Applying the principles of data feminism in agricultural research leads to more innovative outcomes

# Abstract

Agricultural systems are a function of complex institutional structures that have historically had, and continue to have, power imbalances embedded within them. The seven principles of data feminism were developed to aid data scientists in identifying, examining, and addressing power inequities related to data generation, interpretation, and distribution. We believe these principles provide an accessible but under-utilized framework for helping agricultural researchers understand and actively work towards mitigating power inequities prevalent in our discipline. Here we interpret the tenets of data feminism in the context of agricultural research within three overarching discourses: power, reciprocity, and framing. Many researchers already apply these principles in their work, but we hope that providing this explicit framework in an agricultural context will make the work more intentional, visible, and ubiquitous. We present evidence that working within these three frameworks concomitantly fosters creativity and leads to more transformative outcomes for agriculture and sustainability as a whole.

# Introduction

In a broad sense, the intersection of data and power has become a focal point of global discourse and concern (CITE). Potential power imbalances exist along the entire data lifecycle, from data provenance to utilization, and include a suite of complex interactions that require novel ethical, technical, and regulatory considerations (CITE). This has catalyzed the creation of new academic fields dedicated to understanding and addressing these complex dynamics. Fields such as data ethics (CITE), algorithmic accountability (CITE), and critical data studies (CITE) interrogate the ethics and power structures embedded within algorithms. Data justice (CITE) and techno-politics (CITE) explore how data and power intersect within socio-political contexts. These themes have not been isolated to academic realms; numerous books, films, series, and art pieces grapple with tensions between power distribution in data-driven societies. Many of these concerns arise from the understanding that without intentional examination of these issues, existing power differentials will likely be exacerbated, and/or new ones created (CITE). In a time when human ingenuity is arguably most needed (CITE), eliminating barriers to the full expression of all human’s potential is advantageous to society as a whole (CITE). However, this requires reflexivity from actors not normally accustomed to such activities.

Researchers and scientists in technical fields work with data at many levels, but have traditionally operated under the assumption of value-neutrality, relegating ethical considerations to separate domains while technical advancement is pursued independently from such considerations. Though social science has long acknowledged the use of research as a means of maintaining the status quo (see the work of Bullard 1993, Du Bois 2007 [1903], or Sachs 2007, among others), non-social science researchers are increasingly realizing the potentially profound ethical and social implications of their work as it relates to data and power (CITE). As such, researchers must become adept at recognizing their role in either reinforcing or challenging existing power differentials, and engaging available frameworks, theories, and tools to address power differentials, if their work is to contribute to the public good. The need to foster such awareness and action has been widely discussed within domains such as technology, health care, and criminal justice (CITE). We argue that despite being particularly salient themes within the agricultural sector, less awareness has been built within the technical agricultural research community concerning the intersection of agricultural research, data, and power. To our knowledge, discussions of ethical issues in technical agricultural publications appear primarily in the context of ‘big data.’ Highly cited papers on this subject mention data privacy issues, and some mention ethical or power-related implications, but to our knowledge little guidance has been given regarding *how* to consider such implications (e.g., XXXX). There is an implicit assumption that those considerations remain outside the scope of technical agricultural research.

This gap has been acknowledged within the larger food studies community, and methods for addressing concerns about power distribution and fairness are becoming codified within the field of agroecology (MacInnis et al. 2022, Wezel et al. 2009;). The Agroecology Research-Action Collective has published an excellent resource with Principles and Protocols for scholar-activists, but they are framed primarily in the context of social science (Wit et al. 2021). Agricultural researchers may not self-identify as public scientists, scholar-activists, or agroecologists, and scientists working in the physical science realms may have unique needs with regards to guidance on these topics (Longino 1988). Recognizing this, we first review the frameworks foundational to data feminism, specifically power, feminism, and intersectionality, before defining data feminism itself.

**Literature review/call this section something like Data Feminism’s Engagement of Power, Feminism, and Intersectionality**

The work of two critical theorists—Max Weber and Michel Foucault—shapes the conceptualization of power in social theory today. Weber (1968) defined power as a relationship through which one is able to obtain one’s will even in the face of resistance by others. Importantly, he theorized how specific groups of people whose authority in a situation or on an issue gives them status may use their status to gain social approval for behavior through domination, which may happen through explicit (such as physical control) or implicit (such as the normalization of certain behaviors) means. Implicit dominance requires obedience. In the case of agricultural science, an example of implicit control includes how the prioritization of commodity crop production for export has come to define US agriculture through the ongoing influence of agribusiness in shaping federal policy. Foucault’s (1977) more nuanced definition of power as a means of control explains how power works within institutions to maintain the status quo. Foucault (1977) argued that power encourages and normalizes conformity. This is easy to see in agricultural policy and practice today, in everything from the corporate capture of a public agency, such as the USDA, by agribusiness to the hesitancy of farmers to try something new in their fields. Importantly, both define power as relational, not a one time event but something that is created and maintained over time. Further, power is not only a means for identifying the establishment and continued dominance of a demographic group, such as white male farmers in US agriculture, but also the dominance of specific ideologies and beliefs, such as employing the “feed the world” mantra of Christian settler colonialism to justify extractive agricultural practices and land theft.

Patricia Hill Collins’ (1990) conceptualization of the matrix of domination defines four dimensions of power; D’Ignazio and Klein (2020) engage these in their definition of data feminism to make visible the may implicit ways that power works throughout the research process to maintain the status quo and limit innovation. Collins (1990) identifies these dimensions as the 1) structural domain, 2) disciplinary domain, 3) hegemonic domain, and 4) interpersonal domain. The interpersonal domain might be the easiest for most to see. This fourth domain includes the discrimination and danger that some researchers may experience in the field (Demery and Pipkin 2021) and has recently gained more attention in the US, as the National Science Foundation requires planning for safe and inclusive off-site field research. However, the first three domains include laws and policies (structural domain), implementation and enforcement of laws and policies (disciplinary domain), and the cultural acceptance and circulation of oppressive ideas (hegemonic domain) that may not usually be included in many scientists’ development of their research.

Feminism is both a philosophy and a practice that names and challenges sexism and other forms of oppression (e.g., homophobia, transphobia, xenophobia, ableism, racism) while working toward a more just future for all (D’Ignazio and Klein 2020; hooks 2000). Per this definition, feminist research and scholarship can be applied to research design, analysis, and sharing of research on many fronts, not only in the study of gender, but also in the study of inequalities readily present in the US and global agricultural systems such as land and market access, prioritization of commodity crop production for export over production of food crops to address local food insecurity, agricultural labor, or conservation adoption. In engaging feminism in their research life cycle, researchers acknowledge that the status quo was not destined but rather made, and that research is not neutral, just as it was made, can be unmade, revised, or restructured to serve more people better.

Intersectionality’s intellectual traditions began in the work of Black feminist activists in Boston who, in 1977, created The Combahee River Collective Statement, stating that dimensions of power, including race, class, gender, religion, geography, age, sexuality, ability, and on, cannot be examined in isolation; instead, analysis and practice must be based in the understanding that such inequalities are interconnected and interlocking. Legal scholar Kimberlé Crenshaw then developed the theoretical framework of intersectionality to examine how these dimensions of power work to maintain status quo both within and among groups (Crenshaw 1991).

Agricultural scientists may struggle to see the connections between a statement created by a coalition of Black feminist activists and the science practiced through their research and teaching; however, these concepts are not new in agricultural research. Early rural sociologist W.E.B. Du Bois (2007[1903]) was among the scientists in the US to employ empirical sociological methods rural people in his research studying agrarian production and rural life in the South’s Black Belt. In addition to the Souls of Black Folk (2007 [1903]), Jakubek and Wood (2018) point to his series of case studies funded and conducted for the US Department of Labor as foundational examples of early empirical research studying agricultural production and agrarian communities, including questions of rural demographic shifts and farm size changes due to agrarian economic restructuring, landownership, seasonal agricultural labor. Importantly, Du Bois put this research into the practice through applied sociological work that focused on policy and social reform (Green and Wortham 2018). More recently, rural sociologists William Freudenberg (2006) and Carolyn Sachs (2007) urged those engaging in rural research collaborations to step beyond the role of researcher as “expert” and to interrogate issues of power, reciprocity, and trust.”

If agricultural science aims to contribute to the greater public good, not merely to the creation of increased profits for transnational corporations, then equity must be a key component of its development and practice. Data feminism can assist in this effort by incorporating power as a multi-dimensional influence within our research process—including funding, protocol design, data collection and analysis, and data reporting—rather than merely a one-dimensional variable to be tested in comparison to others. In the US-context, this looks like treating racism as an outcome of the continued production of white supremacy rather than merely a demographic variable; reducing complex systems of power to historical outcomes rather than an ongoing project, such as the production of white supremacy in the US, limits opportunities for intervention and change (Harvey 2017).

Attention to power dimensions throughout the research cycle may be newer to biophysical science, but social science, too, has work to do to better attend to how power shapes research development, collection, analysis, and diffusion. Sociologists, and even rural sociologists, continue to treat race, class, gender, sexuality, citizenship status as variables or even as defaults rather than (see discussion of this in Carter and Roesch-McNally 2024; Carrillo et al. 2021; Horst and Marion 2019; Thompson and Carter 2022).

This is a mess of something that could be a paragraph about how the more implicit modes of power id’d by collins (domains 1-3) are already documented as limiting agricultural science and practice – do with this whatever is helpful!

* Data remains a limitiation to the work toward a more just, equitable, and healthy agricultural system (Horst and Marion 2019
* Limitations identified by Horst and Marion (2019) include the inability of comparing contemporary agricultural landownership paters to historic data, as only three surveys prior to 2014 including non-operating agricultural landowners, the USDA changing the definition of “farm” over time which may have falsely overcounted farmers of color, Hispanic farmers, and women farmers and the USDA’s counting of all farmers within a reservation as a single farm, and the lack of data about farmworkers. The correction of some of these inaccuracies and attempts to improve methodology to increase response rate among underrespresented and marginalized farmers may have resulted in “false trends,” in which it seems these farmers numbers have increased when really improved methodologies (Gilbert et al. 2002, Horst and Marion 2019
* Numerous inconsistancies in data sampling and collection, including not collecting data on race or gender (Horst and Marion 2019, Pilgeram and Dentzman et al …
* Using data available through USDA-sponsored surveys, such as the 2012 Census of Agriculture and the 2013–2014 National Agricultural Worker Survey, Horst and Marion (2019) document how this structural and institutional discrimination continues to shape US agriculture today in their analysis of farmer and farmland ownership demographics.
* The lack of data about underrepresented or underserved farmers is often treated as an excuse to perpetuate their exclusion; recommendations from Horst and Marion’s (2019) analysis of demographics in US farming and farmland ownership include more public demographic data about farmers, farm laborers, and farmland ownership and more intersectional study of this data. They call upon the USDA and other governmental and public agencies to lead this effort (and add in what the Pilgeram/Dentzman/Lewin et al papers recommend)
* more data is needed about race, ethnicity, and gender-based disparaities using an intersectional lens

Data feminism is “a way of thinking about data, both their uses and their limits, that is informed by direct experience, by a commitment to action, and by intersectional feminist thought” (D’Ignazio and Klein 2020:8). The authors argue that the starting point for data feminism an acknowledgement that power is unequally distributed in the world, including in research (D’Ignazio and Klein 2020:8). In agriculture, this looks like Global North scientists – who, in agronomy, are still disproportionately white, straight, able-bodied cisgender men, setting the agenda…justifies Green revolution…

To engage in data feminism does not require one change the world, or even their own institution. Rather, to engage in data feminism looks like incorporating attention to power relations in the design and implementation of research and committing to using data to challenge and inform change in the distribution of power in support of “*co-liberation*: the idea that oppressive systems of power harm all of us, that they undermine the quality and validity of our work, and that they hidner us from creating true and lasting social impact with data science” (D’Ignazio and Klein 2020: 9) Echoing bell hooks well-known feminist primer “feminism is for everybody,” D’Ignazio and Klein argue that data feminism isn’t only about or for any one gender; it is for everybody. Even as numerous studies identify how women are underserved in agronomy, so too are men whose identities may not align with dominant norms of masculinity, who may not be cisgender, or straight, or able-bodied, or white, or who may farm differently….

The need for tools that foster awareness about the interactions between power and data science inspires the tenets of data feminism (D’Ignazio and Klein 2020). Data feminism principles provide guidance on how to approach data science with an explicit acknowledgement of the power imbalances the work is embedded within, and therefore foment reflection on the ethical implications of the work. The principles are designed to be domain-agnostic, and D’Ignazio and Klein’s (2020) work has been highly cited by a range of disciplinary contexts. However, to our knowledge, it has had limited interpretation in the context of agriculture. A recent study evaluated the National Agricultural Statistics Service (NASS) agency of the United States Department of Agriculture (USDA) on their data reporting practices through the lens of data feminism, demonstrating the utility of applying the principles in new contexts (Rissing et al. 2023).

We paraphrase D’Ignazio and Klein’s (2020) seven principles of data feminism. The first—examine power—asks researchers to analyze how power exists in the larger contexts of their research. The second—challenge power—commits research to challenging unequal power structures and working toward justice. The third—elevate emotion and embodiment—teaches the importance of multiple forms of knowledge, including knowledge that comes from lived experience. The fourth – rethink binaries and hierarchies – challenges researchers to work beyond the gender and other binaries that result in reductive modes of counting and classification. The fifth – embrace pluralism – insists the importance of synthesizing multiple perspectives and prioritizing local, Indigenous, and experiential ways of knowing. The sixth – consider context – assumes that data are not neutral or objective but instead are the products of our social relations, and all the inequalities therein, and so context is important for accurate as well as ethical analysis. The seventh – make labor visible – acknowledges that research “is the work of many hands” and asserts this must be both valued and recognized.

The goal of this paper is not to simply reiterate the principles laid out by D’Ignazio and Klein (2020). Nor do we intend to suggest one set of guiding principles is superior to another. Rather, as agricultural scientists, we found the principles helpful in guiding our own work, and we aim to offer a more bespoke interpretation to aid other agricultural scientists. As such, we present three overarching themes of power, reciprocity, and framing. Under each theme we provide an overview of its connections and relevance to agriculture, as well as tangible examples and evidence that their consideration leads to more impactful and transformative research outcomes. This is not meant to be a comprehensive review of power issues in agriculture, nor a thorough documentation of efforts to address those issues. Rather, our hope is that this effort supports technically trained agricultural scientists in connecting their work to its broader societal implications and in sculpting that work to contribute to a more equitable society. Our perspectives and examples are strongly framed by our collective experiences in the agricultural systems of the United States (US), and specifically of those in the maize-producing areas of the Midwest. However, while the specifics of a given system will vary, the topics discussed are universal and we present these themes with the goal of being generalizable.

# Theme 1: Examining and challenging power disparities

Agriculture has a unique relationship to power inequities compared to other domains. At its most fundamental level it involves the cultivation of land to produce food, which is an essential resource for human survival. Therefore, its very existence invokes potential for abuses of power: those who control access to land hold significant power over others’ access to food. Indeed, there is a large body of scholarly work suggesting the advent of agriculture played a pivotal role in the formation of social classes, and in shaping the dynamics of inequities and hierarchies in human societies (Isett and miller, diamond, against the grain, child, marx). Slavery has been intertwined with agriculture for thousands of years, with several civilizations relying heavily on enslaved labor to cultivate crops.

Moreover, many mid-century colonialism efforts were agriculturally motivated, marking the emergence of oppressive practices and policies such as land seizures for agricultural production, plantation economies, land tenure systems, and self-serving infrastructure investments (CITE). Plantation economies motivated some of the largest slave trades in history, and were notorious for their brutal practices and conditions. While most countries have enacted formal abolitions of slavery, human trafficking still occurs and many of the plantation practices (e.g., coercion, debt-bondage) are mirrored in modern forms of exploitation of agricultural migrant workers (CITE). In the US, agricultural educational institutions (land-grant universities; CITE) were established using state-sponsored systems of Native dispossession (Nash 2019, CITE A NATIVE ACADMEIC; Stein 2017).

These historical trajectories continue to shape the broad features of modern agriculture today, presenting power inequities, and therefore abuse of power. For example, labor-intensive systems invite opportunities for labor exploitation, while highly industrialized systems exclude participants from exchanging labor for capital; large-scale environmental impacts can disproportionately burden certain communities; strong agricultural interest groups can influence public policies related to land use, taxation, trade, insurance, environmental standards, and subsidies; cultural hegemony built on agriculture can legitimize beliefs about landownership, property rights, stewardship, and can dictate which voices are marginalized (CITE). While it is important to recognize how modern systems legitimize or challenge both historical and present power artifacts, it is not reasonable to expect an agricultural scientist to be an expert in these topics. Conceptual tools such as [give more examples], and the matrix of domination (Collins 1990) have been developed to aid non-experts in dissecting where and how power inequities may manifest.

To demonstrate the relevance of these tools in modern agriculture, Table 1 presents an adaptation of the matrix of domination representing the four domains through which power may be expressed or experienced, coupled with select examples from modern US agricultural systems. The examples provided in the table are not meant to be an exhaustive accounting of inequities in US agriculture; their goal is to help agricultural scientists understand that oppression is real and quantifiable, and to aid in understanding how agricultural research may interact with each domain.

### Table 1. Domains through which power may be expressed and experienced (adapted from Collins 1990)

|  |  |  |
| --- | --- | --- |
| **Domains** | **Description** | **Select examples of power inequities in modern US agriculture** |
| **Structural domain** | Organizes distribution of power through laws and policies | Racially tiered implementation and funding of US land-grant university system (Croft 2019; Sharp 2004, Martin 2018)  Discriminatory design of US land heirship laws (Deaton 2007; Baily and Thomson 2022)  Gender biases of the USDA1 bureaucratic model (Viswanath 2022) |
| **Disciplinary domain** | Administers and manages distributions of power by implementing and enforcing (or not enforcing) laws and policies | USDA credit granting discrimination based on race and gender (Carpenter 2012)  Systematic exclusion of groups via USDA NASS2 census collection formats (Pilgeram et al. 2020; Dentzman et al. 2020)  Barriers to participation of American Indian lands in NRCS3 programs (Johnson 2019) |
| **Hegemonic domain** | Circulates ideas related to power | Preferential access to extension services for some groups (Ragasa et al. 2013, Krishna et al 2019)  Extension activities focused on top-down, technological solutions (Belshaw 1979)  Focus on Western science in agricultural curriculums (Snively and X 2001)  Barriers to implementing indigenous practices under NRCS cost-share initiatives (Johnson et al. 2021) |
| **Interpersonal domain** | Individual experiences, expression, and awareness of power | Gendered experiences of fieldwork and farmer interactions (Chiswell and Wheeler 2016; XX  Agricultural student biases (Basche and Carter 2020)  In- and out-group mentalities in agricultural practitioners (Kniss XXXX) |
| 1United States Department of Agriculture  2National Agricultural Statistics Service, an agency responsible for collecting and reporting information related to agricultural production within the USDA  3Natural Resource Conservation Service, an agency that provides technical and financial assistance to land owners | | |

In theory, performing publicly accessible research plays a crucial role in redistributing power within the hegemonic domain by democratizing access to knowledge and empowering diverse stakeholders with information needed to challenge existing power structures. However, public research – connect to land grants and continued focus on maintaining status quo, leaving out underserved and marginalized others…just because knowledge is there doesn’t mean all can access and just because institutions develop special programs for people doesn’t mean the institutional hegemony changes

Unfortunately, the reality is that public institutions may rely on funding sources that can compromise this ideal, and the institutions themselves are built upon and can perpetuate inequality at every level. There are notable efforts correct these issues, but in practice there are many barriers for public research to serve its intended purposes.

Many agricultural researchers may not see direct connections between their work and power domains because the influence of power-holders is so ubiquitous on the land grant university campuses where many of these researchers work; for example, Iowa State University College of Agriculture and Life Sciences meet with their advisors in Bayer Student Services wing of Curtiss Hall or may attend a lecture in the Iowa Farm Bureau Pavilion through the Bayer, and the college receives millions in endowments from transnational agribusiness (Table 1). Indeed, the ubiquitousness is what preserves and continues the hegemony of power imbalences … Here we present thematic opportunities for agricultural researchers to envision how their work may integrate into a larger effort to address inequalities, and provide examples where their application resulted in a rebalancing of power in one or more domains.

### Technical audits

As scientists, agricultural researchers are well versed in formulating hypotheses testable through the use of traditional data sources. Moreover, agricultural science is an applied science, meaning many scientists interface with the users of their work, rendering them privy to unique situational insights that can provoke interesting queries related to power. By leveraging their scientific training, domain knowledge, and personal observations, agricultural scientists have great potential to contribute to documentation of issues in each of the four domains presented in Table 1.

A series of studies provide an example of creatively using agricultural domain knowledge to challenge power dynamics surrounding underground pipeline installations (Brehm and Culman 2022a; Brehm and Culman 2022b; Ebrahimi et al. 2022a; Ebrahimi et al. 2022b). By documenting significant soil degradation and crop yield losses following pipeline company remediation efforts, the research empowers landowners, farmers, and the public to object to proposed pipelines using scientifically-generated data. It also challenges the power of pipeline companies by shedding light on the true costs of their operation, and enables more informed decision-making regarding carbon capture, storage, and utilization efforts (Balaji and Rabiei 2022; <https://arxiv.org/abs/2403.17162>).

As another example, in a literal interrogation of power researchers assessed the statistical power of university-run nitrogen rate trials, exposing flaws in traditional experimental designs used to generate nitrogen recommendations (Miguez and Poffenbarger 2022). This calls into question the appropriateness of the top-down, siloed, and opaque methods utilized by universities in producing these recommendations. This occurs against the backdrop of increasingly urgent conversations regarding the environmental degradation, compromised human health, and public costs born from over-application of nutrients on farmed land (CITE). Recognizing that stakeholders are increasingly demanding more transparency and accountability with regards to nutrient management, in 2022 the state of Iowa launched an ambitious effort to democratize and support horizontal knowledge exchange when generating nitrogen recommendations (Iowa Nitrogen Initiative). As part of the initiative, farmers volunteer (see Reciprocity section) to perform nitrogen rate trials in their own production contexts, and the data is collectively pooled to drive transparently calculated recommendations and to support public model development. Similarly, in 2022 a grassroots farmer organization, Practical Farmers of Iowa, launched a regional program paying farmers to test nitrogen rates of their choice using replicated trials and sharing their individual and pooled results with the public (CITE).

These examples illustrate how traditional, technical agricultural research can be used to challenge established power structures, in the first by empowering the public to contest environmental degradation from pipeline installations, and in the second to demand transparency and accountability in nutrient management research.

### Listening to and serving the margins

Conducting research that is inspired by and/or supportive of those who have been marginalized or subjected to minority status within dominant systems is another effective means for agricultural scientists to challenge entrenched power structures. Marginalization in agriculture can manifest through multiple avenues. Individual characteristics such as gender, race, ethnicity, age, language, sexual preferences, formal education level, technology use and socioeconomic status can lead to systemic and/or cultural exclusion that can translate to exclusion from agricultural research activities (Leslie et al. 2019; Carter 2019; Pilgeram et al. 2022; Pfammatter and Jorgenden 2023; Shih and Fan 2009). Additionally, farm-level features such as the production system, the degree of farm mechanization, farm location, farm size, the market channels utilized, and even the long-term ambitions for the farm can render their needs less important in the eyes of agricultural scientists (Wheeler 2008; Belshaw 1979;). This represents an issue not only for redistribution of power in agriculture, but also for science: marginalization often compels innovation, and listening to and serving the margins can provide a wealth of ideas. In the Midwest, one of the most scientifically impactful long-term diversification experiments was inspired by an Iowan farmer’s low-input system (Davis et al 2012).

Women own almost half of the farmland in Iowa, yet they have been largely ignored by researchers regarding conservation decision-making (Carter 2019). Recent research has shown there are significant opportunities for improving agricultural outcomes through understanding women’s experiences (Mahajan 2019; Diiro et al. 2018; Zhang et al. 2021).

<<Stefan maybe you can say something about PFI’s Latino Engagement program, if that has had any benefits you could mention>>

Serving the margins is a way for agricultural researchers to leverage their privilege to help build legitimacy within the margins (de Wit and Alastair I think)

Needs work….

### Legitimizing other’s knowledge

The idea that there are ’multiple ways of knowing’ likely originated in epistemology, but has migrated into common vernacular as issues with positivism and objectivity have become more widely discussed (see Theme 3). At its most basic level, it recognizes the diverse means through which individuals and groups understand the world around them. This can include empirical observation and logical reasoning, but also intuition, personal experience, cultural traditions, and spiritual insights, among others. Scientists may dismiss others’ knowledge if it originates outside of traditional scientific methods. Therefore, scientists can wield power by dismissing knowledge originating from non-conventional sources. While systematic observation and empirical evidence are crucial tools for scientific inquiry, the exclusion of alternative forms of knowledge overlooks their potential contributions to enrich scientific understanding. It also reinforces the dominance of a single scientific paradigm, which stifles innovation.

Utilizing non-traditional measurements is one way agricultural scientists can honor multiple ways of knowing within a scientific framework. An apposite example is USDA NASS measurement of a ‘workable field day’, defined as day where weather and field conditions allow producers to work in fields a major portion of the day (NASS <https://www.nass.usda.gov/Publications/National_Crop_Progress/Terms_and_Definitions/index.php#days>). While it is based on scientific principles relating to soil moisture (Earl 1997), it represents a personal interaction between the farmer and the land. Attempts to model it have shown acceptable accuracies on monthly timescales, but poorer performance on weekly time scales (Huber et al. 2023), indicating it is a personalized experience that cannot be explained by physical parameters alone. Perhaps because of the connection to personal experience, survey data on workable field days is often used in extension settings, but to our knowledge has not been extensively used within scientific frameworks. In an example of sharing the power of data collection, Practical Farmers of Iowa has launched a study wherein farmers will quantify their experiences with cover cropping through the use of workable field days (CITE). This effort does not detract from nor undermine the numerous scientific publications relating cover cropping to changes in soil-water relationships (CITE). Rather, it will enrich the scientific literature, and will produce results that are based on other ways of knowing which may be more meaningful in certain contexts (Robertson et al. 2001).

Technical audits, listening to the margins, and embracing multiple ways of knowing are three topics within the theme of power that can help guide research activities in distributing power within a given domain (Table 1) more equitably. For myriad reasons, we recognize researchers may not have the ability, resources, or authority to do research that perfectly aligns with their ambitions to challenge power. However, the *way* research is done can also present an opportunity to redistribute power more equitably. This is the subject of the remaining two themes.

# Theme 2: Reciprocity in farmer-researcher relations

For over a century, plots managed by researchers have been utilized for controlled experiments, allowing researchers to isolate variables and study specific phenomena while controlling for other factors. However, as agricultural research has evolved, there has been a growing recognition of the importance of conducting trials at the farm scale to better understand how research findings translate into real-world agricultural systems (Lacoste et al. 2021, Kravchenko et al. 2017; Koehler-Cole et al. 2023; Laurent et al. 2022). Furthermore, advances in the ability to organize and streamline data collection from farm environments has opened the door for more nuance in blending research plots with farm fields to answer novel research questions. There are significant opportunities for performing better, more statistically powerful, and more relevant public research in collaboration with farmers (igancio’s paper, laila’s, mother daughter stuff, participatory breeding thing; Stone 2016). However, these arrangements require careful consideration to support equitable and fair power relations.There are numerous guides for farmers on conducting on-farm research (Chaney 2017, Stefan’s list). However, to our knowledge, there are fewer resources suggesting best practices for the scientists, researchers, and organizations the farmers may be collaborating with in their research efforts. The Agroecology Research-Action Collective’s Principles and Protocols provide useful guidance on working with communities and organizations in general (de Wit et al. 2022). However, we feel the researcher-farmer collaboration merits explicit attention for agricultural scientists.

## Compensation

The context for farmer involvement in research can vary widely (Toffolini and Jeuffroy 2022; Jackson-Smith and Veisi 2023). The research goals, decision-making authority, degree of communication, and participant selection criteria are examples of factors used to describe the typology of collaborations (CITE). While much work has been done to describe collaboration contexts, the topic of compensation within those collaborations is less widely discussed. To our knowledge there are few studies looking at mechanisms for compensation, and even fewer exploring how those mechanisms influence collaboration dynamics. This omission is problematic; farmers should always be compensated, and the form this compensation takes is particularly germane to the topic of power.

In many on-farm research arrangements, farmers are compensated by ‘the experience and knowledge gained from the activities,’ ‘access to research findings,’ ‘better productivity’,

or a similarly non-tangible exchange. From a power perspective this practice is elitist, extractive, disrespectful, and in the authors’ opinions, unacceptable. Participating in research projects requires farmers to allocate significant time, resources, and land for experimentation and coordination of data collection. Projects should provide tangible compensation that acknowledges the farmer’s investments and sacrifices, ensuring fair remuneration for their professional contributions to the research process. Fair compensation also fosters mutual respect and builds more equitable partnerships that are more likely to be sustained in the long-term. Lastly, failing to provide compensation further exacerbates historical biases, favoring well-resourced farmers in access to on-farm research activities.

While individual researchers may not have vast coffers of unrestricted grant money to provide to participants, most researchers are coming from institutions with well-funded endowments. Research participants view the researcher as a representative of said institutions, and so… Many grant funders allow for participant support, including stipend and travel costs. In research led by authors Basche and Carter (2021), farmers and landowners participating in North Central Regional Sustainable Agriculture Research and Education research grant are provided a monthly stipend over the course of the two year project, as well as gift cards that could be used to cover cost of gas to meetings or other material needs that allow the participants to show up, and also provides funding for the farmers and landowners to choose a regional agricultural conference to attend (presentation not required) to gain greater professional development. Additionally, providing resources such as childcare or parking passes to attend meetings helps to offset costs that might keep people at home.

Monetary compensation is the most direct, and often preferable, form of compensation. Paying farmers for their participation in research has been shown to promote a climate of mutual respect between farmers and researchers (Thornley 1990). Many surveys of farmers involved in collaborative projects do not explicitly ask about compensation, but a desire to receive monetary compensation is voluntarily noted when asked about limitations and/or suggestions (Thompson et al. 2019; Pires et al. 2024). Since its inception in 1987, the grassroots organization Practical Farmers of Iowa has incorporated farmer payments in grant proposals for its on-farm research program, wherein a farmer received a set dollar amount for conducting an on-farm trial, and 1.5 times that amount if the trial included a farm tour open to the public (Liebig paper, Thompson and Thompson 1990). The farmer cooperator program is still in operation after more than 30 years with high retention rates and continued growth, fact attributed in part to their policy of monetarily compensating farmers for their participation in on-farm research (but see Metrics for Success section). The Iowa Nitrogen Initiative, for comparison, was not allocated money for farmer compensation, and they have capacity for more participants than they can secure. There are fair criticisms of using monetary compensation for farmer’s collaboration, include warping of incentives, and creating selection biases towards those who are not truly interested in the research. While these unintended artifacts are indeed possible, we feel they are minor compared to the power inequities invoked through non-payments.

Monetary compensation may often be preferable, but we recognize it may not always be possible. The reality of funding limitations and grant restrictions on how monies are spent necessitates exploration of other methods of compensation. ‘Work a day’ compensation, wherein researchers offered to work on the farm for some period of time in exchange for research collaboration, showed benefits to both participating farmers and university researchers (Liebig et al. 1999). In this same vein, the Agroecology Research-Action Collective identifies two practices within the principle of fair resourcing that directly mirror these views – that researchers should provide renumeration of partners for time and expertise, and that researchers should provide valuable work that could include digging fence holes (de Wit 2022). However, the high degree of mechanization on many farms and liability issues may restrict this to unique situations. A recent on-farm study comparing precision nitrogen management approaches found most farmers would not have participated without payment, but they also appreciated the technical training and assistance that accompanied the project (Laila’s paper). Alternatives such as formal training opportunities, technical assistance, provision of inputs, or in-kind support may be acceptable alternatives to monetary compensation, but should be considered carefully, and exact dollar values on the compensation should be calculated and communicated. Furthermore, giving the farmers the power to choose their compensation is an interesting and understudied facet of collaborative research. When farmers were provided with the option of having a researcher do work on their farm, some participants requested that the researcher simply give a presentation about university research at that farm (Liebig et al. 1999). These farmers valued ‘access to research findings’ above the offer of unskilled labor, but the element of choice likely played a part in their satisfaction with the arrangement. However, choice in itself may not always equalize power. Arrangements wherein a donation is made on behalf of the farmer to an entity of their choice as compensation should be approached with deep considerations of the context, transparency, cultural sensitivity, perceived influence, and perceptions of tokenism.

To assist researchers in compensating farmers in ways that equalize opportunities and power distributions, public funding sources and private sources committed to fair and equitable research activities should require remuneration of farmers for their participation in research projects and explicitly provide funding categories allocated to effort.

## Metrics for success

In addition to fair (preferably monetary) compensation, both researchers and farmers should aim for relationships defined beyond simple transactions (**Figure X**). We believe many researchers strive to build rich relationships with their farmer collaborators, however they often lack metrics that help them articulate and measure that success. Building on recommendations from the data feminism framework (D’Ignazio and Klein XX), we suggest the following four broad metrics be incorporated into project evaluations:

1. Was trust was built?
2. Were power and resources shared?
3. Did learning occur in both directions?
4. Were both entities transformed as a result of the collaboration?

Incorporating these metrics *a priori* can help guide activity planning, and help ensure anticipated outcomes are aligned within a relationship of reciprocity.

A collage of images of a farm and a building

Description automatically generated

***Figure X.*** *Expanding the metrics used to evaluate project success can aid in enriching the collaborative process for both farmers and researchers. (A) A simple, transactional, and un-equitable exchange of resources wherein the metrics of project success may be measured in ‘increase in knowledge’ by the collaborating farmers. (B) A richer relationship built on exchanges and associated metrics that promote fair, effective, and sustainable collaboration relationships.*

The success of this type of model can again be demonstrated by the longevity of the Practical Farmers of Iowa (hereafter shortened to Practical Farmers) on-farm research program, which has been in place since 1987. Practical Farmers has continually refined their post-program participation surveys, and through deep, critical reflection and constant iteration, their current survey successfully quantifies outcomes in the four metrics described above. Among other questions, Practical Farmers asks participants if they would recommend the program to a friend or other farmer (trust building), how effective the program was in helping the participant answer their questions (power and resource sharing), changes in knowledge (bi-directional learning), and whether participation spurred new ideas or observations on the farm (transformation). As these questions have become metrics for success, Practical Farmers has designed their program to support these metrics, resulting in highly satisfied participants (Can I cite something? A PFI report?) which translates to more consistent funding. Other researchers and entities likely utilize some form of these metrics, but to our knowledge they are not widely employed by granting agencies or at an individual researcher level. To support reciprocity in farmer collaborations, we provide the post-participant survey questions used by Practical Farmers in supplementary material as a resource (supplementary file).

Another model of reciprocal learning takes place at Women, Food and Agriculture Network’s programs for landowners (Women Caring for the Land). Researchers facilitate these meetings, but the questions and flow of the dialogue is led by the participants themselves as they respond to real-time questions and needs. This sort of learning, built upon Brazilian educator Paolo Freire’s critical pedagogy, engages not only reciprocal learning, but participatory learning in which the learning is directed by the participants themselves.

Equitable research is something that takes active doing – it is not the default. Without conscious attention to this, it is not the result.

Also, relationships take time to form. The best way to build trust is not to reach out to a potential collaborator or participant with little time left before a grant is due and ask for their input—importance of co-design of research and co-production of knowledge

In this section on reciprocity, we have concentrated on designing equitable farmer-researcher relationships. However, many of the ideas presented are not exclusive to these actors. All relationships contain the potential for power inequities, and intentional examination can lead to better collaborations, regardless of the form. While not specific to agriculture, researcher-researcher, researcher-student, researcher-employee relationships all have potential for power inequities based on seniority, discipline, perceived prestige, etc. Is this worth mentioning?

# Theme 3: Framing and the coexistance of multiple truths

Positivism is a philosophical perspective that states empirical evidence based on observable phenomena collected using the scientific method is the only valid foundation for acquiring knowledge. Scientific objectivity refers to the idea that the scientists using the scientific method are not, or should not be, influenced by personal perspectives, values, or vested interests. These ideas relate to data feminism in that they were developed by a narrow slice of human intellect, and their implementation has been entangled with colonialism, racism, and other forms of oppressions(Halpin 1989; Theses 2016;. The appropriateness of positivism for answering certain types of questions has been debated since its inception (CITE). The feasibility and even desirability of objectivity in science has been the subject of rigorous and long-lived philosophical debates, and as the diversity of scientists increases those debates have moved into mainstream dialogues (Reiss 2014; Becker 2021). As a corollary, the acknowledgement of how value systems impact approaches to problems, and perceived solutions has grown (Rykiel 2001).

A slew of paradigms have been introduced in response to these issues in an attempt to support a more nuanced and reflexive approach to scientific inquiry. Topics such as the importance of the role of interpretation, plurality of methods, critical reflexivity, and fallibilism are embraced as inherent in the pursuit of knowledge, while still valuing the foundations of empirical evidence and systematic investigation. While these ideas have been embraced and codified in social sciences (Ryan 2006; others), it has failed to deeply permeate other fields, including agriculture (Clark 2002 (nursing); Norton 2008 (ecology); Nicklay et al. XX; Pretty 1994; Ebel et al. 2020). Here, we collectively group these ideas into the acknowledgement that multiple truths can coexist. We stress that we are not claiming that all perspectives are equally valid, or that there are no objective truths. Instead, we emphasize how this mentality opens us up to diverse perspectives and leads to productive conservations in the field of agriculture. We argue that it is only by adding diverse sets of perspectives can we create a more complete, and just, picture of the ‘truth’.

## Agriculture and values

A book written to illustrate how underlying value systems shape individuals’ perspectives on solutions to complex global challenges unwittingly uses agricultural research as its backdrop. *The Wizard and the Prophet* (CITE) explores the worldviews of Norman Borlaug and William Vogt, two white, Western men working on agricultural topics during the 20th century but coming from divergent backgrounds. Borlaug was raised on a Midwestern US farm, and his life was greatly impacted by the introduction of tractors. This experience likely influenced how he thought of solutions, and he is portrayed as a ‘wizard’, embodying a technocentric worldview the prioritizes technological innovation and human ingenuity as the means to address global issues. Vogt began his life in a rural area surrounded by unbuilt environments, but moved to the city and witnessed the urban development of his place of birth. Vogt is portrayed as a ‘prophet’, emphasizing the need to live within ecological limits. Borlaug researched ways to leverage technology to intensify agricultural practices and increase food production, an effort that contributed to a larger collection of innovations collectively referred to as ‘the Green Revolution’ and for which Borlaug won a Nobel Peace Prize (CITE). Vogt used science to formally develop the idea of carrying-capacity (CITE). He advocated for limiting population growth rather than increasing food production, and developed a model for environmental activism that is still used today. Both Borlaug and Vogt had valid results and conclusions based on using the scientific method to investigate questions that were motivated by their personal values and experiences. The differing motivations do not invalidate their truths, but rather demonstrate how multiple truths can co-exist at once.

In the context of policy making, the acknowledgement of contradictory realities, such as the coexistence of abundance and starvation, is understood as an inherent complexity in addressing multi-faceted issues (Stone 2022). In this context, the broader the set of realities that are available, the more complete the overall picture becomes, and concomitantly the possibility for more equitable solutions. For topics as fundamental to human survival as food production, incorporating the scientific contributions produced using diverse framings will undoubtedly lay the foundation for more equitable outcomes. Ironically, although the worldviews of the two example figures are divergent, they represent those of two American males of European descent as written by an American male of European descent. This demonstrates how even classical delineations such as race and gender portend very little in regard to value systems, and lends us to imagine the insight that would be gained from adding more framings. Today, an increasing availability of diversely framed reflections concerning the Green Revolution have led to significantly more nuanced understandings of the motivations, impacts, and XX of the Green Revolution (PBS series, https://www.pbs.org/wgbh/americanexperience/films/man-who-tried-to-feed-the-world/

others). As calls for a ‘second Green Revolution’ proliferate (XX), the ability of society to leverage diverse voices contributing to the discussion will be a great asset. Scientists who are able to acknowledge and navigate the existence of multiple truths are better equipped to provide solutions that do not preferentially disadvantage vulnerable groups (Jordan about world views paper).

While the set of framings represented in agricultural science is becoming more diverse. Examining how a particular set of values can influence scientific outcomes has produced productive conversations, as well as creative new lines of inquiry. For example, recent research has explicitly analyzed how various framings dictate weed management goals, exposing novel research questions that emerge only when new framings are taken seriously (MacLaren et al 2020; Weisberger et al. 2024). Comparative analyses, article responses, and commentaries are also avenues for productively exploring what analytical decisions are made, what may have motivated those decisions, and how they impact conclusions. Complex agricultural topics such as herbicide use (Kniss), climate impacts of ethanol production (Hill 2022), organic agriculture (Wilbois 2019; Swedish organic reviewer paper), tillage and soil carbon (Miguez/Schulte), and bioenergy (XX) are examples where conversations have benefited from dissecting how different framings may lead to different data analysis choices.

As an agricultural scientist, your background frames your work. We argue that by seeking to eliminate the influence of that framing, we insinuate it is possible, and are concomitantly quelling what our own experiences can proffer to our work. NEED MORE WRAP UP

Is this worth getting into?

On the flip side, researchers should respect that framings create data. There are numerous initiatives that advocate for free and open sharing of data generated by governments, industries, and research institutions ((CITE). The open science movement champions the ethos of transparency, collaboration, and accessibility in scientific research; as a corollary the movement promotes the unrestricted sharing of data (CITE). Indeed, the sharing of data has facilitated more efficient use of resources for research through data re-use (Piwowar), and in some countries freely available governmental data XXX both public and private entities leverage governmental data that is freely available (Piwowar). However, the open sharing of data also introduces risks regarding data misinterpretation or misuse. Data shared openly may be used out of context. By embracing our own framings, we concomitantly recognize the need to understand the framings of others. Failure to do so can result in gross misunderstandings (Cropscape data article, NASS data increasing women producers). Data should be treated within the gift culture of scholarship, in which goods are bartered between trusted colleagues rather than treated as commodities (Wallis).

# Conclusions

In this paper, using the principles of data feminism as our guide, we demonstrate how (1) agricultural scientists can uniquely contribute to examining and challenging power through technical audits, serving and listening to the needs of the minoritized, and embracing multiple ways of knowing, (2) building farmer collaborations with reciprocity metrics codified in the project leads to better outcomes for the farmers and researchers, and (3) embracing framing as an inevitable and positive attribute leads to more transparent, creative, and effective research. SOMETHING MORE.

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