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RESEARCH ARTICLE

Just agricultural science: The green revolution, biotechnologies, and marginalized farmers in Africa

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Contemporary agricultural development has changed in significant ways since the green revolution (GR). Its goals have expanded beyond national development to the achievement of environmental and social goals, and, notably, targeted gains for marginalized farmers. Moreover, advances in molecular breeding have expanded the tools used to achieve such goals. This research examines a prominent agricultural biotechnology program, pest resistant (Bt) cowpea in Burkina Faso, and asks whether and how this program can best achieve its goal of delivering benefits for marginalized farmers. I argue that 2 substantially criticized assumptions of GR-era agricultural development—the scale-neutrality of seeds and the sufficiency of expert technical knowledge—continue to guide the Bt cowpea project and limit its ability to deliver benefits for marginalized farmers. The presence of these guiding assumptions can be located in key programmatic decisions that work at a cross purpose to the project's social goals, notably (a) the choice of parent variety favoring commercial producers, (b) an absence of institutions to extend adoption and benefits, and (c) a lack of meaningful farmer inclusion. This case adds to a body of research that shows that biological innovations alone—what I call "just agricultural science"—are not sufficient to drive socially just outcomes for marginalized farmers without accompanying social innovations.

Keywords: Green revolution, Biotechnology, Cowpea, Africa, Burkina Faso

1. Introduction

The legacies of the green revolution (GR) cast a long shadow over contemporary agricultural development. One such legacy is the power of crop breeding to drive social advancement. The GR, at its most elemental, was an attempt from 1940s to 1970s to drive national development and end hunger in the global South via the creation of higher yielding crop varieties and their dissemination with water and chemical inputs (Hurt, 2020). The breeding work that significantly boosted the yield potentials of globally important crops received the most acclaim, which ultimately led to one of the GR's principal geneticists and breeders, Norman Borlaug, receiving the Nobel Peace Prize in 1970. The ability to achieve yield potential gains and, more recently, the promise of new molecular biological techniques to potentially achieve further breakthroughs have maintained crop breeding as a cornerstone of contemporary agricultural development (Borlaug, 2000; Qaim, 2020).

The deficiencies of the GR also left important legacies. Although widely celebrated, yield potential gains were principally achieved in only 3 major corps: maize, wheat, and rice. For many farmers, a sizable gap existed between actual yields—what was achieved under farmer growing conditions—and potential yields—what was achieved under ideal growing conditions. When those yield gaps were small, productivity increased, often substantially, but productivity gains were largely confined to geographically narrow areas, principally in Asia. Furthermore, reducing yield gaps and achieving productivity gains required access to expensive chemical inputs. Women farmers, marginalized farmers, African farmers, and those who grew other crops did not reap proportional or significant gains from the GR (Conway, 2012; Pingali, 2012). Moreover, the increased use of water and chemical inputs led to noteworthy environmental and public health issues.

Some GR critics examined what they viewed as an excessive focus on crop breeding in agricultural development—what I call "just agricultural science" (Chambers and Ghildyal, 1985). Critics argued that this excessive focus, or rather, the lack of focus on the social and environmental contexts of farming, impeded the ability of GR-era programs to achieve more just and equitable gains for marginalized farmers (Norman, 1978; De Schutter and Vanloqueren, 2011). A focus of critics was on the assumptions guiding GR programs. One such assumption, the

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scale-neutrality of seed-based technologies—that seeds can achieve the same relative gains for farmers irrespective of the size or capital intensity of the farming operation—was roundly criticized for not paying sufficient attention to the institutions, including among others, access to land, credit, inputs, and extension, needed to make the distribution of any gains more equitable (Griffin, 1979; Freebairn, 1995; Niazi, 2004). A related assumption, that expert technical knowledge was sufficient to bring about transformative change, was also criticized for not sufficiently including the knowledge and aspirations of marginalized farmers and communities (Okali et al., 1994). Taking stock of these critiques, a consensus emerged that a new "doubly GR" was needed, not only to address environmental problems, but also to achieve widespread gains for marginalized farmers (Conway and Barbier, 1988). Principal among the proposed changes was to include more social scientists and farmers in the agricultural development process and to understand farming as embedded in social and natural systems. This became known as the farming systems approach (FSA; Norman, 1995; Collinson, 2000).

Since the GR, the desire for agricultural development to achieve gains for marginalized farmers has become more pronounced. GR-era criticisms, as well as expanding understandings of poverty and social welfare, led, in part, to the rearticulation of agricultural development to agriculture *for* development (World Bank, 2007). The goals of contemporary agricultural development now extend beyond national development and productivity gains to include enhancing nutrition, boosting environmental sustainability, alleviating poverty, and addressing inequalities, among many others (Byerlee et al., 2009). An important example of this goal expansion can be found in the very international agricultural development system that drove the GR, the CGIAR system's new 2030 vision strategy. Explicit mention is made of making improved crop varieties "affordable and accessible to women, youth, and disadvantaged social groups, meeting their specific market requirements and preferences" (CGIAR System Organization, 2021, p. 21). This lies in contrast to GR-era breeding programs, which made no such explicit efforts to target marginalized groups or include markets and preferences as important factors.

The creation of agricultural biotechnologies specifically for African smallholder farmers is one of the most prominent contemporary examples, where the modern tools of agricultural science are used to achieve multiple social goals, and specifically, to achieve gains for marginalized farmers. By "agricultural biotechnologies," I refer to crops produced with the use of modern molecular biological techniques. The first agricultural biotechnology crop to be introduced to smallholder farmers came in South Africa, in 1998 (Ismael et al., 2002). The crop—a pest resistant form of cotton called Bt (*Bacillus thuringiensis*) cotton—promised to improve health and economic outcomes by reducing pesticide use and boosting profitability, but this initial introduction, and other subsequent introductions in Burkina Faso in 2008, and later in Sudan in 2013, repurposed a technology originally designed for large-scale commercial growers in the global North and ended with disappointing results for African smallholders (Schnurr and Dowd-Uribe, 2021).

More recently, several newer agricultural biotechnology projects seek to breed a suite of crops designed specifically for African smallholder farmers (Schnurr, 2019; Rock, 2022b). This second generation of biotech crops differs from earlier interventions in that they are driven by public–private partnerships, which negotiate the transfer of technologies to public research institutes, where they can be developed without royalty fees (Pingali and Raney, 2005). These programs also focus specifically on smallholder food crops with a variety of development-oriented traits, including nutrient enhancement, disease resistance, and pest resistance, among others, thereby addressing key omissions in GR-era breeding programs (Schnurr, 2015). The products of these projects—including disease-resistant banana and cassava, drought-resistant maize, and pest-resistant cowpea—have either just reached the hands of farmers (e.g., Bt cowpea in Nigeria) or are poised to do so in coming years, with the so-called gene-edited crops soon to follow (Pixley et al., 2019; Tripathi et al., 2020; Ahmad et al., 2021; Nkott and Temple, 2021).

The wide social goals of contemporary agricultural development, and a renewed focus on crop breeding using advanced molecular biological techniques, raise important questions. Do agricultural biotechnology programs in Africa overly rely on crop breeding advances to achieve wide social benefits? Do GR-era assumptions continue to circulate in agricultural biotechnology programs, and, if so, do they limit the achievement of their social goals? Finally, and most broadly, how can the agricultural sciences be put in the best position to achieve multiple social goals generally, and more specifically, to make targeted gains for marginalized farmers?

In this research, I examine one of the most prominent agricultural biotechnology programs designed to achieve gains for marginalized farmers, the Bt cowpea project in Nigeria, Ghana, and Burkina Faso. I argue that the persistence of 2 GR-era assumptions—the scale-neutrality of seed-based technologies and the sufficiency of expert technical knowledge—helps to explain key programmatic decisions in the Bt cowpea project that work at a cross purpose to achieving targeted gains for marginalized farmers. Instead of learning from decades of critique and research, I argue that the program relies too heavily on crop breeding alone to deliver benefits for marginalized farmers. In brief, I argue that its "just agricultural science" approach limits its ability to achieve more socially just outcomes.

To make this argument, I first examine the roots of the scale-neutrality and expert knowledge guiding assumptions in the GR. This examination identifies key axes of debate and points of disagreement. The outcomes of these debates are then used to structure an analysis of the Bt cowpea program. I specifically focus on the Bt cowpea program in Burkina Faso, where I have conducted research on agricultural development since 2007.[1] I first briefly describe the Bt cowpea program and cowpea production in Burkina Faso before turning to an examination of key programmatic decisions that work at a cross purpose to making targeted gains for marginalized farmers. I follow this with a discussion of the relevance of these findings for current and future agricultural biotechnology projects and for an agricultural science community increasingly charged with achieving multiple social goals.

2. Assumptions

2.1. Scale neutrality

The term scale neutral was used widely during the GR era to denote the ability of a technology to perform independent of the scale of farming operation. Notwithstanding this general definition, it is a term that is not well defined in the literature and is best understood by examining its usage in specific contexts (Fischer, 2016). Whether GR technologies such as improved seeds were scale neutral was hotly debated. Observers wanted to know whether new higher yielding seed varieties disproportionately favored larger producers. I return to these debates below given both the enduring claim that newer seed-based technologies, and specifically agricultural biotechnologies, are scale neutral (e.g., Vitale et al., 2007; Qaim, 2009; Benfica et al., 2022), and given the new focus on agriculture for development to make specific gains for the poor and marginalized (World Bank, 2007). I specifically explore the roots of these debates to understand what might reasonably emerge as takeaways to inform contemporary and agricultural biotechnology development.

2.1.1. Divisibility

Feder (1982, p. 94) comes closest to a working definition of the term scale neutral; Feder states that a technology is scale neutral when "its net returns per hectare are not affected by the number of hectares on which it is applied." In other words, a small farmer and a large farmer can, in theory, reap the same relative reward from a technology. The underlying logic to this claim is that the technology is divisible and therefore doesn't require a specific scale of operation to be profitable (Feder and O'Mara, 1981). This is best understood in reference to nondivisible technologies, such as tractors. It is widely agreed upon, both during the GR and after, that mechanical technologies such as tractors are indivisible—they can't be split apart—and are therefore not neutral to the scale of operation (Hayami and Ruttan, 1985). Put differently, a farmer could only profitably adopt a tractor if their farming operation was of a sufficient size and capital intensity.

The definition of scale neutral as divisible is its most basic, but also its most concealing. It only focuses on the potential for a technology to have even results in different farming contexts. But the raison d'etre of the scale neutrality debate is about outcomes—what happens in actual contexts when seed-based technologies are available and in the hands of farmers. Ending the conversation at divisibility alone fails to account for the considerable evidence from the GR era that the divisibility of seed-based technologies does not ensure even outcomes for farmers with different land sizes or capital intensities (Fischer, 2016).

2.1.2. Institutions

Whether seed-based technologies are indeed scale neutral depends to a large degree on the institutional context of adoption (Pingali, 2012; Patel, 2013). As critic of the GR, Keith Griffin put it in his 1979 book, *The Political Economy of Agrarian Change*, "Unless there is scale-neutrality in the institutions which support the 'green revolution', i.e. to repeat, unless small peasants have equal access to knowledge, finance and material inputs, innovation will inevitably favor the prosperous and the secure at the expense of the poor and the insecure" (p. 232).

On this point, there was wide agreement among agricultural economists sympathetic to the GR (e.g., Feder and O'Mara, 1981). Hayami and Ruttan, in their highly referenced 1985 book *Agricultural Development*, state that "the gains from the new technology [high yielding seeds] can be fully realized only if land tenure, water management, and credit institutions perform effectively" (p. 361). Griffin went one step further arguing that building a level institutional playing field should be pursued independent of the development or diffusion of new seed varieties. Griffin (1979, p. 79) states, "Even if science is able to design a 'peasant-biased' technology, however there is no reason why attempts should not also be made to correct factor prices and improve the markets with supply credit and material inputs. Our analysis indicates that the major cause of polarization in rural areas is inequality in the distributions of land and unequal access to other factors of production."

There was disagreement, however, on whether it was wise to pursue a level institutional playing field prior to the introduction of seed-based technologies. Hayami and Ruttan (1985) assert that a level institutional playing field would be an outcome of technology diffusion, rather than something that necessarily needed to be in place prior to the introduction of a technology. They state that "new income streams generated by technical change represent a powerful source of demand for institutional change" (p. 361). They go on to argue that the introduction of higher yielding technologies can build momentum for other structural measures to increase equity. For example, they state that "unless the potential gains from land tenure and other institutional reforms are enhanced by technological change, it will be difficult to generate the effort needed to bring about those reforms" (p. 361). This can be effectively translated as: There is no need to worry about whether the institutional dimensions for broad and equitable adoption are in place, since the presence of these higher yielding technologies will promote the creation of institutions that advance equity.

1. This research draws from multiple research efforts over 15 years of research on food systems in Burkina Faso, and specifically from a research trip in 2018 where I conducted 26 total interviews of research scientists, members of advocacy organizations, and cowpea farmers in the Comoé, Tuy, and Mouhoun provinces. I supplement these data with additional interviews of research scientists in 2020 and 2022.

2.1.3. Time and geography

In some locations, national-level empirical data are in agreement with Hayami and Ruttan. They show that, over time, higher yielding seed varieties have been equitably adopted across farm sizes, likely as a result of new technologies driving the creation of better institutions. One such example can be found in Bangladesh, where Hossain et al. (2007) and Orr (2012) show that high-yielding rice varieties have been equally adopted by large and small farmers. Moreover, large farmers have not increased in size or number. Orr (2012) argues that GR critics missed these equitable advancements since they relied too heavily on village-level data and used overly narrow research time horizons.

There is little evidence, however, that the even adoption of seed-based technologies occurs uniformly across geographies, farming systems, and over time (Evenson and Gollin, 2003). Irrigated Asian rice systems have been the most studied, and have been areas where equitable adoption has been achieved. Irrigated rice systems, however, have material qualities (e.g., the control over water) that restrain land consolidation and give small-scale producers an advantage (Bray, 1994). Such qualities are not shared across other geographies, particularly Africa, and in other crop systems (Moseley, 2016). Maize systems in Africa, for example, have had highly uneven adoption of high-yielding varieties and uneven outcomes (Otsuka and Muraoka, 2017; Voss et al., 2021).

Choosing to avoid the construction of a more equitable institutional playing field carries significant distributive risks. Hayami (1977, p. 179) notes that targeting different demographics or instituting structural changes would be too costly and take too long. Nonetheless, agricultural economists sympathetic to the GR signal potential drawbacks to a strategy of introducing new technologies without regard to institutional dynamics. Feder et al. (1985, p. 288) note that "the early adopters (usually the larger and wealthier farms) can accumulate more wealth and use the differential in the subjective value of land to acquire more land from the laggards." This preferential treatment could lead to greater wealth accumulation by larger producers, which have negative spillover effects on the equitable distribution of benefits.

2.1.4. Context and intersectional dynamics

GR critics and contemporary social welfare research signals that contextual and intersectional dynamics must also be considered when attempting to understand the distributional impacts of seed-based technologies, particularly as the goals of agricultural development have widened.[2] As GR critics Lipton and Longhurst assert in their 1989 book *New Seeds and Poor People*, "the poor" in many parts of the rural world are not farmers but laborers or farmer/laborers with limited access to land. They document how the rural poor did not benefit from GR high-yielding varieties since, as food consumers, there was not an expected reduction in food prices, and, as agricultural laborers, there was not an expected increase in agricultural wages. Moreover, they state that research "concentrates too heavily on farmers, including 'small farmers'" (p. 404). Their solution is to "develop new approaches in natural and social science [with] greater readiness to analyze the interactions of modern varieties with total systems (of power, of ecology, of economic transactions); and more awareness of history" (p. 404).

Labor dynamics were not the only contextual issue to be highlighted during the GR era. Gender issues in particular were a focal point, where it was shown that women did not benefit to the same degree as men from GR-era technologies (Von Braun et al., 1990; Pingali, 2012). Both labor and gender dynamics pushed researchers to consider a suite of contexts and intersectional dynamics. In a review of research on women farmers in Africa, Doss (1999) notes "it is increasingly clear that we need to understand the decisions and constraints [women] face in their households and communities."

Since the GR, agricultural development practitioners' understanding of inequities and poverty have grown, particularly as a result of contributions from feminist economics and critical development studies (Kabeer, 2015). Key findings from these literatures demonstrate that the geography of inequities does not start and stop at farm size but rather extends into class, ethnicity, land access, gender, age, and other key determinants of status (Luna, 2019). This expanded sense for the processes and dynamics around marginalization raises the question of whether the debate about scale-neutrality, and in particular the assumptions laid out above regarding institutions and dynamic effects, also require an update.

In sum, a reasonable expectation on exiting from the GR era is that agricultural development projects cannot simply produce a seed-based technology and expect that farmers of different characteristics and contexts will benefit to the same degree. Rural institutions including land tenure, land access, credit, and extension must, in the least, be examined, and likely included, when appropriate, in project scope. Attention to institutional dynamics should particularly be the case as agricultural development projects specifically target disadvantaged groups. To do otherwise would signal a narrow understanding of scale neutrality as divisibility. For those interested in producing more equitable outcomes, this is an interpretation that cannot easily be sustained.

2.2. Expert technical knowledge

The guiding assumption I explore in this section is that expert technical knowledge is sufficient to drive equitable agricultural development. Put differently, wider knowledge from different groups including social scientists, civil society, farmers, and rural communities is not necessary to drive equitable agricultural development. Such an

2. An issue not developed here but worthy of future exploration is the role knowledge production plays in obscuring issues of difference as they relate to measure of success. As Gollin (2021, p. 2) recently put it, "In some cases, agricultural productivity growth might drive inclusive growth and poverty reduction; in other contexts, it may deliver growth alongside the displacement of the rural poor. This heterogeneity poses a challenge for research: average effects, at the macro level, may not be greatly informative."

assumption has been roundly criticized, and, as a result, several efforts in multiple institutions have been made to widen participation and inclusion in agricultural development projects (Sumberg and Thompson, 2012). I argue that, nonetheless, this guiding assumption became institutionalized during the GR era[3] and remains an implicit guiding principle of many contemporary agricultural development projects, particularly agricultural biotechnology projects. This section focuses on how GR-era debates regarding the role of expert knowledge set in motion institutional legacies that remain prevalent today in 3 areas: composition of the agricultural sciences, inclusion of farmers, and implications for the scope of agricultural development activities.

2.2.1. Composition

The formation of the leading international agricultural research centers, described in greater detail in the following, is built on an institutional history that excluded social scientists, and in particular those who held contrarian views (Olsson, 2020), and limited participation to "technical" experts in the agricultural sciences. This movement gained traction during the initial stages of GR research in Mexico setting in place an institutional composition that largely remains today. Although some widening of actors in agricultural research centers have been made, particularly via the institutionalization of the FSA, on average, such compositional gains have not been widely sustained.

The initial research for the GR was conducted in Mexico and was driven principally by the Rockefeller Foundation via a partnership with the Mexican Ministry of Agriculture (Fitzgerald, 1986). Jennings (1988), drawing from the Rockefeller archives, notes how the Rockefeller Foundation transformed the composition of the professionals involved in agricultural research and development, narrowing the possibilities for wider, more structural framings of the problems driving poverty and hunger, and more systematic ways to address them. Jennings (1988, p. 114) notes, "Whereas Mexican scientists in the 1930s and 1940s oftentimes saw fields in terms of agrarian reform, those who replaced them and stood in the same fields from the 1960s onward saw only the potential for one or another technique."

The creation of scientific disciplines for agricultural development continued a push to redefine what it meant to be an agricultural professional. To continue from Jennings (1988, p. 102), "The Foundation during the 1950s purged notions of agrarian reform, collectivization, and politics from professional discourse. A central means in the achievement of this objective involved the Foundation's determination of the limits of professional competency." The Rockefeller Foundation actively recruited "young Mexicans with a technical background in science" . . . so that the agricultural research functions "proceeded along scientific, not partisan, lines" (p. 104). This continued with the Rockefeller Foundation creating the only institutions where agricultural science degrees were conferred, further cementing a technical as opposed to political orientation to issues of justice and development.[4] The institutions built in Mexico at that time—and their professional composition—later became CIMMYT and a blueprint for the CGIAR system.

The exclusion of more structural orientations to the issues of rural development, and more narrowly, of social scientists, did not go unnoticed by GR critics. A major critique was that the exclusion of social scientists resulted in reduced efficacy of GR-era agricultural development projects. This led to the institutionalization of FSA, where social scientists joined biological scientists in reorienting research to the "complex ecological, economic, and social components that constitute the farming system" (Collinson, 2000; Schnurr and Dowd-Uribe, 2021, p. 378). FSA became institutionalized in the 1980s across international and national agricultural research centers, with important advancements throughout Africa (Poats et al., 1986; Amanor, 1990; Bingen and Gibbon, 2012). The major gain from FSA was that it expanded the audience of the agricultural sciences to a broader, more diverse group of farmers "very different from those of the commercial farms" (Hildebrand and Keeney, 2000, p. 317).

FSA continues to have an effect on the material and intellectual infrastructures of agricultural development, even if those effects have faded in many institutions. Some observers demonstrate that the reach and extent of FSA has not been sufficient. Haugerud and Collinson (1990, p. 356) lament that "after a decade of rhetoric about 'feedback' of farmer problems to extension workers and scientists, a large gap remains between the ideal and the reality." Others show how even in those areas where farming systems research was well established, biological scientists were full of "skepticism" about the value of social scientists, and their relationship was defined by "antagonism" (Rhoades, 2006, p. 407). In a review of CGIAR programs, Leeuwis et al. (2017, p. 76) note that "while some see place-based systems research with stakeholders as a promising way to catalyse change, others see it as a distraction from the CGIAR's core business of

3. The dynamics I explore here in the green revolution build on and connect to trajectories with deeper historical roots. Notably, in the case of Africa, the creation and concentration of agricultural development research centers in the colonial era put ex-patriate "professionals" in key positions of power in pre- and postcolonial Africa (see Hodge, 2007; Tilley, 2011; Byerlee and Lynam, 2020).

4. The creation of specialized agricultural science disciplines has its roots much earlier in the Hatch Act in the United States and the creation of agricultural experiment stations. As Danbom (1986, p. 248) states, "By encouraging agricultural experimental stations, Congress in a sense created scientific disciplines. This reality, along with the problems occasioned by the hiring of many marginal employees in the early years of federal sponsorship, made professional self-definition a major priority among early scientists. The years between 1887 and 1910 thus witnessed the creation of new learned societies in the new disciplines, the definition and enforcement of professional standards, and the expansion of specialized graduate training, all of which were signs of professional maturation."

producing international public goods." Despite these and other challenges, the legacies of FSA research continue to inform many agricultural development institutions and programs.[5]

2.2.2. Inclusion

Similar to the desire for greater input from social scientists, one of the most important lessons to arise from the GR was the desire to increase farmer participation in agricultural development and crop breeding. Development organizations viewed greater farmer inclusion as a way to improve the understanding of farming context, the adoption of new technologies, and the creation of appropriate technologies. Since the GR, greater farmer participation has taken many forms and resulted in significant gains in many institutions and regions. Such farmer inclusion gains, however, have largely evaded agricultural biotechnology projects.

Farmer participation in agricultural development and breeding activities can take many forms, too many to review in full here (Farrington, 1989; Ceccarelli et al., 2009). Diagnostic activities like rapid and participatory rural appraisal (PRA) can be used to inform development and breeding programs (Amanor, 1990). Extension activities can increase farmer inclusion, improve project outcomes, and serve as a mechanism for feedback (Kumba, 2003). Farmers can also be included to different degrees in the formal breeding process, from upstream activities including co-creation of project goals and germplasm and trait selection, to downstream activities of varietal assessment (Morris and Bellon, 2004). These can be viewed on a continuum of more participatory approaches to less participatory approaches, where farmers in the former interact with, and have a greater degree of control over multiple aspects of the development and breeding process.

Farmer inclusion, however, has many hurdles. In some cases, farmer inclusion can be redundant and inefficient. Greater farmer inclusion can also slow down research efforts without demonstratable gains (Ramisch, 2012). Agricultural development funding streams may not prioritize farmer inclusion or may proceed at time scales that do not make inclusion feasible. Nonetheless, the consensus view is that farmer inclusion, in appropriate ways given specific project goals, can yield significant benefits in multiple areas (Morris and Bellon, 2004).

Despite the hurdles mentioned above, greater farmer participation has been institutionalized in some cases. One such example is the International Potato Center, where an approach titled "farmer back to farmer" formalized linkages with farmers, social scientists, and breeders to improve the applicability of potato breeding (Thiele et al., 2001). Although this model has since shifted considerably, observers note that important participatory linkages remain (Ortiz et al., 2020). A different example is the sorghum breeding program in Burkina Faso, where a decades-long participatory breeding effort has significantly increased both adoption of improved varieties, but also, farmer ownership over the program (vom Brocke et al., 2020).

Notwithstanding the potential gains from greater farmer inclusion, the advances noted above are not emblematic of many if not most contemporary agricultural development programs. A narrow group of technical experts, largely from the biological sciences, continue to drive key programmatic decisions. Where advances have been made, they generally include only the most basic forms of participation. As Sumberg et al. (2016, p. 7) note, these apparent advances in participatory research have generally "simply reproduced conventional on-farm trials prefaced by a 'participatory rural appraisal' exercise."

2.2.3. Scope

Narrow scientific composition and limited farmer inclusion during the GR contributed to a restricted research scope that generally favored larger producers. This can be seen in GR-era India, where the professionalization of the agricultural sciences, and their concentration in India into national, as opposed to state and regional-level entities, led to research being focused on high-yielding varieties that were specifically adapted to high fertility and irrigated environments. As Baranski's (2015) research shows, a focus on optimal growing conditions under the rhetorical banner of "wide adaptation" meant that regional varieties and those bred for marginal environments were no longer pursued. In other words, the agricultural sciences geared their efforts for larger more commercial farmers and failed to focus on the needs of otherwise more marginal farmers.

The narrowing of both the professionals involved in research activities and the constituencies for those research outputs corresponded with a narrowing of research endeavors. In Mexico during the GR era, this resulted in a greater emphasis on "training agricultural scientists to develop resistant cultivars as opposed to creating delivery systems for the subsistence sector" (Flora and Flora, 1989, p. 20). Harwood's (2009) analysis of the Mexican wheat and maize development programs was similar, where the desire to make a quick impact led to a focus on projects that would benefit larger producers while "setting aside the needs of peasant farmers" (p. 387). Similarly, Fitzgerald (1986, p. 459) found that the Mexican program maize program benefited larger, more capitalized farmers who were "similar to American farmers both in attitudes and circumstances." In other words, the concentration of control in the hands of technical experts, and a reduced composition in the agricultural sciences, led to a narrowing of research development priorities. They favored quicker and easier targets for larger farmers and left out institutional dynamics that could promote more even adoption and sharing of benefits.

The agricultural development funding landscape has reinforced these tendencies and made it more difficult

5. The same calls for more social scientists to be involved in agricultural development as a means to improve outcomes continues. See, for example, digital agriculture (Fielke et al., 2022).

to make and sustain greater inclusivity. Public funding has generally declined over the last several decades (Stads, 2011). International funding for national agricultural research activities declined from 14% of overseas development assistance (ODA) in 1980 to just 4% of ODA in 2007 (Food and Agriculture Organization, 2009; Quartey, 2014). Over that time, national research institutions were largely left to seek out constituencies who could fund their work, effectively shifting research priorities to the needs of larger, commodity crop growers, leaving aside more long-term breeding priorities, and those of poorer and marginalized farmers (Flora and Flora, 1989, pp. 24–25). Moreover, other barriers existed to improving inclusivity, since "science bureaucracies and the political elites that fund them, resist being accountable to poor farmers as clients" (Ashby, 2009, p. 666).

Exiting from the GR, there was a wide appreciation for the inclusion of social scientists and farmers in agricultural development research. Most agreed that the agricultural sciences alone could not achieve the creation of appropriate technologies, nor spur their wide and even adoption without broader scientific composition and greater farmer inclusion (Conway and Barbier, 1988; Baranski and Ollenburger, 2020). Specific institutional advancements were made, most notably FSA, which have left some important legacies still present in particular centers and programs. Nonetheless, partially due to a lack of funding but also logistical issues, these advancements have not been systematically sustained in many institutions and programs. Notwithstanding these challenges, wider scientific composition and greater farmer inclusion were key takeaways from the GR era. These takeaways are especially important for those programs aiming to achieve multiple social goals—and in particular, those targeting marginalized farmers.

2.3. Legacies

Two key guiding assumptions, the scale-neutrality of seeds and the sufficiency of expert technical knowledge, have withstood strong criticisms since the GR era. Since then, both the suite of seed development techniques and the goals of such efforts have widened. Breeders now employ modern molecular biological techniques to expand the traits used and quicken the pace of crop development. The outputs of these breeding efforts seek to achieve a growing number of goals related to social justice, environmental sustainability, food security and nutrition, and among others.

At least one critic of the GR appears assuaged by the evolution in focus of new breeding techniques toward development-oriented traits for smallholder farmers. In a 2011 interview, Keith Griffin, author of *The Political Economy of Agrarian Change* said, "scientists have responded to their critics" . . . because . . . "more emphasis is now placed on the search for 'peasant-biased' technical change." He cites advances in breeding varieties which are "resistant to drought . . . resistan[t] to disease . . . or which [depend less] on nitrogen fertilizer for higher yields" (Griffin and Boyce, 2011, p. 271).

But is the focus of new breeding efforts on smallholder crops and development-oriented traits sufficient to achieve multiple development goals? Have agricultural biotechnology programs that specifically target marginalized farmers integrated key takeaways from the GR era in order to best meet their goals? I offer answers to these questions via an examination of one noteworthy agricultural biotechnology program with multiple social goals—pest resistant Bt cowpea in Burkina Faso.

3. Bt cowpea and marginalized farmers

The Bt cowpea project emerged at a time of great interest in bringing a new GR to Africa. It was initiated in the early 2000s and funded by the U.S. Agency for International Development (USAID), the Rockefeller Foundation, and the Donald Danforth Plant Science Center and is coordinated by the African Agricultural Technology Foundation (AATF), which negotiated a royalty free transfer of the Bt toxin (Cry1Ab) from Monsanto (Ignatova, 2017). Australia's Commonwealth Scientific and Industrial Research Organization led the transformation of Bt cowpea varieties, with initial field trials conducted in Puerto Rico beginning in 2008 (USAID, n.d.). National scientific institutes in Nigeria, Ghana, and Burkina Faso then conducted further field trials beginning in 2009, leading to, as of the time of publication, a commercialization in Nigeria in 2021, an approval for commercialization in Ghana in 2022, and the preparation for commercial approval in Burkina Faso (The International Service for the Acquisition of Agri-Biotech Applications, 2019; Interview C, 2020; Rock, 2022a).

As with other second-generation agricultural biotechnology projects in Africa, the Bt cowpea project has multiple goals and specifically seeks to make gains for resource-poor farmers and women. As noted earlier, second-generation agricultural biotechnology programs are distinguished from first-generation programs because the underlying technology is royalty-free and is placed on smallholder crops with development-oriented traits, in this case pest resistance. The many goals of the Bt cowpea project include: boost productivity, reduce pesticide use, improve nutrition and health, improve soil fertility, and target smallholders and women (Coulibaly et al., 2008; Murdock et al., 2008; Huesing et al., 2011; Murdock et al., 2013). The framing of the project can be seen in its characterization by project leaders. In one example, some project leaders note that "the impoverished cowpea farmers of Africa, a great many of whom are women, stand empty handed and largely helpless against the ravenous insects that take their crop" (Ba et al., 2018, p. 1168). The Bt cowpea project is designed to address this problem.

African farmers account for 96% of global cowpea production and Burkina Faso is its third largest producer (FAOSTAT, 2022). Burkina Faso plays an important role in regional cowpea production and trade, producing a national surplus and exporting that surplus to neighboring countries (Bill and Melinda Gates Foundation, 2014). Cowpea is also the subject of increasing government attention and is increasingly viewed by Burkinabè farmers as a viable cash crop (Tignegre, 2010; Dabat et al., 2012).

This is evidenced by the recent spike in cowpea production in 2019, the year with the most recent official numbers; cowpea production reached its highest level yet of 707,994 tonnes, or a 27% increase from 2017 (Ministere de l'Agriculture et des Amenagement Hydro-Agricoles [MAAHA], 2020).

Since the 1970s, crop scientists at the International Institute for Tropical Agriculture in Nigeria and in national scientific research centers across Africa have sought to breed cowpea varieties for improved resistance to pests, disease, viruses, drought, heat tolerance, and yield (Murdock et al., 2008). One goal of those breeding efforts was to improve natural resistance to one of the cowpea's most important pests—the legume pod borer (LPB; *Maruca vitrata*; Syn *Maruca testulalis*). Breeders welcomed modern breeding technologies, and specifically the transfer of the Bt gene, to aid in these efforts given difficulty using conventional methods (Adati et al., 2007; Baoua et al., 2011).

Advocates claim that Bt cowpea will have several advantages for smallholder farmers. It has been shown to repel LPB, which, for those farmers spraying pesticides, will reduce chemical pest control and have important environmental and public health improvements (Dzanku et al., 2018). The reduction in LPB pest pressure should result in a yield increase as well. The USAID Feed the Future (2012) program has hailed the potential of Bt cowpea to "double the yield," but experts are more cautious, pegging a likely yield gain at between 5% and 30% (Dzanku et al., 2018). Depending on seed cost, lower insecticidal and labor costs, as well as increased yield, Bt cowpea could result in a significant jump in profitability (Coulibaly et al., 2008).

Key Bt cowpea project personnel make it explicit that cowpea is grown by resource-poor farmers and women and that they are target beneficiaries of the project (Murdock et al., 2013). However, as I outline in the following, important program-level decisions were made that make it less likely that resource-poor farmers and women will reap significant benefit. I argue that one compelling explanation for such misguided programmatic decisions is the persistence of scale neutrality and expert technical knowledge assumptions in the Bt cowpea project.

3.1. Scale neutrality, varietal selection, and institutions

The persistence of a narrow definition of scale neutrality as divisibility can be identified in 2 main ways in the Bt cowpea project. The first is in the choice of varietals onto which to confer the pest resistant trait. The second is in the virtual absence of institution building in the scope of the project. Viewing Bt cowpea seeds as scale neutral simply because they are divisible leads to project decisions that limit the ability to benefit marginalized farmers.

3.1.1. Varietal selection

The cowpea parental varietal on which to backcross the Bt gene was an important choice for who will benefit most from this technology. Cowpea can be grown in a variety of cropping systems that can be generally categorized into (a) monoculture, where cowpea is grown in its own plot independent of other crops, and (b) intercropping, where cowpea is grown in association with different cereal crops.[6] In general, cowpea monocultures are more connected to commercial production, though can also be used for household consumption. Intercropped cowpea is primarily geared to household consumption.

Monocultures are typically planted with cowpea varieties that grow in the form of a bush (as opposed to a creeping variety). Cowpea breeders in Burkina Faso and elsewhere in Africa have focused on producing bush-like varieties over the past several decades, which grow in shorter growing cycles, with grain qualities geared toward commercial production (e.g., large grain size and white color). The Bt gene was backcrossed onto 3 such bush-like varieties, Songotra (IT97K-499-35), Niizwe (IT98 205-8), and Gourgou (TZ1-Gourgou), making them ideal for monocultures.

The problem is that in Burkina Faso, a large portion, if not a majority of cowpea farmers—and, in particular, resource-poor farmers and women—continue to grow cowpea intercropped with cereals. In other words, the bush-like varieties upon which the Bt gene has been conferred are not designed for cowpea farmers who grow cowpeas intercropped with cereals. They are designed for more commercially oriented growers who sow cowpeas in monocultures. Cowpea varieties that crawl across the ground are strongly preferred by farmers with intercropped systems since they quickly cover the soil and climb cereal stalks, which reduce the need for weeding and can be harvested multiple times. Bush-like cowpea are not adapted for these systems.[7] Currently, there are no known plans to produce a 1 or 2 gene creeping Bt cowpea variety adapted to intercropped systems (Interview D, 2022). This means that the Bt cowpea project has produced a cowpea variety that is destined to only serve some cowpea farmers, and notably, those most interested in commercial production.

It is difficult to know with certainty the amount of cowpea production that is intercropped and monocropped in Burkina Faso. Dabat et al. (2012) draw from the most recent agricultural census data to show that over 90% of all cowpea production is intercropped. Crucially, at the time varietal decisions were being made in the mid-2000s, all available national statistics clearly demonstrated that intercropped cowpea dominated the farming landscape. Moreover, key project personnel acknowledged this fact in early publications: "Cowpea is mostly grown as an intercrop with cereals" (Murdock et al., 2008, p. 26). In other words, when decisions were being made about which varieties to use as hosts for the Bt toxin, project managers favored varieties that were destined for a slim

6. Cowpea farmers in southwestern Burkina Faso also grow early season cowpea varieties intercropped with peanuts.

7. One interviewed farmer mentioned also that modern bred varietals rot quickly in the fields—which is another reason why they don't work in intercropped field. One benefit of intercropped cowpeas is that they are harvested multiple times depending on maturity and labor availability (Interview B, 2018).

minority of cropping systems, and notably, those designed for commercial production.

The best available contemporary data show that intercropped cowpea likely still occupies a majority of area devoted to its production. According to the Ministry of Agriculture statistics, 37.8% of cowpea growing household sprayed cowpea with pesticides (MAAHA, 2020). Interviews with farmers and cowpea breeders indicate that most intercropped cowpea are not sprayed with pesticides, while most monocropped cowpea are sprayed with pesticide. This would imply that intercropped cowpea is still the most important cowpea cropping system. Nonetheless, monocropped cowpea is becoming more common. This shift has likely occurred given ongoing cowpea breeding efforts delivering bush-like varieties tailored to monocropping, and most recently, a shift in farmers viewing cowpea as a commercial crop (Dowd-Uribe, 2018).

If resource-poor farmers and women are indeed target beneficiaries of the Bt cowpea project in Burkina Faso, the choice to breed Bt cowpea bush-like varieties, as opposed to creeping varieties, will reduce the applicability of this technology for these populations. A focus on creeping varieties would have immediately made the technology appropriate for the most dominant cropping systems, and thereby available to the majority of resource-poor and women farmers who farm in these systems. The crucial choice of parent variety, and its implications for primary beneficiaries of the technology, has, surprisingly, received little attention in the debates surrounding its proposed introduction.

Relatedly, Bt cowpea's implied transition to monoculture production could contribute to a reduction in cowpea intercropped systems and their many documented benefits, and notably one of the program's stated goals: boosting soil fertility. Cowpea-cereal intercropping is viewed as a growing practice that conforms to the socioeconomic and agroecological contexts and risks present for resource-poor farmers (Zongo et al., 2016). It also has many documented advantages including reducing soil erosion, conserving humidity, and nitrogen fixation (Dabat et al., 2012). Cowpea cereal intercropping is also generally regarded by both farmers and many scientists to reduce pest pressure (Singh et al., 1990; Adati et al., 2007). Moreover, improved intercropping has the potential to increase total crop productivity, improve soil fertility, and increase animal fodder (Singh and Ajeigbe, 2002); millet and cowpea intercropping outperforms monocultures of each under the partially shaded agroforestry conditions common throughout Burkina Faso (Osman et al., 2011).

3.1.2. Institutional void

Another way that a narrow version of scale neutrality appears in the Bt cowpea project is in the lack of attention to the institutional aspects needed to advance equitable adoption and even outcomes. This absence is particularly noteworthy given the expressed desire to reach resource-poor farmers and women.

The one institutional dynamic that has received attention is seed multiplication. Seed multiplication is likely to proceed via private seed companies in conjunction with Institut de l'Environnement et Recherches Agricoles (INERA), Burkina Faso's Scientific Research Institute. INERA has worked previously in seed multiplication of other varieties and plans to take advantage of these facilities and networks to reproduce Bt cowpea seeds with private seed brokers. INERA does not have sufficient space to produce enough seed, so must work with private seed multipliers to reach desired quotas (Interview D, 2022).

Access to seeds will be a crucial fulcrum upon which adoption and benefits of Bt cowpea will hinge, yet has not received sustained attention by the Bt cowpea project. Interviews with farmers and research scientists confirm that most cowpea farmers—in both monocropped and intercropped systems—either save their seeds or derive their planting seeds from local exchange networks. Most do not purchase seeds. In the past, INERA has subsidized and distributed improved seed via local extension agents. This was one way to deal with the issue of distributing improved seeds and getting them quickly adopted by farmers, but the Bt cowpea project currently does not have plans to subsidize and distribute seeds in this way.

A related area that demonstrates a lack of attention to the institutions needed for even adoption and accrual of benefits is seed cost. High seed prices associated with transgenic crops have been shown to dissuade adoption by resource-poor farmers (Dowd-Uribe, 2014). Bt cowpea has been produced without a technology fee and funded by donors. Nonetheless, Bt cowpea seed will need to be multiplied and is likely to fetch a higher price than other modern varietals (Dzanku et al., 2018). Seed multipliers in Burkina Faso—the national research institute or private seed companies—will likely charge a higher price than what cowpea farmers are accustomed to paying. Given these current dynamics, those who are most likely to purchase Bt cowpea are those who currently purchase modern bred varietals, a small minority of current cowpea producers.

Extension is another area where clear gains can be made for resource-poor and women farmers, yet are absent from project activities (Mohammed and Abdulai, 2022; Okori et al., 2022). If Bt cowpea is to achieve wide adoption and targeted results for marginalized farmers, it implies a change in cropping systems from intercropping to monocropping. Such a cropping systems change cannot be successfully nor equitably achieved without more farmer extension. Despite the necessity for farmer extension to achieve equitable results, it has not thus far been a part of the Bt cowpea project mission or goals.

How can the Bt cowpea project with the stated goals of directing benefits to small-scale and marginalized farmers sustain programmatic decisions which make the achievement of that goal more difficult? I argue that the guiding assumption of the scale neutrality of Bt cowpea seeds allows these apparently counterproductive decisions to be sustained. When seeds are viewed as scale-neutral, the diversity of cropping systems—and in this case, the difference between intercropped and monocropped cowpea systems—can be overlooked. Similarly, if the seeds can operate the same across growing conditions, there is no reason to consider the institutional dimensions of targeted farmers.

3.2. Expert technical knowledge and farmer exclusion

Expert technical knowledge as a guiding assumption of the Bt cowpea project is demonstrated via (a) top-down program conceptualization and (b) limited farmer inclusion. This orientation leads to decisions that limit the ability of the program to benefit marginalized farmers.

3.2.1. Top-down program conceptualization

The Bt cowpea program has its origins in elite breeder-identified issues and technology availability. This has been described elsewhere as a technology-push as opposed to a goal pull pathway to identifying and addressing interventions (Heinemann and Hiscox, 2022). The program origin narrative—told via project reports, peer-reviewed articles, presentations from researchers, and in popular media—begins with breeding challenges around the LPB (Finkel, 2021). It continues that breeding efforts via conventional methods were not yielding adequate natural resistance to the LPB and note the availability of a transgenic technology to address such challenges. The Bt cowpea program thus emerged to address these needs through the application of a relevant technology.

The points from the above narrative are all important. LPB is a significant pest, and plant breeders have struggled with conventional methods to incorporate LPB resistance. What is notable isn't the veracity of the claims, but rather the genesis of the Bt cowpea program: breeders and technology. Such a program with a preidentified problem making use of an available technology can have beneficial outcomes for farmers, but it forecloses on a basket of orientations and tools that can improve the inclusion of marginalized farmers, their ownership over the program, and their accrual of benefits. Such a foregone basket includes approaches outlined above, like participatory breeding, which co-constructs with farmers the very conceptualization of the breeding program. One could imagine a different origin story, where a diversity of farmers expresses their challenges in relationship to cowpea production, and from there, decisions are made regarding project formation and breeding decisions. Indeed, some of the building blocks for such a process were already in place but went unacknowledged and unused.

PRAs as part of other ongoing cowpea breeding programs, however, did not identify LPB as a significant production constraint. Two prominent cowpea breeders in Burkina Faso conducted PRAs of cowpea farmers to identify key production constraints in 2007-2008, and 2012. Farmers in these studies did not identify LPB, or insect damage more broadly, as a major constraint. Rather, farmers prioritized soil degradation, access to inputs, equipment, improved seeds and markets, climatic issues, and *Striga* damage (Tignegre, 2010; Batieno, 2014). LPB was not mentioned as a major constraint in 5 of the 6 PRA villages. In the one village where it was mentioned, it was ranked fourth. The broader category of insect damage was ranked fourth, sixth, sixth, ninth, and ninth (Tignegre, 2010, p. 44; Batieno, 2014, p. 31).

Understanding farmer preferences is a difficult task, and a "participation fix" doesn't necessarily lead to more appropriate technologies and more equitable outcomes (Thompson and Sumberg, 1994). Moreover, it isn't clear the extent of viewpoints expressed in the aforementioned rural appraisals, nor how these appraisals were conducted. Nonetheless, they do appear to signal that if Burkinabè cowpea farmers were included as co-collaborators at the very initial stages of the Bt cowpea project, it would likely look very different. It may not have focused exclusively on LPB and would likely have a wider scope. An interview with a Burkinabè researcher confirmed that farmers do not view LPB as their primary constraint. Moreover, the same researcher expressed a desire to seek alternative and more appropriate pest control or other measures to address expressed farmer concerns. However, the researcher indicated that LPB was still a problem and that Burkinabè researchers were happy to go along with these funded efforts (Interview A, 2018).

The point is not to imply that all agricultural development interventions must necessarily derive from farmer-expressed constraints, nor that farmers must be co-collaborators in order to achieve equitable outcomes. Rather, the Bt cowpea project's disregard of expressed cowpea farmer constraints, and of existing knowledge of Burkinabè researchers, signals that key program-level decisions occurred outside of their consultation and control. This top-down conceptualization forecloses on several ways to breed more appropriate seeds, enhance adoption, and achieve more equitable outcomes. Top-down conceived projects still have other entry points for meaningful farmer inclusion, which could enhance equitable ownership, adoption, and outcomes. These are the subjects of the following section.

3.2.2. Limited farmer inclusion

The Bt cowpea project engaged farmers in 3 main ways, via (a) farmer surveys, (b) consultations from previous cowpea breeding efforts, and (c) farmer field trials. Such engagements, however, did not lead to meaningful inclusion, feedback, or ownership.

The AATF commissioned 2 surveys to "better identify the apprehensions and opinions of the various target groups on biotechnology" (INERA, 2015, p. 7). The first was conducted in 2010; it surveyed 100 consumers and 100 farmer/consumers regarding their attitudes toward biotechnologies in general and Bt cowpea in particular. Respondents were read a script regarding Bt cowpea and then asked their opinions regarding its proposed efficacy, and whether it was a good idea to adopt. Eighty-six percent were convinced that Bt would control LPB, while 83% signaled that the introduction of Bt cowpea was relevant. The second, in 2014, surveyed 239 farmers in 3 rural communes to assess their knowledge and perceptions of biotechnologies and Bt cowpea. Here, again, respondents were read a script regarding Bt cowpea and then asked to give their opinions. Most signaled that the technology would be profitable for producers, transformers, and sellers of cowpea (INERA, 2015).

Several things are important to note about these farmer surveys. First, they have effectively no bearing on project orientation or outcomes, much less farmer ownership over the program. Notably, farmers were not asked about crucial decisions, such as their preferences for traits or their preferences for varieties upon which to confer the Bt gene. The surveys appear more geared to understanding potential barriers to adoption, which is an appropriate objective, but such a goal takes the project as already formed and farmers as recipients of a technology for which they have little to no input, reminiscent of heavily criticized GR-era programs. Even if the goal of these surveys was for greater farmer input and inclusion, they were conducted after crucial project formation and scope decisions had already been made.

A second way farmers tangentially participate in the Bt cowpea project is via feedback to cowpea researchers in previous cowpea breeding engagements. Cowpea breeding efforts are long-standing in Burkina Faso. Over multiple cowpea breeding efforts across different scientists, contexts, and initiating organizations, a variety of farmers, consumers, and sellers have given feedback shaping those efforts (Ishikawa et al., 2020). The feedback from these processes has informed the creation of higher yielding, early maturing, white color cowpea varieties. A subset of these same improved varieties is used as the parent varieties onto which the Bt trait has been conferred. So, in this context, though Burkinabè cowpea farmers have not had a significant role nor have ownership over substantial parts of the Bt cowpea project, they have contributed to the production of the varieties onto which the Bt trait has been conferred.

A final point of inclusion is in farmer field trials, where farmers grow improved varieties on their fields as a final step in the research process. Outcomes from farmer field trials are then used as a final assessment for how these technologies may perform under actual farming conditions. Such trials have a history in biotechnology research in Burkina Faso, first being used in 2008 as part of the research and commercialization of Bt cotton in Burkina Faso (Dowd-Uribe, 2014). Notably, research have noted significant biases in farmer field trial exercises, which tend to overestimate likely impacts for average and marginalized farmers (Stone, 2012; Luna and Dowd-Uribe, 2020). Although farmer field trials are a part of the Bt cowpea project scope, they have not been realized as originally envisioned. Farmers have been invited to experiment with Bt cowpea varietals, but only on the grounds of the research station. This could exacerbate the cultivation biases noted above.

Burkinabè cowpea farmers have had entry points for participation in the Bt cowpea project, most notably through previous breeding efforts of parental varieties, but these entry points were not crucial to Bt cowpea project formation. This is best witnessed by the timing and scope of official surveys, which came after key programmatic decisions, most notably the choice of parent varieties.

One is left to wonder what could have happened in the Bt cowpea project had expert technology knowledge been softened to allow for greater inclusion and control of farmers and other key constituencies. In the least, greater farmer inclusion in the Bt cowpea project would likely have identified issues with parental varietals—asking for a wider diversity of parent varieties including those useful in cowpea-cereal intercropped systems. Greater farmer inclusion also may have steered the project toward wider goals more in line with farmer constraints, including toward more prominent breeding-related issues (e.g., thrips), but also toward institutional dynamics such as seed distribution and farmer extension.

4. Guiding assumptions, agricultural biotechnologies, and marginalized farmers

Two guiding assumptions of GR-era agricultural development—the scale-neutrality of seed-based technologies and the sufficiency of expert technical knowledge—were roundly criticized leading to important adjustments in the decades that followed. Critics of seed scale-neutrality showed that without adequate institutions, including, among others, access to land, credit, inputs, and extension, marginalized farmers could not achieve equitable gains. Narrow expert-driven projects were also criticized since they didn't adequately understand the social context of target areas, nor include views from implicated constituencies. Critics pointed out that greater inclusion leads to more appropriate technology development, improved adoption, and a more even sharing of benefits. As a result, contemporary agricultural development rhetorically, and in many ways materially, has altered institutions and particular projects to be more inclusive, participatory, and systems-oriented in scope.

The Bt cowpea project, however, does not appear to have embodied what was learned from the GR. To the contrary, the project appears guided by scale-neutrality and expert technical knowledge assumptions, which impede the ability of the project to reach its social goals, and notably, to deliver more equitable gains for marginalized farmers. This can be seen in a number of key programmatic decisions. First, the decision to select only bush-growing parent varieties—and to have no plans to include creeping varieties—limits the reach of the program to the minority of commercially oriented farmers who already grow cowpeas in monocrops or who have the capacity and desire to do so. The universe of primary beneficiaries is further narrowed by excluding institutional dimensions, such as seed dissemination and farmer extension from program activities.

Improving farmer inclusion and control over the program could have mitigated the effects of these decisions or led the project in more equitable directions, but farmers have essentially been excluded from all key discussions and decisions. Existing knowledge of farmer-expressed cowpea production constraints went unacknowledged. Project-driven farmer surveys were perfunctory and occurred after key programmatic decisions were made. Other entry-points either occurred tangentially and outside of the purvey of the project, or were truncated, as in the case of farmer field trials.

The apparent persistence of scale neutrality and expert knowledge assumptions demonstrates that the biological innovations present in the Bt cowpea project have not been matched with the social innovations present in other agricultural development projects. In this case, innovation appears to have remained in the lab. Learning about social context, derived from decades of studies and reflection on GR-era agricultural development programs, remains outside of program directives.

What remains unclear is who exactly holds these assumptions, how specifically they are operationalized, and why they may be more pronounced in agricultural biotechnology programs as opposed to other agricultural development programs. Further research will have to more definitely answer these questions. I offer some preliminary reflections here. The roots of an answer may lie in the strong role of donors driving these projects and the development ideologies of such donors.

It appears that agricultural biotechnology programs in Africa may be a particularly noteworthy case of donors driving project formation and objectives. The most definitive database of agricultural biotechnology programs in Africa shows that almost all existing and active publicly oriented research programs are funded either exclusively or significantly via external funding (Grzenda et al., 2022). The 2 largest donors are the Bill and Melinda Gates Foundation (BMGF) and the USAID. The projects they fund use patented technologies held by private firms. Therefore, unlocking publicly oriented agricultural biotechnology research first requires the donor-funded creation of an institution to negotiate the transfer of technologies—in this case, the AATF—and then the negotiation of an agreement between technology holders and public research institutions (Schurman, 2017).[8] The licensing agreements that arise from these negotiations include a "business plan that outlines the specific uses of the technology," which includes protecting the technology holder from liability (Schurman, 2017, p. 452). This chain of donor-driven prerequisites coupled with biosafety regulations and limited molecular biological expertise in Africa constrain power in the hands of donors and centers decision-making away from African research institutions, farmers, and civil society organizations. A recent review of agricultural biotechnology projects in Africa further asserts this point. Rock et al. (2023, p. 130) claim that "the effort to bring GM crops to the continent has largely been a top-down model driven by donors, with little space for African farmers, breeders, agronomists and civil society to influence agendas."

But what are the views of these donors vis-à-vis scale-neutrality and expert knowledge? This is more difficult to identify, but some research suggests that the development pathways they pursue are more likely to be informed by scale neutrality and expert knowledge assumptions. The major funder of the Bt cowpea program, USAID, funds several agricultural biotechnology initiatives across the continent. Its funding, particularly in Africa, is described as oriented toward public–private partnerships and toward facilitating innovation for productivity (Moseley, 2017). In Uganda, the USAID has forgone longer term systems-oriented research for programs that are "'product commercialization packages' that [are] likely to see field-ready products in a short time-span" (Schnurr, 2013, p. 649). Similarly, Schurman's (2018) analysis of the organizational culture of the BMGF found that they work at "solving what *they* defined as Africa's agricultural problems" (p. 190) . . . via . . . "an abstract market system based on individual crops rather than on an actual farming system" (p. 187).

Although these data points are few, they suggest a lack of systems orientation on the part of major agricultural biotechnology funders and the power to shape programs at their points of inception. It follows that if the guiding assumptions of scale-neutrality and expert knowledge are held by key individuals, and more specifically, key individuals at USAID and BMGF, then these assumptions may guide key programmatic decisions. In other words, what matters are the key assumptions held by project leaders, which may not necessarily be shared by all project participants or participating organizations. These findings suggest that future research is needed to better locate the dynamics that drive agricultural biotechnology project formation, the key actors and forums of debate regarding program decisions, and the embedded assumptions guiding how projects endeavor to achieve their goals.

This research has important implications for agricultural biotechnology development in Africa, particularly given that the Bt cowpea project shares many features with other previous and current programs. As noted above, similar funders are one point in common, but even in those agricultural biotechnology programs not funded by the USAID or BMGF, there appears to be several points where donor power and the lack of inclusion and systems orientation has, or will likely, limit their success. Private-sector-oriented programs, such as the Bt cotton introductions in South Africa and Burkina Faso, failed to fully understand and integrate the institutional needs for these programs, leading to disappointing results for smallholder farmers (Witt et al., 2006; Dowd-Uribe, 2014; Vognan and Fok, 2019). Other second-generation agricultural biotechnology programs, such as the biofortified and disease resistant banana in Uganda, prioritized the donor-preferred trait, biofortification, over the farmer-preferred trait of disease resistance, indicating the power of donors to drive decision-making (Schnurr et al., 2020). Other programs, such as the WEMA maize program, have similar issues in parent varietal selection, which likely limits the universe of beneficiaries to more capital intensive and commercially-oriented farmers (Schnurr and Dowd-Uribe, 2021). All of this signals that inclusion and a systems orientation to program objectives are needed for these programs to have a better chance to achieve their social goals and to achieve gains for marginalized farmers.

Alternative explanations outside of those explored here may better explain the key programmatic decisions of the Bt cowpea program that work at a cross purpose to bringing gains to marginalized farmers. One potential explanation is that the Bt cowpea program simply does not seek

8. Further, the African Agricultural Technology Foundation, which has received at least $225 million USD in contributions from 2008 to 2020, shares the U.S. Agency for International Development and Bill and Melinda Gates Foundation (BMGF) as its major funders (Dowd-Uribe et al., 2022).

to make gains for marginalized farmers. Perhaps, capital-intensive and commercially oriented farmers are its targeted beneficiaries. This would go against much of the framing of the project, and be contrary to USAID's broader development mission, and BMGF's stated moto of "impatient optimists working to reduce inequity."[9] The absence of program documents which express such a targeted audience suggest this isn't likely, and if it were true, that it may not be politically tenable.

A more plausible-related explanation is that the Bt cowpea program intends to make gains for marginalized farmers, but its recipe for doing so involves the evolution of marginalized farmer growing practices toward those of more commercially oriented farmers. This is what I call earlier in this article an implied transition to monoculture production. Under such a scenario, marginalized farmers, many of whom currently grow cowpeas intercropped with cereals, would need to transform their modes of production. Facilitating such transitions would further underscore the need for greater institutional development to be a part of the program activities. It would also suggest that there needs to be a more explicit explanation for how the program intends to address marginalized farmers and the presence or absence of crucial support structures to do so.

It would be a mistake to interpret the findings presented here as a blanket statement of the deficiencies of agricultural biotechnologies or even of the intentions and wisdom of many individuals involved in these projects. This research is not an indictment of agricultural biotechnologies, per se, as unable to deliver benefits for marginalized farmers. Moreover, many of the research scientists and project personnel have immense knowledge and respect for a diversity of farmers—and have devoted their careers to finding ways to best serve them. Rather, the key finding of this research is that GR-era guiding assumptions continue to circulate in agricultural biotechnology programs despite the wide view that they limit the ability of these program to achieve more equitable gains for marginalized farmers. The power of these guiding assumptions lies in their ability to allow certain key program-level decisions to persist, despite an abundance of evidence that they make the achievement of their social goals more difficult.

What becomes clear from this examination is that more than a narrow, "just agricultural science" approach is needed to achieve more socially just outcomes for the rural poor and marginalized. Revisiting and dispelling these GR-era guiding assumptions is one pathway to reimaging what a more robust approach to achieving these goals may entail.

Data accessibility statement

No publicly available data were collected for this research.

9. This moto is the lead quote to the BMGF Instagram and Twitter accounts.

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