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Toward thick legitimacy: Creating a web of legitimacy for agroecology

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Abstract

Legitimacy is at the heart of knowledge politics surrounding agriculture and food. When people accept industrial food practices as credible and authoritative, they are consenting to their use and existence. With their thick legitimacy, industrial food systems paralyze the growth of alternative agricultures, including agroecology. Questions of how alternative agricultures can attain their own thick legitimacy in order to compete with, and displace, that of industrial food have not yet attracted much scrutiny. We show that both agroecological and scientific legitimacy grow out of a web of legitimation processes in the scientific, policy, political, legal, practice, and civic arenas. Crucially, legitimation often comes through meeting what we call 'credibility tests'. Agroecologists can learn to navigate these co-constituted, multiple bases of legitimacy by paying attention to how credibility tests are currently being set in each arena, and beginning to recalibrate these tests to open more room for agroecology. Using a schematic of three non-exclusive pathways, we explore some possible practical interventions that agroecologists and other advocates of alternative agricultures could take. These pathways include: leveraging, while also reshaping, the existing standards and practices of science; extending influence into policy, legal, practical, and civic arenas; and centering attention on the ethical legitimacy of food systems. We conclude that agroecologists can benefit from considering how to build legitimacy for their work.

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Introduction

In 1950, J.I. Rodale appeared before a US Senate committee hearing to attest to the benefits of what would become organic agriculture. Listening to Rodale proclaim the merits of compost, crop rotations, and strictly limited synthetic inputs, the politicians and fellow scientist witnesses rejected his evidence as emotional, irrational, and unscientific (Peters, 1979). Two decades later, Secretary of Agriculture Earl Butz declared: "We can go back to organic farming if we must – we know how to do it. However, before we move in that direction, someone must decide which 50 million of our people will starve" (Obach, 2015). Remarkably, organic food appears less oddball today, gracing the covers of popular magazines, supplying shelves from the White House to Whole Foods to Wal-Mart, and expanding market sales at a rate faster than conventional production.

One critical reason for this transition is legitimacy: organic agriculture has become more authoritative for many actor groups. In industrialized countries from Europe to North America, advocates have labored for decades to attract farmers to organic methods, build certification schemes to draw consumers and companies, convince government officials to enact rules, and magnify scientist interest in doing research (Obach, 2015). In the US, the past decade has seen the launch of numerous organic product lines and the conversion of substantial acreage to organic farming (Reganold and Wachter, 2016). Nonetheless, the legitimacy of contemporary organic agriculture remains somewhat tenuous in an era of dominant neoliberal economic philosophy. What we call 'thin legitimacy' derives mostly from market demand and policy interventions that enable consumers to identify and purchase certified products. Nationwide surveys suggest that most consumers value organic agriculture primarily as a means to eat more nutritiously and protect their families from toxic risks (Szasz, 2007). Thus, if organic food were to lose any of its health appeal (perhaps through scientific controversy over its nutritional merit), consumers could turn away. Similarly, if foreign competition in the organic sector achieves a lower price, shoppers and retailers might redirect their purchases to imports, undercutting local and regional producers. In other words, as long as the market is still largely 'disembedded' from society, instrumentalist and market impulses (c.f. Hinrichs, 2000; Polanyi, 1944) will tend to direct development of any alternative agri-food paradigm.

Agroecologists, organic food advocates, and others can learn much from considering the potential power of legitimacy in hastening the wider use of alternative agricultures. Legitimacy, put simply, means that people accept something – knowledge, norms, customs, or technologies – as credible and authoritative, and express or practice it widely (e.g., Heazle and Kane, 2016; Leino and Peltomaa, 2012; Jasanoff and Martello, 2004; Dogan, 1992). To date, how legitimacy is attained and upheld has been insufficiently accounted for in alternative agricultures. In this article, we investigate the knowledge politics that underwrite, and provoke challenges to, the dominant political economy of agriculture. Agroecologists can help expand the legitimacy of alternative agricultures by carefully analyzing how – and by whom – knowledge comes to be considered authoritative in particular contexts. We show that, crucially, legitimacy does not have a single base: something can become legitimate through a 'coproduced' bundle of processes, including: scientific validation, recognition in policy-making and government, practical testing against experiences, and verification by civil society actors. [1] Collectively, these processes can engender 'thick legitimacy': authority that cannot unravel easily because it is multi-stranded and broad-based. It is authority that is woven into the knowledge-making of scientific and political institutions, and embedded in widely practiced social conventions. Understanding the nature of thick legitimacy can help agroecologists better appreciate why, how, and by whom their knowledge and activity has been marginalized – and begin to transform their situation.

Drawing on Science and Technology Studies (STS) scholarship,[2] we examine the ways in which scientific knowledge is legitimated, not only in scientific but also in policy, political, legal, and civic contexts. We then argue that, to garner greater legitimacy, agroecology and other alternative agricultures can follow at least three 'paths':

(1) **Building from, but updating, the existing standards and practices of science in assessing rigor in agricultural research.** By increasing the transparency of scientific research, encouraging methodological diversity and transdisciplinary work, and fostering publicly funded inquiry-based science related to agroecological principles, we can ease the way for agroecology to be considered scientifically legitimate.
(2) **Extending influence into policy, political, legal, practical, and civic arenas.** By learning how to meet the standards of knowledge-making and evidential proof prevailing in these arenas, agroecologists can gain greater legitimacy for their work. By devising new kinds of credibility tests tailored to the arenas, agroecologists can reshape these standards.
(3) **Centering attention on the ethical legitimacy of food systems**. By advancing an ethics of regeneration that emphasizes cyclical – not extractive – processes, we can create conditions for agroecology to become widely regarded as a new normal.

These paths are not mutually exclusive: they can reinforce each other. Sketching the paths, however, can help agroecologists better understand the strategies they could pursue over the next two decades. We end with examples of how the paths could be implemented; our hope is to instigate discussion of the importance of thick legitimacy in nurturing alternative agricultures.

Mapping agroecology epistemic politics

Before we discuss how STS can help agroecologists in their pursuit of legitimacy, we map the epistemic terrain of agroecology. Three questions warrant attention: First, who are agroecologists? Second, what is the external politics of legitimacy that agroecologists are getting into? Third, who is agroecology trying to reach? Our purpose in this section is to highlight that even within agroecology, there can be contests over legitimacy (who has it? how to achieve it?). Agroecologists must also wrestle with an industrial food system that has thick legitimacy. To achieve change in that system calls for creating *alternative* thick legitimacy. Yet, builders of this robust authority must recognize legitimacy has varying meanings that depend on the particular actors, audiences, and context.

Like organic food proponents, agroecologists can take diverse identities. Several surveys of agroecology have considered the people who are agroecologists, their backgrounds, and their affiliations (Wezel et al., 2009; Wezel and Soldat, 2009; Méndez et al., 2013; Gliessman, 2013; Méndez et al., 2016). These works have mapped the history and evolution of agroecology dating back to at least the 1930s, in terms of Western scientific recognition. Wezel et al. (2009) traces distinct lineages of agroecology with separate emergences of 'science' in Germany, 'practice' in France, and 'movement' occurring alongside science and practice in both the US and Brazil, albeit with different emphases (more science in the US, more practice and movement in Brazil). By contrast, Méndez et al. (2013) and Gliessman (2013) depict agroecology as a co-production of science, practice, and movement. For these authors, the practice of agroecology reciprocally informs scientific theory, and the science is rooted in social movement resistance to Green Revolution interventions. Below, we explore how these dimensions of science, practice, and social movement create space for building legitimacy within and beyond agroecology, including whom agroecology is trying to reach, and what it aims to achieve.

Science

Many, if not most, people who describe themselves as 'agroecologists' would probably self-identify as qualified technical and scientific experts of some ilk. They tend to be largely agronomists and ecologists, but may be trained in other natural sciences (e.g. entomology, hydrology, conservation biology), social sciences (such as economics, political ecology, and anthropology), or humanities including law and philosophy. There can be wide variation in their understandings of what agroecology means, the importance of transdisciplinary research and practice, and the role of social movements (Méndez et al., 2013). Many agroecologists construe themselves as predominantly natural scientists focused on elucidating the ecological processes underlying farm and landscape-scale diversification practices. Others see themselves as 'transdisciplinary,' integrating methods and perspectives from fields such as political ecology and ethnography into ecology and agricultural science (e.g., Altieri and Toledo, 2011; Vandermeer and Perfecto, 2013). Some agroecologists are reluctant to recognize political questions or practice as intrinsically part of their research. Conversely, other agroecologists explicitly take on movement organizing roles, working directly with farmers and communities. Either of these two camps is likely to view the other as a less legitimate form of agroecology. Agroecology scientists also diverge in their conceptions of whether farmers and indigenous peoples can collaborate with researchers in generating valuable knowledge. The legitimacy of experiential and informal knowledge is thus another fracture line. These divergences notwithstanding, agroecology scientists on the whole still tend to exist on the fringes of agricultural science, and its established disciplinary hierarchy. Their knowledge and methods are considered less prestigious and valuable, raising the question of their legitimacy inside and outside science.

Practice

Many agroecologists are practitioners of some kind. They may be farmers, extension staff, NGO workers, and government and international policy-makers who work with agriculture. They have a spectrum of expertise, from agriculture to policy analysis, from practical inter-cropping in the field to modeling pest-plant dynamics. Farmers alone are remarkably diverse as a group, consisting of peasants, family farmers, and large-scale growers, pastoralists, dairy farmers, and fishers. As aforementioned, some agroecologists (especially those of the transdisciplinary bent) insist that farmers are doing agroecology. Nonetheless, we suspect, many, if not most, farmers do not describe themselves as agroecologists. They may or may not have familiarity with the nomenclature of 'agroecology' and its scientific concepts, even if they use or develop quasi-scientific methods in everyday work. Sometimes, farmers may hesitate to identify themselves as agroecologists for fear of local community ostracism or loss of access to government aid (Holt-Giménez, 2006). In turn, government and NGO technical staff, even social movement leaders (Delgado, 2008), may sometimes perceive themselves as the experts on agroecology, bringing knowledge to 'deprived' rural farmers to improve their productivity. These complicated relationships highlight the politics of expertise: who is counted as an expert, and how legitimacy is often bound up with seeking the identity of 'expert'.

Movement

Many agroecologists are part of social movements, though they may or may not be scientists. For example, La Via Campesina and the Landless Workers Movement (MST) in Brazil have accepted agroecology as a key philosophy in their organizing work, following perennial, and still open, internal debates (Delgado, 2010; Rosset and Martínez-Torres, 2012). Many sustainable food movements espouse some of the principles and practices of agroecology, albeit under names such as organic agriculture, permaculture, and biodynamic farming. Importantly, NGOs, community groups, and publics diverge in their views of the legitimacy of science. Some believe that science can provide valuable allies and evidence in support of alternative agricultures. But some farmer groups and peasant movements may reject science as subjugation, based on the history of Green Revolution science and on the contemporary politics of genetically engineered crops and animals (Shiva, 1991). In their eyes, science has a habit of devaluing the cultural heritage and experiential knowledge of local or indigenous peoples. Similarly, many farmers embrace organic practices out of suspicion of agricultural science's tendency to destroy what they see as healthy soils (Obach, 2015). Their skepticism is not necessarily rooted in antipathy to science per se – but in the ways that science has favored certain Western-centered and reductionist worldviews. By contrast, some consumer groups and popular health movements may rebuff science on principle; they may have religious, mystical, or other interpretations of what counts as meaningful knowledge. Science, then, can have multi-layered legitimacy questions, even amongst those who would endorse alternative agricultures.

Sitting in the shadow of industrial agriculture

What is the external politics of legitimacy? Like other alternative agricultures, agroecology is developing within not just a larger political economy but a larger epistemic political space. Most agroecologists in both the North and South have an inkling that they are treading in quicksand when they confront the supremacy of industrial food. They are already forced to defend their work as legitimate vis-à-vis seemingly impregnable industrial agriculture technologies and science (Rosset and Martínez-Torres, 2012). Reinforcing their historically accreted 'thick legitimacy', industrial agri-food actors skillfully argue that only their technologies, science, and research can feed people adequately and inexpensively. They portray alternative approaches as inefficient, anachronistic, elitist, exorbitant, or marginal (e.g., Stuart and Woroosz, 2012, 2013; Hamerschlag et al., 2015; Hinrichs, 2003). A number of European and Latin American policy institutions, along with the United Nations system, are beginning to accept agroecology as credible science.[3] Nonetheless, within North America in particular, agroecology still lacks credence amongst many influential actor groups and in powerful societal institutions. This situation exists because alternative agricultures rest in the long shadow of a highly legitimate (not just economically and politically powerful) industrial food system.

As many STS scholars observe, industrial food is publicly viewed as legitimate for a number of reasons (Iles et al., 2016). Scientific research and development have overcome many of agriculture's 'obstacles to nature' for productionist goals: the Haber-Bosch process enabled the capture of ambient nitrogen for synthetic fertilizers; plant breeders developed high-yielding, hybrid crop varieties; and a synergy between nutrition science, genetics, and pharmaceutical research bequeathed the modern broiler chicken. Technical standards, from the 1930s onwards, became a powerful way for government agencies and food companies to specify how crops and animals should be raised and processed into packaged products (Busch, 2011). These standards allowed industrial food companies to build complex supply chains; assure quality control and food safety across far-flung geographical locations; and transform agricultural matter into fungible ingredients. As numerous examples – including white bread and ground meat – attest to, consumer preferences for a modern industrial diet were cultivated through co-evolving technologies for production, processing, transportation, retail, and marketing (Otter, 2015; Bobrow-Strain, 2012). As industrial food systems began offering fish, fruits, nuts, meat, and leafy greens year-round, consumers grew accustomed to the apparent reliability of this bounty; seasons and biological constraints, they assumed, no longer played any role. Industrial agriculture therefore reflects science's powerful attributes, and has been internalized by most people within food systems as universally applicable and empirically true.

An underlying logic contributing to the strength of industrial agriculture is that humans should exert control over nature. There has been much scholarly work in anthropology, ethnobiology, and human geography, among other disciplines that investigates how societies relate to their environments (e.g., Ostrom, 1990; Maffi, 2005; Berkes, 2008). Some researchers have suggested the largest schism is between industrial and indigenous cultures: the former tend to view themselves as separate from – even dominant over – nature, while the latter view themselves as interdependent with nature, or simply *as* nature (Pretty et al., 2009). The success of modern agro-industry has been in coaxing this industrial-world epistemology into productivist practice. Whether in the form of pesticide sprays, clear-cut landscapes, or breeding technologies for an ever-bigger bird, people are understood to be fundamentally distinct from nature, with the responsibility to bring it under control. The job of scientists, then, becomes developing the tools and technologies to enable such subjugation to occur (Henke, 2008). The job of farmers, in turn, has become wielding those tools on the ground. Simplifying and rationalizing landscapes, they strive to make unwieldy ecosystems more legible; buoyed by science, their practices coalesce around achieving yield and increased labor efficiency litmus tests for (apparent) control (Scott, 1998; Van der Ploeg, 2008). Both farmers and scientists can pursue such activities with all the authority vested in approaches whose authority stems in a deep-rooted societal belief that nature's domination is a good (or even possible) idea (Merchant, 2015).

Industrial agriculture is also woven deeply into the market and into government institutions from legislatures to agricultural departments (e.g., Pretty, 1995; Magdoff, 2015). Policy systems imbue industrial agriculture with considerable legitimacy through favoring particular lines of research, technologies, and market development. Particularly in the US, subsidies have gone primarily to commodity crop producers but not to farmers who use diversified methods.[4] Government agencies are staffed and organized in terms of industrial farming needs. They fund research, education, and extension in sustainable agriculture at a pittance compared with funding for industrial/conventional agriculture (Vanloqueren and Baret, 2009; Carlisle and Miles, 2013; De Longe et al., 2016). The result is more research, more publishing, more technological development in arenas supporting productivist farming – a snowball effect creating heightened authority for industrial agriculture.

The food regimes literature (e.g., Friedmann and McMichael, 1989; McMichael, 2009) underscores the power of international trade and world markets in legitimating industrial food in many regions since the 1940s. Governments and firms first used trade rules to 'modernize' agricultural production in countries of the global South (the 'development project'), and later greased the rise of transnational companies, new international divisions of labor, export-led development, and relatively standardized conditions of production and consumption (the 'globalization project'). In the current neoliberal food regime, an array of bilateral and multilateral free trade agreements makes it increasingly difficult for smaller, diversified producers, particularly in developing countries, to maintain their indigenous food production systems. In sum, this agri-food system benefits from thick legitimacy reflecting its history of increasingly path-dependent advantages.

Many actor-audiences and bases of legitimacy

In such a situation, agroecologists must consider who and what they are trying to reach. Many studies have reflected on the challenges of how agroecology might expand and displace industrial food systems. They note strategies such as 'scaling out', enshrining agroecology in government policies, changing how agricultural technicians are trained, or investing more resources into research and development (R&D) (e.g., Nelson et al., 2009; Altieri et al., 2012; Gliessman, 2013; DeLonge et al., 2016). Less considered is how agroecology must secure its legitimacy amongst multiple audiences with widely divergent epistemologies, values, histories, and concerns. In considering the foregoing examples of how industrial agriculture's thick legitimacy has been created over many decades, we have seen a good number of actor groups, some of whom benefit from the dominant system, many more of whom do not, but nearly all of whom actively support it through their behavior and beliefs. They may not intentionally do so – it may stem from their socialization or habits. Shoppers, for example, may buy processed macaroni & cheese or boxed pancake mix because it is convenient and familiar (Warde, 1997; DuPuis, 2002). Industrialized food systems benefit from widespread habituation and internalized suppositions that cheap, efficient food benefits society on the whole. These groups can be enabled to see the current system as historically contingent and structured by and for a relatively elite few. It is constructed through policies, markets, standards, the media, advertising, science and technology, and historical shaping of cultural norms and beliefs (Strasser, 1989; Freidberg, 2004; Busch, 2011). It is anything but natural or normal.

Discussing the use of science as a political resource in modern democratic societies, Ezrahi (1990) emphasizes that legitimacy is created through dialogue: between actors who are invoking this property and audiences who are attesting that it exists. That is, legitimacy exists when 'witnessing' audiences recognize, engage with, and accept its presence (willingly or not), according to their conventions and beliefs. Conversely, legitimacy can be eroded through substantial challenges that these audiences come to accept as authoritative in their own right. People may be both actors and audiences at once (e.g, government officials are audiences for NGOs but are also actors performing for civil society). Much work to create legitimacy entails creating and sustaining both witnesses and practices of witnessing. As a consequence, STS scholars suggest, legitimacy can take on different characteristics, depending on the settings, the actors, and the audiences involved. For both alternative agricultures and industrial food, key actor-audiences include farmers, government officials, NGOs, publics, consumers, business people, and scientists, each of whom must come to believe that agroecology and other alternative agricultures offer substantial merits compared to industrial agriculture. At an institutional level, government departments, courts, universities, and other bodies must also come to integrate agroecology into their cultures and procedures.

Creating thick legitimacy, then, requires the bundling of scientific, political, civic, legal, practical, economic, and other means of building and stabilizing authority (Table 1). These means depend on 'credibility tests' that must be satisfied before something can be recognized as legitimate. Such tests take the form of standards of evidence, reasoning conventions, compliance with values, support through relationships of trust, and other mechanisms of corroboration. Different institutional and social arenas can develop their own credibility tests that reflect their histories, epistemologies, and cultures. To be legitimate in civic terms, for example, scientific knowledge may need more than authorization by a community of scientists according to peer review norms. It needs to survive the questions and arguments of a diverse lay public, some of whom distrust science. Similarly, for scientific knowledge to be considered legitimate on legal grounds, it must meet the criteria that judges use to determine whether technical evidence and expert testimony can be admitted into trial proceedings. Judges can assert the authority to rule on the status of science, particularly on the frontiers of new science, such as DNA testing.

If each of these scientific, political, civic, legal, and practical means constitutes a 'thread,' their coproduction creates a web that legitimates the knowledge in question (or does not). We suggest that it is this web that can enable thick legitimacy to develop in particular (Figure 1). As various threads of legitimacy intertwine more densely, the legitimacy of something becomes more robust in the face of challenges, whether these are political, knowledge-based, economic, or legal. Importantly, thick legitimacy does not imply that something is environmentally and socially positive or benign. Either industrial agriculture or agroecology could have thick legitimacy, despite their diverging effects on humans and ecosystems. Rather, it is the politics of creating a thick legitimacy – in which one paradigm can displace another – that is our focus in this paper.[5]

Table 1. Bundled 'threads' of legitimacy[a]

Categories[b]	Threads
Scientific	Knowledge becomes legitimate because it is generated and certified through scientific reasoning procedures (e.g., scientists using peer review to appraise a scientific claim).
Policy/Politics	Knowledge is legitimate when it meets the demands and reasoning procedures of legislative and government institutions (e.g., reaching a political agenda; policy analysts using cost-benefit analysis to make decisions).
Legal	Knowledge becomes legitimate once it has been tested according to legal standards and judicial reasoning (e.g., courts deciding that expert testimony or scientific claims can be admitted, or making a ruling).
Practical	Knowledge is made legitimate through being tested in everyday practices and experiences (e.g., farmers deciding whether a farming method is effective; farmers entrusting in the experiences of other farmers).
Civic	Knowledge becomes legitimate according to the criteria and demands of social movements, citizens, and civil societies (e.g., NGOs applying their standards to gauge the trustworthiness of science; citizens discussing scientific developments in terms of their ethical compass).

[a]An economic thread of legitimacy also exists. Here, knowledge is made legitimate through meeting economic tests, such as generating monetary revenues or livelihood wealth, or aiding farmers to survive in the market. Economic tests vary according to the economic system in question; this may range from capitalist markets and global trade to peasant markets and use value exchanges. We do not examine economic legitimation in this paper because we focus on non-economic forms of legitimation. Economic legitimation in North America is also very much tied to a dominant market model.

[b]In practice, these categories are highly fluid. Many farmers who authenticate 'practical' legitimacy, for example, belong to social movements where knowledge is validated in a 'civic' context.

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Building legitimacy through meeting credibility tests in multiple arenas

In this section, we consider the kinds of credibility tests that prevail in several of the major institutional and social arenas that agroecologists of all varieties must work with or within. Drawing on Science and Technology Studies scholarship, we review what sorts of criteria and processes for authenticating legitimacy and knowledge claims are used in the scientific, governmental (political, policy, and legal), practice, and civil society arenas. For those readers who would like to learn more about STS, please consult Appendix S1 for a brief primer on STS and the role of boundary work in producing knowledge claims.

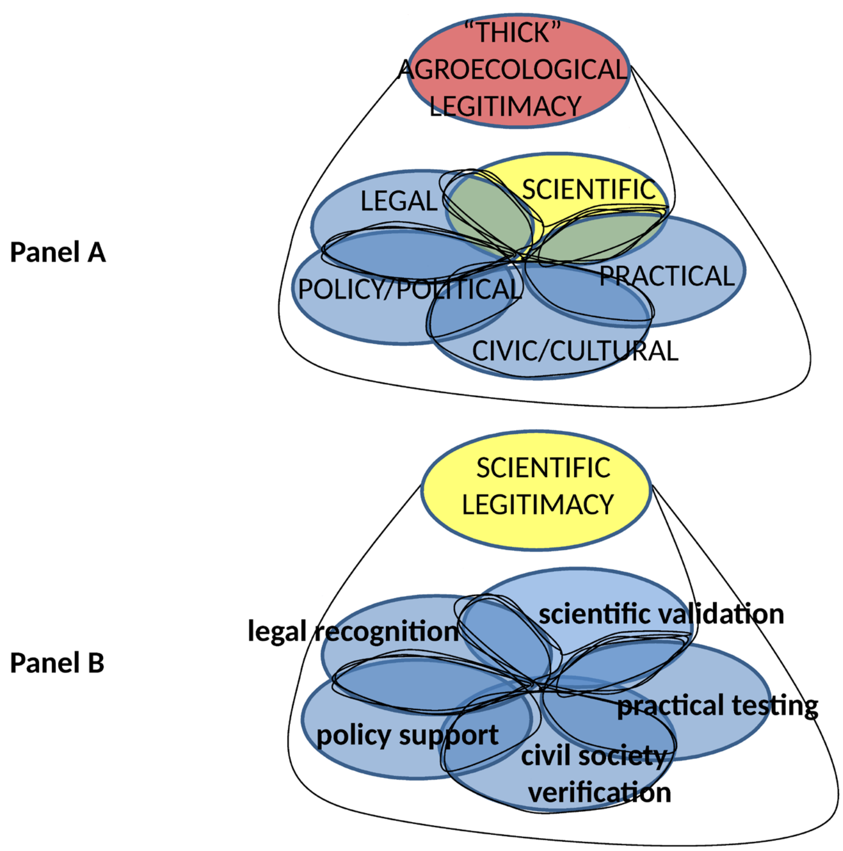

Figure 1

Bases of agroecological legitimacy.

Agroecology legitimacy does not have a single base: something can become legitimate through a bundle of processes, based in science, policy, practice, law, and civil society (panel A). Agroecologists have long implicitly recognized this breadth in defining agroecology as an inseparable science, practice, and social movement. Less recognized is that the legitimacy of science is also not borne up only by its own legs. Science requires, for example: scientific validation, recognition in policy-making, practical testing in everyday practices and experiences, and verification by civil society actors (panel B). Thick legitimacy comes from creating a web of legitimation founded on these multiple overlapping bases of legitimacy. When you "tug" at the scientific basis of legitimacy (panel A), you discover that it cannot be disentangled neatly from the other bases of legitimacy with which science/knowledge is co-constituted.

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Scientific validation of knowledge

Most scientists would say that science is intrinsically authoritative because it uses empirical methods for studying the world impartially. Yet the history of science reveals long-running efforts by early scientists to build infrastructures for investigating nature. For example, the scientific experiment emerged as a new form of trial, in which theories and hypotheses were tested against evidence, and the procedure and results observed by authoritative witnesses, such as socially prestigious aristocrats (e.g. Shapin and Shaeffer, 2011). In modern times, internal community debates, peer review, and publication serve as major witnessing mechanisms, relying on fellow scientists to authenticate science (Jasanoff,1990; Shapin, 1995). The authority of science is not a natural property but has been built through the very practices and institutions science needs to function: these systems constantly work to define and validate knowledge as scientific, objective, and reliable. Underlying these systems is the boundary work that scientists and others engage in.

Scientists also gain legitimacy within scientific communities through the eyes of others both inside and outside of science: through being regarded as 'experts' in producing scientific and technical knowledge. The politics of recognizing expertise therefore play a central role in shaping legitimacy. Scientists frequently qualify as trustworthy experts through their cumulative education, training, and work practices. They have fulfilled certain standards of competency (a PhD, a post-doc, a tenure-track job); they have mentored and taught students; they have carefully cultivated a publishing record. Critically, they belong to knowledge communities – for example, the chemistry profession – that are defined as scientific or technical disciplines. This membership in itself strengthens their credibility, particularly when, as Knorr-Cetina (1999) argues, scientists are socialized into using sets of research methods, tools of investigation, theories, and objects of research that characterize their field. Outside of these scientific communities, governments can bestow recognition on scientists through inviting them to provide expert advice, appear at public hearings, and do research for policy purposes (Hilgartner, 2000). Similarly, journalists and civil society members can affirm scientific expertise (and not other types of expertise) by seeking it out.

Over the past 150 years, scientists have increasingly reserved the power and capacity to make and judge science to themselves – a role that lay people without scientific training supposedly cannot perform. They have developed and regulated the criteria and conventions by which we recognize knowledge as 'sound science' or 'good economics', with comparatively little questioning from civil society actors or government officials (Sismondo, 2009). Scientists typically ask questions such as: Are the correct methods being used? How much evidence is needed to prove that something exists? Can we trust these other scientists, or are they veering into political territory they should leave untouched? (Latour and Woolgar, 1986). However, with the advent of greater societal skepticism toward science (see below), such tests have now spread to policy-makers, to the mass media, and to civil society organizations. Scientific cultures have become more interwoven with other knowledge communities.

Policy, law and politics: Integrating knowledge into institutional reasoning

In modern societies, public institutions such as legislatures, government departments, and courts form hugely powerful arenas for recognizing and using knowledge. Through their political and legal capacity, they can each set tests of credibility within their arenas that knowledge must meet before it can enter into their organizational domains and influence their decisions. Complicated dynamics surround the knowledge of public institutions. The prestige and reach of particular kinds of scientific and technical (S&T) knowledge can rise when it is incorporated into the reasoning processes of public institutions. In turn, institutions can enhance their legitimacy through being publicly seen to rely on science, an authoritative form of knowledge, in their reasoning. Importantly for agroecology, the shift from subaltern to dominant epistemology can occur through subtle changes of political behavior, as legislatures and bureaucratic departments change the nature of the science they draw upon, gradually acknowledging other knowledge as relevant.

Also important from the standpoint of agroecology is recognizing that public institutions tend to share foundational assumptions and practices when soliciting, evaluating, and using knowledge. S&T knowledge is peculiarly potent in the politics and decision-making of US public institutions, reflecting deep-rooted colonial prejudices against experiential, historical, and traditional narrative knowledge (Brickman et al., 1985). But the epistemic cultures of public institutions can diverge considerably, making for strong tensions between decision-making arenas at times.

Government agencies

This pattern is perhaps most obvious in how science has permeated the organization and practice of government agencies such as the Food and Drug Administration or the US Department of Agriculture. Beginning in the Progressive era, bureaucratic departments formed their administrative repertoires around technical knowledge and tools, often in alliance with scientists and engineers (Porter, 1996). Using scientific management principles, agencies endeavored to maximize efficient extraction of forest, water, and land resources for the public welfare. They pioneered the use of quantitative tools, such as cost-benefit analysis and risk assessments, to standardize and justify their decisions on objective grounds.

Since the 1960s, the regulatory state has materialized to govern societal challenges ranging from environmental protection to food safety assurance.[6] Legislatures, courts, and government agencies now often require the use of technical knowledge to guide policy-making. The resultant 'regulatory science' combines "elements of scientific evidence and reasoning with large doses of political judgment" (Jasanoff, 1990: 229). It is a science "that combines elements of scientific evidence and reasoning with large doses of social and political judgement" (Jasanoff, 1990: 229). It commonly deals with great data uncertainties and nascent scientific methodologies. In implementing a Congress law on chemicals, for example, US EPA staff are mandated to review existing toxicological data and convene a panel of external scientific advisors to reach a recommendation as to whether a chemical poses an unreasonable risk to human health (Cranor, 2011). Drawing on economic and business information, the law forces the agency to compare the benefits and costs of controlling the chemical. Within this regulatory science culture, government agency regulators do credibility tests to evaluate whether knowledge can be used in their procedures. They question: Have the right scientists been put on advisory panels? Do economic benefits warrant intervention? Have the data been put through the appropriate technical analysis procedures?[7] Are the results defined in terms of risk probabilities?

Legislatures

In principle, politicians supervise government bureaucracies as the democratic representative of public voices. While legislators and their staff rely extensively on technical analysis in designing and enacting laws, they also function in a densely political space. They can be driven by an array of political considerations – including lobbying, donations, voter demands, their own ideological predilections – that override any reasonable interpretation of what science would suggest (Lahsen, 2005; McCright and Dunlap, 2011).[8] Science may not play an influential role at times, especially in an era of neoliberal economic philosophy and increasingly volatile party politics (e.g., fissures within the Republican Party leading to a fortified right-wing bloc). Politicians may engage in vastly different credibility tests, compared to those of government agencies. In judging political viability, they wonder: Can this evidence satisfy most people in my party? Do my donors want me to do this? Does this science fit with my religious beliefs?

Court system

The US courts also use – and help commission – substantial amounts of S&T knowledge in their legal decision-making. They are supposed to supervise the decisions of legislatures and government bureaucracies to assure compliance with the Constitution, for example. The legal system approaches fact-finding differently from science. Whereas science attempts to prove, through experimentation and observation, whether a hypothesis is correct and may not reach complete certitude for some time, courts determine – based on adversarial cross-examination what the facts appear to be (Jasanoff, 1995). They then apply legal precedents to decide the outcome definitively. Courts and lawyers often apply specialized credibility tests (Cranor, 2011): What scientific evidence is needed to prove the link between pesticide exposure and health effects? Are new forms of science 'knowledge' according to legal standards?

In lawsuits brought by industry and citizen groups against government agencies, courts have a modern history of throwing out rules or laws that are not adequately based on science. They can set standards that effectively require more science to be made. Therefore, governments have progressively invested even more resources in producing risk assessment science, increasing the legitimacy of certain types of science in authorizing decisions (e.g, Brickman et al., 1985). As a result, a path dependency occurs, in which testing required by regulation produces more science, and legal systems gain credibility through upholding this scientific evaluation. It can be difficult for other forms of science to enter into the conversation, especially when the norms of establishing knowledge are different in science and the law.

Public funding

Legislatures and government agencies can substantially influence scientific research directions through their funding decisions and priorities. Legislatures, especially Congress at the federal level, can allocate funds through government agency budgets to scientific research. Government departments such as the USDA and the US Environmental Protection Agency not only have their own in-house research facilities but also maintain competitive grant schemes targeted at university and industry researchers. Typically, legislatures and government agencies devote inadequate resources to sustainable agriculture, let alone agroecology. For example, in 2014, the USDA provided $294 million to its NIFA competitive grant scheme – itself a tiny fraction compared to the overall USDA budget of $157.5 billion (De Longe et al., 2016). Of this NIFA money, only about $44 million (15%) was spent on researching agroecological practices and only $12 million (4%) went to 'transformative' agroecology research, combining both ecological and economic elements.

Another distinct challenge facing agroecology research are its amorphous disciplinary boundaries. Public funding institutions (and private foundations) often provide streams of resources that are narrowly framed within traditional disciplinary boundaries, making it difficult for agroecology to compete (Vandermeer and Perfecto, 2013; Méndez et al., 2016). Moreover, public research has increasingly emphasized the priorities of commercial interests, such as precursors for seeds that industry can patent or animal science that can improve livestock productivity (Kloppenburg, 2004). In 2002, the National Academy of Sciences reported that the USDA favors commodity crops, industrialized livestock production, technologies geared toward large-scale operations, and capital-intensive practices (Food and Water Watch, 2012).

Agroecology now confronts a new funding reality: eroding public funding for agricultural research means that the private sector has emerged as an important gatekeeper of both industry and academic science. In 2007, the USDA reported, private sources provided $6.7 billion for agricultural and food research, dwarfing the contributions from the federal government ($3 billion) and state governments ($1.37 billion) (King et al., 2012; Fuglie et al., 2012). Two years later, corporations, trade associations and foundations were spending $822 million on agricultural research at land-grant schools, compared to only $645 million from the USDA (Food and Water Watch, 2012). In the US, private investment has swung sharply since 1980 from agricultural chemicals and machinery to crop seeds and biotechnology. Unsurprisingly in this context, overall allocation of monies to agriculture (both public and private) has also shifted over time to industry-based research. In 2007, the private sector performed roughly 53% of total food and agricultural research in the US (King et al., 2012) – a proportion that has since expanded.

For obvious reasons, industry research prioritizes areas with the highest return on investment. They are unlikely to do agroecological work that refutes intellectual property, that leads to farming with fewer commercial inputs, and that thereby endangers the bottom line of the agricultural input complex. The growing dominance of privately funded research therefore colors the science used in policy-making, law, and politics.

Practical validation: Testing knowledge against experience

In modern societies, legitimation-by-practice is pervasive yet unnoticed by governments and many technical experts. From biologists to car mechanics, practice commonly serves as an authoritative trial of knowledge. Practice is an ancient means of making knowledge credible. Through watching how plants with different characteristics fared, and learning which animals were more responsive to human contact, early farmers domesticated crops and animals (Murphy, 2007). Practice can generate authority through overlapping processes. First, in many cases, credibility comes from testing ideas and activities against their practical consequences: people can attest whether or not these are 'effective' or 'working' (Dewey, 2005 [1932]; Hassanein and Kloppenburg, 1995). People can produce empirical evidence through their observation and experience even if they are not formally trained as scientists. Depending on their cultural mores and cognitive frames, people may find practical tests more compelling and trustworthy than the arguments that scientists and technicians offer, particularly ones they have reason to doubt (Carolan, 2006a; Delgado, 2010). Farmers, for example, are often suspicious of advice to change their traditional methods.

Second, practical credibility is also social, and can be built through relationships that people form with their peers. There are many ways in which relationships may make knowledge more authoritative. People may willingly accept knowledge that they believe has been validated by other people in whom they trust, or find influential, because of their everyday expertise, power, charisma, or social status (e.g., Siegrist and Cvetkovich, 2000). STS scholars suggest that the modern definition of expertise as exclusive to technically trained people is limited. Expertise can be found in people who hold local, situated, or embodied knowledge under conditions in which conventional experts may not have sufficient information – or may not have access to the sites and people for attaining it (Fischer, 2000; Jasanoff and Martello, 2004; Corburn, 2005). People may also engage in peer-to-peer exchanges and audits of knowledge.[9] There are numerous examples of farmer-led groups, from Landcare in Australia to the Latin American *campesino-a-campesino* movement (Sobels et al., 2001; Bell, 2004; Holt-Giménez, 2006; Rosset et al., 2011). In many cultures, peers are more culturally familiar and credible than technical experts. There are hierarchies in this form of legitimation too: Some farmers become *promotores* – leading farmers who take responsibility for educating their peers.

STS scholars have studied the varied tests that practitioners have developed to determine whether knowledge has practical legitimacy. 'Field trials' are one way in which visual or material evidence emerges through practical demonstrations. As the US agricultural cooperative extension system emerged in the early 1900s, advisers developed an official practice of undertaking field trials whenever they introduced a new technology or method (Henke, 2008). Farmers frequently reject new knowledge as 'unsuitable' for their local soil, water, and climate conditions. By using field trials, advisers could gradually enlist leading farmers into new practices about which they were wary. Farmers could verify that adopting a new practice resulted in a pile of squash higher than that of the adjoining plot using existing practices. Framing scientific evidence in terms of the concerns that people hold can also establish practical legitimacy. Warner (2007) shows that agroecological partnerships in California's wine industry succeeded in part because they emphasized building scientific evidence that applying biocontrol methods could substantially reduce pesticide use. In the context of intensifying concerns about the human and ecological costs of pesticides, vintners found this proof highly compelling. Other food system participants can generate their own demands for demonstrations. Financial spreadsheets can show organic food is generating sales; gardens can prove to skeptical schools and hospitals that it is indeed feasible to source vegetables locally. Crucially, many of these means of proof are not developed by technical experts but by practitioners.

Legitimation-by-practice may occur through diverse food system actors asking questions and seeking answers in their experiences. Drawing on their experiences, farmers and gardeners might ask: does agroecology actually work in their field? Can inter-cropping lead to higher soil fertility? For many conventional farmers and small retailers, proof that supplying organic food benefits them comes from consumers buying larger amounts or being willing to pay higher prices (Obach, 2015). While practical testing of credibility can be powerful, it may be partial and thus deceptive. Experience may not, in fact, be informative. Practical testing depends on the making of conventions to measure whether or not something stands up to experience. How is experience interpreted? Whose practice counts? Do these conventions reflect power inequalities between people in their status in peer-to-peer networks? Moreover, practically verified knowledge tends to have low or ambiguous status in the scientific community, despite the sympathy of some scientists. A scientific study, however poorly done, usually outweighs a farmer's testimony or a NGO report regarding the efficacy of an experimental practice. Inversely, practically legitimated science can incite significant civil society organizing and government attention.

Civic validation: Remaking societal norms of legitimacy

Over the past 60 years, civic tests for legitimating knowledge have become increasingly influential in shaping policy and politics, at least in some areas. Matters from hazardous waste dumps to indigenous land rights have turned into national controversies, felt in everyday conversations and seen in newspaper headlines. In these civic skirmishes, a large assortment of social actors have disputed over whether governments or industry must recognize and respond to the petitions of local people. These actors have tussled over whose pollution measurements are accurate, which normative judgements are valid, and what the law requires. Debated in schools and churches, communicated through the mass media, and permeating family circles, the social issues have become civically salient. In other words, civic actors are changing the criteria and evidence that people use to gauge the legitimacy of knowledge. In doing so, these actors may achieve real power: their views cannot just be disregarded by indifferent bureaucrats or amoral managers, since they can potentially sway public opinion, or direct spending habits. Dominant expert knowledge can be destabilized and subaltern science normalized.

Civic tests occur in a complex milieu of both heightened public regard and deep societal skepticism towards science. Following the post-World War II burst of optimism, public and industry critics grew more willing to interrogate scientific claims. The dubious legacies of DDT, petroleum-based fertilizers, and nuclear technologies, amongst others, dampened faith in science as infallible and drew attention to its unforeseen consequences (Fischer, 2000; Sismondo, 2009). Today, such scrutiny continues and spans the political spectrum: Republican wars on climate science, consumer campaigns against bisphenol-A (e.g., McCright and Dunlap, 2011; Lubitow, 2013). Invoking science as the sole basis of legitimacy for one's practices has not only become insufficient; in some contexts, it has become a liability. At the same time, science remains a peculiarly powerful touchstone: almost everyone refers to science as the dependable arbiter of what knowledge is. On the political left, it can be seen in the belief that climate science will compellingly convince people that transitions to low-carbon economies are essential. Simultaneously, industry-supported groups have become remarkably adept at leveraging the authority of science. From downplaying the perils of lead in paint (Markowitz and Rosner, 2002) to crafting scientific consensus around GMOs (Wise, 2015) to sponsorship of climate skeptics rebutting scientific consensus (Oreskes and Conway, 2011), companies have worked hard to achieve "the gloss of impartiality and weight of authority that come with a professor's pedigree" (Lipton, 2015).

One significant upshot of these developments has occurred within the sphere of scientific communities. Societal criteria have become more explicitly integrated in procedures for validating science. Gieryn (1999) stresses that credibility is now "not decided in tinkerings at the lab bench or in the refereeing of a manuscript or in the machinations of instruments, statistics, or logic" (p. 27). Nowotny, Scott, and Gibbon (2001) coined the concept of 'socially robust knowledge' to demonstrate that policy, political, legal, and civic communities – not just scientists – are involved in validating much S&T knowledge through imposing their own credibility tests (Table 1). Governments, NGOs, journalists, and others have learned to use scientific criteria (for example, whether adequate peer review exists) to scrutinize technical assertions. These 'external' communities are influencing research design, data collection, and reports through their engagement with scientists (e.g., Epstein, 1996; Brown et al., 2012). They sometimes even become part of scientific communities. Through recognizing and building on these new arenas and practices of validation of science, the resulting knowledge is more durable and less susceptible to skepticism and manipulation.

In turn, lay people, NGOs, and community groups are producing their own scientific knowledge (e.g., Fischer, 2000; Ottinger, 2013). These struggles are forms of citizen science, in which lay people are recognized as participants in making technical knowledge. Citizen science efforts, however, can have many levels of participation from passive engagement (providing information) to collective action (acting together) (Kindon et al., 2007). Many scientific projects now rely on citizens to report their observations of animal movements, tree diseases, weather, and other phenomena (Bonney et al., 2009). "Crowdsourcing" data and using distributed networks of citizen-operated computers are also rapidly becoming popular in sciences from astronomy to biology (Kitchin, 2013). These activities typically recruit volunteers to conduct specific tasks according to an externally organized sampling and research framework. The connection of lay data collection to larger analytical frameworks and outcomes can therefore vary widely in terms of who sets the initial research agenda, and how the analysis and communication of results are managed (Brown et al., 2012).

In a more proactive and participatory way, many social movements are generating their own observations, technologies, and data instead of allowing technical experts to frame research directions (Iles, 2007). One example is the pesticide catcher that Pesticide Action Network North America developed to empower farming communities to learn whether they are being exposed to harmful chemicals drifting across farm fences (Harrison, 2011). By using a seemingly low-tech device to gather air samples for toxicological screening, concerned immigrant families can create tangible proof of exposure to use against corporate farmers. Such evidence could be used in negligence or nuisance lawsuits and help change local attitudes toward pesticide spraying through report-backs to communities. The pesticide catcher, however, encapsulates the epistemic challenges that civic legitimation faces. Regulators and industry actors contend that the pesticide catcher is not scientifically legitimate: data are not collected according to rigorous protocols, therefore weakening the ability to prove that community risks are significant. Moreover, the resulting knowledge can be confined to a tiny local patch, and may not enter wider civic consciousness because of communication barriers. More generally, the potential of civic legitimacy to affect dominant political institutions can be limited at times. Civic attention can be capricious, veering from issue to issue, or atrophying. The ability of people to defy such institutions may be stunted by prevailing neoliberal economic ideologies. Given their power, corporations can also shape civic tests to reflect their commercial interests.

Material infrastructures: A hidden dimension of legitimacy

Underlying all of the above processes of legitimation is the ability to direct the material infrastructures and systems of producing and propagating knowledge. As seen in the history of the agricultural sciences, greater power and visibility has come through specific ensembles of research, industry, policy, and civic actors gaining control over capacity building. They establish university departments and educational programs, enlist students into disciplinary cultures, and engage farmers through extension and outreach. By doing so, powerful groups have reshaped the cognitive space and social incentives both within university organizations (where science is frequently understood to reside) and in multiple sectors of governance, policy, and economy with which they intersect.

For example, Jennings (1988) depicts the transformation of Mexican agriculture in the 1940s, as a generation of Latin American trainees were made experts in Green Revolution strategies. Courtesy of Rockefeller funding, thousands of *agrónomos* received 'state-of-the-art' training abroad: at US land grant schools where Borlaug's breeding principles (broad adaption, centralized selection) were dovetailing with postwar 'better farming through chemistry.' These trainees would go on to found their own research labs, propagating the knowledge widely and inter-generationally; many would also make their way into ministries of agriculture, trade, and commerce, creating multiple paths of political reinforcement – not least, reinvestment in Green Revolution R&D. In the US, the land-grant research infrastructure – universities, extension, and experiment stations – has been particularly important in mobilizing resources towards productivist knowledge-making. While exporting Green Revolution practices to the global south, this system responded domestically to 'fencerow to fencerow' policy mandates, developing a yield-centric apparatus for agricultural science that persists to this day.

Conversely, the history of biocontrol research from the 1920s to the 1980s suggests that its success depended on institutional support by the University of California system (Warner et al., 2011). Biocontrol research once had its own departments, research facilities, and faculty at the land-grant universities of UC Berkeley, UC Riverside, and UC Davis, combined with an experiment station at the Albany Gill Tract. This infrastructure could generate scientific evidence of effective control of pests; and produced numerous graduate students who become research leaders at other universities and government agencies. Access to research funding, land and buildings for biocontrol experimentation, and talented scientists enabled a legitimacy for biocontrol research that was achieved through practical trials, scientific publications, and proven economic benefits for the California produce industry. Starting in the late 1970s, however, the land-grant complex underwent a strong shift towards the "molecularization" of agricultural technology (Buttel, 2005). Applied biology departments were dismantled in favor of the trendier molecular biology and genetics. By the 1990s, universities were competing for prestigious grants, publications, and patents for molecular research, and retrenching their applied research programs in plant breeding and horticulture (Busch et al., 1991). As a result, biocontrol scientists could no longer generate publications, attract students and grants, and demonstrate their capacity to address ecological problems in agriculture. Biocontrol is a microcosm of agroecology's failure to gain access to the material infrastructures that have propelled industrial science to the apogee of modern farming.

Toward thick legitimacy for agroecology

In this section, we examine examples of practices that agroecologists and other alternative agriculture advocates can pursue to create thick legitimacy for their efforts. Based on our foregoing analysis of STS scholarship on the politics of legitimacy, we identify at least three broad reinforcing paths, distinguished by their underlying processes of change and appeals to bases of legitimacy. They are: (1) building on and updating the existing standards and practices of science; (2) extending influence into policy, legal, practical, and civic arenas; and (3) centering attention on the ethical legitimacy of food systems. Together, these paths can challenge industrial agriculture's thick legitimacy, which differs markedly in its character and epistemology from agroecology.

Path 1: Extending the master's tools

Over the past 30 years, numerous activities have already affirmed the scientific foundation of agroecology. Universities with departments or programs in agroecology; journals dedicated to agroecology research; and conferences such as the Latin American Scientific Society of Agroecology (SOCLA) gatherings attest to the growing recognition of agroecology as a rigorous arena of scientific investigation (e.g., Fernandez et al., 2013). In addition, the explanatory power and empirical aspects of agroecology science have drawn the attention of peasant organizations (e.g., La Via Campesina), policy NGOs (e.g., the Union of Concerned Scientists, Center for Food Safety, Institute for Agricultural Trade and Policy, Pesticide Action Network North America), and, most recently, international food and hunger agencies such as the FAO and the UN Special Rapporteur on the Right to Food. France has recently enacted a national law calling for agroecology to be integrated into its agricultural policy. Government officials in a small number of developing countries, including Brazil, Ecuador, and Uruguay, have endorsed agroecology. Nonetheless, agroecology largely remains on the margins of science and policy.

To overcome this disadvantaged position, agroecologists can use – and *revise* – existing scientific approaches to gain legitimacy. Engaging in boundary work, they can characterize agroecology as a valid field on the same plane as the canonical (natural) sciences, sharing similar empirical and theoretical bases. They can find ways to communicate these scientific attributes to researchers in agri-food systems who may be unfamiliar with, or resistant to, agroecological work. By using the standards of dominant scientific and technical knowledge – i.e. invoking the master's tools – they can deploy science as a resource in scientific, political, and societal debates. In this sub-section, we delineate a few examples of how the master's tools can affirm agroecology. We also suggest how existing scientific approaches could be updated to better encompass diverse agroecologies.

Demonstrate that agroecology "works"

Agroecology must deepen its empirical foundation to build credibility in agricultural science and policy. A criticism sometimes levied at agroecologists is that their science is more ideological than empirical, more aspirational than real world. In response, agroecologists can develop innovative field studies without falling into the trap of assuming that there must be a foregone conclusion that the researcher intends to "prove" through field experiments. One approach is to conduct densely detailed, site-specific research into the ecological, social, and environmental consequences of using agroecological practices compared to conventional practices. For example, a recent study in California's Salinas Valley found that farms with clear-cut landscapes were no less likely to suffer pathogenic contamination than farms surrounded by non-crop vegetation – they might even be more vulnerable (Karp et al., 2015). Vegetational complexity, the research showed, provided multiple entwined ecosystem benefits, from providing habitat for pollinators to filtering agrichemical runoff. Another recent study found that roughly 32 percent of variation in ecosystem functions is due to soil biodiversity (as opposed to vegetative biodiversity which accounts for about 42 percent). Storing carbon, pollinating plants, acting as habitats or shelter, creating soil and acting as raw materials are all ecosystem services significantly enhanced by healthy, biodiverse soils (Jing et al., 2015). Both of these studies provide strong support for agroecological theory, which has long emphasized enhanced biological interactions in both above- and below-ground spaces.[10]

However, this type of research – albeit attentive to heterogeneous farmer and ecological conditions – can "fail" to meet the challenge of conventional scientific replication, an idea which continues to exert considerable power in evaluating science. Replication has been fairly simple to achieve in the simplified agroecosystems of post-War productionist agriculture. During that era, the Borlaug breeding approach was promoted widely, and researchers in land grant breeding programs across the US were trained in a paradigm of 'broad adaptation' for universal conditions. Of course, as Dawson et al. (2008) point out, the reality is that these programs were breeding for the locally specific environments of high-input experiment stations, in which crops were dosed with heavy applications of fertilizer, pesticides, and irrigation inputs. The presumption was that agricultural landscapes around the country would be agronomically re-engineered to mimic such conditions. Replication, then, has been constructed at both landscape and genetic scales in a paradigm of reinforcing centralized crop selection for universal and homogenous agricultural conditions. The power of these evaluation criteria continue to this day, even after it has become evident that Green Revolution intensification often delivered short term yield gains for long-term tradeoffs in weed and pest resistances, soil degradation, water and air pollution, and biodiversity loss (Shiva, 1991; Perfecto et al., 2009; Mazoyer and Roudart, 2006). Recently, for example, Warner (2007) found that agroecology projects in California struggled to win recognition as legitimate research from University of California scientists because they took place as complex experiments that could not readily be reduced to specific explanatory variables. The scientists asserted there were just too many confounding variables to determine whether something caused an outcome. There were too few research sites to enable broader patterns to be discerned.

A different approach, therefore, is to design and validate a research model that does integrate local variability, without relying on controls or standardized research conditions to assure scientific merit. Much ecology and complexity science already build in innovative techniques to generate valuable insights in terms of principles that can be locally contextualized. For farming, new experimental infrastructures are needed that will not only embody the diversity of agroecological landscapes but can generate more empirical data, over a greater range of decentralized farm systems than the centralized model of conventional extension stations. Along with many collaborators, Hannah Wittman at the University of British Columbia is working to create a network of numerous small agroecological research sites across North America.[11] University farms can join the network and allow researchers to study agroecological practices *in situ* over longer time periods, under changing environmental, socio-economic, and climate conditions. Instead of attempting to replicate findings across all sites, and certainly instead of re-engineering all sites to fit the same mold, participating farms assist researchers in accumulating the knowledge that all farmers in the network will find useful. Such a system overcomes the challenges of limited data and statistical significance by creating a large-scale network comprised of small-scale contributors. If patterns emerge across many settings and remain consistent over time, the knowledge is therefore more likely to be scientifically and socially robust. This is one example of the wider discussion of agroecology principles that needs to occur in societies (as we further explain below).

Various agroecological research stations in this model could be created around the world, potentially building upon the FAO system of globally important agricultural heritage sites (GIAHS). These plans will, of course, require greatly expanded public investment in agroecology. They will also demand innovations in reporting and communicating to illustrate the diverse dynamics and outcomes of diverse, *in situ* science.

Forge new transdisciplinary alliances between rural and urban food growers, and academic scientists and extension specialists

Farmers, peasants, and indigenous peoples have long practiced scientific investigation in the field (Busch, 1995), but in a spectrum of contexts that Western science has not accommodated. Agroecology scientists can play a powerful role in affirming the scientific legitimacy of practitioners as experts in their own right, through directly collaborating with them and aiding them to publish in scientific journals. Scientists can also 'translate' practical and experiential knowledge into a scientific idiom for communicating with policy-makers and the public. Broadly speaking, this strategy is one of formalizing informal knowledge to endow it with greater credibility vis-à-vis the language and logic of established science. This boundary work draws 'non-scientific' knowledge into the scientific sphere, making it more legible and actionable in the judgment of the predominating socio-technical order. There is some evidence that such approaches work. Carolan (2006b) notes that one reason why organic agriculture has become increasingly legitimate is because farmer groups have allied with sympathetic university sustainable food programs such as the University of Iowa's Leopold Center to carry out research, to certify their practical results as robust science, and to turn organic methods into scientifically credible forms. Nonetheless, this work can unintentionally reproduce a hierarchy between scientists and practitioners at times if care is not taken.

Scientists and practitioners can also take this scientific research further into the transdisciplinary realm. Transdisciplinary work "integrates multiple knowledge systems including academic disciplines and nonacademic knowledge (e.g. local or indigenous), to seek solutions to complex, real world issues and problems" (Schattman et al., 2014, p. 327). Such research is already being discussed within many academic institutions, which could give agroecology ready purchase in mainstream funding and research bodies: disciplines from ecological economics to climate studies are adopting the methods, and the USDA has recently issued calls for "transdisciplinary" research in climate change (USDA, 2013 and 2014).[12] Whereas scientists can contribute technical knowledge in complexity science, farmers can share their experiential, culturally/historically situated knowledge.

To this end, a number of experiments are underway already, such as the Agricultural Resilience in a Changing Climate Initiative at the University of Vermont (Schattman et al., 2014). In this project, university researchers have collaborated with about 15 vegetable, dairy, livestock, and diversified farmers to identify best management practices for adapting to or mitigating climate change impacts. Prior to applying for funds and starting research, extensive informal dialogue took place through workshops, surveys, and conversations to define the problems to research. Activities included developing landscape visualizations to allow farmers and government officials to imagine how agroecological management practices might work on actual farms. Transdisciplinary research holds many challenges. Researchers and practitioners must learn to communicate across what can be profound epistemological, political, methodological, and language divides (Lélé and Norgaard, 2005). Frictions between scientific and local knowledges can also persist despite best efforts to resolve these. Researchers need to be sensitive to how power is distributed across their team and throughout the scientific process (Schattman et al., 2014). However, agroecologists can demonstrate that transdisciplinary science is much better able to tackle complex issues, such as climate change and agricultural sustainability, compared to more traditionally siloed disciplinary perspectives.

Path 2: Extending agroecology into other bases of legitimacy

As STS scholars have shown, scientific legitimacy can be significantly weakened through practical, political, and social challenges to its authority. Therefore, it is likely that science alone will not suffice to achieve thick legitimacy: other bases of legitimacy are needed to buttress agroecology in order to permeate into societies and public institutions. These bases are political, policy, legal, and civic in their character. A common assumption is that science informs policy in a unidirectional manner, through vehicles such as the National Academies of Science and the Office of Science and Technology Policy (OSTP) that advise Congress and the White House. A more interactive STS accounting, however, suggests that science and policy are always changing each other – with science 'coproducing' the direction, priorities, quality, and scope of policy, and vice-versa (Jasanoff, 2004). Similarly, the multiple bases of legitimacy and their associated knowledge communities create and shape one another.

Consider, for example, the following hypothetical scenario, which illustrates a coproduction of policy, law, civic life, and science that supports alternative agricultures. If agroecologists can convince government agencies to invest even a few million dollars more in agroecology R&D, the resultant research outcomes could lead other scientists to take agroecology more seriously as a scientific domain. Civil society groups may then turn their attention to agroecology, creating new opportunities for NGO-agroecology alliances. Strategic lawsuits against government agencies and industry could be brought to block approvals of harmful chemicals or to break monopoly behavior. Through this legal legitimacy, they may influence officials to begin changing their regulatory norms. Over time, these respective arenas can influence governments to begin allocating subsidies to diversified crops, requiring schools to source food from local farms, and challenging destructive international free trade agreements. Such coproductive processes, in time, serve to build a thick agroecological legitimacy.

In the following subsection, we explore specific ways in which agroecologists can take advantage of this coproduction phenomenon.

Work with, and gradually change, the existing standards of proof and reasoning used in various institutional and social arenas

Agroecologists must consider how material infrastructures and resources might connect across different arenas. They must learn to translate agroecology into the discourses and framings of the particular settings and actors they engage with.

To succeed in gaining first entry, agroecologists must study – and appropriate – the criteria and reasoning conventions prevailing in a specific arena. For a USDA official, this may entail showing that agroecology satisfies cost-benefit requirements. Namely, using biocontrol techniques results in X-billion dollars of preserved crop yields, with relatively few costs outside of research and facilities infrastructure. Agroecologists can then better meet the credibility tests used in arenas beyond science: they can gain political and civic support, obtain approval from practitioners, and create enabling policy environments. Standards of evidence are particular to organizational cultures and histories: for example, the USDA has accumulated a century's worth of customs and laws when evaluating whether something warrants attention. Standards of proof may also vary according to the political culture of the country. In the US, this includes a federal system of government agencies that are dependent science-based reasoning and that work with highly combative NGO and industry involvement.

Later, after gaining entry, agroecologists can work to change the standards that scientists, governments, industry, and societies use to evaluate agriculture and food outcomes. For instance, agroecologists can encourage agroecologically educated students to pursue positions at USDA, EPA, and FDA, where they can climb through the bureaucratic ranks and begin to make rules and decisions supporting agroecology. With more agroecology R&D investment, and more students drawn to pursue agroecology science, there is concomitantly greater latitude for filling the ranks of government, industry, institutional systems – like schools, hospitals, and private foundations – with such trained individuals. Overcoming a currently anemic engagement with lay publics in the US, agroecologists can work with journalists and community advocates to frame agroecology according to prevailing civic reasoning conventions. Working with psychologists and anthropologists, they can incorporate agroecology into the cognitive and cultural models that people hold regarding food, using community dialogues and the media. Such translation and training work calls for collaboration with the political, policy, legal, and media communities. Because agroecologists have largely neglected these communities, they are not gaining this type of legitimacy. To date, their main strength is having gained practical legitimacy through their work with farmers, atop some scientific legitimacy.

Develop mechanisms for 'witnessing' agroecology

To build thick legitimacy, actor-audiences must be empowered to *attest* to agroecology's benefits. Substantial knowledge about these advantages exists amongst some farmers, scientists, and NGOs. Yet this wisdom remains isolated, little observed, and lacking in salience for other societal audiences – especially the large urban populations of North America. Consequently, few people can testify to agroecology's nature: large cognitive, spatial, and cultural distances exist between people and agroecology. Certainly in the US, agroecology is treated with suspicion because it seems far removed from everyday experiences of food and appears foreign. Urban dwellers, for example, have few ways to evaluate for themselves whether or not agroecology might meet their credibility tests more effectively than industrial farming. The support of urban consumers and citizens, among others, is essential for agroecology (Gliessman, 2015). Much agroecological practice draws on peer-to-peer attesting of knowledge amongst farmers. Here, we consider ways to enable people who are not involved in agroecological practice to join and amplify this attesting practice.

Several steps are involved in creating mechanisms for witnessing. First, agroecologists must imbue the 'agroecology' term with content that diverse actor-audiences can engage with. They must gather and pool empirical evidence of agroecological practices (see above). Agroecology will not take hold until a substantial mass of citizens and consumers have learned to 'speak agroecology' fluently (Montenegro, 2015) and can thus start setting their own civic credibility tests. To date, agroecologists have only shallowly explored the possibilities of using communication to reach a broader set of actor-audiences. The media is now a complicated territory: alongside the mainstream media, there are smaller, more independent publishing outfits, and an entire universe of user generated social media. The decentralized nature of internet media is especially amenable to communicating agroecology (since both share local production and consumption features). Journalists and citizen authors can help develop stories about how agroecology can transform food systems. We are inspired by examples of inventive podcasts and programs such as Delicious Revolution, the Perennial Plate, and the Secret Ingredient. These audio and video forms of storytelling have begun to link agroecology to other resonant discourses such as climate change, fair employment, food democracy, and community health.

Language is an important variable. It is often said that 'agroecology' is a difficult term to wrap one's head – and tongue – around. While we reject the notion that agroecology is plainly too esoteric (the people of Latin America seem to have caught on just fine), we acknowledge that cultural cachet is important. Agroecologists could coin resonant (and catchy) words: 'agroeco'(-coffee, -corn, -community) could be used alongside 'organic' to begin familiarizing people with agroecology. The Community Agroecology Network has already begun marketing "agroeco coffee".[13] As with all idioms, we suspect that when people learn more about agroecology, and more importantly *practice* its grammar, syntax, and structure, they are likely to become more conversant. Moreover, this dialogue should extend to raising the profile of conditions agroecology stands for and wants to achieve – a goal as important as raising the profile of 'agroecology' itself. If people are convinced that agrobiodiversity and human health are interconnected, then agroecologists can more easily make their case that agroecology is a legitimate solution.

Second, agroecologists can learn to develop new credibility tests that industrial agri-food will find increasingly difficult to satisfy. Credibility tests can take many forms. They include bureaucratic procedures, lawsuits, community dialogues, consumer purchases, and peer-to-peer farmer reviews. The vast majority of existing tests are currently defined in terms of industrial agriculture. Does this production system generate enough low-cost volume for retailers? Will a new product in the seed R&D pipeline please shareholders? Has this meat been inspected for food-borne pathogens? Alternative tests aimed at enabling agroecology might include: Does working the land provide adequate livelihoods and food security to farmers? Are policy-makers listening to a range of farmer experiences when making a decision? Is this meat humanely bred and raised? Credibility tests can also be posed in technical terms more customary to a particular arena or organization. For example, critics have long argued that industrial food has numerous hidden social and environmental costs. Now, projects such as 'the true costs of food' are plugging in the numbers to tally the externalized economic tolls of industrial farming. These are experiments in building credibility for a new kind of agri-food system by devising tests the old system cannot meet.

An important question, of course, is what these alternative credibility tests are based upon and who decides. Several agroecologists (Bland and Bell, 2007; Timmermann and Felix, 2015; Gliessman, 2015; Bacon et al., 2012; Koohafkan et al., 2012) have formulated principles for appraising whether a practice or system constitutes agroecology. But for the most part these principles have not been developed into readily applicable credibility tests. Developing such tests calls for participatory discussions with the stakeholders who will be most affected by agricultural transitions; that is, not through industry-dominated roundtables but through mediating institutions that truly reflect societal and community viewpoints.

Third, agroecologists can design new, and strengthen old, institutions for testing credibility. Organic agriculture has already sought to create testing processes to garner greater legitimacy. These include direct marketing where consumers can interrogate farmers about their practices; and certification schemes that do the work of testing for consumers. However, many of these mechanisms work through the market, constituting a narrow basis of credibility, and hence, thin legitimacy. Agroecologists might explore developing peer-to-peer auditing schemes that allow farmers to verify whether other growers are practicing agroecological or organic farming methods (e.g., Carlisle, 2015; Dumont et al., 2015). They could also form widely decentralized citizen tribunals to conduct civic credibility tests in many local places, helping to democratize food discourse and practice (Carlson and Chappell, 2015). STS scholars have long studied participatory technology assessment and have proposed an array of structured mechanisms to increase citizen input. These mechanisms have already been trialed successfully in countries from Germany to the US, and on matters from renewable energy to nanotechnology. They include citizen juries, consensus conferences, commissions of inquiry, community-based budget mechanisms, and direct user shaping of technologies.

Path 3: Rebuilding the food system around a regenerative ethics

Alongside reinforcing the scientific basis of agroecology and finding ways to benefit from multiple bases of legitimacy, agroecologists can continue to seek fundamental change in the ethos of the food system itself. Both paths 1 and 2 begin by working within the constraints of this system, only gradually or indirectly transmuting the values embedded in its constitution. By contrast, agroecologists can explicitly appeal to ethical thought as a formidable source of legitimacy. Many scholars have already developed critiques of the biophysical, epistemic, and economic ruptures associated with industrial agriculture – which they broadly term "the metabolic rift" (e.g., Wittman, 2009; Foster et al., 2011; Moore, 2011). As Marx showed long ago, industrial agriculture and urbanization creates a spatial separation between producers and consumers that impedes the replenishment of soil fertility. Wittman investigates how the MST in Brazil has used agroecology and food sovereignty principles to bridge this metabolic rift. Their work, she proposes, evinces an 'agrarian citizenship' based on both political representation and "on a relationship with the socio-ecological metabolism between society and nature" (Wittman, 2009, p. 806).

In recent decades, legitimacy has largely been understood in its political economic sense. Yet something is *also* legitimate because it is regarded as morally appropriate (Thompson, 2015). Behind legitimacy is social consent: the willingness of people to accept (or tolerate) a particular order. This power derives from the capacity to exercise ethical agency. In the world of neoliberal economics, governments and corporations have debased this agency, turning democratic politics and market choices into hollow mechanisms for supporting their own values (Norgaard, 2016). In June 2015, Pope Francis released an encyclical on climate change, *Laudato Si*, in which he ruminates on the values that configure life in the 21st century (Francis, 2015). The Pope identifies a major shortcoming in contemporary societies: human and ecological well-being is now subordinated to the logic of continually growing economies and control over nature.

How can awakening ethical agency begin to pare away the thick legitimacy of industrial food? Historian Taylor Branch (1989) suggests possibilities in his trilogy tracing the evolution of the Civil Rights movement. Between 1957 and 1964, organizers arriving from outside the region found it difficult to animate community activism in Black neighborhoods across Mississippi, Alabama, and Georgia. Most locals did not perceive their exclusion from political and economic power as abnormal; they were petrified to defy the White sheriffs, judges, storekeepers, and town clerks ruling in their towns. Campaigners struggled to persuade farmers and janitors they held the right to vote, because they were habituated to a culture of racist oppression with thick legitimacy. Only once Black communities began experiencing their situation as unjust – through organizing, marching, and subsequently, watching their kin bloodied and taken to jail – did they grow more courageous in rejecting the 'normalcy' of their world.

Similarly, people can withdraw their tacit consent to industrial agriculture as something that is normal, weakening its moral legitimacy. They can simultaneously consent to enshrining agroecology and other alternative agricultures as part of food systems. Pervasive cultural change is needed, in which people increasingly understand that the industrial food system is abnormal. By contrast, agroecology can support a fundamentally ethical food system founded on regeneration, renewal, and a polyculture of knowledges. We examine how agroecologists might gain ethical legitimacy through creating new discourses and institutions built on such characteristics.

Agroecologists can help assert the right to regenerate throughout the food system. By contrast to the extractive focus of industrial farming, the right to regenerate urges that societies revive and mend the environmental cycles on which they depend. Rejecting human dominion over nature, regeneration insists upon the interdependency of all living things. While incipient in policy, the right to renew is beginning to acquire civic and scientific legitimacy as a human right. Naomi Klein concludes her recent book on climate change with a chapter on the right to regenerate. She draws an analogy between her personal toil to become pregnant and the fertility problems prevalent in human and animal populations worldwide (Klein, 2014). Numerous scientific studies – along with the experience of local communities – reveal that exposure to toxic chemicals can cause plummeting birth rates, gender swaps, sickly offspring, and life-shortening diseases such as cancer. For humans to generate new life, they need defense from contamination, warming temperatures, and habitat disruption – and in turn the extractive activities of industries such as fossil fuels. But human reproductive capacity is only part of the right to renew: it also encompasses the ability of ecosystems to replenish themselves and the capacity of communities to transfer their biocultural knowledge within and across human generations. Renewal does not mean that there is no extraction. Agriculture will always entail some extraction, but many lost nutrients, biomass, and knowledges can be restored through healing the metabolic rift.

How can agroecologists re-frame public discourse around the right to renew in practical terms? We outline three practical strategies, hardly exhausting the possibilities for creative elaboration.

Translate the right to renew into national policy

Many indigenous peoples are rallying for the right to renew as part of a global movement for environmental and planetary protection. One example is Bolivia's proposal in 2009 for the United Nations General Assembly to enact the Universal Declaration of the Rights of Mother Earth ('Pachamama').[14] Amongst other clauses, the declaration would oblige governments and societies to "respect, protect, conserve and where necessary, restore the integrity, of the vital ecological cycles, processes and balances of Mother Earth". They must guarantee that the damage caused from interrupting these cycles be repaired and "those responsible are held accountable for restoring the integrity and health of Mother Earth". These obligations are also enshrined in the national constitution of Bolivia. Ecuador has a similar constitutional law, and other countries could follow suit. Importantly, the right to renew is not only an indigenous, matrilineal, or 'female,' concept: many peoples hold centuries, even millennia, of such experience in their local cultures and conditions. Practices of ecological farming and stewardship traditions abound everywhere, and these can be translated into environmental integrity norms.

A more legally and politically familiar approach is to treat the right to regenerate as underlying the right to food. Olivier De Schutter makes a forceful case for available, accessible, and adequate food as a human right. To realize the right to food, he contends, agroecology is essential to agricultural systems globally. Agroecology "not only shows strong conceptual connections with the right to food, but has proven results for fast progress in the concretization of this human right for many vulnerable groups in various countries and environments" (De Schutter, 2010). The right to food entails valuing the capacity of agroecology to generate and regenerate the ecosystem services – from soil nutrient cycling to bee pollination – that industrial farming disrupts. In addition, the right to regenerate arguably underlies many other human rights: to life, employment, housing, and health. Governments therefore might use existing human rights law obligations to introduce policies to nurture agroecology.

Join mass movements struggling against extractive agriculture and food

Growing numbers of communities are fighting against fossil fuel extraction, using non-violent means such as obstructing tar sand oil shipments in Canada and refusing to allow workers to begin digging coal mines in Australia (Klein, 2014). Similarly, non-violent actions can be taken against food companies to interrupt their exploitative practices and constant growth ideology. One example is the March on Monsanto campaign, which began in 2013 in response to growing civic concerns about the power of biotechnology companies in political processes. A significant number of demonstrations have occurred worldwide, in which people have picketed Monsanto labs and protested against products containing GM soy and corn. Agroecologists could also join the burgeoning farmworker and fast-food worker campaigns against supermarkets and retail chains in the US (Greenhouse, 2014). In return, farm- and food workers can lend their support to the agroecology movement by calling for food businesses and growers to adopt anti-extraction and renewal principles. The Black Lives Matter movement also offers important, unrealized connections to agroecology: criminal justice is also food justice.

Create social spaces to facilitate an open dialogue of knowledges that includes the least powerful and visible

The industrial food system is founded on the assumption that only a few dominant, universally used, standardized kinds of knowledge can make the system function. These knowledges include agricultural science and economics aimed at productivist needs; food science used to design processed products; the skills needed to navigate agricultural policy; and business and marketing expertise. Strong epistemic superiority is built into the industrial food system. Numerous other voices are muffled, particularly those who are the least powerful participants. Consequently, proponents of alternative agricultures flounder in demonstrating that different normals do exist (Magdoff, 2015).

Inspiration can come from a key value many agroecologists prize: *diálogo de saberes* ('dialogue of knowledges': Leff, 2004; Martínez-Torres and Rosset, 2014). Instead of starting with dominant knowledge, agroecologists believe in bringing diverse knowledge and actor-audiences into conversation. Extending this notion, epistemic humility acknowledges our fallibilities and biases, rather than presuming that technological knowledge justifies growing mastery of the world. We need to "to make explicit the normative that lurks within the technical; and to acknowledge from the start the need for plural viewpoints and collective learning" (Jasanoff, 2003, p. 240). Towards diffusing *diálogo de saberes* into food systems, two specific interventions are giving labor, knowledge, and skill opportunities to the least seen and heard; and creating a well-governed commons throughout the food system (c.f. Ostrom et al., 2002).

In the US, subaltern peoples include undocumented migrants, military veterans, prisoners, the urban homeless, and an increasing number of ghost town rural communities. They include Native Americans, Latinos, and Blacks, the poor, disabled, and mentally ill, and numerous other racial, ethnic, religious, class, and gender minorities. These marginalized groups, systematically treated as throwaway people, suffer from a lack of right to renew but in different ways. Former prisoners find it almost impossible to gain employment or to qualify for housing, thus hampering their ability to regenerate their lives. Finding ways for subaltern peoples to achieve a powerful voice requires many experiments with programs and activities across the country. These could be – and are – farmer field schools in prisons, agricultural clubs for returned veterans (often suffering from war trauma), and elementary school programs focused on identifying and preserving culturally important agrobiodiversity. They already exist but only in patches, due to lack of financial investment and state/local government opposition to actually helping people.

The second intervention that agroecologists can aid is to start building 'protected commons'. These are institutions for collaboratively sharing knowledge and resources in the agricultural system, rather than allowing dominant capitalist market economic relations to dictate what can be made, owned, and exchanged. According to Elinor Ostrom, such commons are accessible to everyone but only on condition that participants comply with the commons rules (Ostrom et al., 2002). Traditionally, protected commons were the normal in many agrarian societies: villages shared land, seed, water, and other resources needed for farming but within a regulated framework. In the US and other industrial countries, protected commons could be given a firm legal backing, and could be publicly funded from government taxes on agribusiness for its environmental damage. These conditions could counter the tremendous power of agri-food companies and the structural conditions that favor the status quo. Small experiments in making protected commons could help allow communities to re-possess the resources they need to build flourishing local food systems. In the seed arena, for example, the Open Source Seed Initiative and public seed libraries are starting to provide germplasm to farmers for free use, without interference from corporate control (Kloppenburg, 2014).

Conclusions

Attaining thick legitimacy is fundamental to the power of agroecologies and other alternative agricultures to continue 'scaling out' into food systems at large. The industrial food system holds pervasive thick legitimacy because of its conventional scientific basis, ideology of mastery over nature, and interpenetration with political-economic and government systems. Displacing industrial agri-food, then, calls for meticulous attention to making agroecological knowledge compellingly authoritative. Legitimacy is something formed between actors and audiences; it comes from people attesting to knowledge as credible in their various institutional and societal contexts. We showed that agroecology legitimacy does not have a single base: something can become legitimate through a bundle of processes, based in science, policy, practice, law, and civil society. Agroecologists have long implicitly recognized this breadth in defining agroecology as an inseparable science, practice, and social movement (Sevilla Guzmán and Woodgate, 2013). Less recognized are the processes of legitimation that thread these elements together. Science requires scientific validation, recognition in policy-making, practical testing in everyday practices and experiences, and verification by civil society actors. Thick legitimacy comes from creating a web of credibility and trust founded on these multiple overlapping bases of legitimacy. Thus, agroecologists need to understand the evidence, criteria, and reasoning that prevails in each base. They can then use and gradually transform these elements into more agroecology-friendly forms.

We characterized three possible pathways that agroecologists can experiment with to expand their endeavors. Agroecologists can achieve greater legitimacy by (1) building on and revising the existing standards and practices of science; (2) extending influence into policy, legal, practical, and civic arenas; and (3) centering attention on the ethical legitimacy of food systems. Science offers a familiar means of gaining epistemic authority, while drawing on the power of government officials can add rule-making credibility, and invoking the right to regenerate can make agroecology more morally acceptable than industrial food. These pathways are not sequential in time, nor do they represent progressively better strategies. While it is true that path 3 contains some of the most emancipatory, revolutionary potential, it will likely remain just mere possibility unless bolstered by legitimation along pathways 1 and 2. Thick legitimacy requires all three. This mutually reinforcing tendency can benefit agroecology, since it means an 'all hands on deck' approach, mobilizing people with disparate dispositions and skill sets, who work within and with very different (practice, legal, cultural, and civic) communities.

Nonetheless, contradictions and frictions are almost certain to arise. Paths 1 and 2 could potentially result in 'scientization.' That is, growing use of scientific standards could mean that agroecology comes to be treated as "objective, value free, and best based on scientific evidence of quantifiable risks, while avoiding relevant ethical, cultural, and social dimensions" (Teller, 2014). Further dangers exist in trying to exploit standards of evidence that dominate in political, policy, and legal arenas. If agroecologists begin speaking in the language of government bureaucrats, judges, and legislators, they may internalize the very values and worldviews they seek to upend. Scientific and technical experts could seize primary decision-making power from farmers and social movements (Delgado, 2008; Kinchy, 2012). In turn, path 3 could see only inspiring but marginal activism. Without substantial resources – particularly public money – calling for a dialogue of knowledges is only aspirational. Without emphasis on building new institutions to enable putting agriculture to credibility tests, legitimacy may remain thin. Confronting these perils requires the mutual articulation of the three paths, their guiding principles and strategies. Integrating the path 3 tenets of right to regenerate and dialogue of knowledge can make paths 1 and 2 less predisposed toward capture by dominant scientific and technical interests. In turn, paths 1 and 2 can contribute the resources that path 3 requires.

We close by recognizing that nothing about the path ahead – or the three entwined paths – will be easy. The very idea of legitimacy is something that most people take for granted. It can also be not only 'thick' or 'thin' but also recalcitrant and sticky. Society is now finally recognizing that fossil fuels may be illegitimate as a source of energy, yet driving a fossil fuel-powered automobile to the supermarket to buy a cartload of fossil-fuel rich foods could not be more ordinary or legitimate. In some cases, people may not fully recognize the connections of such activities to fossil fuels. In other cases, recognition exists, but few viable alternatives do. Legitimacy for an illegitimate condition, then, can linger on through such paradoxical reinforcement.

Making the active construction of legitimacy visible for researchers, farmers, and social movements is one way to counter this inertia. As we have shown, what counts as legitimate is contingent on the norms and standards of science, civil society, and politics of the day – all of which agroecologists have a hand in molding. Agroecologists can work towards the world they want – diverse, just, productive, and regenerative – by understanding this politics and remaking what counts as legitimate.

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Notes

1. In some ways, the bundle of legitimation threads resembles the 'theory of access' that Ribot and Peluso (2003) develop to investigate the politics of gaining access to resources such as land and knowledge. By 'coproduced', we mean that the bundled processes are building, shaping, and strengthening each other. Paraphrasing Jasanoff (2004), coproduction traces how knowledge-making work is incorporated into practices of political economy-making and governance, and in reverse how these practices influence the making and use of knowledge. Scientific knowledge and political order are co-produced at multiple stages in their joint evolution, from stabilizing findings in agricultural stations, to developing technologies based on this science, to creating legal and bureaucratic regimes to manage the technological applications.
2. STS is an interdisciplinary field that studies the politics of science and technology in contemporary societies. STS researchers often begin from the premise that scientific knowledge is produced within a social and cultural context (e.g., Jasanoff and Martello, 2004). Many STS ideas are intuitively known and practiced in agroecology. Despite their common interests in challenging dominant knowledge-making practices and cultures, STS and agroecology have rarely engaged with each other. Agroecologists can benefit from a more systematic analysis of the knowledge politics, barriers, and possibilities they encounter. Inversely, little STS scholarship has considered agroecology as a subject until recently (see Iles et al., 2016).
3. Internationally, Jose Graziano de Silva, Director-General of the Food and Agriculture Organization, the United Nations Conference on Trade and Development, and Olivier De Schutter, former UN Special Rapporteur on the Right to Food, have recognized agroecology as an important pathway toward making food systems more sustainable and equitable (De Schutter, 2010). Certain European countries are beginning to embrace agroecology officially. France has recently introduced a new law to reduce pesticide use and integrate agroecology into agricultural teaching schools (Crosskey, 2016). Across Latin America, agroecologists have successfully influenced some national and regional governments to take their science and practice more seriously. In Brazil, for example, the federal government has established a ministry for agroecology, and a national plan that includes investing in programs for schools to source food from agroecological farms. Many PhD graduates from US and European agroecological programs now work inside Brazilian universities, research institutes, and government agencies such as EMPRAPA (Altieri and Toledo, 2011).
4. The European Union Common Agricultural Policy does include agri-conservation programs that make subsidies available to farmers on the condition they comply with environmental requirements. Many national and sub-national governments in the EU also support more diversified methods to some degree (Burton and Schwarz, 2013).
5. Industrial and developing countries often diverge greatly in their legitimacy threads and credibility tests for historical, cultural, institutional, and political economic reasons (Jasanoff and Kim, 2015). For example, agricultural policy-makers in Brazil could construe social movement activities in very different terms compared to their American counterparts; legislators can be more willing to take precautionary action in Europe than the US. Acknowledging this case-specificity, we focus primarily on the US in this study, though our observations can be adapted to other geographical places and people.
6. As a result of these developments, organizations from FAO to the White House, and from the US Department of Agriculture (USDA) to the California EPA, now employ numerous staff members who are trained to research, design, and implement policies. Lawyers, engineers, and scientists perform largely unseen but significant work in selecting what knowledge to use in their day-to-day planning and management. In some cases, government organizations have their own laboratories devoted to producing scientific research in support of regulatory or industry development missions. USDA is known for its extensive network of agricultural extension stations and extramural funding programs.
7. In the case of bee colony collapse disorder, regulators in the US have tended to ignore the experiential and practical evidence of beekeepers regarding the possible role of pesticides in disrupting bee behavior. These data did not match the dominant technical template of toxicological knowledge, with its idiom of 'dose-response curves' and 'lethal doses' generated from animal tests in the laboratory (Kleinman and Suryanarayanan, 2013). As a result, regulators discounted the idea that low-dose exposures to neonicotinoid pesticides could be harmful to bees.
8. Such influences, of course, can also quietly pervade government agencies. Officials are subject to directives from the White House or state legislatures; sometimes they are political appointees with their own ideologies; they meet often with constituencies; and they have considerable decision-making discretion. Agencies are also not impervious to the pressures of the private sector. The case of US GMO regulation illustrates this: compared to their European counterparts, regulators in the EPA and USDA tend to ease the passage of GM crops designed to survive pesticide applications. They could consider a wide variety of human health, ecological, and socio-economic data that arguably show that the GM crops have significant uncertainties as to their consequences. However, these regulators may selectively evaluate extant technical data in ways that favor commercial interests. It is these concealed influences that can be particularly pernicious in shaping credibility tests within the government apparatus.
9. People may also form communities of practice in which they share a concern or passion for what they do, develop skills, and learn to practice through interacting with one another (Lave, 1991). They create a shared repertoire of experiences, stories, and techniques. It is through their collective discussions that people decide whether something can be considered 'knowledge'. Authority comes from deepening participation and learning how to assess and give feedback on each other's work.
10. Accumulating more empirical data can be an opportunity to create new ties between agroecologists and researchers with mutual interests. These studies, for example, were not conducted by self-identified agroecologists, yet their work reflects interest in biologically diversified systems. By nurturing a larger constellation of researchers not only in, but around agroecology ('friends of agroecology'), agroecologists will be in a position to draw from a deeper and more extensive pool of scientific data.
11. Personal communication, April 2016.
12. The publications resulting from this USDA funding have used the term: see Basche et al. 2014 for an example.
13. See: http://www.canunite.org/our-work/alternative-trade-model-agroeco-coffee/
14. See: https://pwccc.wordpress.com/programa/.

Contributions

- Substantial contributions to conception and design: AI, MM
- Acquisition of data: not applicable
- Analysis and interpretation of data: AI, MM
- Drafting the article or revising it critically for important intellectual content: AI, MM
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Competing interests

We are not aware of any competing interests in preparing this paper.

Supplemental material

- **Appendix S1. STS Primer. (DOC)**
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