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Situating Political Agronomy: The Knowledge Politics of Hybrid Rice in India and Uganda

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ABSTRACT

The emergence of 'political agronomy' — a research agenda that interrogates the knowledge politics through which agronomic debates are constructed, shaped and contested — has added a new and important tool for the analysis of agricultural research and policy making in development contexts. This article seeks to advance the scope of political agronomy by providing an enhanced framework to link the analysis of agronomic knowledge production to the study of new agricultural technologies in practice. Using case studies of hybrid rice promotion in southern India and western Uganda, the article illustrates the power relations and unanticipated outcomes that accompanied the translation of agronomic research into agrarian settings characterized by pronounced social polarization and marked environmental transformations. These case studies affirm how the starkly uneven outcomes of technological change refract back into the politics of agronomic research and extension as both researchers and policy makers react to the unintended impacts of previous interventions when designing future agendas.

INTRODUCTION

Through a series of focused conferences and publications, James Sumberg, John Thompson and collaborators have consolidated an important new research agenda into the design, practice, dissemination and legitimation of agronomic research within development contexts. Labelled 'political agronomy', this paradigm seeks to critically interrogate how the values of agronomic research are established, how core research questions are framed, how insights and outputs are translated into policy practice and disseminated, and

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how success stories are constructed and propagated within the field (Andersson and Giller, 2019; Sumberg, 2017; Sumberg and Thompson, 2012). Although at times implicit, the project's normative purpose is to promote a more reflexive and equitable approach to agricultural research by demonstrating the varied ways in which the operation of power shapes priorities and practices across the discipline.

While the political agronomy research agenda has duly advanced our understanding of the knowledge politics that constitute agronomy as a field, this article seeks to further its critical potential by incorporating insights drawn from agrarian studies and political ecology into an enhanced analytical framework. Our synthesis perspective aims to better account for how agronomic knowledge is translated into practice within agricultural landscapes characterized by pervasive social hierarchies, networks of inclusion and exclusion, active processes of environmental change, and structured inequalities over access to key productive inputs such as land, labour, water and knowledge. Although these socio-ecological dynamics are typically ignored within agronomic research, they actively configure the conditions under which agronomic knowledge is enacted, validated and contested. Concurrently, they also create important feedback loops that influence the direction of future research and policy making. On this basis, they form a vital extension of the political agronomy agenda.

In response, to help address the interface of how agronomic knowledge translates into agricultural practice, this article provides a synthesis framework that incorporates a fuller consideration of three processes often left implicit in the political agronomy agenda: 1) the political-economic drivers of agrarian change that shape the substantive outcomes of agriculture as a form of livelihood; 2) the hierarchies and power differentials through which agriculture is realized as a localized practice; and 3) the ways in which new agricultural technologies actively reshape agrarian landscapes in both their social and ecological characteristics.

The article then uses two case studies of hybrid rice in India and Uganda to illustrate the framework. Such 'improved' rice varieties — the products of vested agronomic research — are important empirical reference points because they have served as touchstone issues within political agronomy debates. Over the past decade, political agronomists have analysed the institutional context for the roll out of such agricultural innovations, the success claims made on their behalf, the associated evidence bases that accompany such claims, and the political contestations that have invariably followed (e.g. Berkhout et al., 2015; Brooks, 2010; Orr et al., 2008; Whitfield, 2015). Our research, however, takes this enquiry a step further by linking debates over how these agendas are constructed with an analysis of the power dynamics and unintended outcomes that accompanied their translation into tangible agricultural innovations in southern India and western Uganda respectively. This, we believe, unites the interrogation of how agronomy determines 'what works' with the political ecology question of 'for whom do

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agricultural innovations work and why', therein forging a stronger explanatory framework for future research.

THE POLITICAL AGRONOMY RESEARCH AGENDA

With analytical foundations rooted in discourse analysis and science and technology studies, political agronomy seeks first and foremost to excavate the political-institutional dimensions of how agronomy is constructed as a field of research and practice (Sumberg et al., 2012). It asks who produces what forms of scientific knowledge, through what means, and enquires as to how some forms of knowledge predominate over others. As set out by Sumberg et al. (ibid.), a rigorous unpacking of the normative assumptions and political contexts that orientate agronomy as a field enables scholars to have a more finely tuned understanding of how prevailing institutional and technological logics shape agronomic knowledge production in ways that are often — although not always — implicit. Through diverse case studies — ranging from the use of genetically modified crops (Brooks, 2010; Stone and Glover, 2011) to conservation agriculture (Andersson and Giller, 2012) and participatory rural development programmes (Ramisch, 2012) — scholars analyse how the legitimacy of research is determined, the political agendas in which agronomic knowledge production is embedded, and how claims about the validity and value of new agronomic technologies and techniques are made and justified.

To pose such questions does not imply that agronomic science is inherently compromised or that the knowledge it produces is not vital for our understanding of the world. On the contrary, the political agronomy agenda calls for greater reflexivity about how scientific knowledge is produced, by whom, through what means, and why some forms of knowledge count over others. This is the basis on which analysts can formulate prescient questions concerning how agricultural research and extension priorities are constructed at both national and international levels. Specifically, by tracing how the institutional contexts of funding, collaboration, partnerships and stakeholder engagement shape the goals, processes and results of research, political agronomists have helped to problematize the interactions between agricultural governance and development policy from the level of international institutions through to extension initiatives at a regional scale (Whitfield, 2015).

One accomplishment of this research has been to illustrate persistent tensions within the field's self-representation as a purely evidence-based science that exists outside of politics. In creating authoritative representations of plant and soil systems, agronomy is often assumed to operate as a technical realm of crop improvement in which the application of universal scientific knowledge determines 'what works' in an apolitical manner. Once appropriate innovations are designed, extension programmes are then

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anticipated to deliver improved agricultural knowledge, management practices and technological inputs into the hands of end users. While the outputs of agronomic research might be used for political ends, the epistemological workings of agronomy as a field are assumed to be impartial and apolitical.

In contrast, political agronomy asserts that knowledge from plant or soil science is not simply used politically. Rather the epistemological foundations, forms of practice, and therein the questions agronomy has sought to address are already imbued with an intrinsic yet silent political content (Sumberg et al., 2012). Historically, this can be seen in the way that agronomic research and practice have been intimately shaped by the deeply political processes of state formation, agricultural rationalization and colonial aspirations. Within colonial South Asia, for example, agronomy emerged as the science of improvement, a necessary tool of colonial governance to both overcome 'wasteful' traditional agricultural practices and to promote plantation-based resource extraction (Gidwani, 2008; Ludden, 1999). It was developed and deployed in this fashion as a form of authoritative expertise to help establish new patterns of land use that consolidated political power over both people and natural resources (Blaikie, 1985; Ross, 2014). Likewise, during the Cold War era, agronomy was mobilized as a 'technical fix' to help solve the perceived problem of underdevelopment in the 'Third World' through the modernization of agriculture (Escobar, 1995). This broader political project framed what issues agronomy was set to work on and the questions it was to address, and circumscribed the range of answers it could find and who had power to profess expertise (Gupta, 1998). Such trends were particularly conspicuous when agronomic research became embroiled within global geopolitical strategy, as most evident in the way that Green Revolution technologies such as the 'miracle rice' IR8 were designed and diffused as a key weapon in the ideological battle for Asia (Cullather, 2010).

The production of agronomic knowledge has therefore had a persistent political hue. Yet political agronomists hold that three primary trends have changed the trajectory of agricultural research in recent decades and opened up its political character to renewed scrutiny and contestation (Sumberg et al., 2012). The first trend is the shift towards neoliberalism in international policy making, which has reshaped public agendas around agriculture and agronomic research, placing a stronger emphasis on private sector engagement as the driving force of agrarian change. Agronomic research has been reshaped around an explicit normative goal of entrepreneurship-driven modernization in which rural producers are closely tied to output markets that are directed towards an expanding urban economy that is global in scope (World Bank, 2007). With the liberalization of agricultural markets occurring simultaneously with new fiscal constraints on public research, outreach and subsidies, this shift has altered power relations across all realms of agricultural research and practice. Notably, the private sector is now a key player in determining 'what works' in agronomy and the latter question has become

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increasingly shaped by an explicitly profit-driven rationale (Akram-Lodhi, 2013).

The second trend is the rise of an environmental agenda within agricultural policy that has transformed the core questions that agronomists must fundamentally address. With a growing recognition that some of the big successes claimed by agronomists — specifically Green Revolution technologies — have incurred major unanticipated impacts on environmental and human health, agronomists have been forced into a rear-guard action to engage substantively with questions of sustainability. The scope of determining 'what works' has therefore broadened substantially beyond traditional criteria of yields, pest resistance, fertilizer response and so forth. This has raised new and fundamentally contested questions about what sustainable agriculture should look like and how it should be pursued, with debates erupting over concepts such as sustainable intensification (Loos et al., 2014), agroecology (Gliessman, 2013), multi-functionality (Renting et al., 2009) and, most recently, climate-smart agriculture (Taylor, 2018).

The third trend highlights how a growing grassroots movement has questioned whose knowledge and goals should be prioritized within agronomic research and practice. In this way, agronomy became politicized around the question of who gets to determine 'what works'. Major contributions such as Paul Richard's *Indigenous Agricultural Revolution* (1985) probed the elitism of established models of agronomy and highlighted the ways in which top-down transfer of technology orientations led to problematic outcomes owing to their marginalization of local needs and knowledge. This wave of critical literature reflected a growing unease about the entrenched colonial legacies of agronomy as a field of practice and presaged calls for a more decentralized, experimental and bottom-up form of agricultural development. Such a perspective was expressed within a populist 'Farmer First' movement that prioritized giving farmers greater voice to shape the goals and conditions of agricultural research and extension (Chambers et al., 1989; Scoones and Thompson, 1994, 2009). Within the profession, this countermovement led to a widespread acknowledgement that agricultural research and dissemination could — at a minimum — become more effective by engaging a participatory ethos and recognizing local knowledge (Leeuwis, 2004). How participation should be realized in practice and the specific goals that it should facilitate, however, remain contested (Moseley, 2017; Ramisch, 2012). Models of participatory agricultural research and extension continue to diverge sharply over the appropriate level of control that farmers should exercise over project design, implementation and evaluation (e.g. Westengen and Winge, 2020).

The political agronomy agenda holds that these three trends have fundamentally reshaped the norms and practices of agronomy as a field, leading to a shift in how core research areas are selected, what kinds of assemblages of actors, funding and normative claims drive research forward, and how the products of research are disseminated within the diverse worlds

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of agricultural practice (Sumberg, 2017; Sumberg and Thompson, 2012). Specifically, they have catalysed new areas of contestation over agricultural research focused on what Andersson and Sumberg (2017: 8) term 'alternative, rival or contending priorities, methods, observations, interpretations and explanations'. To engage this terrain, political agronomists have encouraged analysts to focus on the drivers of changing priorities; the actors, values and interests that shape them; the central objects upon which debates focus, including both technologies and institutional arrangements; and the new domains or fields of agronomy that have become politicized, including questions of epistemology and values that previously were untouched. In emphasizing these core areas of enquiry, political agronomists both recognize and simultaneously embody contestation by asking pointed questions about how research is designed, legitimized and embedded within distinct political agendas.

BEYOND POLITICAL AGRONOMY

Notwithstanding these vital contributions, we argue that the paradigm of political agronomy as currently formulated could gainfully expand the depth and breadth of the questions it poses. As Ken Giller et al. note, the challenge for political agronomy as it moves forward is to bridge the gap between knowledge politics and placed-based practice (Giller et al., 2017: 156). To do so is to recognize that knowledge politics is not formed within a vacuum but is framed within the changing landscapes of world agriculture with respect to both its social and agro-ecological dimensions. This reflects what Norman Long (1989) termed the 'rural development interface' at which the boundaries of knowledge politics are permeated by the driving forces of agrarian political economy. To adapt the words of Henry Bernstein (2010), questions such as 'who designs what?' and 'who measures success in agronomic science?' need to be paired with the questions of 'who owns what?', 'who does what?', 'who gets what?' and 'what do they do with it?'. We argue that it is precisely the interplay of knowledge politics with these political economic and cultural dynamics that give agronomic debates their dynamism and intensity.

This point is implicit in many political agronomy analyses. For example, the heuristic framework provided for political agronomy by Andersson and Sumberg (2017: 8) allows room for what they term 'drivers', described as the 'long running arguments and struggles around agrarian relations, dominant and alternative models of agriculture and visions for rural areas and food systems'. Despite such positive intent, however, there has been little explicit indication of how to bring these elements together. To provide a suitable framework, we argue, requires a fuller and focused engagement with insights drawn from the fields of critical agrarian studies and political ecology. Drawing explicitly from both can link the focus on contested knowledge

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politics at an institutional level with a more finely graded understanding of the socio-ecological contexts under which agriculture is practised, researched and governed.

Three areas of synthesis are pivotal. First, the study of agricultural knowledge politics should better engage the political economy of agrarian change that dynamically shapes: 1) who performs agriculture; 2) under what circumstances; and 3) with what livelihood implications. Within agrarian studies, this concern has often been termed the 'agrarian question' following foundational debates over the stratification of agricultural producers under commercialization (Akram-Lodhi and Kay, 2010). To emphasize the political economy of agrarian change is not to suggest that agronomic research simply mirrors socio-economic patterns in some form of structural determinism. On the contrary, as political agronomists have noted, professional agronomists can remain strongly insulated from engagement with the dynamic social contexts of agricultural practice. Rather, it is to ask how social differentiation within agrarian environments shapes the identification of the problems that agronomic research responds to and the solutions it derives. As our examples below serve to highlight, while agronomic research often represents itself as scientifically driven, its goals and activities are inherently political because they are inescapably drawn into dynamic processes of agrarian change in which the productive functions of agriculture are contested among different categories of farmers, public functionaries, landowners, corporations and other interest groups that have distinct goals and expectations. What critical agrarian studies contributes is a fuller sense of how these dynamics play out over time and how changing social dynamics and patterns of accumulation inform distinct political projects at regional, national and international levels (Akram-Lodhi, 2013; Edelman and Borras, 2016).

Second, translating this question to a more localized scale of analysis allows us to engage more fully with how the target communities of agronomic research are themselves structured through social hierarchies and power relations. Agricultural landscapes are — literally and figuratively — fields of power. This means that agricultural innovations — whether inputs or changed management practices — have uneven and frequently unexpected political impacts that almost inevitably refract back into the realm of research and policy design. This is particularly the case given that the positive and negative impacts of change are typically unevenly distributed between different social groups, as our case studies below pointedly highlight (see also Nyantakyi-Frimpong and Bezner Kerr, 2015). As such, there needs to be a stronger recognition that the interface between research, extension and adoption is a messy realm in which the socio-ecological factors that are typically silenced in agronomic research — such as divisions of class, ethnicity and gender — play out, interrupt and reshape extension projects. In turn, these dynamics of power, accommodation and contestation within agrarian settings seep back into the politics of agronomic research and extension as

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researchers, scientists and policy makers deal with the intended and unintended consequences of previous interventions when setting future agendas, goals and projects (Kumar, 2016; Mosse, 2005).

We consider this task to be particularly important because much research within the field of agronomy seeks to hold aside socio-economic cleavages as unwelcome external context that gets in the way of figuring out 'what really works'. Even within critical work on public extension and farmer knowledge, there can be a tendency to replicate the undifferentiated concept of 'farmers' used within agronomy, who are often counterposed as a unitary block to other agents of rural change such as government agencies, extension officers, the private sector and so forth. For example, for all its undoubted achievements, the innovative 'Farmer First' perspective that challenged agricultural research and extension initiatives nonetheless constructed an overriding dichotomy between professional agronomists and farmers, without a full exploration of the marked distinctions between farmers along the lines of class, gender and other social divisions (Scoones and Thompson, 2009). While putting smallholder or resource-poor farmers first was clearly the intent of this paradigm, there was little explicit engagement with the political economy and feminist traditions that emphasized how different categories of farmers face different opportunities and constraints, and relate to each other in often hierarchical fashion, all of which greatly shape agrarian dynamics (Bernstein, 2010; Jansen, 1998; Kyeyune and Turner, 2016; Nightingale, 2006).

Third, we emphasize that the analysis of knowledge politics needs to engage with the way in which agricultural practices and technologies actively produce landscapes in both their social and agro-ecological dimensions. It is not simply the case that the outputs of agronomic research and extension — whether new inputs and varieties or management techniques — have environmental impacts. Rather, as several political ecologists have emphasized, agriculture itself is a process of 'environment making' and new techniques, varieties and inputs shift the way that agro-ecosystems and the landscapes in which they are embedded are reproduced over time (Agrawal and Sivaramakrishnan, 2000). Agricultural technologies — whether they are new varieties, tools or cultivation patterns — require social and environmental contexts that facilitate their operation while simultaneously changing the agro-ecological properties of the landscapes in which they are enacted. For example, a shift towards hybrid rice cultivation as described below must be analysed in terms of a dynamic interplay with changing irrigation systems, soil compositions and pest species at a landscape level. To adopt such a perspective is therefore to think reflexively about the complex ways in which human and non-human forces are wrought together in active processes of environmental production (Taylor, 2015). Agricultural knowledge forms an essential and politicized moment of that process as it provides a mediating link between environmental change and agricultural practices (Flachs and Richards, 2018). This factor, as we demonstrate below, is central to

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understanding the uncertainties of how new innovations and technologies play out in practice.

Incorporating these three research foci within the political agronomy agenda enables an encompassing approach to agronomic knowledge formation within changing agrarian environments. To demonstrate, the following sections provide two illustrative case studies that connect the agenda of political agronomy on the knowledge politics of agricultural innovation to the study of new technologies in practice. The first considers the experience of hybrid rice dissemination in an irrigated rice belt in Karnataka, southern India. The second considers the social and political dimensions of the hybrid New Rice for Africa (NERICA) varieties in Hoima district, western Uganda.

In both cases, we start by emphasizing political agronomy concerns in terms of how research agendas were established and how agricultural innovations were created and debated. Then we draw on a closer level of empirically grounded work — primarily gained through extensive interviews with farmers, extension agents and other key actors within local agriculture conducted in 2017 — to demonstrate how such knowledge politics became reshaped in practice within the complex social and ecological dynamics of the respective agrarian settings. For the Karnataka research in India, Taylor and Bhasme conducted 45 semi-structured interviews with paddy cultivators, millers, input dealers, traders, two sets of extension agents, and scientists at the local agricultural university working on rice breeding, water management and soil health. For the Hoima research in western Uganda, Bargout conducted interviews with 50 smallholders (23 male, 27 female) across five of Hoima's 11 sub-counties. These were supplemented by subsequent interviews with 20 grain traders (five male, 15 female), eight agro-input suppliers (five male, three female), and 11 expert officials (eight male, three female) from NGOs, farmer associations, seed companies and the government. Three focus groups were also conducted with rice traders. For the purposes of this article, the case studies are illustrative and therefore brief, yet demonstrate the importance of the synthesis perspective to illustrate an expanded series of research questions.[1]

HYBRID RICE IN SOUTH KARNATAKA

Our first case study derives from a qualitative study of the diffusion of a new hybrid rice variety produced by researchers at a regional agricultural university in Mandya, Karnataka. Within Indian agronomy, hybrid rice varieties are often argued to present a new frontier for yield gains owing to the heterosis effect by which hybrids grow more rapidly with higher fertility and overall biomass in comparison to open-pollinated varieties (Janaiah et al.,

1. A considerably more detailed exposition of the Karnataka case can be found in Taylor (2020). For the Hoima case, see Bargout (2017).

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1993; Viraktamath, 2011). Reference is often made to China, where hybrid use is widespread and aggregate yields are significantly greater than those in India. On this basis, increasing the use of hybrid rice seeds has been a consistent goal of Indian agricultural policy. In 2009 this was formalized with the creation of a governmental task force to systematically extend hybrid use over the course of six years through coordinated research, extension and subsidies. Despite such institutional prioritization, however, adoption rates remained low. In 2015, between 6 and 8 per cent of sown rice was composed of hybrid varieties, significantly short of the targeted 25 per cent (Janaiah and Debdutt, 2017).

In response, agronomists claimed that the key to increasing hybrid uptake lay in the development of varieties better adapted to local conditions and tastes (Sivagnanam, 2014; Spielman et al., 2013). The process of creating a strong, regionally adapted hybrid, however, is technically exacting and costly. While hybrid research in India was initially concentrated in public research facilities, the private sector soon recognized the latent commercial potential and began to invest systematically in hybrid research. Given that the heterosis effect lasts for a single generation, farmers planting hybrid rice must make annual purchases of seed and must adopt a more exacting regime of synthetic fertilizers, opening significant commercial opportunities. Although private sector investment currently far outpaces the public sector, it has not entirely crowded it out. Agricultural research universities maintain several active hybrid programmes including the University of Agricultural Sciences in Mandya, Karnataka. In 1981, this Zonal Agricultural Research Station became one of three southern Indian research centres seeking to develop locally adapted hybrid varieties and, over the course of the 1990s, it released two hybrid varieties designed for south Indian irrigated agro-ecosystems (Swarna et al., 2010; Viraktamath, 2011). While both varieties showed greater tolerance to local pests and diseases than the imported Chinese hybrids, one of the two was unable to demonstrate a strong yield advantage over standard high-yield varieties, and local farmers rejected the other owing to an aromatic quality that did not accord with regional tastes. After a period of stasis, development of a new hybrid variety of rice called Karnataka Rice Hybrid-4 (KRH-4) began in 2007 and was finalized in 2012.

KRH-4, a medium duration variety of rice that matures faster than some popular inbred varieties in the region, demonstrated superior grain yields of between 8 and 8.5 tonnes per hectare in controlled testing conditions. This represents an improvement on the standard varietal checks used within the Indian system and compares favourably to average field yields of around 5–6 tonnes per hectare under irrigated conditions in the Cauvery region (NRDC, 2016). As such, there is little doubt that KRH-4 represents a considerable technical accomplishment in standard agronomic terms. Beyond yields, the variety scored well in national taste tests and it produces more straw fodder than most semi-dwarf, high-yielding varieties (HYVs). Field tests also

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demonstrated an acceptable tolerance of leaf blast, sheath rot, stem borer and brown plant hopper and moderate tolerance to salinity (ibid.).

As political agronomists have highlighted, however, scientific accomplishment is only one measure — and not necessarily the predominant one — of success in contemporary agronomic research. While the universities had made the intellectual property of previous hybrid varieties in the early 2000s publicly accessible in order to maximize production of what they saw as a public good, 15 years later there were strong pressures upon research departments to create revenue streams through licensing fees. The university researchers who developed KRH-4 would ultimately be judged on the successful commercialization of the variety through sale of the seed's intellectual property to the private sector. Although researchers at the regional agricultural university noted ethical concerns about the tender of a publicly developed innovation to the private sector at what they considered to be a discounted rate, they also recognized that they no longer possessed in-house capacity to mass produce the seed.[2] To scale up production for national distribution, they had little choice but to let the National Research Development Corporation manage a commercialization process on their behalf.

As part of the process of building up towards this national tender, KRH-4 had been released for local usage five years previously and was distributed via public extension agents and select private merchants. For university researchers, there was a pressing need to ensure that an initial local release was deemed successful as a springboard for the commercialization process that would follow. This success, however, would need to be garnered in the context of an increasingly commercialized and competitive market for seeds. Across much of southern India, farmer in-field production of paddy seed has been largely supplanted by commercially produced seed purchased annually from input merchants. The main dealer in Mandya, for instance, typically has around 20 different rice varieties in stock, including both publicly and privately produced HYVs and hybrids. Faced with a growing and shifting array of commercial paddy varieties, most farmers have scant opportunity to develop an experientially based understanding of the relative attributes of different varieties. Instead, farmers tend to either remain true to trusted older varieties — some of which date back to the original Green Revolution period — or to rely on outside sources of information, including neighbours, input dealers and extension agents, to make seed choices (Flachs and Stone, 2019).

Within this context, university researchers and agricultural extension services sought to mobilize a network of model farmers to spearhead the diffusion of KRH-4 within targeted villages. This strategy had two key aims, both of which would be expedient for the later commercialization process. First, by supporting trusted model farmers with subsidized seeds and inputs,

2. Interviews, research scientists, Zonal Agricultural Research Station, Mandya, 12 and 16 August 2017.

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extension officers sought to build up a nucleus of adoption that would act as a demonstration of the variety's attributes to local farmers. Second, the strategy aimed to create a public record of 'success' for the variety in both local and national newspapers. A series of national newspaper articles, for example, spoke of farmers rushing to try a variety that was championed as having the potential to unleash a new revolution in regional rice production (Taylor, 2020).

On the ground, however, the roll out of KRH-4 proved uneven and complex and this is where the expanded concerns of our synthesis perspective are useful to highlight a wider range of social and ecological dynamics that impinge on the knowledge politics of hybrid rice. Farmers' use of KRH-4 was initially concentrated in villages where university extension networks were present. Here, model farmers were engaged to organize farmer collectives to cultivate the variety supported by subsidized inputs and tutelage. Despite these methods, by 2017 (five years after the initial project began) most interviewed farmers in these sites had stopped using the variety and did not view planting hybrid seeds as an attractive option. To understand why this was the case, it is necessary to place the political agronomy of hybrid seed within a broader focus. Specifically, the agronomic knowledge encapsulated in hybrid seed and its associated management practices would generate friction as it encountered a changing agro-ecological environment in which distinct classes of farmers operate with differing levels of access to land, water, labour, credit and extension networks.

Three important elements are noteworthy that draw directly from our synthesis perspective. First, the modes of disseminating the knowledge of hybrid seed and its cultivation served to consolidate local power hierarchies within target villages. The choice to use model farmers as the active proponents of KRH-4 continued long-standing extension practices that sought to facilitate knowledge transfer between agronomists and target smallholders by using such lead farmers as intermediaries. Local demonstrations of KRH-4 were quickly mobilized by model farmers who distributed subsidized inputs to their immediate farmer networks. These showcases served as the basis for producing the success narrative that university agronomists required to satisfy their institutional requirements. In so doing, however, this form of extension consolidated material and symbolic benefits in the hands of the lead farmers who were empowered as conduits of knowledge and subsidized resources from the public system to smallholder farmers. As a result, the feedback loops around KRH-4 knowledge on a local level were easily distorted owing to the self-interest of both scientists and model farmers in maintaining a 'success story' for the duration of demonstrations. Despite projections of success, it is notable that none of the model farmers we interviewed maintained usage of the variety once the subsidized demonstration period came to an end (see Taylor and Bhasme, 2018).

Second, farmers with a stronger asset base were far better positioned to moderate the risks involved and therefore to use the technology

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successfully. This tension was suppressed in the official discourse yet could not be silenced in practice. While agronomists within the public system argued that the agronomic superiority of hybrids could help shore up the profitability of small and marginal farmers, this downplayed the risks of switching to a relatively expensive and demanding crop. Hybrid seed is significantly more costly than standard HYVs and requires an extensive fertilizer regime to produce best results. These demands add to input costs at the start of the year that are frequently covered through informal credit sources, typically at high interest rates and sometimes tied to further social obligations (Guérin, 2014). As Kammardi et al. (2017: 51) note, input costs in Karnataka often account for over a quarter of total cultivation costs and represent a significant constraint. In this context, farmers using intensive cropping systems have faced a reproduction squeeze in which rising production costs have accompanied stagnant prices for key agricultural commodities. As a result, more affluent and well-resourced farmers had the necessary assets, knowledge and fiscal reserves to experiment with hybrids. Most smallholders – even those who were part of the initial KRH-4 demonstrations — reverted to using standard HYVs that were cheaper, could be sold more easily in established markets, and for which they felt greater confidence in cultivating. Others embraced new low-input agriculture models based around traditional varieties that were being promoted by regional political movements and farmer groups (Khadse et al., 2018).

Third, these dynamics were compounded by pronounced landscape transformations across the region. While the shift to intensive rice cultivation had initially been limited to areas directly served by canal irrigation stemming from the Cauvery river system, its geographic expansion since the 1970s has been abetted by the proliferation of further canal infrastructure allied to extensive borewell drilling in the area. This hydrological network was a precondition for the cultivation of high-yield and hybrid varieties promoted by agricultural extension agencies and private vendors. Over the past decade, however, a combination of climate change impacts and increased water demand — in no small part driven by the expansion and intensification of rice production — has rendered this hydrological infrastructure tenuous. With monsoon rainfall patterns increasingly erratic, combined with intense interstate conflicts over the distribution of Cauvery waters, the declining levels of water in the region's canal system has accentuated a vicious cycle of groundwater over-extraction. Under such conditions, farmers from all social classes remain tentative about investing in the higher-priced hybrids and their associated intensive fertilizer regimes all of which might be wasted if drought conditions persist and irrigation fails.

Placed in this wider context, it is notable how — despite its impressive agronomic resume — KRH-4 matched the needs of only a small portion of its intended recipients. For scientists in the regional public agronomic system, developing this hybrid validated their institutional expertise as skilled researchers and breeders. This undoubted success was duly confirmed and

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codified in the impressive scores that the variety received within national testing and commercialization was intended to be the final validation of this process, although researchers were troubled by the slow pace of progress in finding a willing buyer in the private sector. In contrast, for many local smallholder farmers, KRH-4 was the answer to a question they were not asking. Operating within an austere agrarian environment with heightening water constraints, options that minimized risk appeared salient over those that promised greater rewards. The ability to speculate with high-risk varieties was doubly constrained by farmers' limited access to capital and water alongside their dependency on local hierarchies for access to knowledge about new agricultural technologies. As a result, despite being proclaimed an agronomic success story, this hybrid variety failed to achieve its desired impact despite an impressive technical résumé. Notably, researchers quickly moved on to new avenues of agronomic research — specifically stress-tolerant varieties — designed to tackle the very same issues that the hybrid variety was originally argued to address. This cycle emphasizes how the knowledge politics of rice breeding in Karnataka can only be fully understood in a wider context that traces out the intended and unintended socio-ecological impacts of agricultural innovations in practice.

NERICA AND LIVELIHOOD CHANGE IN UPLAND UGANDA

While hybrid rice varieties are argued to be key to advancing Indian rice yields beyond the frontiers established by Green Revolution technologies, debates over agriculture within the African continent have tended to lament the lack of an original Green Revolution in the first place. This has resulted in strong public and private financial backing for a 'Green Revolution for Africa' strategy predicated upon a significant expansion of fertilizer and pesticide usage and the greater deployment of hybrid seeds across the continent (Moseley et al., 2015; Schnurr, 2019). One innovation that stands at the centre of this project is a set of rice varieties known as 'New Rice for Africa' (NERICA). First created in the 1990s through an intricate interspecific breeding method developed at the Africa Rice Center (ARC), these varieties are produced by crossbreeding high-yielding Asian rice (*Oryza sativa*) with locally adapted African varieties (*Oryza glaberrima*). The intention was to create hybrid varieties that combine the yield advantages of Asian rice with the robustness of African strains that are better adapted to local stresses, such as harmful insects or intense sunlight. with the case study in India, creating high-yielding and locally adapted varieties was portrayed as the key to expanding the cultivated area under rice, increasing average yields, improving farmer livelihoods and ensuring food security in the context of growing rice consumption on the continent.

As propounded by institutions affiliated with the ARC and studies connected to major breeding and dissemination initiatives, it is argued that

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NERICA varieties have various technical advantages over African and Asian rice counterparts on the basis of nutrient responsiveness, early flowering, grain count, grain weight per panicle, grain resistance to mill shattering, pest and drought resistance, high protein content, along with good taste and aroma (AfricaRice, 1995, 2002, 2011). On this basis, NERICA has been promoted as a tool for livelihood improvement that can contribute to increased incomes, self-sufficiency and even gender equality (Ajewole et al., 2015; Makosa and Takayanagi, 2014). In a more dramatic fashion, claims of an African 'miracle rice' — echoing those that accompanied the original Green Revolution variety IR-8 in Asia — appeared within the media (Harsch, 2004).

Within the incipient political agronomy canon, however, several authors (Orr et al., 2008; Whitfield, 2012) objected to the projection of an unqualified success story and highlighted notable discrepancies between the nature of claims made and the unevenness of the evidence backing them up. Although Orr et al. and Whitfield did not dismiss the ability of NERICA varieties to aid agricultural livelihoods, these authors suggested that promoter agencies needed to take a more realistic appraisal of the evidence base if such technologies were to have lasting benefit. This intervention, which directly foreshadowed the consolidation of the political agronomy research agenda, identified important gaps between claims and evidence that were largely confirmed by a subsequent CGIAR independent assessment (Tollens et al., 2008; see Wopereis et al., 2008 for response). That said, contesting the evidence base for whether NERICA 'works' in agronomic terms did not open the question of who it might work for in practical terms. In this manner, political agronomy was not asking sufficiently political questions.

In response, this second example broadens the discussion by asking how the agronomic properties embedded within NERICA varieties interact in complex ways with processes of socio-economic differentiation, knowledge deficits and new expressions of agricultural risk within a changing environment. This synthesis perspective allows us to better connect the question about whether NERICA 'works' in agronomic terms with the question of whom it works for in a given context. Our entry point is an examination of NERICA varieties in Bunyoro Kingdom in western Uganda, also known as Hoima District. As a predominantly rain-fed zone, Hoima is not a leading rice-producing area, yet it was one of the first regions where upland NERICA was piloted and disseminated in the early 2000s as part of an FAO-led project to rebuild the livelihoods of farmers following the impact of the civil war. In this context, the West Africa Rice Development Association (WARDA) promoted rice as being a potentially lucrative cash crop that could help households escape poverty (WARDA, 2004). NERICA varieties were widely promoted by a Japanese NGO called Sasakawa 2000 in collaboration with Uganda's Zonal Agriculture and Rural Development Institutes (ZARDIs), ARC, and the Japanese International Cooperation Agency (JICA). At the same time, at a national level, the Ugandan government

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actively solicited farmers to undertake NERICA production and maintained robust tariffs on imported rice to help create a market for local grain. With strong institutional backing, upland rice production increased markedly in the region and NERICA varieties have become the ones most commonly planted by farmers.

At first glance, this NERICA-driven boom in rice production across Hoima would appear to attest to the agronomic superiority of these varieties. Without question, when supported with adequate amounts of fertilizer, herbicide, manual labour and post-harvest processes, both researchers and interviewed farmers alike claimed that NERICA offers higher yields in comparison to existing upland varieties and its early maturation facilitated greater cropping flexibility.[3] The conditions for successful cultivation, however, are far from uniform across western Uganda, where agrarian landscapes are characterized by an uneven distribution of productive resources (i.e. seed, chemicals, land, water, credit) and value-chain resources (i.e. pre- and post-harvest tools, storage, transportation, market access) (Bazaara, 1992; Vetrhus, 2019). In this context, it is vital to consider how the agronomic properties of NERICA varieties become embedded within and transformative of the social relationships of rice cultivation, harvesting and marketing (Bergman-Lodin et al., 2012; Kijima et al., 2006). Such a perspective helps shed light on how the knowledge politics of NERICA specifically, and the A Green Revolution for Africa (AGRA) agenda more widely, is evolving (Gengenbach et al., 2018).

As initial studies noted regarding the constraints to NERICA production in Uganda (see, e.g., Wilfred, 2006), although NERICA varieties offer the potential for strong returns, these crops are difficult to plan and manage. This complexity is compounded by the need to support NERICA varieties with purchased fertilizer to maximize potential output. Given the resulting higher costs of inputs in comparison to alternate crops such as maize, cassava or potatoes, some farmers emphasized that they were only willing to grow NERICA varieties as part of a subsidized out-grower programme for certified seed in which the contracting company provides the fertilizer and other inputs. These out-growing arrangements provide farmers with training, supervision, support and necessary inputs, and typically guarantee to buy out-grower harvests at a rate equal to peak seasonal market price, creating strong returns and relatively low risk for the producers. Such arrangements, however, are typically restricted to more affluent and well-resourced households that possess the technical abilities to ensure the requisite output levels and quality alongside the social networks to connect them to seed companies (see Taylor and Bhasme, 2018).

Outside of such contracts, the agro-ecological uncertainties of upland rice cultivation combined with high input costs at the start of the season

3. Fofana et al. (2010); Sikuku et al. (2010); interviews with smallholder farmers, Hoima District, Uganda, May and June 2017.

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create a strong sense of risk. Rain-fed rice cultivation is a precarious pursuit owing to the fickleness of rains and, while some varieties of NERICA profess drought-resilient qualities, studies in Uganda suggest that other coinciding constraints (i.e. soil degradation, weed competition, damage from birds) limit the effectiveness of these traits in practice (Makosa and Takayanagi, 2014). As a result, farmers try to plant NERICA in areas with higher soil-moisture content and, particularly, in swamp land. Such land, however, is relatively scarce and of high value because it is the only agro-ecological zone that facilitates sequential cropping of rain-fed upland rice across both seasons. At the same time, this land also tends to be more fertile because silt and nutrient run-off collect in such lower lying areas. Perhaps unsurprisingly, therefore, village swamp lands tend to serve as the key location for the high-value activity of seed production, notwithstanding a central government prohibition on the use of swamp land for agricultural or commercial purposes in order to conserve ecologically sensitive ecosystems. Some farmers reported that the spring planting of NERICA on swamp land was driven primarily by the purpose of selling seed to other farmers in August and September for the fall rice season.[4] Such lands, moreover, tend to be in the hands of relatively more affluent farmers who use political connections to ensure the non-enforcement of government restrictions.

Outside of these well-irrigated cultivation zones, farmers adopt several risk-aversion strategies to capitalize on the NERICA boom in less hospitable agro-ecological conditions. Farmers with better resources typically purchase two or more varieties of NERICA as a means to defray risks by harnessing the varied resilience characteristics of each (drought, pest, heat stress, early maturation, etc.). This is an important cultivation strategy that speaks to the limitations of the embedded stress tolerance that the proponents of NERICA represented as one of its defining characteristics. If farmers have inadequate certainty about how these new rice varieties will fare under variable climatic and agro-ecological conditions, planting several varieties in separate plots maximizes the potential of ensuring some returns regardless of the specific stresses that may occur (Mukasa, 2018). A prerequisite of such an approach, however, is to have enough land holdings to be able to devote separate fields to distinct varieties and the capital to invest in the varieties and inputs at the start of the season.

Conversely, for more marginal farmers, this risk mitigation strategy employed by better-resourced farmers has unintended negative impacts. Smallholder households often rely on lead farmers for purchasing seed on credit, along with other agricultural inputs. As noted above, the selling of seed on credit to fellow farmers was found to be a key incentive for better-resourced farmers in Uganda to expand production onto swamp lands. Our research showed that larger farmers purchased seed at the lowest price whereas

4. Interviews with smallholder farmers, Hoima District, Uganda, May and June 2017.

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small-medium farmers owning 2–5 acres of land would pay anywhere between 20 and 80 per cent more for their rice seed. When the interest costs — ranging from 60 to 100 per cent — are added in, the price of NERICA varieties bought from lead farmers can be much higher than the store price of certified seeds. While store prices might be cheaper, more marginal farmers rely on buying from neighbours for two key reasons. First, they need inputs at specific key times of the season and often taking seed and fertilizer on credit from more affluent neighbours is the only way to achieve this. The result of buying on credit, however, is to perpetuate debt cycles over time. Second, high yields are widely viewed as a symbol of success, which sustains the social status of lead farmers who are viewed as performing a more modern and highly symbolic form of agriculture (see Leahy and Brown, 2016). Several farmers indicated that they believed using seed from a lead farmer would give them good fortune.[5]

The major constraint in using seeds provided by lead farmers, however, is that such farmers typically harvest, process and market their grain in a single batch despite it being composed of different NERICA varieties. Known as 'mixing', or *miksiinga*, this practice makes harvesting and the post-harvest processes of threshing, drying and milling more efficient. It can also conceal lower-quality grain, which makes price bargaining easier. The purchase of mixed NERICA translates into new livelihood burdens for more marginal farmers, however, as a medley of NERICA varieties will mature, flower and bear grain at different times leading to distinct growth cycles within the same plot. The planting of mixed NERICA thus creates significant complications in cultivation, harvest and post-harvest processes, leading to reduced yield while increasing invested labour time. At the pre-harvest stage, for example, one of the most significant threats is the arrival of birds that feed upon the crops during seed formation and grain-filling stages. Yield loss from birds was the most reported reason for farmers abandoning rice cultivation. If a NERICA plot has non-uniform flowering, a household may invest 30 to 40 days of labour in guarding fields from birds and rodents, as opposed to 15 to 20 days when NERICA varieties are organized into separate plots where flowering occurs uniformly. For marginal households, women, children, or the elderly typically shoulder these added labour demands.

Seed companies, NGOs, milling companies and agro-input stores claim to advise farmers against NERICA mixing. However, successful farmers are driven to maximize their output through mixing while enjoying the lucrative potential of seed sales to local households. At a cultural level, they rationalize that poorer farmers lack the skill to effectively plant, apply chemicals, or process the harvest properly, thereby pointing to mismanagement as the cause of cultivation problems rather than their own complicity in providing mixed seed. More marginal households in turn do not possess

5. Interviews with smallholder farmers, Hoima District, Uganda, May and June 2017.

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a strong knowledge of NERICA physiology and are typically excluded from extension services, development programmes, farmer associations or outgrower training. There is a tendency among some to rationalize that the yield gaps between themselves and lead farmers are caused by divine phenomena (i.e. spirits, charming, curses). As a result, whether a lead farmer knowingly or unintentionally sells impure NERICA to an unskilled neighbour, such a transaction occurs within a normative worldview shaped by Banyoro sociocultural hierarchy, class-based competition, and the perceived cosmological predetermination of individual status within society.

Ultimately, while the NERICA boom created new avenues of wealth accumulation, the opportunities to profit were concentrated among those with greater access to swamp land, capital and knowledge networks. Like the political ecology of hybrid rice in Karnataka, the Hoima case study shows how NERICA uptake played into the consolidation of material and symbolic benefits among more affluent farmers. More distinctly, it also demonstrates how the very actions of those farmers to maximize output and minimize risks ended up transferring new risks and burdens onto client farmers in the form of mixed NERICA seeds. Such farmers repeatedly end up buying NERICA with little knowledge of which varieties they are receiving, a deficit that compounds their marginal status, cements their dependency, and entrenches the often-exploitative arrangements they have with local lead farmers from season to season. This outcome once again highlights how the knowledge politics of NERICA is incomplete without consideration of socio-economic differentiation and the uneven distribution of risk across the agrarian environment.

CONCLUSION

Through its deep interrogation of the knowledge politics that underpins agronomic research and practice, the research agenda of political agronomy has generated important insights about how power operates and is contested in the creation and application of new agricultural knowledge and technologies, particularly with reference to development contexts. As we have argued in this article, there is now a need to further such advances by better linking the political agronomy agenda with insights drawn from critical agrarian studies and political ecology. We emphasized three core areas of this synthesis: a fuller consideration of the political-economic drivers of agrarian change that configure the social dynamics and substantive outcomes of agriculture as a form of livelihood across scales; the local hierarchies and power differentials through which agriculture is realized as a practice, particularly in relation to how new technologies are introduced and enacted; and the ways in which agricultural innovations are positioned as active forces within evolving agro-ecological landscapes.

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The salience of these three points was reinforced through two illustrative examples of hybrid rice promotion, from southern India and western Uganda. As noted in both cases, the knowledge politics surrounding these agricultural innovations was transformed once situated within regional social and agro-ecological contexts. Intrinsic to these dynamics was the emergence of new forms of power and risk surrounding the application of agricultural knowledge and technologies within contexts marked by deepening social differentiation and pronounced environmental change. As our case studies demonstrate, these forms of power helped to consolidate the unequal distribution of risks and rewards across groups of farmers. Importantly, the uneven and unexpected impacts of these new agricultural technologies in practice refracted back into regional and national agronomic research agendas and policy making, thereby influencing a new cycle of agronomic knowledge politics.

Such dynamics emphasize the salience of a renewed research agenda to analyse the interface between knowledge politics, applied agricultural practices and socio-ecological change across agrarian environments. This agenda, we believe, is crucial to better communicate the uncertainties of new agricultural technologies to farmers, agronomists, extension agents, policy makers and rural social movements alike.

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