

Data Feminism as a guide for agricultural research

Virginia Nichols^{1*}, Angie Carter², Stefan Gailans³, Andrea Basche⁴, David Weisberger⁵

¹Aarhus University, Denmark

²Michigan Technological University, Michigan USA

³Practical Farmers of Iowa, Iowa USA

⁴University of Nebraska-Lincoln, Nebraska USA

⁵University of Rhode Island, Rhode Island USA

*gina.nichols@agro.au.dk

Abstract

Agricultural research reflects complex institutional and interpersonal relationships that have historically been, and continue to be, subject to power imbalances. Recently, interdisciplinary scholars developed the Data Feminism framework to aid scientists in understanding and addressing power in research. Here, we demonstrate the framework's utility in agricultural research and present evidence that explicit attention to power and values concomitantly fosters research creativity and leads to positive societal outcomes.

1. Introduction

Agriculture involves the cultivation of land to produce food, an arrangement inherently primed for power disparities. Indeed, over thousands of years and across civilizations, agriculture has reflected, enabled, and leveraged power hierarchies^{1,2}. It follows that the interpersonal and institutional relationships upon which modern agricultural research is built continues to mirror those artifacts, with profound ethical and social consequences. This is not unique to agricultural research; global recognition of the need to intentionally examine how power interacts with science has spurred the creation of new academic fields, particularly relating to data generation and use³⁻⁶. While social scientists have long recognized these interactions⁷, biophysical scientists are increasingly being asked to consider the context of their work. There have been calls for and attempts to codify reflexivity in the fields of food studies and agroecology⁸⁻¹⁰, reflecting both fields' inclusion of the human experience in their scope^{11,12}. However, carving out space for reflexivity remains a formidable task for those in the technical fields falling under the umbrella of agricultural science. The recently developed Data Feminism framework¹³ is particularly well-suited to support agricultural researchers in interrogating their research context. The framework is rooted in empirical studies of power (the reader is directed to D'Ignazio and Klein 2020 for discussion of these studies) and while the term Data Feminism may invoke an assumption of gender focus, Data Feminism emphasizes intersectionality, or the need to study multiple dimensions of power¹⁴. Because it is action-oriented and domain-agnostic, D'Ignazio and Klein's (2020) work has been highly cited in numerous disciplinary contexts. To our knowledge, it has had limited interpretation in the context of agriculture, though 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 Feminism¹⁵.

We posit that explicit application of the Data Feminism framework would positively contribute to research creativity, stakeholder participation, and agricultural sustainability overall. To support this thesis, we discuss the application of three select Data Feminism themes (power awareness, reciprocity, and framing) in the research process, with accompanying reflections, activities and outcomes (Table 1). We chose these three themes due to their broad implications and ability to be addressed in the typical agricultural research context.

Table 1. Summary of paper structure

Theme	Research phase(s) for application	Data Feminism-derived reflection	Reflection-motivated activities
Awareness of Power	Hypothesis generation and study design	Research for the public good should seek to equalize power	Serving the margins, leveraging science, expanding the concept of scientific measurements
Reciprocity	Conducting and implementing research	Farmer-researcher relations should be reciprocal	Multi-dimensional compensation, metrics for success
Framing	Analysis and distribution	All research is values-informed	Acknowledging the presence of values in research, supporting diverse framings

The goal of this paper is to interpret select themes from the Data Feminism framework in an agricultural setting and serve as an encouraging resource for more intentional work in this area. Our perspectives are strongly framed by our collective personal, academic and professional experiences in the industrialized 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 vary, we believe the topics are universal. 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 perspective empowers technically trained agricultural scientists to reflect on their work's broader societal implications. In this piece we use the term 'imbalance' to collectively refer to both power inequities (which result from contextual situations) and inequalities (resulting from laws).

2. Awareness of Power

Obtaining one's will despite resistance from others is an expression of power¹⁶. Central to Data Feminism is the fact that power is unevenly distributed and experienced in this world and equitable redistribution requires intentional examination and intervention. This foundation is particularly relevant in agriculture; overarching features of agriculture (both historical and contemporary) such as labor exploitation¹⁷, Native land dispossession^{18,19}, and selective land ownership rights²⁰⁻²² intentionally embed power inequalities in agricultural systems. Research seeking to support public good therefore requires an understanding of how research passively endorses or challenges power artifacts. However, because power is a complex topic with dedicated scholars, this pursuit may feel daunting to the average agricultural scientist. To aid non-experts in contextualizing their work, Data Feminism applies Collins' (1990) matrix of domination²³ to elucidate where and how both power inequities (contextual) and inequalities (structural) may manifest, and therefore clarify both their existence and how they may be challenged. To demonstrate its application, here we present a demonstrative (e.g., non-comprehensive) adaptation of the matrix applied to a woman farmer/farm

landowner in the US (Table 2). The reader is directed to Sachs 1983 for a more thorough documentation of the history of women, power, and US agriculture.

Table 2. Domains through which power may be experienced as a woman farmer/landowner in the US (adapted from Collins 1990)

Domain	Description	Example power disparity
Structural domain	Laws and policies that distribute power in inequitable ways	The US Government distributed land with a gender (and racial) bias under patrilineal inheritance, thus privileging male white settlers ²⁴ . Subsequent laws granted limited rights to white women married to white men ²⁵ , yet through the mid-20 th century numerous laws prevented women from independently owning and operating farms and accessing credit ²⁴ . As recently as 1974 women were not permitted to apply for a credit card without a male co-applicant ²⁶ . Laws such as these also shaped hegemonic and interpersonal inequities in power that continue today ²⁷ .
Disciplinary domain	Entities that implement and enforce (or fail to implement and enforce) laws and policies distributing power	The USDA has discriminated based on gender when granting credit ²⁸ . Effects of such discrimination (e.g., wealth accumulation, type of agricultural production) continue; after controlling for farm size and type, farming still has one of the largest (40%) gender-wage gaps of US professions ²⁹
Hegemonic domain	Entities that circulate ideas related to who has power	Until 2017, USDA NASS census collection formats allowed for only one farm operator. This excluded many women from identifying as farm operators ³⁰ . Forcing a farm to identify a single operator also reinforced patriarchal stereotypes about exclusive and unilateral (rather than joint) decision-making power ³¹ . A study completed in 2024 found that online image searches in the US for ‘farmer’ preferentially return images of men at a rate disproportionally higher than expected even using the pre-2017 census values ³² , meaning women farmers, even by conservative estimates, are under-represented in visual media. Additionally, women landowners are ‘not on the radar’ of agricultural professionals who distribute funds and technical assistance ³³ which limits their access to needed resources ³⁴ . Even future agricultural professionals undervalue the experiences and knowledge of women landowners ³⁵ .
Interpersonal domain	Individual experiences, expression, and awareness of who has power	Women farmers and landowners are rendered invisible by male-centric material in popular media ³⁶ and by the abundant use of male pronouns used in agricultural settings when referring to a generic farmer ³⁷ . Women are not perceived as having decision-making authority and experience gender-based discrimination from

		tenants, neighbors, lenders, and service providers preventing them from equitable access to agricultural programs, information, and networks ^{34,38,39}
USDA - United States Department of Agriculture; NASS - National Agricultural Statistics Service, an agency responsible for collecting and reporting information related to agricultural production within the USDA		

For biophysical scientists, traditional training does not often include space nor resources for building awareness of power imbalances, and it will therefore take time and effort. Actively questioning why certain groups seem over- or under-represented in agricultural language or contexts you encounter is a powerful starting point, and the matrix of domination can aid in parsing out the various drivers involved. Once the foundation of awareness has been built, as scientists it is important to reflect on our roles in passively endorsing, or challenging inequities. To help agricultural researchers envision how their work may integrate into a larger effort to rebalance power in one or more domains, we present three research activities with attendant examples of positive experiences: serving the margins, leveraging science, and expanding the concept of scientific measurements.

2.1 Serving the margins

In agricultural production, exclusion can occur due to individual characteristics (e.g., Table 2) as well as farm-level features (e.g., production system, degree of farm mechanization). This systemic and/or cultural exclusion often translates to omission from agricultural research activities^{27,40}. One method for addressing this power inequity is to conduct research with institutionally excluded groups. Beyond the direct benefits, this also leverages a researcher's hegemonic power to culturally label the needs, experiences, and knowledge of the marginalized as equally valuable⁴¹. It can also inspire solutions that benefit everyone. For example, in 1987 a group of farmers formed Practical Farmers of Iowa⁴² (hereafter referred to as Practical Farmers) as a peer-to-peer learning community⁴³, partially in response to being excluded by the Land Grant's extension systems⁴⁴. By listening to these farmers, a researcher was inspired to study low-input systems, implementing a trial that became an influential, long-term crop diversification experiment⁴⁵. Researcher participation in the Women, Food and Agricultural Network⁴⁶ similarly inspired scientifically insightful activities with women landowners^{38,39}. More recently, Latino farmers in the Midwest have little institutional support, and Practical Farmers launched a Latino Engagement program (Supplemental Information). These are select examples, and in US agriculture excluded groups may take many forms, including but not limited to minority, tenant, queer, or immigrant farmers; or organic, low-input, small, diversified, or low-mechanization farms. Seeking to support and serve such groups is therefore a potentially impactful research activity that supports rebalancing of power.

2.2 Leveraging science

By leveraging their scientific training, agricultural scientists have great potential to contribute to documentation of power imbalances (Table 2), and therefore support their mitigation. For example, a series of studies documented significantly longer-term soil degradation and crop yield losses than assumed by the laws dictating required remediation periods accompanying underground pipeline installation⁴⁷⁻⁴⁹. This scientific effort thus documented an important structural inequality. However, science can also be used to passively implement power inequities between the creator and user. For example, US Land Grant universities traditionally wield unique power in generating nutrient application recommendations using top-down, siloed experiments (that often lack statistical power⁵⁰) using data that is not made publicly available and without extensive input from the public, farmers, or peer review. Driven largely by water quality concerns, the public has begun to demand

more transparency with regards to agricultural nutrient management in the US, prompting farmers and universities to reimagine how nutrient recommendations are created. New programs democratize and contextualize recommendations using open-source methodologies and modern computing power capabilities, while also supporting horizontal knowledge exchange. Iowa State University recently launched an ambitious program, the Iowa Nitrogen Initiative, wherein farmers volunteer to perform nitrogen rate trials in their own production contexts⁵¹, increasing the relevance of the data driving the recommendations. The data will be collectively pooled and used to drive transparently calculated, more nuanced recommendations. Similarly, Practical Farmers launched a regional program paying farmers to test nitrogen rates of their choice using replicated trials and sharing their results with the public. These efforts are leveraging science to redistribute power more equitably amongst farmers, scientists, and the public, blurring the lines between science creator and user. It also represents an important and positive shift in awareness regarding detrimental power inequities in previous applications of science.

2.3 Expanding the concept of scientific measurements

While traditional Western science methodologies can have a role in addressing power imbalances, expanding the definition of science is also an important component of redistributing power. The concept of ‘multiple ways of knowing’ originates in Indigenous epistemologies but has recently migrated into common vernacular. The concept recognizes the diverse means through which individuals and groups understand the world around them, including empirical observation and logical reasoning, but also personal experience and cultural traditions extending from place-based knowledges, for example. In dismissing knowledge originating outside of traditional scientific observations, scientists limit the potential contribution such knowledge can have in enriching scientific understanding⁵². It follows that by utilizing non-traditional measurements, agricultural scientists can honor multiple ways of knowing while still working within a scientific framework. An apposite example is USDA NASS reporting of a ‘workable field day’, defined as day where weather and field conditions allow producers to work in fields a major portion of the day⁵³. It has a scientific underpinning⁵⁴ but represents a deeply personal interaction between the farmer and the land that has evaded modelling attempts⁵⁵. Workable-day survey data is commonly used in extension, but to our knowledge has had limited use within research. In an example of challenging hegemonic power around knowledge generation, Practical Farmers recently launched a study wherein farmers will quantify their experiences with cover cropping through the metric of workable field days (Supplemental Information). This effort values farmers’ ways of knowing in a scientific framework, and will uniquely enrich our understanding of how cover crops impact soil-water dynamics. Participatory plant breeding^{56,57} and mother-baby trial designs⁵⁸ are examples of formalized research methods that seek to include non-traditional measurements. There is clearly ample room for creativity in this area.

3. Reciprocity

In addition to what research is done, the *way* research is done presents myriad opportunities to distribute power more equitably in agricultural research. A recent publication provides excellent guidance on working with communities and organizations in general⁸, however we feel the farmer-researcher collaboration merits explicit attention for agricultural scientists in relation to power and chose to focus on that relationship for this perspective. As agricultural research evolves, opportunities abound for blending research plots with farm fields to perform more statistically powerful and relevant public research in collaboration with farmers^{59–61}. As these types of arrangements are becoming more common, the concept of reciprocity in farmer-researcher collaborations requires explicit attention. There are several guides for farmers when conducting on-

farm research^{62,63}, but there are fewer resources suggesting best practices for the scientists, researchers and organizations they collaborate with.

3.1 Multi-dimensional compensation

The context for farmer involvement in research can vary widely^{64,65}, and while there are numerous publications examining the form of those relationships to our knowledge there are few studies on mechanisms for farmer compensation, and even fewer on how those mechanisms influence collaboration dynamics⁶⁶. This omission is problematic; research participants should always be compensated, and the form this compensation takes is particularly germane to the topic of power. It is common for farmers to be compensated by *the experience and knowledge gained from the activities, access to research findings, better productivity*, or a similarly non-tangible exchange. In its most egregious forms, this arrangement is elitist, extractive, and disrespectful. We acknowledge individual researchers may be constrained in their access to unrestricted grant money to pay collaborators, but without an offer of fair compensation, collaborators may reasonably intuit a devaluation. Moreover, failing to provide compensation further exacerbates historical biases, favoring well-resourced farmers in access to on-farm research activities. Funders clearly have a role to play; researchers have highlighted barriers to budgeting for non-university research participants⁶⁷, and while select funding agencies explicitly allow for and expect farmer-participant compensation (e.g., USDA-SARE), to our knowledge none provide guidance on how to craft compensation packages.

Fair remuneration is in everyone's best interests, as equitable partnerships are more likely to be sustained in the long-term⁶⁸. For example, Practical Farmers has a robust farmer cooperator program that is still in operation after more than 30 years, a fact they attribute in part to their policy of monetarily compensating farmers for their participation in on-farm research (Supplemental Information). For comparison, the Iowa Nitrogen Initiative (see *Leveraging Science*) was not allocated money for farmer-participant compensation, and they have capacity for more participants than they can secure. While research on farmer compensation and project outcomes is scarce, blending of monetary compensation with other forms that support learning, sharing, development, and growth are likely to be most effective^{60,66}, and could be used to specifically support institutionally-excluded groups' needs (e.g., childcare, language interpretation). The authors provide examples of blended compensation packages that coincided with high participant satisfaction in supplemental files as a resource (Supplemental Information). Explicit attention to compensation is therefore an accessible way for agricultural researchers to support more equitable power relations in agriculture.

3.2 Metrics for success

Researchers and farmers are often aiming to develop rich and equitable relationships. The form of compensation package can play a role in this goal, but tangible metrics can help articulate and measure success in those efforts (Figure 1). Building on recommendations from various sources^{8,13,69}, we present the following four broad metrics to help guide the construction of equitable projects:

1. Were power and resources shared?
2. Was trust built?
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.

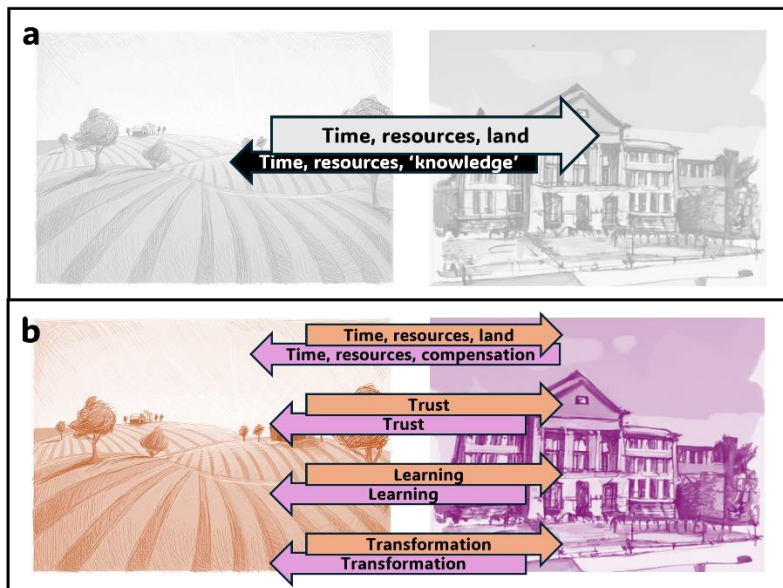


Figure 1. (a) A simple transactional (and in-equitable) exchange of resources wherein the metric of project success is measured by the increase in knowledge by the collaborating farmers (b) A richer relationship built on exchanges and associated metrics that promote fair and sustainable relationships; an example survey for assessing these metrics is available in Supplemental Information. Figure created using BioRender.com

The success of this type of model can again be demonstrated by the longevity of the Practical Farmers on-farm research program, which has been in place since 1987. Practical Farmers has continually refined their post-program participation surveys, and the current form quantifies outcomes in the four metrics presented here (Supplemental Information). As these questions have become guides for program design, participants have been highly satisfied (Supplemental Information) and membership is growing. Other researchers and entities likely utilize some form of these metrics, but more explicit and ubiquitous use would likely benefit project designs and evaluations, while concomitantly promoting equitable partnerships.

4. Framing

The feasibility (or even desirability) of objectivity in science has long been debated, and recent discussions highlight its conceptual abuse in colonialism, eugenics, and other forms of oppression^{70,71}. Today, many disciplines embrace interpretation, plurality of methods, critical reflexivity, and fallibilism as inherent in the pursuit of knowledge^{72,73}. Rather than pursuing objectivism (and insinuating it is possible), Data Feminism acknowledges that all research is framed by the background, experiences, and training of the researcher. Importantly, this plurality is desirable in a Data Feminism framework. To help cement framing as an inherent component of all agricultural research, here we discuss the barriers to and difficulty in acknowledging the frames shaping agricultural research, as well as the implications of such acknowledgement. These sections are designed to help researchers reflect on their training, as well as the values of their institutions.

4.1 Acknowledging the presence of values in research

A book written to illustrate how underlying value systems shape individuals' approaches to complex global challenges unwittingly uses agricultural research as its backdrop: *The Wizard and the Prophet*⁷⁴ explores the worldviews of Norman Borlaug and William Vogt, two white, Western men coming from divergent backgrounds, as they work on agricultural topics during the 20th century. Borlaug, raised on a Midwestern US farm, experienced a rural transformation born from the

introduction of tractors and was trained as a scientist through US Land Grant agricultural programs. These experiences likely informed his approach to problems: Borlaug researched ways to leverage technology to increase food production, an effort that contributed to a larger collection of innovations referred to as the Green Revolution and for which Borlaug won a Nobel Peace Prize⁷⁵. Vogt also began his life in a rural area, but moved to the city and witnessed the urban development of the natural areas he associated with his childhood. He studied languages and moved into science by way of managing a bird sanctuary near his childhood home. Vogt's research emphasized the need to live within ecological limits rather than increase food production, and he formally developed the concept of ecological carrying-capacity⁷⁶ as well as a model for environmental activism that is still used today. Borlaug and Vogt were both scientists, but their divergent approaches and conclusions were strongly shaped by their experiences and training. Their differing motivations do not invalidate their work, but rather demonstrate how multiple valid, but values-informed truths can co-exist. As scientists, we must accept that our training socializes us to value certain processes or outcomes in research. Data Feminism encourages interrogation of these passively inherited values and the attendant limitations these values place on our ability to 'see' the multiple, valid ways of approaching agricultural problems. 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 groups⁷⁷ and are better able to bring clarity to complex topics⁷⁸⁻⁸⁰.

4.2 The importance of diverse framings

Today, an increasing availability of diversely framed reflections concerning the Green Revolution that Borlaug's work contributed to has led to significantly more nuanced understandings of the motivations driving the Green Revolution, as well as the complex and contested impacts it had⁸¹. As society navigates modern challenges to food systems, scientists must value and incorporate diverse voices to create fair and equitable paths for future food production. Policy work has shown that the broader the set of framings available, the greater the possibility for more equitable solutions⁸². It follows that supporting diversity in agricultural scientists is a necessary corollary⁸³.

5. Conclusions

For agricultural researchers, engaging with Data Feminism need not be overwhelming nor demand world changing activities; it simply asks that one reflect on power disparities and values embedded in their research. Agricultural scientists who examine, challenge, and work to redistribute power can uniquely contribute to ongoing work towards agricultural (and social) equity and may concomitantly experience positive impacts on research creativity and stakeholder participation. Furthermore, agricultural scientists who build self-awareness of their socialized values and how those inform their perceived problems and solutions in agriculture are better equipped to recognize, incorporate, and solicit diverse framings, which promotes better outcomes for agricultural research overall. We hope this perspective demonstrates both the worthiness and feasibility of such pursuits.

Author contributions statement

VN conceived and wrote the first draft of the manuscript; AC and SG were major contributors in writing the manuscript; VN, AC, SG, AB, and DW contributed to editing and approved the final manuscript.

Acknowledgements

This study received no funding. Figure 1 was created using the Academic plan of BioRender.com
Nichols, V. (2024) <https://BioRender.com/m69i249>

Competing Interests

All authors declare no financial or non-financial competing interests

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Bibliography

1. Isett, C. & Miller, S. *The Social History of Agriculture: From the Origins to the Current Crisis*. (Rowman & Littlefield, 2016).
2. Scott, J. C. *Against the Grain: A Deep History of the Earliest States*. (Yale University Press, 2017).
3. Dencik, L., Hintz, A., Redden, J. & Treré, E. Exploring Data Justice: Conceptions, Applications and Directions. *Inf. Commun. Soc.* **22**, 873–881 (2019).
4. Iliadis, A. & Russo, F. Critical data studies: An introduction. *Big Data Soc.* **3**, 2053951716674238 (2016).
5. Diakopoulos, N. Algorithmic Accountability: Journalistic investigation of computational power structures. *Digit. Journal.* **3**, 398–415 (2015).
6. Couldry, N. & Mejias, U. A. The decolonial turn in data and technology research: what is at stake and where is it heading? *Inf. Commun. Soc.* **26**, 786–802 (2023).
7. Ryan, A. B. Post-Positivist Approaches to Research. in *Researching and Writing your Thesis: a guide for postgraduate students* (eds. Antones, M. et al.) 12–26 (MACE: Maynooth Adult and Community Education, 2006).
8. Wit, M. M. de et al. Operating principles for collective scholar-activism: Early insights from the Agroecology Research-Action Collective. *J. Agric. Food Syst. Community Dev.* **10**, 319–337 (2021).
9. Allen, P. L. & Sachs, C. E. The social side of sustainability: Class, gender and race. *Sci. Cult.* (1991) doi:10.1080/09505439109526328.
10. Nicklay, J. A., Perrone, S. V. & Wauters, V. M. Becoming agroecologists: A pedagogical model to support graduate student learning and practice. *Front. Sustain. Food Syst.* **7**, (2023).
11. Wezel, A. et al. Agroecology as a science, a movement and a practice. A review. *Agron. Sustain. Dev.* **29**, 503–515 (2009).
12. Almerico, G. M. Food and identity: Food studies, cultural, and personal identity. *J. Int. Bus. Cult. Stud.* **8**, (2014).
13. D'Ignazio, C. & Klein, L. F. *Data Feminism*. (The MIT Press, 2020).
14. Crenshaw, K. Mapping the Margins: Intersectionality, Identity Politics, and Violence against Women of Color. *Stanford Law Rev.* **43**, 1241–1299 (1991).
15. Rissing, A., Burchfield, E. K., Spangler, K. A. & Schumacher, B. L. Implications of US agricultural data practices for sustainable food systems research. *Nat. Food* 1–5 (2023) doi:10.1038/s43016-023-00711-2.

16. Weber, M. *Economy and Society: An Outline of Interpretive Sociology*. (Bedminster Press, 1968).
17. Kelly, C. Exploited: The Unexpected Victims of Animal Agriculture. *Anim. Law* **30**, 103–138 (2024).
18. Brayboy, B. M. J. & Tachine, A. R. Myths, Erasure, and Violence: The Immoral Triad of the Morrill Act. *Native Am. Indig. Stud.* **8**, 139–144 (2021).
19. Nash, M. A. Entangled Pasts: Land-Grant Colleges and American Indian Dispossession. *Hist. Educ. Q.* **59**, 437–467 (2019).
20. Who Owns the Land? Agricultural Land Ownership by Race/Ethnicity. *Rural Am. Rural Dev. Perspect.* (2002) doi:10.22004/ag.econ.289693.
21. Copeland, R. W. In the Beginning: Origins of African American Real Property Ownership in the United States. *J. Black Stud.* **44**, 646–664 (2013).
22. Aoki, K. No Right to Own: The Early Twentieth-Century Alien Land Laws as a Prelude to Internment Symposium: The Long Shadow of Korematsu. *Boston Coll. Third World Law J.* **19**, 37–72 (1998).
23. Collins, P. H. Black Feminist Thought in the Matrix of Domination. in *Black feminist thought: Knowledge, consciousness, and the politics of empowerment* vol. 138 221–238 (1990).
24. Sachs, C. E. *The Invisible Farmers : Women in Agricultural Production*. (Totowa, N.J. : Rowman & Allanheld, 1983).
25. Braunstein, E. & Folbre, N. To Honor and Obey: Efficiency, Inequality, and Patriarchal Property Rights. *Fem. Econ.* **7**, 25–44 (2001).
26. *Equal Credit Opportunity Act. 15 U.S.C. § 1691*.
27. Leslie, I. S., Wypler, J. & Bell, M. M. Relational Agriculture: Gender, Sexuality, and Sustainability in U.S. Farming. *Soc. Nat. Resour.* **32**, 853–874 (2019).
28. Carpenter, S. The USDA discrimination cases: Pigford, in re Black farmers, Keepseagle, Garcia, and Love. *Drake J. Agric. Law* **17**, 1 (2012).
29. Fremstad, A. & Paul, M. Opening the Farm Gate to Women? The Gender Gap in U.S. Agriculture. *J. Econ. Issues* **54**, 124–141 (2020).
30. Pilgeram, R., Dentzman, K., Lewin, P. & Conley, K. How the USDA Changed the Way Women Farmers are Counted in the Census of Agriculture. *Choices* **35**, 1–10 (2020).
31. Acosta, M. *et al.* What does it Mean to Make a ‘Joint’ Decision? Unpacking Intra-household Decision Making in Agriculture: Implications for Policy and Practice. *J. Dev. Stud.* **56**, 1210–1229 (2020).
32. Guilbeault, D. *et al.* Online images amplify gender bias. *Nature* **626**, 1049–1055 (2024).
33. Petrzalka, P., Sorensen, A. & Filipiak, J. Women Agricultural Landowners—Past Time to Put Them “On the Radar”. *Soc. Nat. Resour.* **31**, 853–864 (2018).
34. Trauger, A. *et al.* Agricultural education: Gender identity and knowledge exchange. *J. Rural Stud.* **24**, 432–439 (2008).
35. Basche, A. & Carter, A. Training future agriculture professionals in landowner–tenant conservation decision-making. *Nat. Sci. Educ.* **50**, e20035 (2021).
36. Carter, A. & Lopez, A. L. Rebranding the Farmer: Formula Story Revision and Masculine Symbolic Boundaries in US Agriculture. *Fem. Form.* **31**, 25–50 (2019).
37. Garnica, B. Linguistic Sexism and Society: A Woman’s Representation Through Language. *Language. Text. Society* <https://ltsj.online/2020-07-2-garnica/> (2020).
38. Carter, A. “We Don’t Equal Even Just One Man”: Gender and Social Control in Conservation Adoption. *Soc. Nat. Resour.* **32**, 893–910 (2019).
39. Eells, J. C. & Soulis, J. Do women farmland owners count in agricultural conservation? A review of research on women farmland owners in the United States. *J. Soil Water Conserv.* **68**, 121A–123A (2013).
40. Wheeler, S. A. What influences agricultural professionals’ views towards organic agriculture? *Ecol. Econ.* **65**, 145–154 (2008).
41. Montenegro de Wit, M. & Iles, A. Toward thick legitimacy: Creating a web of legitimacy for agroecology. *Elem. Sci. Anthr.* **4**, 000115 (2016).

42. Home page. *Practical Farmers of Iowa* <https://practicalfarmers.org/>.
43. Asprooth, L., Norton, M. & Galt, R. The adoption of conservation practices in the Corn Belt the role of one formal farmer network, Practical Farmers of Iowa. *Agric. Hum. Values* **40**, 1559–1580 (2023).
44. Richard & Thompson, S. The on-farm research program of Practical Farmers of Iowa. *Am. J. Altern. Agric.* **5**, 163–167 (1990).
45. Davis, A. S., Hill, J. D., Chase, C. A., Johanns, A. M. & Liebman, M. Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. *PLOS ONE* **7**, e47149 (2012).
46. Women, Food and Agriculture Network. *Women, Food and Agriculture Network* <https://wfan.org>.
47. Brehm, T. & Culman, S. Soil degradation and crop yield declines persist 5 years after pipeline installations. *Soil Sci. Soc. Am. J.* **87**, 350–364 (2023).
48. Tekeste, M. Z., Ebrahimi, E., Hanna, M. H., Neideigh, E. R. & Horton, R. Effect of subsoil tillage during pipeline construction activities on near-term soil physical properties and crop yields in the right-of-way. *Soil Use Manag.* **37**, 545–555 (2021).
49. Brehm, T. & Culman, S. Pipeline installation effects on soils and plants: A review and quantitative synthesis. *Agrosystems Geosci. Environ.* **5**, e20312 (2022).
50. Miguez, F. E. & Poffenbarger, H. How can we estimate optimum fertilizer rates with accuracy and precision? *Agric. Environ. Lett.* **7**, e20075 (2022).
51. Iowa Nitrogen Initiative. *Department of Agronomy* <https://www.agron.iastate.edu/portfolio/iowa-nitrogen-initiative/>.
52. Peltier, C. An Application of Two-Eyed Seeing: Indigenous Research Methods With Participatory Action Research. *Int. J. Qual. Methods* **17**, 1609406918812346 (2018).
53. USDA - National Agricultural Statistics Service - Publications - National Crop Progress - Terms and Definitions. https://www.nass.usda.gov/Publications/National_Crop_Progress/Terms_and_Definitions/index.php#days.
54. Earl, R. Prediction of trafficability and workability from soil moisture deficit. *Soil Tillage Res.* **40**, 155–168 (1997).
55. Huber, I., Wang, L., Hatfield, J. L., Hanna, H. M. & Archontoulis, S. V. Modeling days suitable for fieldwork using machine learning, process-based, and rule-based models. *Agric. Syst.* **206**, 103603 (2023).
56. Bellon, M. & Reeves, J. *Quantitative Analysis of Data from Participatory Methods in Plant Breeding*. (International Maize and Wheat Improvement Center, 2002).
57. Ceccarelli, S. & Grando, S. Participatory plant breeding: Who did it, who does it and where? *Exp. Agric.* **56**, 1–11 (2020).
58. Snapp, S. Quantifying farmer evaluation of technologies: the mother and baby trial design. in *Quantitative Analysis of Data from Participatory Methods in Plant Breeding* (CIMMYT, Mexico, 2002).
59. Macedo, I., Pittelkow, C. M., Terra, J. A., Castillo, J. & Roel, A. The power of on-farm data for improved agronomy. *Glob. Food Secur.* **40**, 100752 (2024).
60. Puntel, L. A., Thompson, L. J. & Mieno, T. Leveraging digital agriculture for on-farm testing of technologies. *Front. Agron.* **6**, (2024).
61. Lacoste, M. *et al.* On-Farm Experimentation to transform global agriculture. *Nat. Food* **3**, 11–18 (2022).
62. Chaney, D. *How to Conduct Research on Your Farm or Ranch*. <https://www.sare.org/resources/how-to-conduct-research-on-your-farm-or-ranch/> (2017).
63. Orozco, J. P., Hathaway, M., Velez, T., Estrada, H. & Tobey, E. Farmers Guide to Conducting On-Farm Research. *Organic Farming Research Foundation* <https://ofrf.org/reports/farmers-guide-to-conducting-on-farm-research/> (2023).
64. Toffolini, Q. & Jeuffroy, M.-H. On-farm experimentation practices and associated farmer-researcher relationships: a systematic literature review. *Agron. Sustain. Dev.* **42**, 114 (2022).

65. Jackson-Smith, D. & Veisi, H. A typology to guide design and assessment of participatory farming research projects. *Socio-Ecol. Pract. Res.* **5**, 159–174 (2023).
66. Liebig, M. A., Doran, J. W. & Francis, C. A. “Work-a-Day” Compensation in Farmer Participatory Research. *J. Nat. Resour. Life Sci. Educ.* **28**, 37–40 (1999).
67. Neher, D. *et al.* Proceedings - U.S.A Agroecology Summit 2023. *Coll. Agric. Life Sci. Fac. Publ.* (2023).
68. Thornley, K. Involving farmers in agricultural research: A farmer’s perspective. *Am. J. Altern. Agric.* **5**, 174–177 (1990).
69. Sherren, K., Thondhlana, G. & Jackson-Smith, D. *Opening Windows: Embracing New Perspectives and Practices in Natural Resource Social Sciences.* (Utah State University Press).
70. Thésée, G. A Tool of Massive Erosion: Scientific Knowledge in the Neo-Colonial Enterprise. in *Anti-Colonialism and Education* 25–42 (Brill, 2006). doi:10.1163/9789087901110_003.
71. Halpin, Z. T. Scientific objectivity and the concept of “the other”. *Womens Stud. Int. Forum* **12**, 285–294 (1989).
72. Norton, B. G. Beyond Positivist Ecology: Toward an Integrated Ecological Ethics. *Sci. Eng. Ethics* **14**, 581–592 (2008).
73. S, B. Science may be objective, scientists are not always. *Facts Views Vis. ObGyn* **13**, 1–2.
74. Mann, C. *The Wizard and the Prophet.* (Vintage, New York, NY, 2019).
75. Borlaug, N. E. The Green Revolution: For Bread and Peace. *Bull. At. Sci.* (1971).
76. Sayre, N. F. The Genesis, History, and Limits of Carrying Capacity. *Ann. Assoc. Am. Geogr.* **98**, 120–134 (2008).
77. Jordan, N. *et al.* To meet grand challenges, agricultural scientists must engage in the politics of constructive collective action. *Crop Sci.* **61**, 24–31 (2021).
78. Hill, J. The sobering truth about corn ethanol. *Proc. Natl. Acad. Sci.* **119**, e2200997119 (2022).
79. Kniss, A. Have genetically engineered herbicide-resistant crops increased or decreased herbicide use? *A Plant Out of Place* <https://plantoutofplace.com/2018/12/have-genetically-engineered-herbicide-resistant-crops-increased-or-decreased-herbicide-use/> (2018).
80. Weisberger, D., Ray, M. A., Basinger, N. T. & Thompson, J. J. Chemical, Ecological, Other? Identifying Weed Management Typologies Within Industrialized Cropping Systems in Georgia (U.S.). *Agric. Hum. Values* 1–19 doi:10.1007/s10460-023-10530-7.
81. The Man Who Tried To Feed The World | American Experience | PBS. <https://www.pbs.org/wgbh/americanexperience/films/man-who-tried-to-feed-the-world/>.
82. van Ostaijen, M. & Jhagroe, S. “Get those voices at the table!”: Interview with Deborah Stone. *Policy Sci.* **48**, 127–133 (2015).
83. Demery, A.-J. C. & Pipkin, M. A. Safe fieldwork strategies for at-risk individuals, their supervisors and institutions. *Nat. Ecol. Evol.* **5**, 5–9 (2021).