literature forwards assertions that lack evidence. One paper claimed that "Bt cotton increases land productivity compared to conventional cotton, which (all else equal) provides a positive impact on the environment by reducing pressure on agricultural land" (Vitale et al., 2016, p. 128), which is a claim often made by GM crop advocates. However, our own fieldwork found that all else isn't equal. Many larger-scale Bt cotton farmers reported *increased* acreage of cotton because of decreased labor requirements for insecticide spraying. A survey by Sanou et al. (2018) also substantiates this finding. Thus, this claim of reduced land pressure is unsubstantiated and likely to be false.

3.2. Methodological concerns regarding counterfactuals

In addition to issues regarding the reporting of findings and erroneous assertions, the evaluation literature also suffers from methodological issues with the "counterfactual," or what Bt cotton was compared to. Counterfactual issues can be a significant (and often invisible) source of bias and can lead to over-estimates of GM crop yield differences (Stone, 2012). In brief, when Bt cotton yields are compared to conventional cotton yields, all other sources of yield variation need to be accounted for and controlled for. Two common counterfactual issues in the GM crop evaluation literature are "selection bias" and "cultivation bias." Selection bias means that studies fail to control for underlying differences between farmers who "select" into growing Bt versus conventional. Comparisons are then muddled because yield differences may be caused by different characteristics of farmers and not necessarily the GM trait. Cultivation bias means that the studies fail to control for differences in how farmers cultivate the two crops, such as treating Bt fields differently than conventional fields.

³ Negative revenue appears to have occurred for farmers in each region, at each level of pesticide spraying, and for each category of farm size. The paper gives no indication of how many farmers are in each category. This is just one example of contradictory data or confusing claims within these papers.

Here, we briefly discuss how these two sources of counterfactual error were likely present in much of Burkina Faso's Bt yield evaluation literature, in particular 1) the on-farm field trials from 2006 and 2007 and, 2) the post-commercialization farmer surveys conducted by INERA between 2009 and 2014. A third – very different – source of yield data comes from aggregate cotton company statistics, which were used to establish cotton yield trends in a 2015 report (AICB, 2015). Cotton companies calculate yields by dividing the total weight of cotton received at the gin by the total production area. Total production area is derived from cotton cooperative data from individual villages and from data compiled by cotton company extension agents and coordinators. While these aggregate data have benefits (particularly in being a whole population data set, not a sample), they also do not control for selection or cultivation bias in comparing Bt and conventional yields.⁴ Here we focus principally on the issues with the evaluation literature, since this literature produced the data upon which the success narrative was built.

Early on-farm field trials in 2006 and 2007 likely suffered from both selection and cultivation bias. The major article establishing the empirical results of these trials (Vitale et al., 2011) contains no statement about how yield gains were measured, nor any information on the counterfactual (that is, data on conventional cotton yields) used to establish claims of an average 34% yield gain. Yet these trials likely suffered from selection bias, based on our interviews. Bt farmers were selected by the cotton companies and were generally “model” farmers who followed recommended practices. The trials also likely suffered from cultivation bias. Bt farmers were slated to receive an international delegation in their fields, a strong incentive to make sure that GM crops were well maintained. Similarly, the Burkinabè cotton sector officials guiding these field trials had an enormous incentive to make sure that the farmers were following advised protocols – including but not limited to advised fertilizer application rates and pesticide spraying regimes. These incentives and differences in treatment likely exaggerated the difference between Bt and conventional cotton yields.

Subsequent on-farm evaluation studies (Vitale et al., 2010, 2016) also likely suffered from selection and cultivation bias. The 2010 paper claims to compare yields and profits between Bt and conventional cotton, yet provides *no explanation* of how researchers obtained data for conventional cotton yields. Stone (2012, p. 67) ascertained that the counterfactual likely came from refugia: areas of conventional cotton that are designated primarily to grow insects, not cotton, in order to forestall the emergence of pest resistance to the Bt toxin. Comparisons with conventional cotton grown in refugia would result in over-estimates of Bt cotton yield differences since farmers would be unlikely to treat refugia with the same care. Additionally, our research spanning several years never came across a refugia, and numerous interviews with cotton sector actors indicated that refugia were unlikely to have been planted. A survey in 2015 (Sanou et al., 2018) found that 92% of farmers had never heard of them. Moreover, INERA was conducting research on whether non-cotton crops and natural plants could serve as refugia. These findings raise further questions about how conventional cotton yield data were obtained.

Other forms of selection and cultivation bias also likely skewed results. Comparing farmers growing Bt with those growing conventional can be problematic because of selection bias in the types of farmers who grow Bt versus conventional. A 2016 paper pro-

vides evidence for this, yet ignores and obfuscates its own evidence. The paper finds that “Bt cotton farms were 60% larger in field size than conventional farms and also had a larger household supply of agricultural labor and working animals than conventional farmers” (Vitale et al., 2016, p. 127). The paper also finds that larger farms have higher yields than smaller farms, for both conventional and Bt cotton farmers. Farm size and fertilizer use differences between Bt and non-Bt growers were also found by Vognan and Fok (2019). These differences matter because the claim of Bt “yield advantages” appears to be based on non-controlled comparisons. In other words, these are not paired studies with replicated field trials to account for soil variability, rainfall, pest pressures, and farming practices such as timing of planting, cultivation techniques, and the crucial factor of fertilizer application (which we examine below). Instead, yields from Bt cotton farms were simply compared with yields from conventional cotton farms, which is our best guess given the limited methodological descriptions in the literature. An additional source of error in these comparisons may have resulted from cultivation bias, or differences in how farmers attended to Bt cotton fields. For example, farmers may have given more inputs and attention to Bt cotton than conventional cotton because of the higher seed cost of Bt cotton, more scrutiny from extension agents, or the higher potential for debt if the Bt crop failed (see below), as has been documented with Bt cotton adoptions in other parts of the Global South (Stone, 2011, 2012).

Taking a step back, it is remarkable to consider that these few studies from a narrow evaluative epistemology, with significant methodological issues and biases in the reporting of findings, became the basis for a Bt cotton success narrative. Data that showed significant variation were glossed over with optimistic claims about average gains, and study designs failed to properly account for the effects of selection and cultivation bias in shaping yields. More critical studies (many of them independently conducted) have begun raising concerns about the dominant success narrative, with several studies finding that poorer/smaller-scale/less-equipped farmers were more likely to lose money by growing Bt cotton, and faced higher risks with Bt cotton (Dowd-Urbe, 2014a; Fok, 2016; Renaudin et al., 2012; Sanou et al., 2018; Vognan & Fok, 2019). Furthermore, aggregate data from the Burkinabè cotton sector showed that Bt cotton farms only had a 13% yield advantage over conventional cotton farms between 2009 and 2015 (AICB, 2015). Nonetheless, the success narrative and its inflated yield numbers remained the dominant story of Bt cotton in Burkina Faso. Why and how were these narrow and problematic knowledge claims produced and disseminated?

4. The political economy of knowledge production

We now turn to analyzing the political economy of the knowledge production process, highlighting the structures and incentives that shaped Bt cotton evaluation research in Burkina Faso. As Stone has argued, “we are naïve in swallowing empirical claims without a careful consideration of how vested interests affect the creation of facts” (2012, p. 64). We focus on the conflicts of interest inherent to the Bt cotton evaluation process, and in particular how Monsanto funding and control over the research process – principally through a contract with INERA – significantly influenced the production and reporting of research findings. In this context, some Burkinabès expressed that their concerns challenging the success narrative were either silenced or left unexamined. These findings echo the broader literature on how industry influences science and biotechnology evaluation, and specifically how Monsanto has regularly sought to shape and control scientific evaluations of its products in order to advance its economic interests (see McHenry, 2018).

⁴ Further, as we discuss below, there are various reasons for farmers to mis-report their cotton production area, which consequently reduces yield estimate accuracy. We do not, however, know, nor have reason to believe, that production area reporting dynamics are significantly different (i.e. trending to over- or under-report acreage) between Bt and conventional farmers. In this sense, the aggregate data produced by SOFITEX may be the best available yield comparison estimates in the absence of the paired control experiments we suggest, and without more information regarding how evaluatory literature yield estimates were derived.

4.1. Conflicts of interest

Bt cotton adoption in Burkina Faso provided an important financial boost for struggling public research institutions, and for Burkinabè researchers. Bt cotton was introduced through a partnership between Monsanto, INERA, and the AICB. Of particular interest is the connection between Monsanto funding and Bt cotton evaluations. Data from our interviews indicates that Monsanto provided funding for multiple years of field trials, evaluation studies, a lab to support breeding efforts, trainings for Burkinabè staff for breeding efforts, and for Burkinabè scientists and cotton sector officials to disseminate results in conferences and other venues.

This financial support came as public funding for agricultural research in Burkina Faso (and sub-Saharan African countries more broadly) had declined significantly since the mid 2000s, following the completion of two World Bank loans for agricultural research (Beitema & Stads, 2014; Author interviews). In 2016, INERA's director explained that the state "keeps the lights on," but research funds generally come from outside donors. Several research directors explained that this dependence on external funding severely limits the kind of research they can do, because donors (and certainly corporations) have specific interests regarding what they will fund and short-term time horizons. While cotton sector research in Burkina Faso is better off than other sectors, it was nonetheless affected by these cuts. INERA was severely affected, relying on contributions from the cotton companies, and experiencing budget shortfalls that occasionally delayed salary payments for INERA employees (Dowd-Urbe, 2014a). This institutional situation meant that the opportunity to cooperate with Monsanto – and receive research funding from Monsanto – was an appealing opportunity for the Burkinabè cotton sector, research centers, and individual scientists.

The importance of Bt cotton funding for INERA highlights the power imbalances between African countries and the private and philanthropic organizations who fund biotechnology research (Ignatova, 2017; Rock & Schurman, 2020; Schurman, 2017; C. B. Thompson, 2014). Funding from these entities is often portrayed as a much-needed lifeline for African research institutes. However, this funding also tends to come with explicit and implicit messages about the kind of research that will be done (Schnurr, 2013; Schurman, 2018), and often comes with Material Transfer Agreements, which may contain confidentiality and non-disclosure agreements regarding research processes (Mirowski, 2011; Tansey & Rajotte, 2008).

It is in this political economic context that Monsanto-funded North American researchers and Burkinabè researchers from INERA collaborated to evaluate Bt cotton. Several academic papers and book chapters evaluating Bt cotton were even published with Monsanto co-authors, without accompanying "conflict of interest" statements (Vitale et al., 2008; Vitale & Greenplate, 2014). Further complicating the institutional ties connecting researchers with Monsanto, INERA was also part of a contract with Monsanto. According to one scientist, "because INERA had signed a contract with Monsanto, Monsanto reviewed all our publications and presentations." This scientist explained that there were clear (if unstated) expectations for the kind of findings they should report, and felt that ongoing employment or promotion was implicitly dependent on meeting those expectations:

We saw photos of the Monsanto presidents with our president, and we knew they (Monsanto) had access to all of the ministers, but we do not. And so we self-censored... If you are in the good camp, you will be rewarded. If you are not, you will be set aside or marginalized.

Researchers in Burkina Faso – like other researchers worldwide – may also fear retribution or slander campaigns (Waltz, 2009). It

should be noted that there is a small community of research scientists in Burkina Faso, with revolving doors between INERA, SOFITECH, Monsanto (during its time in Burkina Faso), and related organizations. Working for Monsanto was highly sought after since these positions had higher and secured pay, and international travel opportunities. These jobs are extraordinarily valuable in a country with few employment opportunities for specialized researchers.

Our point here is that there were significant conflicts of interest shaping the research context that produced the Bt evaluation literature. Those charged with gathering and publishing data were not "independent" evaluators, which is ostensibly the role of state agencies and scientific researchers. Instead, they were dependent upon funding from a corporation that sought to sell the product they were evaluating, and bound by a contract that gave Monsanto oversight of their research. In addition to being constrained by this contract, many may have felt that their careers depended on facilitating this partnership.

4.2. Silences

Building from this, we can also examine how this situation of institutional dependence shaped relationships between Burkinabè scientists and non-Burkinabè Monsanto employees. Several scientists and senior employees at various institutions in Burkina Faso said their knowledge and concerns had been sidelined by Monsanto. In particular, Burkinabè scientists said they were aware early on of problems with Bt cotton's ginning ratio and fiber length. Monsanto was also aware of these concerns, as revealed in interviews with a Monsanto employee in 2008, and later by the fact that Monsanto paid financial compensation for the 2009/2010 and 2010/2011 cotton seasons for these issues (AICB, 2015). These issues were thus known (on all sides), yet completely silenced in the success narrative of Bt. None of the Monsanto or INERA co-authored papers mentioned these issues, even in papers published as late as 2016.⁵

Some Burkinabè scientists felt that part of this silencing was due to a systematic – and potentially racialized – disrespect for Burkinabè scientists and their knowledge (also see Eddens, 2019; Luna, 2018; Rock, 2019; and see Ezezika et al., 2012 for similar comments from Burkinabè scientists). One senior scientist explained that he felt that non-Burkinabè Monsanto employees viewed African scientists as less qualified, and that because of this, Burkinabè scientists' concerns were dismissed. In an interview, following a discussion of the fiber-length issues, he explained:

Respondent: What happened, I don't think it would have happened if they had taken us seriously. Because we had the impression that they underestimated the local (Burkinabè) researchers.

Interviewer: Who did?

Respondent: Monsanto. We had the impression that... so a PhD is a PhD. When we began to talk about problems (such as the short fiber length issue), they didn't believe us. Otherwise, we could have found a solution much earlier.

Interviewer: So the Monsanto people weren't believing local Burkinabè researchers.

Respondent: Exactly... I remember one time, I had to say to their director, I said, ma'm, you are a lawyer, when you speak, we listen to you when you are talking about the law, correct? So why, when I talk about agronomy, why do you tell me that what I'm saying is false? Ma'm, you must respect me. Diploma for diploma.

⁵ More recent papers with INERA authors have been more critical of Bt cotton (Sanou et al., 2018; Vognan & Fok, 2019). Interestingly, these were published after the end of Monsanto's contract.

Another senior researcher recounted that many Burkinabè scientists were aware of fiber length issues early on, and also had concerns about high seed costs for farmers, but that their concerns and input were pushed aside. This researcher explained that:

In 2006, they backcrossed into Burkinabè varieties. In 2008, Monsanto said, 'It's ready.' We (Burkinabè) scientists, we said no, we need to do more backcrossing. But Monsanto said there's no problem. . . But in 2006, already, they knew that the fiber length was shorter. The ginning ratio was also a problem. But Monsanto said, when we make a few changes, and do it at a broader scale, it won't be a problem. And the deals were done (gesture to indicate behind closed doors), and it was introduced. And the researchers didn't have a whole lot of say in it. And we thought, well maybe this will work out. Maybe Monsanto knows how to fix the issue.

As both of these scientists indicate, there was a significantly unequal power dynamic between Monsanto and Burkinabè research institutions. Rather than this being a story of "knowledge sharing," as is often promoted in discourses of bringing GM crops to Africa, many Burkinabè researchers felt that Monsanto side-stepped local actors, and in some cases, failed to heed their input. Of course, this wasn't a simple power dynamic of Monsanto versus Burkina Faso. Local Monsanto employees were Burkinabè researchers (most of whom previously worked for INERA or SOFITEX), and multiple actors and institutions were jockeying for influence (Compaoré Sawadogo, 2018). Nonetheless, our findings indicate that Monsanto's substantial power in a country like Burkina Faso likely created a situation that silenced some voices and kept significant issues with Bt cotton from coming to the public eye.

5. Apolitical knowledge production

In this section we examine how the knowledge produced to evaluate Bt cotton was partial and in some aspects even wrong, largely because it was framed by an apolitical view that technology can – and should – be evaluated separately from the world in which it is embedded (Flachs, 2019; Glover, 2010; Luna, 2020a; Schnurr, 2019). This builds on our earlier analysis of the problematic methodologies and narrow epistemologies of the Bt evaluation literature. Here, we add an analysis of power, showing the additional issues that resulted from a methodology that failed to acknowledge or examine the power dimensions affecting research processes as well as outcomes for farmers.

5.1. Power relations shape data collection

The social dimensions of the data collection process are almost entirely absent from the evaluatory literature. In fact, the published literature says very little about the data collection process in general. For the papers based on INERA surveys, authors simply note that data were gathered via household surveys and were collected by "local extension agents" (Vitale et al., 2010, p. 322, 2016; Vitale & Greenplate, p. 256, 2014).

The lack of discussion around how data were collected is particularly worrisome given the substantial literature documenting local-level power dynamics within the Burkinabè cotton sector. Power imbalances between cotton companies and cotton farmers have been at the center of cotton farmers' mostly unsuccessful mobilizations to gain greater power (Dowd-Urbe, 2014b; Gray, 2008). A deep sense of mistrust and "demotivation" pervades the cotton sector and interactions between cotton farmers and cotton sector employees (Diallo, 2008), where many farmers feel marginalized, unheard, and exploited. Cotton extension agents reinforce a hierarchy that systematically marginalizes and dispar-

ages poorer and smaller-scale farmers (Luna, 2019). Other research points to how cotton sector re-organizations have favored wealthier producers to the detriment of small and poorer producers (Gray et al., 2018).

These power dynamics likely influenced the Bt cotton data collection process, particularly given that "local extension agents" were apparently the main data collectors. Many farmers have various reasons to mis-report farm statistics to extension agents, and may have reported these same numbers when responding to these surveys. Our research identifies several circumstances in which farmers give false accounts of cotton acreage to extension agents. For example, if a farmer reports having a big enough field, they can get a truck to pick their cotton up directly from their field, rather than having to transport and weigh their own cotton. Second, farmers who report growing more than three hectares of cotton qualify for corn fertilizer and get additional inputs – and some farmers over-report acreage in order to obtain additional inputs for their corn. In the opposite direction, some farmers under-report cotton acreage because they want to purchase inputs on the market rather than receive SOFITEX insecticides (which they view as inferior quality), but which are mandatory and tied to acreage. Others simply want to limit debt, and spread inputs across a wider acreage and multiple crops. While these incentives to under- or over-report cotton acreage are not necessarily rooted in power dynamics, this information is channeled through extension agents, who hold substantial influence as the gatekeepers of resources. In other words, the hierarchical relationship between farmers and extension agents shapes the kind of knowledge farmers share with extension agents, complicating the ability of extension agents to conduct accurate surveys.

These critical dynamics are not acknowledged by the evaluatory literature despite their likely impacts on data validity. These articles do not discuss how the social conditions of data collection may have influenced findings, or how such dynamics were (or were not) addressed in research protocols. We should be clear that these dynamics existed for both Bt and conventional farmers (though differences may exist that we are unaware of). We do not suggest that these dynamics necessarily produced exaggerated yield claims for Bt cotton. Rather, we argue that any data collected by extension agents in this setting should be treated with considerable skepticism, and in the least must be acknowledged, discussed, and addressed in order to produce high quality data and comparisons. Our point here is that power-laden relationships between actors in the cotton sector may have shaped supposedly objective and neutral data, yet these very relationships were left invisible and unacknowledged.

5.2. Invisibilization of structural power: the case of fertilizer

The evaluation literature also overlooked how local-level power relations and structural inequalities shape farmer outcomes. We consider this in relation to fertilizer use and, in the following section, seed costs. Fertilizer rates influence Bt cotton profitability, and fertilizer application rates vary between wealthier and poorer farmers. However, none of the Bt cotton field trials or later studies assessed how fertilizer application rates would influence Bt outcomes. By assiduously ignoring the structural differences in farm practices for wealthy and poor farmers – differences which have been established in the social scientific literature in Burkina Faso (Gray, 2005; Gray & Dowd-Urbe, 2013) – apolitical evaluation studies produced knowledge that likely overestimated the benefits of Bt cotton, particularly for the poorest farmers.

Cotton production is linked to fertilizer use in several key ways. First, the cotton sector is the principal form of credit for Burkinabè farmers, and the main vehicle to receive fertilizers on credit. These fertilizers are then used not only on cotton but also other crops.

They are also sold, particularly by poorer farmers, as a way to gain access to money in times of need. The uneven access to and use of manures and fertilizers have been shown to be a primary mechanism by which social differentiation occurs at the village-level in rural Burkina Faso (Gray & Dowd-Urbe, 2013), particularly when wealthier farmers are able to purchase fertilizer at discounted rates from their poorer neighbors, who fall further into debt.

Differences in synthetic fertilizer (NPK and urea) application rates likely disproportionately benefited larger and more capitalized Bt cotton farmers. A recent study by Vognan and Fok (2019) of the differentiated impacts of Bt cotton found that less-equipped farms (those with one pair of oxen or no oxen) used less fertilizer than better-equipped farms, and that conventional cotton fields received less fertilizer than Bt cotton fields. This study also found that well-equipped Bt farms (those applying higher rates of fertilizer) had the highest yields. Previous research by Gray and Dowd-Urbe (2013) also found that wealthier/larger farms had higher yields and applied more fertilizer. Additionally, numerous scientists at SOFITEX, INERA, and Monsanto indicated (in 2016) that lower rates of fertilizer use had produced *differentially bad outcomes* for poor farmers growing Bt cotton. One senior scientist at Monsanto explained it this way:

Respondent: Following the technical itinerary (official recommendations for input use) is even more important with Bollgard2 (Bt). Given that there is less insect damage, the cotton plant produces more capsules that need to be nourished with fertilizer, at the very minimum the amount recommended With conventional, the insects will pierce some of the capsules so it will take less than Bollgard.

Interviewer: Less fertilizer?

Respondent: Yes, less fertilizer than Bollgard. So if the farmer doesn't apply much fertilizer (to Bollgard), it's true that there will be a lot of capsules, but they will be tiny.

Interviewer: And thus the yield will be low.

Respondent: Yes, exactly.

This senior scientist (along with many others) thus explained that Bt cotton was more dependent on fertilizer than conventional cotton. This respondent also explained that farmers apply one third or two thirds of recommended inputs, and that the "smallest farmers have the lowest yields, because they use less fertilizer." These observations also raise the important question of whether fertilizer use, not Bt seed, was driving observed yield differences between Bt and conventional, as Kranthi and Stone (2020) argue is the case in India. According to the AICB (2015), aggregate cotton sector data recorded an average conventional cotton yield pre-2008 (pre-Bt) of 1025 kg/ha, scarcely distinguishable from their data on Bt cotton yields (1034 kg/ha) from 2009 to 2015.

Given widespread awareness among Burkinabè cotton sector employees about differences between farmers in terms of fertilizer application rates, the question emerges: *why* were these differences never incorporated into studies carried out in conjunction with INERA and Monsanto agronomists? Why were studies not done where fertilizer application rates were varied to account for farmer practices? Again, the problem is not that cotton sector employees were unaware of these inequalities between farmers. It is more likely that these issues were not considered to be within the purview of a "scientific," meaning strictly *apolitical*, assessment of the technology (Kinchy, 2012), as the dominant epistemologies of agronomy and agricultural economics (and used in corporate-funded evaluation studies) tend to overlook social and power dynamics (Sumburg, 2017). Furthermore, despite the "pro-poor" discourses attached to crops like Bt cotton, cotton sector employees are rarely interested in helping the poorest farmers, and tend to focus their efforts on "professionalizing" the larger-scale farmers

who are already well-off (Dowd-Urbe, 2011; Luna, 2019). Additionally, recognizing and studying inequalities between farmers may have raised potential red flags and concerns about whether Bt cotton was as beneficial as claimed, or whether the seed price was too high. While some Burkinabè scientists were concerned about these issues, these questions were not in Monsanto's interests.

5.3. Power relations shape outcomes: the case of seed cost

Our second case of how the evaluation studies overlooked local-level power dynamics examines the standard estimates of farmers' seed costs. Many critics of GM crops have argued that high seed costs would disproportionately hurt small farmers. Part of this argument is that in rainfed agriculture, farmers risk losing a planted field due to gaps in rainfall and may have to replant – and thus repurchase – expensive GM seeds. However, proponents of Burkina Faso's Bt cotton adoption noted its unique "per-hectare" pricing for seeds – which, in theory, meant that if seeds did not germinate uniformly, farmers could receive additional seed free of charge to complete the seeding process. This was viewed as a significant advancement, since farmers would not have to incur additional seed costs should their seeds not germinate uniformly.

The evaluation literature used the per-hectare price in calculating Bt cotton's profitability. Most cotton sector employees interviewed in 2016 also stated that farmers had access to free seeds for replanting should they need them. However, here, we show how power imbalances between farmers and cotton sector employees meant that in many cases farmers in fact had to pay to get additional seed. The omission of these "hidden" but altogether expected additional costs resulted in overestimates of farmer gains, while obscuring the power dimensions mediating farmer outcomes. Not surprisingly, given the overall slim margins of cotton production (Gray, 2008; Gray, Dowd-Urbe, & Kaminski, 2018; Luna, 2020b), farmers explained that this extra cost had dramatic effects on the profitability and risks of Bt cotton production.

To understand why farmers ended up paying more despite a "per-hectare" policy, we need to understand the context of cotton planting and the power relations shaping the process by which farmers obtain additional seeds. There are two categories for farmers to order additional seeds: *re-semi* (replanting, in the case of seed loss) and *demande complémentaire* (additional order, in the case of wanting more seeds to expand acreage). Both orders are made through local extension agents (ATCs). These catch-up orders are placed in a context of utmost urgency: farmers are anxious to get cotton planted early, particularly given what farmers (and Burkinabè scientists) describe as increasingly variable rainfall and pest outbreaks in the late-season. Planting time is also a critical labor bottleneck for families, as children are still in school, and families are rushing to get all their fields planted (Luna, 2020b). Germination problems are thus extraordinarily stressful and time sensitive.

According to many farmers, "early on" (2009, 2010), Bt seeds for re-planting were free, and the amount of original seed provided was more generous. However, farmers said that over time the original amount of seed was reduced. SOFITEX also got stricter regarding *re-semi* orders, telling farmers that they needed to take responsibility for their actions and that oftentimes poor germination was the farmers' fault or that farmers were lying. This is where power relations became a critical mediator shaping farmers' seed costs, with SOFITEX employees shifting responsibility for germination problems onto farmers. In order for a farmer to qualify for *re-semi*, the farmer needed to prove a legitimate loss of seeds, with the ATC inspecting the farmer's field to verify. However, a single ATC is responsible for hundreds if not over a thousand farmers (the farmer to ATC ratio in SOFITEX is roughly 170,000: 200, or

850:1, according to 2016 SOFITEX data). Many smaller-scale farmers reported that ATCs would not verify their fields in the case of seed loss. Even if the ATC came, he might say the farmer had planted at the wrong time, or the density was wrong, and it was the farmer's fault. Rather than go through this lengthy and potentially humiliating process, many farmers explained that – given the urgency of planting – they either purchased more seed from another farmer or ordered seed as a *demande complémentaire* (extra seed), which was more quickly and easily available, but was added – at full price, 27,000CFA per hectare – to their debts. In other words, these farmers' lack of power meant that they paid more. Other actors in the cotton sector suggest that *re-semi* requests were written down by ATCs as *demande complémentaire*, perhaps under orders from managers to reduce the quantity of *re-semi*. Other actors suggest explicit corruption.

These findings indicate that Bt seeds may have significantly increased some farmers' risk of falling into debt – above and beyond recent studies finding that farmers viewed the basic seed cost as “barely acceptable” (Fok, 2016; also see Sanou et al., 2018) and that poorer farmers faced higher risks and negative outcomes with Bt (Vognan & Fok, 2019). Additional per-hectare costs would only happen when a farmer lost seed and purchased additional seed, but based on 2016 interviews, this was relatively common and a widespread concern for farmers. When repurchasing seed, a farmer could repeatedly lose 27,000CFA per hectare in one go, which was a potentially greater economic risk than the risks associated with conventional cotton (e.g. insecticide sprays can be washed off by rain, but this does not happen to all six sprays at once).⁶

These findings demonstrate the critical importance of paying attention to how power relationships between actors – in this case between farmers and cotton sector employees – shape both the research process, as well as how a technology plays out for differently situated actors. Evaluation studies that assume a world without power overlook these critical dimensions. The lack of awareness of these power relations and their effects on both the data collected, and the profitability of the technology for farmers, likely produced skewed and overly optimistic estimations of the accumulation and distribution of benefits from Bt cotton.

6. Apolitical knowledge exacerbated power imbalances

In this last section, we explore the material consequences of the evaluation literature, which bolstered a broader success narrative that reproduced and exacerbated power imbalances. In other words, the success narrative not only relied upon and invisibilized relations of power, it also served to produce material outcomes that benefited those with vested interests. Optimistic yield claims produced by early studies were used to calculate royalty prices for Monsanto, and to promote the expansion of GM crops across Africa (Schnurr, 2012, 2013).

6.1. Skewed royalty distributions

The original 2008 agreement that brought Bt cotton to Burkina Faso stipulated a distribution of benefits whereby Monsanto would gain 28% of the value added, and its Burkinabè partners (cotton companies, cotton farmers, and INERA) would receive the remaining 72%. This agreement relied on a number of assumptions in order to calculate the added value of Bt cotton. It assumed yield increases of 30% and a reduction of four pesticide sprays, meaning lower pesticide costs and higher yields for farmers, and more cot-

ton to commercialize for cotton companies. The agreement used these estimated value additions to set the Bt cotton seed price paid by farmers, and to set the royalty payments for Monsanto. Royalty payments were first based on bags of seed, and in 2011 were fixed at 26 euros per hectare of planted Bt cotton. This unusual system was designed because individual royalty contracts were deemed unfeasible.

As we have shown in this paper, this use of the 30% yield estimate overestimates the actual yield increase, and thus overestimates the value being received by Burkinabè farmers and cotton companies from Bt cotton. Thirty percent yield gains are the highest number that emerged from pre-commercialization studies, and yet this was the number that Monsanto mobilized in calculating its own monetary benefits. Later, aggregate data from the Burkinabè cotton sector found only a 13% yield advantage of Bt over conventional cotton between 2009 and 2015. The Burkinabè cotton body AICB thus argued in 2015 that the 30% yield advantage number was problematic and should be revised in any future calculations of seed price or Monsanto's royalty payments (AICB, 2015). The fact that the 30% number was used provides a clear example of how Monsanto leveraged certain types of knowledge (knowledge which was produced through a particular set of power relationships) to further their own material interests. Here cotton seed prices (as an input cost), and the politicized assumptions that go into their creation, became a site for extracting more value from farmers than stipulated in the royalty agreement. This mirrors decades of scrutiny of seed cotton (farmgate) prices paid to West African cotton farmers, and how the lack of transparency surrounding price setting leads to farmers receiving a proportionally smaller percentage of the total value of their labor (see Bassett, 2014).

It is also significant to point out that Monsanto was *guaranteed* payment, since their payment was based on the total area planted to Bt cotton. Yield increases could be lower than 30% – and indeed they were – but this did not affect the amount of money Monsanto received. The supposed “value-added” component for farmers and the cotton companies was dependent on what we have shown to be flawed assumptions about a fixed seed cost and consistently high yield gains (and ignored issues with fiber quality).⁷ This means that Burkinabè cotton companies and cotton farmers shouldered higher risk, needing to have optimal conditions to secure their negotiated percentage of benefits (also see Fok, 2016). In effect, although Monsanto only negotiated for 28% of the value, it received a much higher proportion of the total value generated by Bt cotton. Nonetheless, Monsanto and other pro-GM advocates claimed that farmers were capturing a majority of the benefits (James, 2010; Karembu et al., 2014).

6.2. Claims of success produce success

The success narrative – which relied upon the studies we have examined in this paper – helped pave the way for the expansion of GM crops in Africa, one of the central goals for agribusinesses in the African market (Schnurr, 2013; Schurman, 2017). This was achieved via the widespread promotion of the success narrative in news articles, briefings, press coverage, and by organizing tours and visits from other African countries. Yearly reports from the pro-GM crop group ISAAA put Burkina Faso front and center as an example of the rapid and successful expansion of GM crops in Africa. These reports drew on and reproduced the problematic claims that we have analyzed in this paper to promote GM crops more broadly to other African countries.

⁶ Furthermore, farmers had some cost flexibility with conventional cotton since they could potentially reduce insecticide sprays in the event of low pest pressure, and sell their remaining insecticide.

⁷ According to our fieldwork, the cotton companies also had unaccounted-for expenses in trying to manage two separate seed supply systems (Bt and conventional), keeping the Bt seed supply uncontaminated while processing both types of cotton through the same infrastructure of trucks and ginning facilities.

Burkina Faso's success story rapidly replaced South Africa as the principal "showcase for how GM crops can perform in the hands of African smallholders" (Dowd-Urbe & Schnurr, 2016, p. 165). The Burkinabè story was used to make a case for easing restrictions on GM crops across the continent, as when it was prominently featured in debates over biosafety legislation in Nigeria. Additionally, Burkina Faso regularly hosted visiting delegations from other African nations. This included "Seeing is Believing" tours, organized by Monsanto and ISAAA, in which government and agriculture sector actors from more than 17 African countries were invited to Burkina Faso to "see for themselves" the successes of Bt cotton. These tours, also organized in South Africa, were used to promote and expand the success narrative throughout Africa (Schnurr, 2012). The explicit aim of these tours was "that the participants will use this experience to expedite the commercialization process in their respective countries for the benefit of cotton farmers" (ISAAA, 2010).

However, the information, statistics, and narratives that tour participants received came from the problematic studies we examined in this paper. In other words, these studies were not only built upon (and disguised) relations of power, but they also served to reproduce power for the biotech industry by providing a model of success for the expansion of GM crops in Africa. We should also highlight the fact that many of the visiting delegations and field tours happened "well after Burkinabè cotton sector officials knew about cotton quality issues with Bt cultivars" (Dowd-Urbe & Schnurr, 2016, p. 165). This underscores the disjuncture between the prominent promotion of the success narrative and the other forms of knowledge that were known, but silenced or rendered less visible.

7. Conclusion

In the context of highly politicized GM crop introductions, many scientists and politicians assert that impartial scientific knowledge should drive decision-making (Gilbert, 2013; Herring & Rao, 2012). This may explain why knowledge claims have been a cornerstone of GM crop advocacy. The ISAAA home page in 2020 features the heading, "We feed the world with knowledge." Similarly, the United States Department of Agriculture (USDA) Undersecretary of Agriculture rhetorically asked at a 2004 GM crop conference in Burkina Faso, "What is the best thing that this conference can bring to Africa? *Knowledge*" (Traoré et al., 2014). Perhaps the central form of knowledge regarding GM crops comes from pre- and post-adoption evaluation studies, which are ostensibly neutral and objective. In Burkina Faso, a small set of evaluation studies produced the knowledge used to create a broader success narrative, which claimed widespread and unequivocal gains from Bt cotton.

This paper untangles the puzzling disconnect between the visible success narrative that surrounded the eight years of Bt cotton production in Burkina Faso, and the less visible (and invisibilized) knowledges of uncertainty, inequality, and problems that were present all along. Our close examination of the empirical basis for the success narrative reveals narrow evaluation epistemologies and methodological shortcomings similar to other GM crop evaluation studies in India and South Africa (Glover, 2010a; Schnurr, 2012; Stone, 2012), with major issues of farmer selection and cultivation bias that undermine the empirical validity of claims made about yield and profit increases. These shortcomings alone cast doubt on success narratives built upon narrow evaluation studies.

An analysis that ends at a methodological critique, however, would miss a more careful reading of the ways in which political-economic relationships shaped (while at the same time were rendered invisible in) Burkina Faso's Bt cotton success narrative. We articulated three primary connections: how material relationships such as funding structures and research contracts shaped

the context of knowledge production, how the resulting knowledge production process ignored local-level dynamics that shaped data collection and farmer outcomes, and finally, how the knowledge produced by this process served to reinforce the material benefits and favorable standing of the biotech industry. Each of these ways of thinking about the relationship between knowledge and power is distinct, but together help to explain why and how the success narrative was produced and why it endured.

First, the disproportionate power held by Monsanto produced a knowledge production context conducive to favorable findings. Monsanto funded the evaluatory research. The Burkinabè research organization (INERA) which executed these studies depended heavily on this funding and was confined by a contract with Monsanto controlling their data and findings. The research scientists carrying out this work knew that favorable results (and certain kinds of methodological choices) were an expectation. This context helps to explain how the significant issues with Bt cotton – notably the inferior lint quality and corresponding significant economic losses, but also unequal outcomes between farmers and problems with seed cost – remained largely unknown to the public for nearly ten years, until Burkina Faso announced its phase-out of Bt cotton.

Second, evaluation studies invisibilized power at the local level, despite a significant literature demonstrating how local-level dynamics shape farmer outcomes. Studies did not acknowledge, nor apparently account for, how the hierarchical position of cotton extension agents could hinder their ability to generate valid data. Furthermore, in at least two cases – fertilizer application rates and seed costs – evaluatory studies overlooked how local inequalities between farmers and between farmers and extension agents could significantly affect the returns accrued by Bt cotton farmers. Importantly, the invisibilization of these dynamics likely caused the evaluation literature to over-estimate Bt cotton results in general, and in particular, overstate outcomes for marginalized farmers.

Third, the success narrative that emerged from these studies was then used to improve the material benefits Monsanto accrued and bolster the position of GM crops across the continent. The highest field trial yield numbers – over two times higher than later estimates – were used to calculate Monsanto's royalties. Monsanto was guaranteed payment and received a higher percentage of the total value added than had been originally negotiated. Furthermore, "Seeing is Believing" tours were organized to promote GM crops to other African decision-makers, all while knowledge of the problems with Bt was kept silent.

This analysis is important not just because it helps explain the puzzling persistence of the Bt cotton success narrative in Burkina Faso. It also reveals the implications of the careful construction of politics-free data – what we refer to as "apolitical knowledge." Evaluation methodologies which invisibilize politics are an epistemological choice, born from the asymmetric power held by Monsanto. As we have shown here, the evaluatory studies conducted in Burkina Faso were funded by Monsanto, were shaped by a contract stipulating Monsanto's control over the research, and findings were sometimes published with Monsanto co-authors. Monsanto has a real material interest in findings that benefit them yet appear neutral. Narrow, quantitative economic studies that focus solely on yields while ignoring the broader social and political landscape are best suited to do this, as these kinds of quantitative studies are broadly viewed as scientific, neutral, value-free, and objective, despite the studies themselves and the objects/processes they study being thoroughly shaped by power relations. Our point here is that broader power dynamics shape the very terrain on which evaluation methodologies are chosen. In theoretical terms, powerful actors invisibilize power in order to reproduce their power.

As numerous African countries consider GM crop approvals and new biotechnologies such as CRISPR, the issues raised in this paper

will only become more pronounced and more important to address. Many of the dynamics reported here, from the conception of research protocols, industry control over research and findings, choice of evaluation approaches, collection of data, to representation of findings to a broader public, are areas of concern and require critical attention. Our analysis offers several key considerations for these ongoing debates and, in particular, for efforts to evaluate these new technologies.

We recommend major revisions to the current paradigm of technology evaluation studies. This means greater transparency and accountability in the reporting of data and how data are collected, inclusion of critical qualitative literature which explores the social dimensions of production, and the integration of findings from this literature into research protocols to reduce forms of bias. We would also urge broader (open, transparent, reflexive) discussions of the knowledge production process itself (Stone, 2012). If indeed GM crop organizations and advocacy groups are committed to knowledge sharing and the scientific process, they should recognize that knowledge is partial and contains biases, and that such partiality and bias should be the subject of examination and critical scrutiny. Moreover, we argue for the need to critically examine how power dynamics shape knowledge production as well as agricultural outcomes. This would involve organizations – and scientific disciplines – scrutinizing epistemological choices made for evaluation studies, and could lead to multiple epistemological approaches being adopted and mutually considered. They must also address the clear conflict of interest inherent in industry contracts which limit the independence of scientific researchers. These suggestions do not undermine science. Instead, they would help produce a more self-reflexive and transparent science that takes into account how knowledge itself is produced (Neimark et al., 2019; Robbins, 2012), and would create a more nuanced space to debate and consider the relative merits of GM crops.

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