Inventing Makhathini: Creating a prototype for the dissemination of Genetically Modified crops into Africa

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Abstract: This paper evaluates the experiences of smallholder farmers in the Makhathini Flats, South Africa, who have been cultivating Bt cotton since 1998. I begin by focusing on the high adoption rates achieved soon after its introduction and re-emphasize the context – geographical, institutional, historical – that underpinned this initial period of success, arguing that the story of Bt cotton in Makhathini reflects these structural processes as much as it serves as an endorsement of Genetically Modified (GM) technology. The paper then shifts to an investigation of how the representation of Makhathini's success has been used as crucial ammunition to help convince other African nations to adopt GM crops. In the final part of the article I emphasize the disconnect between the dominant representation of Makhathini that is celebrated in the scholarly and popular literature and the realities faced by its cotton growers. I argue that the representation of Makhathini's success with Bt cotton has outlived the realities recounted by its farmers.

Keywords: Makhathini Flats; Genetic Modification; Bt cotton; smallholder farmers; South Africa.

1. Introduction

The Makhathini Flats, in the northern-most part of the South African province of KwaZulu-Natal, first entered the war of words over the potential offered by genetically modified (GM) crops to African farmers in 1997. In that year South Africa passed the *Genetically Modified Organisms Act*, making it the first nation in Africa to legislate the dissemination of GM technology. One year later, the transnational biotech company Monsanto completed its government-regulated trials and made its patented Bt cotton seed – genetically engineered via the insertion of a protein-producing gene from the bacterium

Bacillus thuringiensis, which makes them resistant to most species of *Lepidoptera*, including American, pink and spiny bollworms – available to Makhathini farmers, targeting those with holdings of only a few hectares.[1]

Following the 1999/2000 growing season, a group of British and South African researchers published a series of articles, based on a single survey, which incorporated responses from one hundred cotton farmers, including both Bt adopters and non-adopters (Beyers et al., 2002; Ismael et al., 2002a; Ismael et al., 2002b; Bennett et al., 2003; Thirtle et al., 2003). Their findings revealed that after only two growing seasons, adoption rates among these smallholder farmers had swelled from 7% to over 90%. They reported two significant explanations for these sky-high adoption rates: increased yields (equivalent to a 40% increase for smallholder farmers), and reduced pesticide applications (which lowered costs, reduced exposure, and lessened labour requirements). Financial savings were significant: on average Bt cotton adopters recuperated between 400-700 Rand (equivalent to between US $55 and $100) per hectare (Bennett et al., 2007). This research further emphasized the corollary benefits for Makhathini farmers who embraced GM. Bt cotton saved women valuable time, allowing them to care for children and the elderly, or engage in other income-generating activities. Children were freed from spraying insecticide and were now able to return to school (Ismael et al.,

[1] The Bt cotton varieties planted in South Africa were developed and supplied by Delta Pineland (DP), which purchased the license rights for the Bt technology from Monsanto. The most popular Bt variety planted in Makhathini from 1999-2003 was NuCOTN 37-B, which was based on an old DP 90 variety owned by South African ginners Clark Cotton. The Bt gene was subsequently introduced into DP's popular OPAL variety to create NuOPAL, which replaced NuCOTN 37-B as the most popular variety grown throughout Makhathini from 2003 on. In the past few years a new 'stacked' version, with both Bt resistance and Monsanto's Roundup Ready herbicide resistance, has been introduced in Makhathini, which is known by the name NuOPAL RR (Gouse, 2009, p. 208).

2002a). In response to the title of their lead academic article 'Can GM technologies help the poor', these researchers replied with a resounding 'yes'.

News of Makhathini's success with Bt cotton spread rapidly. Then Provincial Minister of Agriculture and Environmental Affairs Narend Singh hailed the region as the centerpiece of South Africa's new 'Green Revolution' (Singh, 2002). Industry websites portrayed Makhathini's success as indisputable evidence of GM's potential to transform regions hampered by stagnating agricultural production (CropGen, 2002, cited in DeGrassi, 2003, p.20). Feature articles on Makhathini's transformation appearing in newspaper and magazines chronicled how these poor farmers were now finally able to afford cell phones, generators, and medicines, all thanks to the benefits of Bt cotton. These accounts were accompanied by evocative images of Zulu farmers literally swimming in bales of lush, white cotton (Seattle Times, 2003; Funnis, 2006). The Chairperson of the Ubongwa Farmers' Association was flown to thirteen different countries to give his first-hand account of how the lives of his family and community had improved since adopting GM.[2] This particular version of Makhathini's experience with Bt cotton became extremely well traveled.

These reports of Makhathini's success soon became emblematic of the potential that Bt cotton could offer to poor, smallholder farmers throughout Africa. The researchers who sparked this publicity were explicit about this potential, hypothesizing that the savings achieved at Makhathini could be extrapolated to the other 2.5 million hectares of African land currently under cotton, generating additional incomes in excess of US $600

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[2] The Ubonwa Farmers' Association and its Chairperson T.J. Buthelezi have been very active in voicing farmer support for GM crops in South Africa. For a description of their activities surrounding the 2002 World Summit on Sustainable Development in Johannesburg see Freidberg and Horowitz, 2002.

million (Thirtle et al., 2003, p.731). One industry observer suggested that as many as twenty-one other African nations could replicate the success achieved at Makhathini (James, 2001). According to Monsanto South Africa, Makhathini was the model that other African farmers should strive to emulate: 'the successful and rapid adoption of this more expensive technology in the Makhathini Flats provides an initial model for smallholder cotton farmers in Africa, and testifies to the incredible benefits that can be achieved through the responsible implementation of agricultural biotechnologies' (Bennett, 2002, p.34).

This article interrogates this portrayal of Makhathini as a prototype demonstrating the potential benefits Bt cotton can offer to African farmers. My analysis has three strands. First, I focus in on the high adoption rates achieved in the early part of the decade and re-emphasize the context – geographical, institutional, historical – that underpinned this initial period of success. Agricultural technologies are not inserted into a vacuum; their outcomes in any particular place are determined in part by the specific institutional, economic, and political circumstances that frame their introduction (Oudshoom and Pinch, 2003). This co-production, or mutual shaping, of technology and context means that, 'in a given context, only some of the possibilities associated with a technology will be manifest' (Russell, 2008, p. 214). To unravel the contextual factors that contributed to this initial technological success, I draw on archival research, thirty in-depth interviews with the leaders of local cotton associations, government officials, processors and suppliers, together with the findings from three workshops involving a total of more than eighty farmers from the area. I argue that the success Bt cotton enjoyed at Makhathini is context contingent. The story of Bt cotton in Makhathini reflects these structural processes as much as it serves as an endorsement of Bt technology.

Second, I suggest that the representation of Makhathini's success, and the example of South Africa more generally, have been crucial ammunition used to help convince other African nations to adopt GM technology. This recognition that technologies and their contexts are co-produced is key to interrogating this version of technological determinism, that 'depict[s] technology as an essentially autonomous entity, which developed according to an internal logic and in a direction of its own…[and] moulds society to suit its needs' (Russell and Williams, 2002, p.39). Reasserting the context that underpinned Bt cotton's initial success in Makhathini problematizes the claim that this triumph can be replicated in other African environments (Law and Singleton, 2000). My aim is to unravel the dominant representation of Makhathini as a showcase that demonstrates the potential for GM to rescue African farmers suffering from destitution and hunger.

In the final part of the article I emphasize the disconnect between the dominant representation of Makhathini celebrated in both the scholarly and popular literature and the realities faced by its cotton growers. This technological storytelling stresses the high adoption rates that were achieved ten years ago, but these have since been overshadowed by declines in the number of adopters and stagnating yields. I argue that the representation of Makhathini's success with Bt cotton has outlived the realities recounted by its farmers.

2. The Socio-Spatial Context of Adoption

The first distinguishing element of Makhathini's representation as a prototype for the potential that Bt cotton can offer to farmers throughout Africa is its portrayal as a space without place. As Harsh and Smith (2007) emphasize, the contentious debate over the potential GM technology can offer to African farmers is bereft of place-based analyses that seek to understand how culturally and ecologically embedded variables contribute to the relative success of agricultural biotechnology. This section highlights the geographical and institutional factors that underpinned Bt cotton's takeoff in Makhathini, in an attempt to re-emphasize the structural factors that were critical to its success.

The Makhathini Flats refer to the region encompassing the floodplains on either side of the Pongola River in the far north of KwaZulu-Natal. More generally, though, the Flats have come to designate the entire low-lying area that flows out from the Pongola River, covering some 13 000 hectares. Annual precipitation throughout the region averages only 580mm, which is concentrated in the summer months between September and May, typically falling in short, heavy late afternoon storms (Camp, 1995). The extreme heat that dominates during the summer months makes it too dry for all but the hardiest crops to succeed. The region falls within the uMkhanyakude district, and is characterised by chronic poverty, with 90% of households within the municipality earning less than R1600 (approximately US $235) per month (Jozini Local Municipality, 2009). Socioeconomic data place the district as one of the poorest in the province.

Makhathini is predominantly rural and extremely isolated. It is bounded to the east by the Indian Ocean, to the west by the Lebombo Mountain Range, and to the north by the border with Mozambique. These boundaries leave agricultural producers with restricted access to South African markets. Farmers emphasize in interviews and workshops that they chose to grow cotton – Bt or otherwise – because it was the only crop in the region with a guaranteed market:

> 'Most of our crops are for subsistence but they also lack markets. The market only exists for cotton. We'd like to grow sugar cane because you can harvest it more often, and vegetables that can feed the starving family next door…you can't feed them with cotton…cotton is the only market....farmers plant cotton because of market availability. They even plant cotton though they are not interested in it.'[3]

> 'Out of all the crops, cotton is the only one that brings in money. Maize used to be a crop…but because of the absence of milling equipment, there's no profit...we want to plant vegetables that have a market…we will continue with cotton because it has a market.'[4]

> 'Many prefer to plant maize, [but we] suffer from transport problems for moving it to Jozini [over 70 km away]. Many prefer sugar cane on paper, but the main problem's transport. The problem with sugar cane is the transport, because we don't have enough to be able to have our own transport. There are lots of labourers involved in land preparation, as the process takes 9-10 months, but you only need to plant it once for 6-7 years, but it needs irrigation. Cotton… [has] less profit than sugarcane but the market is more readily available.'[5]

Conversations with Makhathini farmers suggest that the biggest single advantage conferred by Bt cotton is the close, stable market it provides to producers. Many were adamant that they would prefer cultivating crops they were more familiar with, such as maize, beans, pumpkin, tomatoes, but turned away from these crops because there was no place to sell them. These findings are corroborated by a separate survey of one hundred cotton farmers undertaken in 2003, in which farmers identified 'secure cash income' as the second most important factor motivating them to grow Bt cotton, just after 'technical assistance obtained' (Fok et al., 2007). The omission of geography within the dominant

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[3] Mboza workshop, Day One, 1 February 2005.
[4] Ndumo A workshop, 25 January 2005.
[5] Mboza workshop, Day Two, 2 February 2005.

representation of Makhathini thus serves to focus all the attention on the twin pillars of Bt cotton's excellence – increased yields and reduced pesticide applications – but erases the third and crucial benefit it provides to the region's farmers: a stable market with a guaranteed buyer.

A second structural factor that has privileged the adoption of Bt cotton is that its dissemination has been inextricably linked to the disbursement of credit. From 1998 to 2001 the sole buyer in Makhathini was the private enterprise Vunisa Cotton (literally 'to harvest' in isiZulu). Vunisa sold seed and inputs, bought cotton, offered extension services, and provided credit in conjunction with the South African Land Bank. The company used its monopsonistic power to supply credit to farmers who did not own their land by allowing the forthcoming crop to be used as collateral (the amount owed was deducted before paying farmers for their output). Farmers suggest that many people adopted Bt cotton as a means of accessing credit supplies, and that Vunisa's privileged position as the region's sole provider of credit was a key factor that helped account for Bt cotton's rapid takeoff in 1998.[6]

The lending system implemented by Vunisa in conjunction with the Land Bank succeeded in buoying adoption rates and keeping loan repayments rates over 90% during the first three years of operation (Gouse et al., 2005; Fok et al., 2007; Gouse et al., 2008). But in 2001/02 a new gin was constructed near the Vunisa depot, undermining its monopsony position. This competing gin destabilized Vunisa's credit system by providing farmers with an alternate market for their cotton, prompting Vunisa to abandon lending in 2001. The Land Bank continued some sporadic lending on its own for one more year, before withdrawing in 2002 with more than R22 million owed in defaulted

[6] Mboza workshop, Day One, 1 February 2005.

loans.[7] The number of cotton farmers crashed once this credit dried up, dipping by more than 90% between 2001/02 and 2002/03 (Cotton South Africa, 2003, in Fok et al., 2007, p.469).

As Shankar and Thirtle (2005) emphasize, Vunisa's operations were the single most significant factor shaping the trajectory of adoption rates in the first five years after Bt cotton was introduced. Bt cotton in Makhathini was driven by supply more than demand: adoption rates were shaped by Vunisa's business strategies, lending capabilities, and monopsony position as the sole cotton buyer in Makhathini, more than any need or desire voiced by farmers (Shankar et al., 2007, p. 290). The high adoption rates recorded during these years reflect the wide availability of credit as much as they do demands for Bt technology.

This link between adoption rates and credit availability persisted throughout the decade. The only farmers who were able to continue with cotton once the credit dried up were the elderly, who were able to finance input by using their pension income (Fok et al., 2007, p. 480). In 2005/06, after more than two years of protracted negotiation, the KwaZulu-Natal Department of Agriculture stepped in to subsidize inputs by making more than R6.4 million available as 'bundles' designed to improve farmer access to the more expensive Bt seed. Predictably, farmers planting Bt cotton spiked, from 548 in 2004/05,to 2169 in 2005/06, only to rebound back to 853 once the program was discontinued in 2006/07 (Cotton South Africa, 2011). The wide swings in adoption rates during this first decade of adoption reflected these fluctuations in credit availability.

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[7] Data on loan accounts provided to Makhathini farmers were obtained directly from the Land Bank in March 2005.

Some observers have suggested that the sudden credit vacuum that opened up following the collapse of Vunisa's lending operations and the subsequent decline in cotton adopters would have occurred irrespective of Bt technology (Morse and Bennett, 2008, p.227). But Bt adopters are more dependent on credit than non-adopters: with the additional technological fee factored into the seed cost (600-785 Rand for large-scale farmers and 210 Rand for small-scale farmers), the price of Bt cotton is more than double that for non-Bt seed. Fok et al. 2007 (p. 478) estimate that conventional seed represented somewhere between 40-60% of a farmer's total input cost, while the added technology fee associated with Bt cotton increased this figure to 70-80%, making Bt cotton farmers more reliant on credit to cover these increased costs accrued at the start of the growing season, and less able to continue on once the credit dried up. These higher seed costs increased the financial risk for Bt cotton farmers and made them more dependent on credit than non-adopters (Glover, 2010a).

In the 2001/2002 growing season a new cotton buyer arrived in the region, the Makhathini Cotton Gin (Pty) Ltd, more commonly known as the Makhathini Cotton Company (MCC). In 2002 the MCC replaced Vunisa as the region's sole cotton buyer. The MCC's business structure is predicated on processing huge amounts of cotton. Profit levels are dependent on volume; the MCC's Head of Operations estimated that the company needs to process over 10 million kg of cotton a year in order to turn a profit.[8] In its first year of production (2002), the gin processed approximately 1.5 million kg. This figure rose to 2.5 million kg in 2003 and to 8 million kg in 2004.

This rise in production was due to the least publicized component of the company's operations: in addition to buying cotton from smallholder farmers, the MCC

[8] Interview, Operations Manager, Makhathini Cotton Company, 23 November 2004.

embarked upon joint-ventures in which the company takes over the management of individual farmers' fields and splits the profits fifty-fifty (Witt et al., 2006). This allows the MCC to put vast swaths of land (in the hundreds of hectares) under a centre-pivot irrigation system. With the pivot installed, the marginal cost of adding an extra section of irrigation boom decreases (because the surface area covered by each extension to the radius of the pivot increases with scale). This irrigation technology favours large-scale operations. Production data reflect this trend: production area in the year 2000/2001 was made up of 3587 hectares under dryland cotton and 528 hectares under irrigated cotton. Under the MCC's new business model the total land under irrigated cotton in 2006/07 has almost doubled to 1030 hectares, while the land under dryland cotton has been nearly halved to 1900 hectares (Gouse, 2009, p. 205). The number of independent smallholder farmers cultivating cotton continues to decline: from 2260 in 2007/08 to 750 in 2008/09 to 210 in 2009/10 (Cotton South Africa, 2011). The business model now driving expansion in Makhathini is thus based on expanding huge plots of contiguous land under cotton, not empowering the autonomous smallholder farmer to better manage his or her own field.

The MCC helps to maintain high adoption rates by systematically excluding non-Bt growers from the market. The MCC will only gin cotton that is delivered in specially marked woolsacks, ostensibly to limit confusion and conflict between the farmers and the gin. These marked sacks are allocated to farmers at the beginning of the growing season based on lists provided by Wenkem, the seed distributor who operates from a container adjacent to MCC property. Only those farmers who purchase Bt cotton seed make it onto Wenkem's list. Thus, MCC excludes the potential of non-GM growers by only allowing

Bt cotton to pass through its gin.[9] Seed price and availability further constrain farmer choices. While Delta Opel, an improved non-Bt variety, is available for purchase at Wenkem, it is only sold in quantities of 25kg, which is enough to seed over ten hectares, meaning it is too much and too expensive for all but the wealthiest Makhathini farmer. Bt cotton seed, on the other hand, is marketed in an 'ecombi' 5kg package, an ideal size for the area's smallholder farmers. The high adoption rates recorded in Makhathini are thus due in part to these restrictive buying and selling arrangements.

To properly evaluate the performance and potential of new agricultural technologies both the technology and its context must be taken into account. A. Wendy Russell (2008) has termed this interaction 'biological embeddedness', the enmeshing of a technology in its social, spatial and ecological settings by virtue of its biological nature. This geographic analysis suggests that Makhathini is a good fit for Bt cotton: it's geographically isolated with little market opportunity for other commodity crops, with a cotton market structure dominated by successive monopsony buyers. The first buyer facilitated the dissemination of Bt cotton by providing easy credit; the second profits from economies of scale and systematically excludes non-GM varieties by allowing only Bt cotton to pass through its gin. Bt cotton's much-lauded performance in Makhathini was due, in large part, to a socio-spatial context that privileged its adoption.

3. The Historical Context of Adoption

Exponents of the benefits Bt cotton has conferred on Makhathini farmers often portray GM technology as a separation from the past, a revolutionary new technology

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[9] Interview, Operations Manager, Makhathini Cotton Company, 3 February 2005.

that will irrevocably alter the livelihoods of smallholder farmers. Serious engagement with the region's history complicates this notion. In this section I take a long view of the region's agricultural history to show how the past makes itself felt in the present. As historian Allan Isaacman has demonstrated in the Mozambican context (1997, p. 758), contemporary efforts to transform rural African landscapes into cotton monocultures remain steeped in legacies of large-scale, modernized projects initiated by colonial experts disconnected from local realities. Development planners who ignore the story of cotton's past in Africa are destined to repeat mistakes made by their colonial predecessors:

> 'In the search for a viable future, historical analysis is often absent and the past simply treated as a backdrop. This presentist bias leaves insufficient analytical space to explore critically ways in which current crises are the product of previous policies and practices. Such a short-sighted perspective also precludes a discussion of how history can provide valuable insights about the contradictions, negotiations, tensions, and struggles which must necessarily be at the centre of any discussion of sustainability writ large' (Isaacman, 1997, p. 758).

Viewed within this historical lens, Bt cotton emerges as the latest in a long series of technocratic interventions that have consistently failed to transform Makhathini into a hotbed of commodity production.

Makhathini, like the rest of northern Zululand, was considered ill suited for European inhabitation throughout the 19th century. White settlers barely penetrated the area until the turn of the century. The first mention of Makhathini in colonial documents was the Zululand Delimitation Commission of 1902, which sought to demarcate the as-yet-unexplored lands of northern Zululand between white spaces suitable for settlement and black spaces designated as Reserves, designed to contain the colony's African population (Marks, 1970). The Commission designated Makhathini, along with most other sections of Zululand that were heavily malarial and considered unsuitable for white inhabitation, as Reserve land. But these planners recognized the agricultural potential of the floodplains themselves, and expropriated the closest thirty kilometers on either side of the Pongola River as Crown Land, which consolidated power and management decisions for the most fertile tracts of land in Makhathini within the national government. This unstable land tenure regime continues today, with the most productive agricultural land along the floodplains of the Pongola River under state control. Farmers complain that this unstable ownership arrangement favors short-term, quick fix solutions, which promise fast returns and are less concerned with lasting consequences.[10]

This centralized state control precipitated a century-long process of single crop solutions designed to rescue this neglected corner of the South Africa. The first surveys to assess the potential for large-scale cotton production in Makhathini were initiated in 1931. These concluded that more than 200 000 hectares in northern Zululand could be brought under irrigated cultivation, and that yields of between two and two-and-a-half times greater than those for dryland cotton could be expected.[11] Agricultural entrepreneurs proposed an irrigation scheme that would divert water from the Pongola River just south of the border with Mozambique. Dubbed the Pongola Irrigation Scheme (PIS), this massive undertaking was completed in 1934, with an eleven kilometre canal providing water to an estimated 5 500 hectares.[12] The PIS was hampered by a series of obstacles, including a lack of coordination among administering departments, market

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[10] Ndumo workshop A, 25 January 2005.
[11] National Archives, Tshwane (hereafter NA), Department of Lands II (hereafter ACT) Vol. 287 Ref 10785, Pongola River – Natal – Irrigation Upper Scheme Land West of Rooirand, Grobler, Minister of Lands to Secretary of the Natal Land Board, 7 October 1931.
[12] NA, (ACT) Vol. 287 Ref: 10785, Pongola River – Natal – Irrigation Upper Scheme Land West of Rooirand, Pongola Soil Survey, prepared by T. Arthur Warner, Chairman, Local Land Board, 12 March 1934.

isolation, heavy insect infestations, and inadequate irrigation during drought years.[13] By the end of World War Two, the Pongola Irrigation Scheme was, according to one of its founders, a 'white elephant' in the region.[14] Just under R30 million was spent without any cotton ever having been grown.

With large-scale irrigation having proved unmanageable, officials within the Department of Agriculture shifted their attention to another of the region's major constraints to production: damage wrought by insect pests. Experts became convinced that the most significant obstacle to cotton production in northern Zululand was the jassid, a small winged leaf hopper that breeds on the underside of the leaf. In 1926 they invited the Empire Cotton Growing Corporation – established to extend and promote the cultivation of cotton in the interests of empire – to set up a regional experimentation centre dedicated to breeding strains resistant to jassid. Corporation breeders enjoyed some initial success with hairy varieties that prevented the female from laying eggs on the underside of the leaf (jassid attacks were reduced by as much as 90% in some years), but then progress stalled, due in large part to an irruption of cotton bollworm, which accounted for losses of up to 80% (Schnurr, 2011). Subsequent experiments revealed that northern Zululand's two most pernicious insects pests worked in tandem: bollworms attacked the crop early in the growing season, depleting it of bolls; jassids set in later and prevented any further setting.[15] Corporation breeders abandoned their efforts soon after,

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[13] NA, Department of Agricultural Education and Extension (hereafter LON) Vol. 268 Ref A157/10, Pongola Irrigation Settlements, Report on Visit to Pongola Settlement from Mr. B.W. Sutton, Senior Dairy Officer for Natal, 13 November 1939.

[14] NA, Secretary for Agriculture (hereafter LBD) Vol. 1967 Ref 3365/27, Economic Survey of the Land Settlements of the Pongola Irrigation Scheme, R.A. Rouillard to Dr. Jansen, former Minister of Lands, no. 308, 11 November 1949.

[15] Agricultural Research Centre, Institute for Industrial Crops, Rustenburg Research Centre (hereafter ARC-IIC), ECGC Files, ECGC Annual General Meetings, 10th AGM, 20 May 1931.

concluding that an exclusive focus on jassid resistance was insufficient for cotton to achieve widespread success.

This futile attempt to breed for insect resistance is instructive because it highlights the inter-relationship between the region's two most pernicious insect pests. The Empire Cotton Growing Corporation's breeding program failed because it focused exclusively on jassid and ignored bollworm. Monsanto's Bt technology privileges bollworm resistance but ignores the jassid, a pest absent in the United States where the technology was developed. Reports from South African agricultural experts suggest that jassid attacks are becoming more pronounced in northern Zululand.[16] This reemergence of jassid has forced farmers to increase their spraying of organophosphates (which target sucking pests such as jassids) by as much as 25%, negating much of the supposed savings in reduced sprayings that accompany Bt cotton (Hofs et al. 2006a, Hofs et al. 2006b).[17]

In the late 1930s hopes of white settlement were abandoned, as government officials shifted their efforts towards converting existing irrigation infrastructure into an African agricultural project.[18] These efforts stuttered, and plans for using irrigation as a means of encouraging the region's white settlement were re-energized with the election

[16] Interview with Entomologist, ARC-IIC Research Center Rustenburg, 15 April 2005. A similar increase in secondary pests has been documented in both China and India, where Bt cotton has precipitated a significant upsurge in attacks by sucking pests such as mirids. For more on the Chinese case see Wang 2006, Wang et al. 2008 and Lu et al. 2010, for more on the India case see Stone 2011.

[17] There has been some recent effort by Delta Pineland to insert the stacked gene (conferring resistance to both Bt and Roundup Ready) into a 'hairy' cotton variety that has long been favoured by Zululand farmers because it minimizes jassid damage. But initial trials with this new variety, called DP Lebombo, have stalled due to its vulnerability to white flies (*Aleyrodidea*), a major prey of the jassid pest. See Gouse, 2009, p. 210.

[18] NA, Department of Native Affairs (hereafter NTS) Vol. 7983 Ref: 260/337, Pongola Irrigation Scheme, Follow-up Report by the Commission on Northern Zululand, by Heaton Nicholls and W.R. Collins, 24 January 1937.

of the reunited National Party and its policies of apartheid in 1948.[19] Enthusiasm for a new, expanded Pongola Irrigation Scheme was buoyed largely by the prospect of settling destitute, marginalized whites onto these state-subsidized plots: the PIS was re-envisioned as a scheme for the rehabilitation of poor, white farmers.

Between 1950 and 1955 the Department of Water Affairs invested over R11 million to update existing infrastructure and increase delivery capacity in Makhathini and its surroundings.[20] White settlers were offered just over twenty hectares of land each; by 1953 over 155 plots were occupied. Farmers invested heavily in mechanization, spending an average of more than R7 000 on machinery. Average holding size increased accordingly. By 1959 white settler farms along the Pongola River averaged just under 1600 hectares in size, and their average capital investment was R11 000. Yields varied widely, due primarily to fluctuations in precipitation. Only three farmers managed to squeeze profits from cotton; the rest operated at a loss (Kassier and Graham, 1968, p. 13).

In the 1960s and 70s the apartheid regime tried again, implementing a plan to dam the Pongola River to provide a reliable source of water for unemployed white farmers who were to be settled on twenty hectare plots. The Pongolapoort dam cost nearly R500 million and was opened in 1974. But the influx of white farmers never materialized, due to protracted negotiations with Swaziland over the location of water catchments, and the rapid economic growth in the 1960s which mopped up much of the surplus 'poor white' labour, deflecting the expected mass white migration into urban centres (Witt et al, 2006).

[19] NA, NTS Vol. 7983 Ref: 260/337, Pongola Irrigation Scheme, Memorandum on the Future of the Pongola Irrigation Scheme, n.d.

[20] NA, NTS Vol. 7983 Ref: 260/337, Report on the Proposed Pongolapoort-Makatini Flats Government Water Scheme 1960/61, n.d.

Unable to attract white growers to the region, the apartheid state sought to recruit black farmers to cultivate cotton on lands watered by the Pongolapoort dam. Beginning in 1982, five thousand farmers – most of them amaZulu and amaTsonga – were resettled along the floodplains of the Pongola River and encouraged to cultivate irrigated cotton. The crop was expected to be the region's growth engine, but high levels of institutional mistrust and crippling levels of indebtedness hampered production. Household surveys undertaken in the late 1980s recorded average yields of approximately 1400 kg per hectare, well below the break even level of 2000 kg per hectare (Bembridge, 1991). Over 65% of farmers reported operating at a loss.

The apartheid regime continued to invest in a variety of settlement and irrigation schemes through the 1980s, designed to ensure economic and political stability in a time of increasingly violent upheaval. Management for the dam and the corresponding irrigated lands passed between the hands of no fewer than seven government agencies during the 1970s and 80s: Corporation for Economic Development (CED), South African Development Trust Corporation (STK/SADT), Department of Cooperation and Development (DCD), Department of Development Aid (DDA), Department of Regional and Land Affairs (DRLA), Department of Agriculture (DA), and the Natal Provincial Administration (NPA). This constantly mutating administration, 'did not address the needs of the community. They plan for the communities and not with them…there was no communication that should link the community and the local government'.[21] The ever-changing responsibility led to shifting visions and unstable management, leaving

[21] Mboza workshop, Day Two, 2 February 2005.

Makhathini as one of the most underdeveloped parts of South Africa following the emergence of multi-racial democracy in 1994.

This long history of attempts to integrate cotton in Makhathini reveals some uncomfortable realities regarding the region's suitability for cotton, particularly for the vast majority of Makhathini farmers who focus on dryland (rain fed) cotton. Despite its reputation as a drought-tolerant crop, cotton is quite fickle in its water requirements. Dryland cotton requires an initial burst of rain for germination: cotton seeds will not germinate until they have absorbed approximately half their weight in water. A minimum of 90 to 120 mm is then required for seedling development; early water shortages stunt all subsequent growth (Grimes et al., 1969; Stegger et al., 1998). The most sensitive period for water stress is during peak flowering (Kock et al., 1990). Steady, even rains are required: too little inhibits boll formation; too much soaks the roots and damages cotton already on the bolls. Lint yield, boll density, boll weight, and lint percentage are all positively correlated with rainfall, up to a threshold (Cull et al., 1981). Within southern Africa, the optimal precipitation distribution lies between 700 and 1100mm. Poor stands will result if rains are late, irregular, or insufficient.

Long-term analysis of precipitation patterns in Makhathini reveals that these water requirements are seldom met. High levels of inter- and intra-annual variability characterize the region's rainfall, which conflict with cotton's growing requirements.[22] As a result, all of Makhathini is considered to be only marginally productive for dryland cotton, with the entire region incapable of attaining average yields beyond one ton per

[22] Rainfall in southeastern Africa is determined primarily by two oscillation patterns – an 18-20 year fluctuation underpinned by shifts in the Intertropical Convergence Zone, and the less predictable Southern Oscillation Events – which together account for 50% of inter-annual variability. For more see Preston-Whyte and Tyson, 1988. Precipitation is also variable within any given year, and is distributed primarily in short, violent storms in the late afternoons.

hectare, the minimum that the KZN Department of Agriculture estimates is necessary for the crop to be viable (Camp, 1995). Farmers consistently identified uneven precipitation as the region's most significant obstacle to productions in our workshops.[23] These results were corroborated by a recent survey in which 82% of farmers cited drought as the number one constraint to successful cotton farming (Morse and Bennett, 2008, p. 229). The performance of Bt cotton, like other technologies that came before it, remains susceptible to erratic precipitation, which continues to be the region's single most important ecological constraint to production, a point acknowledged by even the technology's most ardent supporters: 'Bt cotton did not address the major perceived constraint to cotton production in Makhathini' (Morse and Mannion, 2009, p. 242). Cotton technologies that fail to address the region's high variability in precipitation stand little chance of long-term success.

Viewed against this backdrop of continued intervention, Bt cotton appears as the latest in a long series of technological ventures that have consistently failed to entrench cotton production in Makhathini. Each new technology – large-scale irrigation, insect-resistant breeding, the Pongolapoort dam – was accompanied by a wave of initial optimism, some encouraging trials, and promises of future success. Each failed to deliver on this promise. Efforts to promote Bt cotton on the Makhathini Flats remain steeped in the legacies of earlier failures: the bias in favour of large-scale, monoculture agricultural interventions, the recasting of social and political problems as technical ones that can be fixed by rational planning and expert knowledge, the propensity for scientific research that studies ecological variables in isolation rather than as an interaction (Harsh and

[23] Ndumo A workshop, 25 January 2005; Ndumo B workshop, 26 January 2005; Mboza workshop, Day One and Two, 1 and 2 February, 2005.

Smith 2007, Shah 2008, Binimelis et al. 2009). The history of cotton in Makhathini is, in Allan Isaacman's terms, a story of historical amnesia: each new technological intervention promised to revolutionize production, while furthering the rationale for ignoring previous histories of failed interventions. Bt cotton is the latest chapter in this nearly century-long history of heightened expectations amid successive failures.

4. Makhathini as Prototype

This third and final section of the paper investigates Makhathini's influence within debates over Bt cotton's potential in other African nations. Since its dissemination to South African farmers in 1998, experimental trials with Bt cotton have been initiated in four other African countries: Egypt, Burkina Faso, Kenya, and Uganda. East Africa in particular has emerged as one of the most promising sites for Bt cotton, with both Kenya and Uganda reporting successful experimental trials. Both countries have been working hard towards enacting legislation that would allow for the widespread commercialization of GM crops. Kenya became the fourth nation in Africa to commercialize GM technology in 2009; Uganda is hoping to become the fifth within the year. In both countries, Makhathini is being upheld as a model for how GM technology can benefit poor, smallholder farmers. The goal of this section is to tease out the ways that Makhathini's success has been mobilized within this concerted effort to accelerate Bt cotton's expansion throughout the continent.

The major pushers of GM technology in both Uganda and Kenya are not-for-profit organizations – funded by some combination of the Alliance for a Green

Revolution in Africa (AGRA),[24] Bill and Melinda Gates Foundation, and USAID – who act as biotechnology advocates, running highly coordinated media relations and public awareness campaigns designed to convince policy makers, farmers' groups and research scientists of the merits of GM technology. The three most prominent are *Africa Harvest Biotech*, *African Agricultural Technology Foundation*, and the *Program for Biosafety Systems*. Interviews with representatives from these organizations underline the crucial role Makhathini plays within their promotional campaigns:

> 'Makhathini…[is a] successful case that smallholder farmers can adopt this technology…It dispels all those arguments that it cannot be adopted, it is not suitable for smallholder farmers, and it proves that the technology can be adopted by anybody, it is scale-neutral.'[25] (Acting Chief Deputy Executive, *Africa Bioharvest*, 2009)
>
> '…What people have in mind whenever you talk about biotechnology, they see a huge farm, commercial farmers, with maybe ten or hundred of thousands of hectares benefiting from this technology, but when you have this example of KwaZulu-Natal, of small-scale farmers, less than one, one or two acres, benefiting and talking, so it [has] already opened eyes for African farmers because most of them – particularly in this part of [Africa] – are small-scale farmers… to bring small-scale farmers, who [are] ploughing a plot of a quarter of an acre, like you have in western Kenya, to see the benefit, that says a lot.'[26]
>
> '[Makhathini] has been important, it's very important because we always use it in our presentations explaining that small-scale farmers can actually benefit.'[27]

As these excerpts suggest, the most important lesson gleaned from Makhathini's experience with Bt cotton is not that it increases yields or lowers the need for pesticide

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[24] AGRA was established in 2006 with funding from the Rockefeller Foundation, the Bill and Melinda Gates Foundation, and USAID. Under the Chairmanship of former UN Secretary-General Kofi Annan, AGRA promised a 'uniquely African Green Revolution' that would rescue farmers from destitution and hunger. So far AGRA has committed more than US $330 million towards a technological transfer package that includes improved seeds, inputs such as fertilizers and pesticides, extension services, and market development (AGRA 2011).

[25] Interview with Acting Chief Deputy Executive, *Africa Harvest*, 10 June 2009.

[26] Interview with Technical Operations Manager, *African Agricultural Technology Foundation*, 10 June 2009.

[27] Interview with East African Coordinator, *Program for Biosafety Systems*, 4 June 2009.

applications. The appeal of Makhathini is that it shows that the benefits associated with GM technology can accrue to smallholder farmers, the intended beneficiaries of Africa's long awaited Green Revolution. This trope that 'smallholder farmers can benefit from GM technology' is escalated into an argument for the desirability of GM crops throughout Africa (Shah 2008). Within this framing GM technology represents a promising means of uplifting the continent's small-scale farmers by helping them escape the cycle of debt and poverty that constrain Africa's development. GM is the hero of this story: a potential solution to the continent's intractable problems of hunger and poverty.

Promotional materials stress South Africa's role as a continental role model that will convince others to emulate Makhathini's success: 'South Africa plays a pivotal role in sharing its rich experience with other countries in Africa, interested in exploring the potential that biotech crops offer' (Karembu, 2009, p. 16). Pro-GM literature has exported this vision of Makhathini to demonstrate the promise that GM can bring to the continent's millions of smallholder farmers. Stripped of its geographical and historical context, Makhathini becomes a template whose success can be replicated throughout Africa.

Decision-makers in both Kenya and Uganda have been flown to see South Africa's success first-hand on visits funded entirely by these promotional campaigns. Nicknamed 'seeing-is-believing' tours, invited guests have included Members of Cabinet, research scientists, university lecturers, high-ranking civil servants, and journalists. While time limited the ability to travel to Makhathini directly, farmers were brought in to give first-hand testimonials of their successes with Bt cotton.[28] East African visitors were encouraged after hearing accounts of Makhathini's success, convinced that Bt cotton

[28] Interview with Agronomist, Ugandan Cotton Development Organization, 5 June 2009.

offered the small-scale farmer 'an opportunity to join the mainstream of economic farming' (Republic of Uganda, 2008, p.11). Recommendations arising from these visits stressed the need for more aggressive policies to accelerate GM's entry into east Africa, confident that Bt cotton specifically and GM technology more generally were needed to 'improve farming, increase productivity and income' (Republic of Uganda, 2008, p.10).

The well-trodden version of Makhathini's success has been harnessed by proponents as proof that GM technology can benefit Africa's rural poor. Within this narrative GM is characterized as an industrial innovation that circumvents or outflanks nature; its performance disembodied and disembedded from the natural and social system in which it operates (Russell, 2008, Glover 2010b). Makhathini emerges, in Les Levidow's terms, as a 'homogeneous agri-environment', an amorphous place is that is at once everywhere and nowhere, a one-size-fits-all version of GM that can be implemented across the diverse range of African environments. (Levidow, 2005, p. 134. See also Harsh and Smith, 2007, p.255). But this mobilization of Makhathini ignores the crucial geographies of difference that distinguish it from environments in Kenya and Uganda where proponents hope to replicate its success (McAfee, 2004). Makhahini's success was context-specific and context-dependent: to assume that it can unproblematically be replicated in another African context underestimates the importance of the geographical, institutional, and historical circumstances that shaped its farmers' experiences with GM.

5. Discussion: Interpreting Makhathini's Success

The representation of Makhathini's success with Bt cotton clashes with the realities its farmers have experienced since 2001. What were over 3 000 smallholder farmers cultivating Bt cotton between 1998 and 2001 have shrunk down to 200 in the 2010/11 growing season. Approximately 500 hectares are now under cotton cultivation, which represents a decline of more than 90% from the average land under cultivation during the period of Bt cotton's oft-reported success (1998-2000) (Cotton South Africa, 2011). Yields for both irrigated and dryland farmers continue to vary widely according to fluctuating precipitation levels, hovering within 10% of what they were before Bt cotton was introduced (Cotton South Africa, 2011).[29] Overall pest control costs remain significantly higher with Bt cotton (65% of total input costs) than with non-Bt cotton (42% of total input costs) (Fok et al., 2007).

The research team originally responsible for generating the well-travelled account of Makhathini's success have revisited their characterization in a series of recent publications. Updates tend to follow one of two scripts. Some of these researchers continue to uphold the version of Makhathini's success with Bt cotton by supplementing the original data set of one hundred farmers with additional data provided by Vunisa, as well as a second follow-up survey with another one hundred cotton farmers between 2003 and 2005, in which 88% of respondents reported a higher income from Bt compared to non-Bt varieties (Bennett et al., 2007; Morse and Bennett, 2008; Morse and Mannion, 2009). These studies focus primarily on how the extra income was used to advance worthy community development goals such as children's education, debt repayment, and

[29] According to data on smallholder production provided by Cotton South Africa, overall yields for the past two growing seasons (average of 237.5 kg/ha from 2009-2011) are only 8% higher than they were in the two years before Bt cotton was introduced (average of 190.0 kg/ha from 1996-1998). As Fok et al. (2007) suggest, the relative high yield increase (expressed as 40%) trumpeted in early reports of Makhathini's success was due in part to a low base yield of non-Bt cotton, against which any relatively small improvement in Bt cotton yield would appear exaggerated.

increased investment in other crops (Morse and Bennet, 2008, p. 227). However, they ignore deeper methodological issues, including the small sample size, the fact that the analysis relies on figures provided by Vunisa, as well as issues of sampling bias.[30]

Others have been more reserved. A second group of scholars have accepted the recent declines in both overall production and adoption rates, arguing that fluctuating weather conditions and poor institutional structures undermined Bt cotton's long-term prospects (Gouse et al., 2005; Hofs et al., 2006b; Gouse et al., 2008; Gouse et al., 2009). These accounts stress that it is the institutional arrangements, not the technology, that are flawed, suggesting that the lesson learned from Makhathini is that 'farmers can benefit from technological innovation only if the correct infrastructure is in place' (Gouse et al., 2008, p. 105). Within this view Makhahini's experience with Bt cotton is characterized as a 'technological triumph but institutional failure' (Gouse et al., 2005).

Within these assessment Bt cotton's potential to transform agriculture in other African nations remains undiminished. These researchers are unanimous that the environmental variability and institutional arrangements that hampered long-term success in Makhathini do not detract from Bt cotton's potential in other African environments. One publication boasts that 'technologically, Bt looks like an excellent technology for African countries' (Gouse et al., 2005, p.1), while another suggests that 'the history of Bt cotton in Makhathini Flats shows the technological potential of GM crops in an African smallholder environment' (Gouse et al., 2008, p. 118). Despite recent declines in adoption rates, cultivated areas and production values, the optimism that pervaded during

[30] All one hundred farmers in the follow-up study were members of the Hlokoloko farmer's association under the Chairpersonship of T.J. Buthelezi, the same farmer whom Monsanto flew to over thirteen different countries to give his first-hand account of his success with Bt cotton. T.J. Buthelezi actively assisted in all phases of this research project.

those initial growing seasons remains. The evidence, these researchers contend, continues to demonstrate that Bt cotton is 'technologically superior', and well suited to the needs of smallholder African farmers (Gouse et al., 2005, p.7. See also Bennett et al., 2007).

My analysis disputes these conclusions. As John Law, Wendy Russell ,and others make clear, technologies and their contexts cannot be understood in isolation; GM crops are only as successful as their interaction with their surroundings allows them to be. Yet the perpetuation of Bt cotton's narrative of technological promise relies precisely on this illusionary separation of technology and context, suggesting that the technology is sound but the implementation model is flawed. As Dominic Glover argues:

> The positive evaluation of Bt cotton's socio-economic impacts has depended on a reductionist analysis, which has sought to detach the technical performance of the Bt trait from the agro-ecological and institutional context where it has been put to use. (Glover 2010b: 974)

The contentious debate over the potential GM technology can offer to African farmers is bereft of site-specific analyses that seek to understand how culturally and ecologically embedded variables contribute to the relative success of agricultural biotechnology (Harsh and Smith 2007). This omission is a crucial part of the process of technological storytelling: it serves to perpetuate the myth of success, thereby extending the significance and promise of this technological intervention (Mosse 2005). Detailed, empirical studies are needed to unravel the specific conditions that frame the introduction of GM crops in order to expose the gap between aspirations and experience.

This study shows how and why the trajectory of Bt cotton unfolded as it did in Makhathini, and problematizes the possibility of extrapolating these temporary successes to other sites in Africa. When Makhathini's geographical and institutional contexts are taken into account, the dominant representation of Makhathini as a prototype for how

GM crops can elevate the position of Africa's rural poor collapses. In its place a more vulnerable view of Makhathini emerges, one in which certain pre-conditions exist that have significantly contributed to the success Bt cotton has enjoyed there: geographical isolation which eliminated the possibility of alternative crops, monopsony structures that encouraged production by providing easy credit, in the case of Vunisa, or excluded the potential for non-Bt cotton and profited from economies of scale, in the case of the MCC.

6. Conclusion

Supporters portray Bt cotton as a crop in search of a context, a viable technology waiting for an appropriate African environment in which it will be able to thrive. But technologies and their contexts are co-produced, with successful outcomes dependent on their mutual shaping. Bt cotton is a technology that requires a certain context in order to succeed: large-scale, heavily capitalized, with credit widely available. Makhathini satisfied these conditions for the first few years after Bt cotton's release, creating a context in which the technology was able to thrive. But sustaining these monopsony market structures and profligate lending strategies over the long-term proved impossible. As James Smith (2005, p. 648) argues, 'the potential utility of technologies can be exaggerated or misunderstood precisely by not understanding the contexts under which a technology must work, or the conditions under which it is adopted'. To assume that other African contexts will be more amenable to this technology is to misrepresent the nature of the technology itself.

Historical analysis reveals Bt cotton to be the latest in a long series of technocratic interventions that have consistently failed to transform Makhathini into a hub of commodity production. As Stone (2011, p.388) reminds us, farms are not 'ahistoric laboratories': farmer decision-making today is shaped by those made in the past. Technocratic interventions designed to accelerate cotton production in northern Zululand oscillated among attempts to solve key ecological constraints: first came irrigation schemes to overcome drought, then insect-resistant varieties to combat jassid, then a new dam to regulate water availability, now a current push that emphasizes bollworm resistance conferred by genetic modification. But each of these interventions misses the point. For cotton cultivation to succeed in Makhathini *all* of these ecological variables need to be considered within the same analytical frame. Historical analysis underlines the fallacy of attempting to manage these ecological constraints to production in isolation rather than as an interaction.

For GM to be embraced as an appropriate technology by African farmers it will need to begin by responding to farmers' own understanding of their environments and their agricultural and production systems (Hall 2008). The GM traits currently favoured by industry such as insect and herbicide resistance aim to increase yields per hectare by reducing losses associated with pests and weeds. These technologies were designed for North American farmers operating in contexts that are completely distinct from those confronting most African farmers (McAfee, 2004; Zerbe, 2008). Smallholder farmers in Makhathini are committed to adopting technologies that will insulate them against the greatest challenges they face in their farming systems, such as drought resistance, greater market access, and more control over crop selection. Appropriate technologies will only emerge by creating solutions that begin with these context-specific realities.

References

Alliance for a Green Revolution in Africa, 2011. http://www.agra-alliance.org/

Binimelis, R., Pengue, W., Monterroso, I. 2009. "Transgenic treadmill": Responses to the emergence and spread of glyphosate-resistant Johnsongrass in Argentina, Geoforum, 40, 623-633.

Bembridge, T.J., 1991. Farmer characteristics, innovativeness and cotton production at Makhathini Irrigation Scheme, KwaZulu. Development Southern Africa 8, 61-77.

Bennett, A., 2002. Efforts to expand genetically improved cotton in Africa. http://www.icac.org/cotton_info/tis/biotech/documents/techsem/Effortsafrica_tis01.pdf.

Bennett, R., Buthelezi, T.J., Ismael, Y., Morse, S., 2003. Bt cotton, pesticides, labour and health. A case study of smallholder farmers in the Makhathini Flats, Republic of South Africa. Outlook on Agriculture 32, 123-128.

Bennett, R., Morse, S., Ismael, Y., 2007. The economic impact of Genetically Modified cotton on South African smallholders: yield, profit and health effects. Journal of Development Studies 42, 662-677.

Beyers, L, Ismael, Y,, Piesse, J., Thirtle, T., 2002. Can GM-technologies help the poor? Efficiency analysis of Bt cotton adopters in the Makhathini Flats of KwaZulu-Natal. Agrekon 41, 62-74.

Camp, K.G.T., 1995. The Bioresource Units of KwaZulu-Natal. Cedara Report N/A/95/32. KwaZulu-Natal Department of Agriculture, Pietermaritzburg.

CropGen, 2002. Growing GM cotton in South Africa: A smallholder farmer's experience. Cited in De Grassi, A., 2003. Genetically Modified crops and sustainable poverty alleviation in sub-Saharan Africa: an assessment of current evidence. http://allafrica.com/sustainable/resources/view/00010161.pdf

Cotton South Africa, 2011. Small-Scale Farmer Production Estimates. http://www.cottonsa.org.za/

Cull, P.O., Heam, A.B., Smith, R.C., 1981. Irrigation for crops in a subhumid environment. Irrigation Science 3, 17-20.

Fok, M., Hofs, J.-L., Gouse, M., Kirsten, J. (2007) Contextual appraisal of GM cotton diffusion in South Africa. Life Science International Journal, 1, 4, 468-482.

Freidberg, S., Horowitz, L. 2004. Converging networks and clashing stories: South Africa's biotechnology debate. Africa Today 5, 3-25.

Funnis, C., 2006. The new GM revolution. Geographical.

Glover, D., 2010a. Is Bt cotton a pro-poor technology? A review and critique of the empirical record. Journal of Agrarian Change 10, 482-509.

Glover, D., 2010b. Exploring the resilience of Bt cotton's pro-poor success story'. Development and Change 41, 955-981.

Gouse, M., Kirsten, J., Shankar, B., Thirtle, C., 2005. Bt cotton in KwaZulu-Natal: technological triumph but institutional failure. AgBiotechNet 7, 1-7.

Gouse, M., Shankar, B., Thirtle, C., 2008. The decline of Bt cotton in KwaZulu-Natal: technology and institutions. In: Moseley, W.G., Gray, L.C. (Eds.) Hanging by a Thread: Cotton, Globalization and Poverty in Africa. Ohio University Press, Athens, OH, pp. 103-120.

Gouse, M., 2009. Ten years of Bt cotton in South Africa: putting the smallholder experience into context. In: Tripp, R. (Ed.) Biotechnology and Agricultural Development: Transgenic Cotton, Rural Institutions and Resource-Poor Farmers. London and New York, Routledge, pp. 200-224.

Grimes, D.W., Yamada, H., Dickens, W.L., 1969. Functions for cotton (Gossypium hirsutum L.) production from irrigation and nitrogen fertilization variables. Agronomy Journal 61, 773-776.

Hall, C. 2008. Identifying farmer attitudes towards Genetically Modified (GM) crops in Scotland: are they pro- or anti-GM?, Geoforum 39, 204-212.

Harsh, M., Smith, J., 2007. Technology, governance and place: situating biotechnology in Kenya, Science and Public Policy 34, 251-260.

Hofs, J.-L., Fok, M., Vaissayre, M., 2006a. Impact of Bt Cotton adoption on pesticide use by smallholders: A 2-year survey in Makhathini Flats (South Africa). Crop Protection 25, 984-988.

Hofs, J.-L., Fok, M., Gouse, M., Kirsten, J., 2006b. Diffusion du cotton génétiquement modifie en Afrique du Sud: Des leçons pour l'Africa Zone Franc. Revue Tiers Monde 188, 773-796.

Isaacman, A., 1997. Historical amnesia, or, the logic of capital accumulation: cotton production in colonial and postcolonial Mozambique. Environment and Planning D: Society and Space 15, 757-790.

Ismael, Y., Bennett, R., Morse, S., 2002a. Benefits from Bt cotton use by smallholder farmers in South Africa. AgBioForum 5, 1-5.

Ismael, Y., Bennett, R., Morse, S., 2002b. Farm-level economic impact of biotechnology: smallholder Bt cotton farmers in South Africa. Outlook on Agriculture 31, 107-111.

James, C., 2001. Global review of commercialized transgenic crops, 2001-2002. http://www.porquebiotecnologia.com.ar/doc/documentos/pdf/cotton%202001.pdf.

Jozini Local Municipality, 2009. 2009/10 Integrated Development Plan Review. http://devplan.kzntl.gov.za/idp_reviewed_2009_10/IDPS/KZ272/Adopted/Jozini%20Final%20IDP%202009_2010.pdf

Karembu, M., Nguthi, F., Abdel-Hamid, I., 2009. Biotech Crops in Africa: The Final Frontier. ISAAA AfriCenter, Nairobi.

Kassier, W.E., Graham, J.D., 1968. Survey of the cost of production of cotton in the Pongola extension area. South African Department of Agricultural Technical Services.Technical communication no. 72.

Kock, J., de Bryun, L.P., Human, J.J., 1990. The relative sensitivity to plant water stress during the reproductive phase of upland cotton. Irrigation Science 11, 239-244.

Law, J., Singleton, V., 2000. Performing technology's stories: on social constructivism, performance and performativity, *Technology and Culture* 41, 765-775.

Levidow, L., 2005. Divergent concepts of sustainability: the case of GM crops. In: Banse, G., Hronszky, I., Nelson, G., (Eds), Rationality in an Uncertain World. Edition Sigma, Berlin.

Lu, Y., Wu, K., Jiang, Y., Xia X., Li, P., Feng, H., Wyckhuys, K.H.G., and Guo, Y. 2010. Mirid bug outbreaks in multiple crops correlated with wide-scale adoption of Bt cotton in China', Science 328(5982), 28 May, 1151-1154.

Marks, S., 1970. Reluctant Rebellion: The 1906-08 Disturbances in Natal. Clarendon Press, Oxford.

McAfee, K., 2004. Geographies of risk and difference in crop genetic engineering. Geographical Review 94, 80-106.

Morse, S., Bennett, R., 2008. Impact of Bt cotton on farmer livelihoods in South Africa. International Journal of Biotechnology 10, 224-239.

Morse, S., Mannion, A.M., 2009. Can Genetically Modified cotton contribute to sustainable development in Africa? Progress in Development Studies 9, 225-247.

Mosse, D. 2005. Cultivating development: an ethnography of aid policy and practice. Pluto Press, London and Ann Arbour.

Oudshoorn, N., Pinch, T., 2003. How Users Matter: The Co-Construction of Users and Technologies. MIT Press, Cambridge, MA.

Preston-Whyte, R.A., Tyson, P.D., 1988. The Atmosphere and Weather of Southern Africa. Oxford University Press, Cape Town.

Republic of Uganda, 2008. Draft Report: Biotechnology Study Tour to the Republic of South Africa by Uganda Government Officials, 18-25 March 2007.

Russell, A. W., 2008. GMOs and their contexts: a comparison of potential and actual performance of GM crops in a local agricultural setting. Geoforum, 39, 213-222.

Russell, S., Williams, R., 2002. Social shaping of technology: frameworks, findings and implications for policy with glossary of social shaping concepts. In: Sørensen, K.H., Williams, R. (Eds.), Shaping Technology, Guiding Policy: Concepts, Spaces and Tools. Edward Elgar, Cheltenham, pp. 37-131.

Schnurr, M.A., 2011. Breeding for insect-resistance across imperial networks, 1924-1950. Journal of Historical Geography. 37, 223-231.

Seattle Times, 2003. Sowing costly seeds yields rich rewards.

Shah, E. 2008. What makes crop biotechnology find its roots? The technological culture of Bt cotton in Gujarat, India. The European Journal of Development Research 20, 432-447.

Shankar, B., Thirtle, C., 2005. Pesticide productivity and transgenic cotton technology: the South Africa smallholder case. Journal of Agricultural Economics 56, 97-116.

Shankar, B., Bennett, R., Morse, S., 2007. Output risk aspects of Genetically Modified crop technology in South Africa. Economic Innovations in New Technology16, 277-291.

Singh, M. N., 2002. Address by Mr. Narend Singh, KwaZulu-Natal Minister of Agriculture and Environmental Affairs, at the launching of a preliminary development plan entitled 'Towards an Agricultural Development Plan for the Makhathini Flats.

Smith, J., 2005. Context-bound knowledge production, capacity building and new product networks. Journal of International Development 17, 647-659.

Stegger, A.J., Silvertooth, J.C., Brown, P.W., 1998. Upland cotton growth and yield response to timing the initial postplant irrigation. Agronomy Journal 90, 455-461.

Stone, G.D. 2011. Field versus farm in Warangal: Bt cotton, higher yields, and larger questions. World Development 39, 387-398.

Thirtle, C., Beyers, L., Ismael, Y., Piesse, J., 2003. Can GM technologies help the poor? The impact of Bt technology in Makthathini Flats, South Africa. World Development 31, 717-732.

Wang, S., Just, D.R., Pinstrup-Andersen, P., 2006. 'Tarnishing silver bullets: Bt technology adoption, bounded rationality and the outbreak of secondary pest infestations in China', paper presented at the American Agricultural Economics Association Meeting, Long Beach, California, USA, 22-26 July.

Wang, S., Just, D.R., Pinstrup-Andersen, P., 2008 Bt cotton and secondary pests. International Journal of Biotechnology 10(2-3), 113-121.

Witt, H., Patel, R., Schnurr, M., 2006. Can the poor help GM crops? Technology, representation and cotton in the Makhathini Flats, South Africa. Review of African Political Economy 33, 497-513.

Zerbe, N., 2005. Agricultural Biotechnology Reconsidered: Western Narratives and African Alternatives. Africa World Press, Trenton, NJ.