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'They think we are delaying their outputs'. The challenges of interdisciplinary research: understanding power dynamics between social and biophysical scientists in international crop breeding teams

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Public sector crop improvement for development programmes aims to produce varieties tailored to the needs of smallholder farmers and their environments. Understanding how social heterogeneity, including gender, drives trait preferences is essential to ensure that crop improvement objectives meet farmers' and stakeholder demands. This requires an interdisciplinary approach, integrating social science knowledge with crop breeding. Although the necessity of interdisciplinary research is recognised and promoted, it is impeded by a multitude of challenges including ontological and epistemological differences, institutional and global hierarchies, disciplinary power relations and struggles for scientific authority. The Agricultural Research for Development (AR4D) sector is marked by entrenched power differentials, including dominance of the biophysical sciences, a historical emphasis on technical solutions which ignores social contexts, and the underrepresentation of women scientists and farmers themselves. Nevertheless, there is limited theoretically informed analysis of power dynamics within AR4D settings. Drawing on qualitative, ethnographic observations of the Feed the Future Innovation Lab for Crop Improvement (ILCI), this article seeks to understand how power affects interdisciplinary research processes. Critical ethnography and power theory is used to analyse power within international crop breeding collaborations and the implications for inclusive knowledge production and research impact. The Powercube is used to examine how visible, hidden and invisible forms of power manifest within local, national, and international relationships across closed, invited and claimed spaces. Our findings suggest that these intersecting power dimensions, which include disciplinary, gendered, institutional and global hierarchies, constrain the contributions that individual researchers can make – particularly social scientists – thereby hindering disciplinary integration. The ILCI case study reveals the complex multi-dimensional dynamics that emerge within agricultural research teams and highlights structural limitations constraining efforts to build socially inclusive and gender-responsive crop improvement programmes. The article contributes to a small but growing literature studying the social construction of agricultural science, and provides insights that can enable interdisciplinary research strategies to more effectively meet the needs of farmers and other stakeholders.

KEYWORDS
power, interdisciplinary research, crop breeding, critical ethnography, AR4D

1. Introduction

Public sector crop breeding that focuses on achieving high yields may contribute to food production and alleviating food shortages, but has been less successful at reducing poverty, hunger and malnutrition (Pingali, 2012). Difficulties meeting the needs of low-income, smallholder producers in marginal environments is partly due to a mismatch between crop improvement goals and farmer realities (Polar et al., 2022), and contributes to low adoption of varieties, particularly in Sub-Saharan Africa (McDougall et al., 2022).

Plant breeding research efforts have been criticised for uneven social and spatial effects (Kingsbury, 2009; Sumberg et al., 2013), leading to a growing emphasis on more equitable and inclusive approaches. It is argued that if breeders overlook traits – such as taste, colour, size, shape – that are important to different end users (for example women), varieties will not be adopted (Walker and Alwang, 2015; Tufan et al., 2018; Ashby and Polar, 2019). This in turn can potentially affect household food insecurity and poverty (Polar et al., 2022). To address this, more inclusive trait prioritisation processes and tools are being developed to understand the range of preferences that matter to different social groups and identities (Orr et al., 2018; Tufan et al., 2018; Ashby and Polar, 2021; Teeken et al., 2021; McDougall et al., 2022). It is assumed that if crop improvement can 'get the traits right', this will result in more desirable and beneficial varieties for a diversity of user groups, leading to increased adoption, improvements in productivity, and reduced poverty and malnutrition. This new orientation also aims to produce varieties that have greater value or success in 'the market'. The rise of demand-led (Persley and Anthony, 2017) and market segmentation and targeting (Donovan et al., 2022) approaches for crop breeding conflates markets, demand and social inclusion (Tarjem, 2022). However, it also expands the requirements of crop improvement programmes, necessitating the inclusion of social scientists to carry out these new agendas.

Historically, crop improvement has been carried out by plant breeders and biophysically trained scientists (i.e. agronomists, plant pathologists and entomologists), with limited input from social sciences (i.e. agricultural economists, rural sociologists, anthropologists, gender specialists and nutritionists). Despite the recent emphasis on multidisciplinary research teams that incorporate social scientists, little is known about how such arrangements work in practice. In particular, there is limited understanding of the realities of designing and implementing socially inclusive research, how collaborations are experienced by researchers, the extent to which disciplinary integration is achieved and how these arrangements influence crop breeding practices and outputs. Critical reflexive analysis of research processes is rarely undertaken, maybe because as a social science domain this is not prioritised within a technologically oriented sector dominated by natural sciences.

Within AR4D, social scientists often struggle to influence the work of biophysical scientists. Social scientists who are women can be 'doubly marginalised' by a lack of respect for their discipline and their status as women (Verma et al., 2010: 272). Qualitative social scientists, again who are often women, are especially challenged as their work is often referred to as 'anecdotal' (Verma et al., 2010: 268). Racial and global hierarchies further contribute, but have largely been ignored and so occupy an 'absent presence' (Pailey, 2019). The 'deeply masculinised' character of modern agriculture, historically shaped by Anglo male scientists (Farhall and Rickards, 2021: 11), can be traced back to colonial models of development; and the separation of public and private spheres and gendered divisions of labour that fostered male dominance of technology (Polar et al., 2021: 80). As a result, 'women and people of colour have had little influence over the directions that agricultural research has taken' (Hassanein, 2000: 52). Research by Marks et al. (2023) suggests that plant science suffers from ongoing underrepresentation of marginalised identities. Due to global disparities, established under imperial colonialism and perpetuated through modern Eurocentric frameworks, researchers in the global South face multiple barriers to participating in plant science, with gender and race intersecting to generate particular constraints for women of colour (Marks et al., 2023).

As plant breeding embarks on a shift towards rapid, data-intensive approaches whilst also attempting to be more socially inclusive, it is necessary to critically assess past experiences and the current research landscape to see what lessons might be learned. This will illuminate 'the dynamics of power that determine what (and whose) ideas and technological solutions prevail' within research domains (Leach et al., 2020: 7). This article attempts to begin 'researching the researchers', with an explicit emphasis on power, to gain a better understanding of the social dynamics of agricultural science, specifically crop improvement, and its implications. We begin with the overarching research question: How does power manifest within multidisciplinary crop improvement collaborations and what are its impacts on integrating knowledge from the social and biophysical sciences? We attempt to answer this question through qualitative, ethnographic research that explores power dynamics through a case study of a multi-country agricultural research for development (AR4D) project, the USAID-funded Innovation Lab for Crop Improvement. While our findings may conform to certain stereotypes of power dynamics within the AR4D sector, and beyond, they reflect the lived experiences and perceptions communicated by our respondents.

Our research framing and data interpretation has been informed by our own experiences as women and socially oriented scientists working in the AR4D sector. Our gender, disciplinary training and experiences guide our perspective on power and our understanding of how power influences individuals, research processes and disciplinary relations. In accordance with feminist theory, we do not consider our experience a 'bias' but rather a strength, giving us insights that improve our analysis and interpretation (Harding, 1991). As white researchers from the global North, we acknowledge that we are writing from positions of privilege. We do not claim to speak on behalf of others but rather act as 'observing participants' (Mostad and Tse, 2018: 54). In this article, we turn our ethnographic gaze to reflect on and question the construction of Western/Northern agricultural

knowledge with the aim of facilitating processes that can decentre and decolonise existing power structures.

2. Interdisciplinarity and power: a review of the literature

Interdisciplinary research is widely promoted by donors and research institutions alike (Kelly et al., 2019).[1] It is increasingly recognised that many of the current global challenges 'are invariably 'wicked problems', to which there is no single solution' (Fraser, 2017: 139). This understanding calls for new approaches to science and knowledge production to tackle 'complex and highly interconnected problems' (Fritz and Binder, 2020). This argument assumes that interdisciplinary research 'generates more nuanced and robust understandings of the social and natural world than knowledge emerging from within traditional disciplines, and will lead to more innovative or more holistic solutions' (Frickel et al., 2016). However, the challenges faced in such work are often unacknowledged. Promotion of interdisciplinarity presumes that scientists from different disciplines know how to work together effectively, and ignores inequalities between them.

A growing body of academic literature exploring interdisciplinary endeavours indicates that hierarchies, prejudices, and power asymmetries shape many interdisciplinary interactions (MacMynowski, 2007). As disciplinary collaborations rise in number, it is increasingly apparent that 'how the idea of interdisciplinarity gets put into practice, what form it will take and what goal it will be assigned, depends on the configuration of power between epistemic communities, economic actors and political stakeholders, as well on their interests in, and views on, legitimate science' (Albert and Laberge, 2017). The presence of entrenched disciplinary hierarchies indicates the importance of being 'attentive to power relations and status hierarchies between disciplines and knowledge areas … and struggles for scientific authority' (Frickel et al., 2016: 6).

Studies on how interdisciplinary initiatives work – and do not work – in practice are rare (Freeth and Vilsmaier, 2020: 58). As Callard et al. suggest, 'We still know remarkably little of the mundane detail of what it looks and feels like to labour in an interdisciplinary setting' (2015: 1–2). In particular, the structural conditions, political and power dimensions that influence or hamper such collaborations and, thus, knowledge production are rarely addressed in scientific discourse (Dannecker, 2020: 1). Within the AR4D sector, power dynamics have been analysed between agricultural scientists and farming communities (Cooke and Kothari, 2001), global science and indigenous knowledge (Sillitoe, 1998; Sillitoe, 2007), but there has been limited analysis of power dynamics within research teams themselves. Agricultural anthropologist Todd Crane (2014) argues that to better understand research processes and professional practices of agricultural scientists, they should also be subjected to an analytical lens. He proposes that applied anthropological research should take inspiration from science and technology studies (STS), which takes the social configuration of scientific knowledge production and technology development as its focus (Felt et al., 2017). Crane argues that 'empirical social research on scientists' … will enable better theorization of how and why certain forms of applied agricultural research work (or do not work)' (2014, 47). Analysing the social construction of agricultural science, particularly 'technical practices, social organisation, and institutional norms' (Crane, 2014: 47) may provide a fuller understanding of crop improvement and make interdisciplinary research more effective.

There have been successive attempts to improve disciplinary integration, and make AR4D more demand-driven – from farming systems research to participatory plant breeding (Ludwig et al., 2022). Yet despite four decades of agricultural research institutions initiating such approaches, they have never become mainstream in the technology development cycle (van de Gevel et al., 2020). Retrospective analysis indicates that reversing well-established research models implies shifts in power, authority and control. A review of participatory plant breeding (PPB), for example, concluded that disciplinary power struggles thwarted its success (Ceccarelli and Grando, 2020). It suggested that breeders were resistant to PPB because it rendered technical breeding issues subordinate to social factors. Breeders felt 'they had been expropriated of their science, and scientists (social and gender scientists, anthropologists and socio-economists) … [were seen as] trespassers on 'their' territory' (Ceccarelli and Grando, 2020: 237). As Hilgartner argues 'new paradigms and new technologies have the potential to perturb extant regimes' (Hilgartner, 2017: 19) and are accompanied by struggles for control.

In AR4D settings power dynamics are not confined to struggles between disciplines and 'knowledge regimes', but include gendered, racial, and global hierarchies which overlap and intersect with disciplinary and institutional contexts in complex ways. Research communities, like agrarian communities are heavily stratified by social divisions, including, gender, class and ethnicity (Evans et al., 2020; Taylor, 2021:4). From this perspective, 'forms of social differentiation, based on gender, class, and ethnicity … are not peripheral to the research process but are at its centre' (Ferguson, 1994: 545). In sum, 'interdisciplinarity is entangled in much thicker structures of power than either its promoters or its practitioners are willing to recognise' (Callard and Fitzgerald, 2015: 98).

The role of power in interdisciplinary processes is a nascent research area. Analyses of interdisciplinary power indicate that 'studies have rarely been grounded in explicitly articulated understandings of power' (Fritz and Binder, 2020: 2). Nor have existing studies of disciplinary interactions and institutional environments in an AR4D context referenced power theory (Horton, 1984; Rhoades et al., 1986; Cernea and Kassam, 2006; Verma et al., 2010). Marcus Taylor, writing on the political economy of development, notes that 'although authors are clearly aware that power keenly matters, they often seem reluctant to … [delve] into the kinds of critical theory that seek to systematically engage with such issues' and so 'conceptualisation remains superficial' (Taylor, 2015: 82). One challenge to analysis is that 'power is fluid, dynamic, and difficult to measure' (German et al., 2010: 8). Nevertheless, Knapp et al. (2019) argue that it is imperative for researchers to engage with critical theory, particularly branches of

1 According to the National Academy of Sciences, 'interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialised knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice' (2005).

feminist and de-colonial theory which help to understand how power shapes collaborative approaches, how identity influences outlook and positionality, and how different types of knowledge are valued.

Power analysis draws on critical social theory, anthropology, political sociology and feminist theory (Acosta and Petit, 2013). In a review of existing work, Svarstad et al. (2018) distinguish between actor-oriented, Foucauldian post-structuralist and Neo-Marxist approaches. In actor-oriented approaches, actors possess and use power to exercise influence over others. In contrast, Foucault's understanding of power is relational, indicating that power is not 'a privilege that one might possess' but rather operates within a network of relations (Foucault, 1977: 26–27). Power is thus co-produced in social interactions, vested not in individuals but in organisational structures, social rules and shared cultures (Heizmann and Olsson, 2014: 758). Marxist perspectives highlight how human agency is constrained and produced by historically established social structures and exercised through economic domination and exploitation, drawing attention to the control and allocation of resources.

An influential approach to power analysis is the Powercube framework (Gaventa, 2006), informed by Lukes (2005) 'three faces of power' which incorporates actor-oriented, post-structural and Marxist perspectives. The Powercube (Figure 1) identifies three forms of power: visible, hidden and invisible. *Visible* power looks at formal decision-making processes and 'who gets what, when and how'. *Hidden* power, focuses on how certain issues and/or participants are excluded from decision-making including how agendas are set and the unwritten rules embedded in social structures that can directly and indirectly influence decisions and interactions. *Invisible* power, focuses on more subtle or diffuse forms of power. Identifying this form of power involves analysing internalised norms, values, ideas and customs which shape people's perception of their roles and actions, often serving the interests of the more powerful. The Powercube extends analysis beyond the three forms or faces of power to include different levels (local, national and global) and different spaces of power (closed, invited and claimed), thereby providing a framework for identifying the multi-faceted dimensions of power. While the Powercube utilises an image that makes the 'levels', 'spaces' and 'forms' of power seem clear and definitive, this is just a heuristic device. In reality, the various aspects of the cube are intermeshed in complex ways. This makes it important to consider interactions between dimensions, and how they overlap and intersect.

Feminist power theorisations influence and add to this framing by arguing that conceptions of power which remain limited to 'power over', or domination and control, are implicitly masculinist. To provide alternatives, feminist scholars argue for a recognition of power as a capacity to act, which includes the capacity to empower or transform oneself and others. Such approaches utilise alternative concepts – 'power within', 'power to', and 'power with' – that highlight the transformational dimensions of power and possibilities for change (VeneKlasen and Miller, 2002). *Power within* refers to an individual's sense of self-worth, self-knowledge and self-efficacy, including the capacity to imagine alternatives. *Power to* refers to the unique potential of individuals to shape their life worlds and make decisions to achieve goals, which opens up possibilities for action. *Power with* refers to finding common ground and building mutual support, solidarity and collaboration, which can help build bridges between different interests.

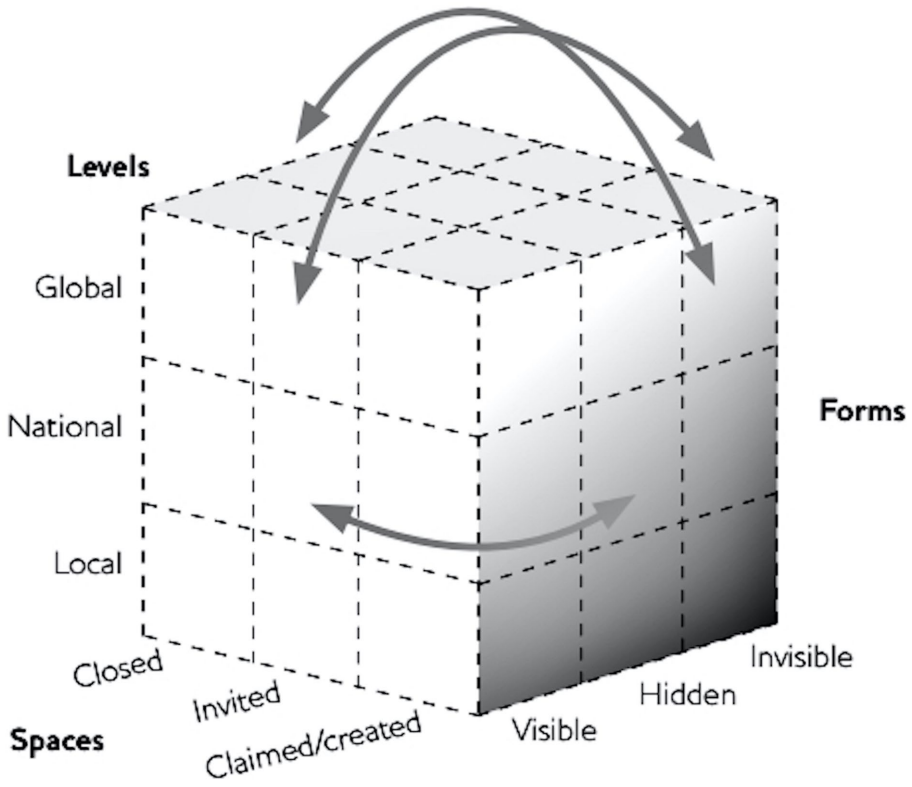

FIGURE 1
The Powercube: the levels, spaces, and forms of power (Gaventa, 2006).

Power through is a recent addition, and refers to the individual power that can be won and lost through relations to others (Galié and Farnworth, 2019). Such conceptions recognise that power is not just negative, coercive or repressive, but can be productive (Gaventa, 2003: 2). These framings have been applied in A4RD, particularly work focusing on gender relations, social exclusion and women's empowerment (Kabeer, 1999, 2000, 2005). Others draw on Rowlands (1995) discussion of intrinsic (power within), instrumental (power to), and collective (power with) (Malapit et al., 2019).

These perspectives offer significant insights and demonstrate that how we perceive and address power depends on our frames of reference, disciplinary lenses, and the methods we use to analyse it (Petit, 2013). The complexity and multi-faceted nature of power dynamics require us to take into account different forms of power; the various actors, institutions, relationships and spaces where it arises; and how dimensions of power intersect. As Svarstad et al. (2018) argue, combining different theoretical perspectives can contribute to richer and more nuanced understanding of how power manifests.

3. Context: the innovation lab for crop improvement

This research is focused on the Feed the Future Innovation Lab for Crop Improvement (ILCI), part of the US Government's efforts to address global hunger, food security and malnutrition. ILCI aims to drive 'bottom-up' strategies in crop improvement by bringing together scientists and stakeholders to co-develop and implement tools, technologies and methods tailored to the needs of specific communities (ILCI, 2021). The overall goal is crop varieties that enhance productivity, growth, resilience and nutrition, while providing equitable benefits to women and youth. The effort is led by a coordinating team at Cornell University, together with other US-based institutions.[2] Research is conducted in collaboration with four 'centers of innovation' (COIs) in Uganda, Costa Rica / Haiti, Malawi and Senegal, with subsidiary teams in affiliated countries including Kenya, Tanzania, Mozambique, Burkina Faso and Niger. COI researchers are largely based within National Agricultural Research Institutes (NARIs) and associated Universities.[3] Research is oriented around a number of themes, referred to as 'objective areas' (OAs). These consist of priority setting, trait discovery, phenomics, genomics, breeding informatics and institutional capacity, with 'cross cutting themes' focusing on gender, youth, nutrition and resilience. OA researchers, mostly from US-based institutions, support COI researchers, mostly based in NARIs in the global South. Both OAs and COIs consist of researchers from a range of biophysical and social science disciplines.

ILCI is described as an interdisciplinary initiative (ILCI, 2021), where working across different biophysical sciences and between biophysical and social sciences are both considered interdisciplinary efforts. By 'forming linkages between previously siloed disciplines' the lab aims to develop approaches that can 'enhance and scale capacity for national breeding programs' (ILCI, 2021). One of the conditions in the call for proposals was the incorporation of social scientists within research teams, to focus on gender, youth and social inclusion and ensure that breeding approaches consider the needs of diverse stakeholders. An ILCI publication (Merchán, 2021: 29) states that while social issues 'are at the centre of why crops are bred in the first place', they are 'often detached from breeding programs'. ILCI is seeking to change this, with a 'multidisciplinary, systems approach' that incorporates 'economists, social scientists and specialists in … gender, youth, nutrition, and inclusion' within 'integrated teams' (Merchán, 2021), to achieve holistic, demand-led crop improvement.

The project also attempts to address North–South power dynamics by placing NARIs in the driver's seat. It acknowledges that NARIs play a critical role in the research and development of agricultural products, but are often unable to determine their agendas and visions due to pressures and demands from donors and national governments. In contrast, ILCI intends to make science work for NARIs rather than agendas being imposed from the top down (Tufan, 2020). The emphasis on co-equal relationships, co-creation and partnerships, 'founded on principles of shared dialogue and idea formation' (Merchán, 2021: 29), endeavours to make crop improvement more demand-driven. It is assumed that supporting NARIs to develop and implement localised strategies and approaches will improve the effectiveness of breeding processes and ensure they address national priorities.

Despite these efforts to change the way in which crop improvement processes work, preliminary observations by research coordinators within ILCI suggest that power dynamics within these international, multi-disciplinary crop improvement collaborations inhibit equal voice and decision-making, raising questions about the functionality of such teams and their capacity for generating interdisciplinary outputs (Tufan, 2020).

4. Methods

This article uses ethnographic and qualitative approaches. The first two authors are anthropologists with experience working in interdisciplinary AR4D teams. As researchers' external to the ILCI project, they worked collaboratively with ILCI team members and liaised throughout with the second two authors, an anthropologist and plant scientist, who acted as an advisory team and provided guidance on the approach. Research was conducted over approximately 15 months from October 2021 to December 2022. The first step involved carrying out an extensive review of literature on social science in agriculture, crop improvement and theoretical and practical studies of power, particularly in interdisciplinary contexts. The next step examined and analysed project documents to understand project history and structure. These included the Notice of Funding Opportunity, Request for Applications, COI proposals, annual reports, and the project website. Then, a brief questionnaire was distributed to project members to gather basic information about respondents, to assess how they understood interdisciplinary research and challenges

2 These include Clemson University; Colorado State University; Kansas State University; University of Missouri; Cultural Practice, LLC; RTI.

3 These include National Semi Arid Resources Research Institute (NaSARRI) in Uganda; Instituto Nacional de Innovacion y Transferencia Tecnologia Agropecuaria (INTA) in Costa Rica; and Institut Senegalais de Reserches Agricoles (ISRA) in Senegal; Quisqueya University in Haiti; University of Costa Rica; Lilongwe University of Agriculture and Natural Resources (LUANAR) in Malawi; and Makerere University in Uganda.

faced. A total of 53 members responded. Selected questionnaire respondents were then contacted for follow-up interviews. These Zoom interviews were conducted with 32 project members (16 women and 16 men). Participants were selected based on their position, gender, discipline, and level of experience to ensure a range of perspectives. These included three members of the project management team, nine US-based objective area researchers and 20 COI researchers from each of the four regional 'hubs'. Interview questions focused on a number of key topics namely: individual disciplinary experiences; team dynamics; project communication and decision-making; resources and deliverables; and project leadership. Conversations were framed around interdisciplinary team dynamics rather than an explicit focus on power. We deliberately avoided using the word 'power' in most interviews, due to its negative connotations, such as abuse of power, lack of transparency, and unilateral decision-making (Boni et al., 2009). Instead, we used open questions and neutral language to facilitate discussion. As well as interviews, we observed recordings of project presentations, training sessions and team meetings, internal discussion threads and blog posts, drawing on approaches from institutional and digital ethnography. Once interviews were completed we began to 'code' our notes and interview transcripts to identify patterns using thematic analysis. We drew upon the Powercube and feminist theoretical framings, as well as wider literature, to interpret and structure our findings.

5. Results

5.1. Visible forms of power

Drawing upon the Powercube, we first examined visible power, such as the observable aspects of decision-making. We observed who participates and dominates, and thus whose interests prevail in key decisions. Attention to who prevails also led us to examine who may have little influence despite being present.

The historical development of agricultural science, together with established sectoral norms, has resulted in entrenched hierarchies between the biophysical and social sciences. In the case of crop breeding, biophysical scientists, namely 'breeders', have visible power – or 'power over' – other disciplines. Interviews with respondents conveyed an understanding of the history of this power dimension. One social scientist explained, 'Two or three decades ago, the breeder… would just start breeding based on his own interests or interests of the donors … they would produce varieties that would not be adopted or were not needed by the farmers'. Another commented 'Way back, people just used to go to the field and they did not regard the input of social scientists… a breeder would come up with a variety … but they did not take social and cultural issues into account'. These reflections underline the perceived dominance of crop breeders and lack of input from social scientists or farmers.

Within AR4D, social scientists are often seen as service providers to biophysical researchers and therefore of secondary importance. Several ILCI social scientists explained their primary role as helping to diffuse technology or aid adoption. One respondent said 'When they [breeders] want to diffuse the technology, I have to make surveys and studies and speak about the new technologies they [breeders] want them [farmers] to use.. When they [farmers] accept to use the technology, I do an impact study'. Thus, the main input of social scientists to date has been ex-ante and ex-post studies of crop breeding processes, particularly adoption and impact studies carried out in the aftermath, with limited input to priority-setting and varietal design.

The visible power of the biophysical scientists is apparent in their control over the conceptualisation and framing of project proposals, research questions, budget allocations and methodological approaches. In the ILCI development phase, for example, many of the COI proposals were generated by biophysical scientists. As one COI social scientist commented, 'I was involved in the proposal writing phase but only at the point where the PI had already conceptualised the main breeding ideas of the project … I then had to give my input … from a gender and youth inclusion perspective'. Another respondent commented, 'I think, for most participants, including social sciences was more of an afterthought'. In this sense, proposals were not truly co-produced, suggesting that not all disciplines participated in elaborating project objectives.

Social scientists often have limited decision-making power in the sector. Few social scientists, particularly in NARIs, make it into management positions so have little influence over project design, funding allocation, scientific and institutional practices. Within ILCI, the biophysical sciences, responding to the original USAID request for applications, dominate the project, with 79 researchers affiliated to STEM disciplines compared with 48 social scientists.[4] This pattern extends to project decision-making, with biophysical scientists occupying the majority of leadership roles, giving them greater visible power. The project Director and former Associate Director are both plant scientists, eight out of 12 Objective Areas leads, and seven out of eight Centre of Innovation PIs are trained in biophysical disciplines. Social scientists are the minority in both OAs and COIs, and usually occupy more junior positions. Although project members commented that the social sciences are better represented than in many breeding projects, the predominance of biophysical disciplines is still apparent.[5] The original call for proposals which focused on biophysical tools, technologies and methods for crop improvement is likely to have shaped this imbalance.

Visible power in the AR4D sector generally also has gendered, as well as racial dimensions. Although this is shifting, women continue to be underrepresented. This extends to ILCI, which consists of 81 men, and 46 women scientists. Due to these imbalances, those with visible power in the project tend to be men (nine out of 12 OA leads are men and among COIs, women leaders are often co-leads). The visible power of men was apparent in conversations with respondents. A junior social scientist, for example, referred to people he considered to be 'big names' in the project, all of whom were men. A biophysical scientist commented that project PIs are 'male heavy' and then said 'I am used to being in rooms with 10 men and I am the only woman, which is bad, that should not happen'. There are also perceived racial power imbalances, although few respondents referred to these explicitly. One woman COI scientist said, 'generally there is that segregation where the rest of us, based in Africa, always feel like we are

4 STEM is an umbrella term used to refer to science, technology, engineering and mathematics disciplines.

5 It is also important to note that many social scientists are not trained to go into agricultural research but rather pursue topics that are more oriented towards the focus of their respective disciplines.

second class citizens. We do not have the same voice, or if we propose something it's never really that important… if you propose something in a meeting… and then it [the same idea] comes from somebody in the West suddenly it's like whoa, yeah, that's a really great idea'. This is significant because agricultural technologies and the science that produces them are informed by cultural, social and gender relations, and attendant power dynamics (Harding, 1991; German et al., 2010; Polar et al., 2021).

Cognisant of this, ILCI project leaders have attempted to diversify COI teams by inviting social scientists, and women scientists, into more powerful leadership roles and positions. However, conversations with COI scientists suggest that women with visible power are aware of their gender in ways that men are not.[6] One woman (social scientist) commented, 'there is a gender divide… you still feel a sense of resistance in terms of responses from managers from different teams. With PIs who are male sometimes there is a cultural aspect where females are treated differently, or underestimated. This is not expressed in words, but through their actions. There is a sense that women do not make as much impact and are not respected as much'. Another woman (biophysical scientist) explained 'It is difficult to lead a project, to lead people is challenging… and more so if you are a woman … They [men] may not even give importance to the project because it is a woman who is leading'. This indicates that women experience resistance to their leadership regardless of discipline. Importantly, however, both women cited above are engaged in more 'social' aspects of crop improvement, namely product profiling and cross-cutting themes, suggesting that the resistance they face may be due to the socially oriented research they are leading, and their gender.

5.2. Hidden forms of power

While visible forms of power have been a focus of previous research, less attention has been paid to hidden power within the AR4D sector. This dimension pertains to how powerful actors maintain their power, create barriers to participation, exclude key issues or control agendas behind the scenes.

Although ILCI may be opening up breeding processes by including social scientists and gender experts, control of research and project structures remains in the hands of biophysical scientists. This is evident in project creation processes, with breeders inviting social scientists to participate, creating a sense that biophysical scientists are 'hosts' and social scientists are 'guests'. While social scientists are invited to contribute to trait prioritisation and product profiles, socio-economic data and expertise are only incorporated at certain points. As such, social scientists can only influence or feed into the crop improvement process within certain limits, their input restricted to specific stages or particular areas largely determined by those with biophysical expertise. So, the overall terms of the project are outlined by breeders, who establish the 'rules of the game'.

Forms of hidden power include research practices and modes of working. Within COI teams, several social scientists commented on their role as 'intermediaries' or 'bridges' between breeders and end users (i.e. farmers). To service the sector adequately they are charged with understanding both breeders and farmers. While the onus is on them to do this work, biophysical scientists do not necessarily make similar efforts to understand what social scientists do. It is assumed that social science will fit in to existing processes and structures, rather than redesigning research so there is parity between disciplines.

When speaking about project budgets and timelines respondents revealed that social scientists do not have full control over their work. Budgets are a critical component of proposal writing, constructed during the proposal development phase. Determined largely by COI biophysical scientists, these impact disciplinary budget allocations and working arrangements. One breeder commented 'the project is more of a crop improvement project, so our objectives are more important than other objectives. Even the allocation of funds, we allocate more funds to this major objective of the project compared to other disciplines'. Budgeting carried out by breeders, can reduce the scope of activities and affect the quality of social science work. While budgeting can also constitute a visible form of power, differential funding allocation along disciplinary lines behind the scenes, can also act as a form of hidden power – setting the agenda before social scientists are engaged.

Timelines are another way in which biophysical scientists prioritise certain research processes and objectives. According to the inclusive processes established by the project, trait prioritisation information needs to be collected from target populations. Data is gathered primarily by social scientists who then liaise with breeders. However, gathering such information takes time. As one social scientist explained, 'Dealing with humans is complex. You are collecting profiles and qualitative data on different aspects, and that might take a long time'. However, breeding occurs within specific timeframes, influenced by the seasonal growing cycle and other factors. For breeders to produce results within a three-year project cycle they need to embark on their activities from the outset. Gathering information about traits and developing product profiles can conflict with the demands of breeding cycles. Social scientists from several COI teams reported difficulties in providing breeders with desired information at the start of the project, when it is most useful. One person explained, 'Breeders are frustrated … They think we are delaying their outputs'. Delays have led to tensions around data availability and deliverables, which play into pre-existing disciplinary power dynamics.

Objectives underlying crop improvement also exert power over research processes. For example, breeders' tendency to focus on yield can sideline other criteria that may be sought by men and women farmers. One plant breeder explained, they are mainly concerned with 'the development of varieties that are high yielding … so the breeder is looking at that broad objective, but then within that broad objective there are small, small objectives like nutrition status and gender', suggesting that these 'smaller' objectives are less important. Furthermore, another breeder explained that new approaches incorporating gendered traits (i.e. leaves for fodder) are perceived by some as 'going backwards' in terms of yield, posing a risk that 'developing' countries cannot afford to take. This indicates possible tensions between productivity and social inclusion objectives, with breeders trained in productivist paradigms potentially seeing social inclusion objectives as jeopardising improvements in yield because research led by social scientists may prioritise other traits. Thus,

6 While the role of gender inequality was also mentioned by junior researchers, it did not feature prominently in the interviews perhaps due to the focus on interdisciplinary dynamics.

conflicts may emerge around research conceptualisation and objectives, with different disciplines favouring certain goals, knowledge and outcomes over others. In addition, a focus on producing new varieties as quickly as is feasible, driven by institutional and donor pressures, makes attention to processes of knowledge integration difficult.

5.3. Invisible forms of power

Invisible power refers to the social and political culture which shapes the psychological and ideological boundaries of participation, including internalised beliefs that can result in the marginalisation of certain voices and issues (Gaventa, 2006).

Examining expressions of invisible power revealed a sense of disciplinary inferiority among ILCI social scientists. One researcher said: 'crop improvement screams breeding so if you are a social scientist it's like you are entering a room where you already perceive that you do not belong'. When asked to define interdisciplinary crop breeding, another social scientist said 'interdisciplinarity is when there are social scientists working with *real* scientists', indicating an internalised perception that social scientists are not genuine scientists. This contrasted with a sense of disciplinary confidence in the biophysical sciences. As one biophysical scientist explained, 'early in my career, the plant breeder was the king or queen of the domain, they could do whatever they want, they were all knowing', and mentioned a tendency for biophysical scientists to think they can 'roll over other disciplines'. Such perceptions are not necessarily cultivated within the project space, but originate elsewhere, with one person mentioning having inherited their sense of disciplinary inferiority from their University training. These internalised (and often invisible) attitudes become engrained in scientists during their training, and influence how scientists interact with one another in interdisciplinary settings.

Disciplinary inequities internalised by individual researchers are embedded in (and reinforced by) institutional contexts which valorise so-called objective science. Much of the data about men and women farmers' constraints, preferences and objectives, is qualitative. Such data is often not perceived to be 'scientific' or 'rigorous', further undermining the position of social scientists. In general, as one US-based respondent commented, 'social scientists and economists [in ILCI] face the same kind of challenge, how can we provide value and convince the scientists that what we do is valuable'. This view was reiterated by several respondents who asserted that social scientists have to work hard to demonstrate the usefulness and validity of their contributions. As Douthwaite et al. (2003: 244) comment, AR4D 'largely takes place within an 'invisible college' with positivism as the dominant paradigm, and the biophysical sciences as the dominant discipline'. Due to such internalised scientific norms, social scientists bring less power to interdisciplinary exchanges than biophysical scientists.

Another factor affecting many social scientists in crop breeding teams, is that their academic training does not provide them with experience of working with biophysical scientists – and vice versa. As one social scientist remarked 'this experience is new for me – this is the first time that breeders are asking me to be part of a breeding team'. Developing research approaches at the start of the project cycle is often challenging for social scientists, because, as one respondent commented, in many cases they 'do not always understand the mechanisms of the breeding process'. Whereas breeders have clear research methods and processes, there is a lack of established methods for social scientists' due to their historic lack of involvement in breeding processes. As approaches to collecting socially inclusive data are still being developed, this creates a sense of methodological inferiority, placing social scientists further on the back foot. This may also further reinforce perceptions about the inadequacy of social scientists.

5.4. Closed spaces

Within ILCI, we analysed project processes and structures to identify closed spaces controlled by the most powerful actors. We first considered the project development phase. The initial proposal was formulated by a small group in response to a USAID Notice of Funding Opportunity. During this process, 'big names' and 'established people' were invited by project directors to write certain sections. This was a closed space, described by one respondent as consisting of 'researchers in their fields with a lot of influence'. The majority were men from the global North, affiliated to biophysical disciplines, who had already worked together. People included in this process, and discussions in this space, had considerable influence over the project structure. The group determined how the project was framed, what areas to focus on, assessed COI applications, and many later became 'objective area' leaders.

In analysing these processes, lab structures, and relationships built between scientists around these structures, emerged as another potentially significant 'closed space'. A senior project member explained that another senior scientist on the project 'worked with me [as a postdoc] for a bunch of years, we know each other. We know how we think and we are not afraid to debate things'. This statement reveals a common model in the natural sciences where study and hands-on learning in a laboratory setting led by a disciplinary expert or 'lab leader' is the norm (Latour and Woolgar, 1979). This model is rarely present in the social sciences. After graduating, successful scientists eventually go on to lead their own labs, often in other institutions. Relations between mentors and trainees persist over time, forming local and global scientific networks. These laboratory networks build social capital and propel careers. Lab leaders draw on these networks when developing project proposals, and the researchers they involve often go on to assume prominent positions in project implementation. Pre-existing social relations that develop in such closed spaces can also influence project dynamics and constitute a form of hidden power. For example, in project meetings (which operate as invited spaces) those who already know one another may be more confident to express their views. In addition, these forms of power are often gendered because of the predominance of men in the biophysical sciences.

Interviews indicated that significant internal communication about the project occurred within closed spaces. Members of the management team and project leaders consult with one another, and individual researchers, through one-to-one discussions. Such *ad hoc* and informal communication between individuals can be beneficial as it enables frank exchanges that may not be possible in more open spaces, but it can be another way in which power differentials are manifested. More networked individuals, or those with higher social capital, are more informed than others which can potentially influence how they carry themselves in meeting spaces. Conversations within

closed spaces may inform decision-making processes concerning the wider project.

The project framework created by researchers involved in the proposal development stage, seems to have (however unintentionally) created further closed spaces. The core research themes, or 'objective areas', mirror existing academic structures, formulated along disciplinary lines. A significant number of informants suggested that the 'social' objective areas (priority setting and cross cutting themes) mostly work in isolation from the biophysical science domains (genomics, phenomics, breeding informatics). While there is close interaction between priority setting and cross-cutting themes, and between genomics, phenomics and breeding informatics there is limited interaction across these domains. Even 'cross-cutting themes' – which should feed into all areas – is restricted to its own narrow space with limited staff allocation and budget. As such, the structure of the project into silos is contributing to or reinforcing closed spaces rather than challenging them.

The presence of closed spaces prevents disciplinary integration and reinforces existing power dynamics. Organising the project around key 'objective areas' means that different disciplinary groupings can pursue their agendas unhindered by interactions with those they are less familiar with. One respondent commented, 'everyone tends to go where they are most comfortable', and this seems to be mainly along disciplinary lines. This sense of comfort is not necessarily beneficial for interdisciplinarity however, as the friction of disagreement is often necessary to advance ideas. Working in disciplinary silos may be smoother and more comfortable, but it maintains the status quo, rather than facilitating change.

5.5. Invited spaces

Invited spaces are those that facilitate 'participation' and consultation, usually through invitation from authorities within set boundaries. In ILCI, we identified efforts to create spaces and opportunities to encourage interdisciplinary collaboration and integration between biophysical and social scientists.

The earliest example of an invited space, was the project co-creation phase. In this process 11 proposals were selected from over 90 submissions through a tiered review. These groups were invited to take part in a 'co-creation' process of proposal development with assistance from the steering group that had written the original project proposal. From the 11 shortlisted, four proposals were selected. This was in-line with the 'bottom-up' approach intended by the project. Cornell and other US-based researchers helped applicants develop their proposals and ensured they adhered to project (and donor) objectives. This included guiding the focus of certain proposals, advising applicants to merge to form specific COIs, and suggesting the promotion of individuals to more visible leadership roles. While this was an attempt to facilitate more inclusive and interdisciplinary dynamics, it also exemplifies the power of 'donor-researchers', and may have cemented the authority of the 'core group' – mostly male biophysical scientists, including those representing COI institutions.

Another form of invited space was a steering committee, established to break down silos in the project and facilitate communication between objective areas. The committee consisted of people from each project area, with different objective areas selecting their own representatives. As one person explained, 'the senator for phenomics represents their constituency, they come to the meeting, they take their information back to their constituency'. Despite the democratic impetus, and attempt to re-think project structures and modes of working, some perceived this process to be infused with pre-existing power relations. As one respondent commented, they are 'only inviting this core group again … it's not entirely transparent' [referring to the original steering group involved in writing the proposal]. While the committee was an attempt to break down silos, it failed due to a lack of buy-in from established figures and 'only met once or twice' and 'basically did not go anywhere'. Regardless of whether these perceptions are an accurate account, they reflect a perception of status and knowledge hierarchies, and attitudes towards integration.

To address the internally perceived lack of integration, the ILCI management entity tried to introduce incentives, such as providing financial support through an internal application process, to support interdisciplinary collaboration – another form of invited space. Such interventions recognise the scarcity of mechanisms to promote interdisciplinary work within existing academic structures. Indeed, one project member stated 'you have to be disciplinary before you are transdisciplinary to get tenure'. Performance metrics are another factor, as one respondent commented: 'academics are not known for being interdisciplinary, they are not rewarded for that', their rewards are 'publications, self-advancement and getting more funding for your group'. This extends to other institutional contexts, including NARIs where breeders are assessed primarily on the number of varieties they release. Although peer reviewed publications are important, varieties are still the predominant and most prestigious metric. In general, project level incentives to work across silos – in 'invited spaces' that aim to promote disciplinary integration – are not powerful enough to override established institutional structures and incentives.

Ultimately, researchers are unlikely to participate in invited spaces and invest in new ways of working if it risks falling short of the metrics of success instilled by their particular discipline or institution. Integration has a cost, as one respondent said, 'it takes extra time that people do not necessarily have' to learn what other groups do and determine how it applies to their own work. In addition to the time cost, interdisciplinary research can make people feel a sense of inferiority. One respondent mentioned 'interdisciplinary work is challenging, because you might be faced with research topics you know nothing about and that can be very intimidating'. The lack of incentives, compounded by the challenges of interdisciplinary work, hinders attempts at integration.

5.6. Claimed spaces

Claimed spaces are more organic than closed and invited spaces, usually created by less powerful people or groups to shape their own agendas. We are aware of only a few examples of such spaces within the project so far.[7]

7 These spaces are often highly personal and localised, and difficult for detached observers to access.

COI research teams are one instance of a claimed space. Researchers in national institutions described ILCI as a 'bottom-up' initiative where COIs have autonomy to decide what they work on and how, with support from Cornell, which some saw as different to the usual project approach where donors or funding bodies control the agenda. One researcher commented 'they [Cornell] do not have the imperialist point of view I have experienced in other projects. It has been very freeing. I can make mistakes and ask for help'. Another respondent echoed this saying 'it is very different to other projects. Some projects come when everything is already drawn. You cannot change. You just have to implement'. So, although the project is 'led by US universities', and framed by donor agendas, COI institutions have a sense of 'power within' – that they know best the challenges and priorities that concern their *national* contexts. As one researcher commented, 'it's not them telling us what they want us to do … we know our problems, we know our challenges… we can provide the solutions, we just need the support'.

The Innovation Lab model, as it functions within ILCI, seems to play an important role in facilitating communication within and between countries, teams and disciplines. For example, a COI social scientist commented, in reference to the presence of US Universities, 'the involvement of many stakeholders has helped to calm them [the breeders] down. If it was just us it would be too tense'. External input therefore seems to enable scientists from different disciplines, institutional and country contexts to work together. Nevertheless, such statements may be influenced by 'donor-researchers' and 'recipient-researchers' relations, with those receiving support possibly presenting positive accounts due to funding needs.

Organic research collaborations are another potential example of a claimed space. These spaces have emerged largely from individual efforts to cut across project silos, driven partly by a sense of frustration at the lack of integration. As one researcher commented, interdisciplinary research is 'about developing new methods and new tools that cross the disciplines … methods should be melded together'. Efforts to develop integrated approaches tend to be initiated by more junior project members (often women with less visible power) via informal connections. In creating these collaborations, one respondent described looking for someone 'on the same level as me that I can talk to, who is responsive and who is willing to give time'. Such collaborations are an example of 'power with', where individuals organise and act as a group to address common concerns.

An additional claimed space are objective area office hours that enable researchers across COIs and OAs to meet. These are organised by OA leads – usually US-based researchers – to liaise with representatives from COI research teams. Women social scientists participating in priority setting and cross-cutting themes office hours perceived this as a friendly environment where they felt supported and at ease. As one respondent commented, 'the priority setting team tends to be mostly social scientists and we understand each other easily … there is a common language and you feel comfortable'. Such spaces also provide a refuge for social scientists who may be isolated or unsupported within their own institutional or project spaces. As women have not acquired status and influence comparable to their male counterparts, they create their own networks to counter the power of the 'core groups' that dominate the sector. These spaces can be a coping strategy and form of resistance for marginalised researchers.

5.7. Local levels of power

Local levels of power consist of sub-national institutions and associations, including implementing organisations, programmes, and service delivery. With ILCI, we considered implementing structures like field stations and research teams as the local level. Actors include junior researchers, field technicians, support services, administrative staff and those carrying out 'day-to-day' project work. Although they overlap, 'local' dynamics and practices differ from managerial and decision-making processes at the 'national' level, and interdisciplinary power dynamics play out at the local level in specific ways. Within ILCI, certain teams appear to work smoothly, whereas others face challenges due to gendered and disciplinary dynamics, leadership styles and personalities, the nuances of which are difficult to unpack from a distance.

The 'field' emerged as a critical 'space' in terms of power dynamics at the local level, with tensions manifesting around fieldwork, demonstrating how levels and spaces of power overlap and interact. For breeders, 'the field' can refer to research plots or experimental field sites. For social scientists, it can refer to villages or farming communities. COI researchers referred to differential claims over fieldwork, with one social scientist mentioning that breeders in their team asked why they were going to the field, saying 'this is not your business'. Another also referred to breeder's ownership claims over this space, who apparently feel that social scientists are 'going to see their target people who they work with to develop varieties. They [the breeders] ask us what we are doing, why are you going to the field to ask questions?' These comments indicate struggles for control, limited understanding of different disciplinary approaches to fieldwork, and a lack of integration.

Limited knowledge of what scientists from other disciplinary backgrounds do is an important factor influencing relations between researchers at the local level. A COI biophysical scientist commented, 'there's so much work involved in what we do, whereas social scientists can just come up with a survey in three months and they have their results'. Similarly, a COI social scientist said, 'It is very easy for biological sciences … but it is more challenging for social scientists. [We] have to understand farmers and laboratory researchers and what they do'. Another social scientist remarked, 'the practice of science is different than the ideal of science, but you can only understand practice if you go with the people when they are practicing'. They further explained, 'once in a while colleagues who are agronomists follow me during my fieldwork to see what I do. This is always a good experience and we all learn from each other. I wish it could happen more often' – indicating opportunities for change.

The 'field' is also a space where tensions around gender come to the fore. Women can find fieldwork and travel to meetings at short notice challenging, due to childcare and domestic responsibilities. This is not always considered by men on research teams. One COI researcher explained, 'they do not understand that you cannot just up and go because of your children. It frustrates the men who want to do tasks and meet certain deadlines'. The same respondent said 'in my country it is quite common to hear people say ladies should not be part of this [research] because if the husband is sick … [or] if the child is sick she has to take time off'. Such reports indicate that the practice of science is structured to suit a male model. One woman from a COI team mentioned their refusal to go to the field or meetings at short notice, which can be seen as foot dragging or non-compliance

with dominant norms (*cf.* Scott, 1985). This is also a form of hidden power, and 'power to' – the potential of every person to shape their lifeworld through their actions. However, that women at the local level are resorting to such tactics suggests a lack of appropriate sensitisation for men and women field workers, and a gap in institutional or structural support from the national level.

5.8. National levels of power

The national level includes forms of authority linked to nation-states, including institutions, policies, initiatives. ILCI is led by Cornell University, both a land-grant university and a privately endowed research university and prominent national institution, in collaboration with a number of other US-based universities.[8] Actors at this level are responsible for the strategic decision-making that guides the project and include the ILCI management team, PIs, lab-leaders, and external consultants. While these actors may represent the 'national' level, they are not equally powerful, at least in terms of visible power.

The Feed the Future Innovation Lab model, is based on an implicit assumption of the superiority of US-based knowledge and expertise, reflected in language such as 'top US universities' (Feed the Future, 2022), which is internalised by 'donor recipients'. As one COI researcher said, 'we have a kind of hierarchy. They, the Cornell team, forms the first layer because they are like our superiors, like the experts'. Another commented 'they [Cornell] have a big role to play because they are the ones giving us the funding'. Such hierarchies, based on 'national' reputation, and 'global reach', imbue US institutions with visible *and* hidden forms of power, demonstrating the inter-relatedness of national and global levels of power. As well as creating knowledge hierarchies, such assumptions potentially mean that capacities within national institutions are not considered. For example, one researcher mentioned that COI expertise in participatory research was overlooked – despite a long history of work in this area – due to an assumption that recipient countries lack capacity and require assistance with key research skills and approaches: 'They [Cornell] made assumptions about what their role was, and what our capacities were'. Issues of seniority also came into play, 'I've done this for twenty years… this person three years out of graduate school is telling me that I'm doing it wrong'. Further evidence of these dynamics is demonstrated by US-based researchers describing COI teams as more 'advanced' or more 'nascent' than others, assessments largely based on access to technology, research infrastructure and resources. Although such observations may be accurate on a material level, they may overlook other capacities, implicitly placing COIs on a trajectory from 'least advanced' to 'most advanced'. This points to hierarchical notions underpinning research, and power imbalances between 'donor-researchers' and 'recipient-researchers' and global North and global South (Nshobole, 2021), which permeate the process at every level.

Hierarchies also occur between national institutions. COI research groups comprise a range of national institutions, including NARIs and national universities, varying from country to country, whose interactions are also influenced by power relations. One respondent said there can be 'intellectual hierarchies' between national universities, 'for example when a "mother" university is involved' (meaning a university that provides training to other institutions). Another mentioned that national university scientists often think they are better or more advanced than NARI scientists. They commented that NARI scientists are often 'looked on as technicians', and due to differences in resource endowments 'tend to feel inferior'. All researchers indicated that such perceptions affect the performance of teams. In certain country contexts, these institutional hierarchies are partly a legacy of colonial rule. During the colonial and pre-independence period in Africa, agricultural research institutes, specialising in agricultural science and technology, were separated from universities, focusing on social sciences and humanities. This resulted in a separation between research and education, and a sense that agriculture and technical training was inferior to academic, liberal arts training (Lynam and Mukhwana, 2021). This indicates the importance of understanding the historical origins of relations between actors in the AR4D sector, particularly the colonial foundations of current arrangements (Mdee et al., 2021).

Institutional histories at the national level continue to inform disciplinary relations in the present. Our conversations indicate that many NARIs do not have in-house social science expertise, meaning they need to look to other institutions to provide these skills, or appoint biophysical scientists to do socially oriented research. This can be seen within the ILCI project where biophysical researchers, often women, are allocated to 'cross-cutting themes' work. Such dynamics are supported by observations from wider literature which suggests that in African contexts, often NARI researchers are appointed to 'social science' positions without formal training, which is attributed to difficulties in finding and contracting social scientists with adequate training (Roseboom et al., 2005: 9). It has been suggested that social scientists in global South contexts are often not drawn to agricultural research, for many reasons, including divides between 'pure' and 'applied' work, the perceived lower status of technical and applied work, and the lack of rewards and career progression within agricultural research institutes (Roseboom et al., 2005; Verma et al., 2010). Due to the scarcity of agricultural social scientists those working in the sector are thinly spread across projects, with implications for their work.

5.9. Global levels of power

Global levels of power relate to formal and informal sites of decision-making beyond the nation state, including international institutions, and donors. ILCI is funded by the USAID Feed the Future (FTF) initiative, and 'national' agendas to 'advance US national security and economic prosperity', and 'reduce *global* hunger, poverty and undernutrition'.

International ideas about research and development influence national strategies through donor-funded interventions. From inception, approaches prioritised by USAID influenced the way the ILCI research process was conceptualised and designed. The US Government Global Food Security Research Strategy (2022–2026), published by Feed the Future, prioritises partnerships and innovation, as well as diversity, equity and inclusion. It also emphasises 'convergence research' which entails 'integrating knowledge, methods

8 Clemson University, Colorado State University, Kansas State University, University of Missouri.

and expertise from different disciplines and forming novel frameworks' to 'solve complex and specific societal challenges' (Feed the Future, 2022: 9). Once developed, such concepts, policies and frameworks take on a life of their own and influence modes of thinking and scientific practices. The promotion of ideas and research framings, which are shaped by a 'global epistemic community' (Harris, 2019: 121), demonstrate the 'global' power wielded by donors and funding agencies.

Awareness of donor power is reflected in comments from COI members who perceive certain crop improvement objectives as 'donor' agendas. One COI researcher explained in relation to new crop improvement approaches, 'speaking from the African perspective, donors stress having a wider scope of thinking. You have to consider the end user, you are not just doing it for yourself but for others … you need other disciplines, breeders cannot do it alone'. Another researcher said 'gender is an aspect that I have to admit we have not explored a lot, but it is on our menu of things that we are supposed to do'. These comments suggest a perception that certain agendas, such as interdisciplinarity and 'gender inclusion' are driven by donors. As Polar et al. (2022) note, experiences to date indicate that including gender in breeding design can be a slow process that gains importance only due to donor demands. However, if approaches are not jointly conceptualised and understood there is a danger they will be seen as impositions and researchers may refuse to 'buy in' to the overall agenda. There may also be a sense that interdisciplinarity and inclusivity are just the latest trends, resulting in performative attempts to meet donor requirements rather than meaningful engagement.

Despite the visible emphasis on inclusion and disciplinary integration there is evidence of a degree of 'double speak' by donors. Some ILCI researchers have the impression that the main thrust of the interdisciplinary research has been on 'new technology that cuts across plant science disciplines', with one person stating 'If you look where the money is going, I would say that is the case'. This implicit focus may privilege certain disciplinary agendas and methods and preclude others. Several respondents intimated *ad-hoc* communication with donors through one-to-one conversations or meetings during which certain priorities and expectations are conveyed. Project leaders mentioned that they were 'conscious of what USAID were looking for' during the proposal writing phase and as such the project 'addressed issues around tools' and set boundaries around how far the project was going in terms of what it could feasibly address. Another mentioned, that USAID 'wanted Cornell in the program because they wanted razzle dazzle technology' and that 'the project probably got funded based on USAID perceptions of how good the team would be'. So, although there is an emphasis from FTF on inclusion (which places an emphasis on social science input), there also seems to be a perception of an implicit steer towards tools and technical 'solutions' which is communicated to project leaders in closed spaces. The implicit steering and tacit signals of donor agencies constitute another form of hidden power.

6. Discussion

Drawing on Gaventa's Powercube framing, this research examined how power dynamics shape interdisciplinarity and social science inclusion in ILCI crop improvement teams. Our results have shown how global epistemic communities (i.e. donors) influence research agendas at the national level, even when these efforts are intended to be 'bottom-up'. In turn, hidden forms of power, such as institutional reputations and resource endowments, influence national hierarchies. Researchers working within national institutions at the local level experience invisible forms of power influenced by disciplinary and gender norms. These intersecting expressions of power have implications for research team members, with some 'core groups' having more authority and visible power than others. Our analysis also reveals how different groups and individuals express their power through different strategies and using different means. Feminist power theory has enabled us to identify forms of power where researchers are building alliances across local and national levels through claimed spaces. Many social scientists, especially women, are practicing power 'with' their peers to claim power. Power 'through' can also be seen where social scientists are invited into more powerful roles and positions through interaction with supportive leadership or 'allies' who use their social and structural power to support them (Hattery et al., 2022).

Theoretically informed power analysis can help researchers better understand the ways in which power acts to reinforce dominant paradigms, and to identify actors, entry points and positive forms of power that can be mobilised in favour of desired changes (Acosta and Petit, 2013). In the ILCI context, power is not only held by individual scientists but is produced through interactions between, actors, discourses, institutions, knowledge, practices, in a range of spaces and across multiple levels. Certain individuals may exert greater power than others, but this is gained and exercised through social relations, institutions and resources. In this case, playing the host enables biophysical scientists to 'maintain a [hidden] structure of rights' (Gherardi, 1996: 192), and as guests, social scientists are assigned a position but cannot achieve ownership. 'Successful assertions of power are therefore embedded within wider networks of power that contribute to their success' (Ahlborg and Nightingale, 2018: 388). From this perspective, because power is produced through relations, which themselves are dynamic, there is potential for change – if the right leverage points can be identified.

Explicitly analysing researchers' actions and drivers, and the structures they operate within produces a more accurate picture of how research happens (Crane, 2014). It also avoids essentialising science as a monolith and instead construes it as 'a dynamic and heterogeneous cultural institution of which we are a part and can thus change' (Crane, 2014: 52). Although existing power dynamics may seem entrenched, power analysis can identify areas that have the potential to 'trouble' or 'unsettle' dominant paradigms, and open up new spaces (Ahlborg and Nightingale, 2018: 388). In the ILCI example, this includes proposals, meeting formats, team members, budgets and timelines – all of which play a powerful and often unacknowledged role in configuring disciplinary power relations and interdisciplinary research assemblages, and offer potential avenues for intervention.

Importantly, as Crane (2014: 49) stresses, 'analysis of scientific practice is not meant as a critique of "science," nor … individual scientists', rather it offers insight into barriers to more effective technology production. Here we must emphasise that the prevailing power dynamics with AR4D 'do not come about because [biophysical] scientists are especially power hungry' (Callard and Fitzgerald, 2015: 97). Indeed, inequitable relations are 'rarely, if ever, explicitly endorsed by life scientists' (Callard and Fitzgerald, 2015: 97). Nevertheless, the world views held by biophysical scientists make it difficult for them to

recognise the subjective nature of dominant discourses favouring technical approaches and solutions (Verma et al., 2010). Therefore, they may struggle to see that institutional environments and working practices are skewed towards biophysical understandings and practices, and do not facilitate equitable disciplinary exchange (Verma et al., 2010). In addition, rarely do people want to cede power or authority once they have obtained it. Considering this, social scientists may need to work to overcome the 'inferiority complex' that affects social science globally (Brinkmann et al., 2014: 31) in order to assert the value of their contributions and better negotiate positions of influence.

Our analysis of ILCI, and personal experiences, indicate that one way of addressing these dynamics, is the cultivation of allies, thus working with those who exercise visible power (i.e. biophysical scientists) who understand the need to open up and redesign AR4D. As Chambers (2006) argues, working with the more powerful may deliver 'win-win' outcomes. However, building alliances and coalitions requires a recognition that 'such alliances are often themselves filled with power divisions and conflicts' and may require identifying intermediaries who can facilitate and cultivate positive forms of power (Gaventa, 2021: 17). To do this effectively, there needs to be more in-depth understanding of how those exercising power perceive current dynamics, i.e. seeing things from the biophysical point of view, or in anthropological terms, adopting the perspective of the 'other'. This indicates, among other things, the need for further ethnographic work. Conducting such research could help to build understandings and alliances that could shape future collaborative endeavours.

Although working with more powerful members of research hierarchies may be a necessary strategy for change (Chambers, 2006), this does not preclude working with the least powerful to formulate 'bottom-up' empowerment strategies. Just as AR4D social inclusion agendas recognise that certain stakeholder groups may need to be treated differently to overcome barriers – the same may apply to interdisciplinary research teams. The concept of equity acknowledges that not everyone starts from the same place. 'In the context of research teams, equity requires that we elevate specific people to hold as much space as others by providing more responsive support, or even simply more support' (Hattery et al., 2022: 5). Within ILCI, this might mean designing processes and spaces to overcome structural barriers that impede marginalised scientists from shaping research agendas. It also requires acknowledging the 'deep-seated perceptions and experiences of domination and dependency' (Cundill et al., 2018: 4) that exist within multi-country consortia, particularly between 'donor-researchers' and 'recipient-researchers' (Nshobole, 2021), which affect attempts at collaboration and knowledge integration.

In addition, the creation of shared frameworks and objectives is essential. Although research design frameworks will not nullify power inequities, more explicit guidance on interdisciplinary approaches is necessary. As Lyall et al. (2011: 1) point out, 'the sustained development of strategies to help researchers *how* to collaborate effectively and integrate soundly across different domains remains a key research gap'. Such strategies and frameworks require explicit recognition of interactions between different power dimensions in order to build strategies that work across all forms, spaces and levels of the Powercube (Gaventa, 2021). For ILCI this may mean opening up closed spaces such as proposal writing processes, supporting and incentivising claimed spaces that make disciplinary integration happen, whilst acknowledging and interrogating hidden and invisible forms of power such as budgetary processes and scientific norms that valorise certain forms of science over others. Such efforts need to be carried out across all levels to challenge hierarchies.

Furthermore, it is important to revisit the objectives underlying crop improvement to generate a shared understanding of research agendas and priorities. Key assumptions such as the historic emphasis on yield and the current emphasis on social inclusion – and the rationales underlying these – should be interrogated collectively. Such processes may not be smooth, and may entail difficult conversations, but friction is an important part of advancing ideas and developing new frameworks and ways of working. 'Transitioning away from agriculture that is preoccupied with yields and governed by the notion of competitive markets, towards one that aims towards sustainable [and equitable] food security requires different frames, (Acevedo et al., 2021: 122), and these must be developed across disciplinary, gendered and global divides. The friction of engagement is therefore necessary if crop improvement is to become more responsive to the complex social and ecological challenges that face us.

7. Conclusion

Analysing power dynamics within interdisciplinary crop improvement collaborations indicates that successive efforts to make agricultural research more disciplinary and socially inclusive have been thwarted, in part, by entrenched power structures. Visible, hidden and invisible forms of power, operating between spaces and across levels, reinforce positivist scientific paradigms and prevent efforts to open up knowledge production processes. Many of these paradigms are rooted in Western scientific models which have been transposed and imposed, becoming dominant globally. They work in implicit and explicit ways to prevent integration of social science perspectives which threaten established ways of working.

Lessons about the complexities of interdisciplinary power dynamics derived from ILCI researcher experiences highlight possibilities for transformative opportunities – but this is just the first step in what must be an iterative process of change. Insights from this project should inform subsequent phases of research – both for ILCI and wider initiatives. This further indicates the importance of critical reflexive processes and research documentation. Nevertheless, while this study offers a starting point, rather than being conducted from a largely 'outsider observer' perspective, future studies should include a range of 'insiders' from different social positions who can a provide more situated insights. Such processes of reflection should be built into project design and project implementation.

To do AR4D differently, current structures and attendant power dynamics, need to be questioned, challenged and changed. Solutions are not simple or straight-forward. Nevertheless, if such dynamics are not addressed, social sciences will likely continue to play an auxiliary role (Verma et al., 2010). As a result, social inclusion agendas, which strive to address power and politics in order to enhance the voices of the marginalised, will struggle to achieve their goals.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Arizona Ethics Committee, Tucson, Arizona, United States. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because verbal informed consent was obtained from research participants for their anonymised information to be published in this article.

Author contributions

BC, KS, DR and HT contributed to the conception and design of the study. BC and KS conducted data gathering and analysis. BC wrote the first draft of the manuscript. KS, DR and HT wrote and edited sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

BC and KS are independent consultants. DR is an owner of Cultural Practice, LLC. They have no direct or indirect conflict of interest with Cornell University, Frontiers, or the organisations involved in or funded by this study.

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