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OPINION

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Mycorrhizal technologies for an agriculture of the middle

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Societal Impact Statement

Across industrial societies, midsize farms are in decline. A future of sustainable agriculture will require more than industrial and cottage farmers. We show that emergent mycorrhizal science is well-suited to support applications for an "agriculture of the middle," and note two obstacles to the development of more integrated mycorrhizal technologies: an overreliance on commercial inoculants (industrial agriculture) and a tendency to treat soil biology as a black box (cottage agriculture). In this paper, we aim to provoke conversation among policy makers, research funders, and corporate executives on the development of mycorrhizal technologies for an agriculture of the middle.

Summary

Arbuscular mycorrhizal fungi (AMF) are dealt with in agriculture in a strongly bifurcated way: products and techniques to optimize AMF communities are designed for either large-scale (industrial) or small-scale (cottage) farming operations. We show how research and applications with AMF are bound up in these contrasting visions for what agriculture should be—an industrial system based on economies of scale, or small-scale operations that cater to regional societies, economies, and ecologies. These distinct socially and technologically bound initiatives—which involve research institutions, government policies, corporate investment, activism, and public relations campaigns—we refer to as sociotechnical imaginaries. Drawing from emergent mycorrhizal research, we argue that mycorrhizal technologies are well-suited to an "agriculture of the middle," a mode of farming that is not strictly scale-based, yet falls somewhere between the industrial and the cottage. Unlike these two extremes, middle agriculture does not have a well-established sociotechnical imaginary. Developing this collective vision poses a challenge: will a middle agriculture that uses AMF fall short of the established goals of industrial and cottage modes of farming? The process of determining appropriate compromises on a wide range of parameters is likely to be contested. However, we believe that calling attention to these extreme visions of agriculture, along with the divergent (if potential) roles of mycorrhizal applications, will jumpstart a productive dialogue among stakeholders, including farmers, policy makers, scientists, and industrialists. Highlighting extremes may also help stimulate ideas about building bridges between seemingly irreconcilable and contradictory approaches.

KEYWORDS
agriculture of the middle, arbuscular mycorrhizal fungi, biotechnology, inoculation, sociotechnical imaginaries, soil, soil biodiversity, sustainability

1 | INTRODUCTION

As a growing body of scholars and practitioners call to attention, across the U.S. and much of Western Europe, the latter half of the 20th century brought a significant drop in an "agriculture of the middle" (AOTM) (Lyson, 2008). Farmers, it seemed, had a choice to make: pursue an industrialized strategy that achieves economies of scale through homogenization and mechanization of farming practices, with increasing reliance on synthetic inputs and global commodity markets; or remain small-scale and sell value-added crops regionally while following methods that support soil health, agro-biodiversity and local economies. Thus far, the AOTM literature has focused on the pressing issue of existing market structures (e.g. government policies, supply chains, distribution channels), those that support large- or small-scale farms at the expense of the middle (De Master, 2018; McAdams, 2015).

Despite the emphasis on scale, farm size is not everything. While AOTM is certainly "scale related" it is not "scale determined" (Kirschenmann et al., 2008, 3). Put differently, acreage does not define AOTM (midsize farms vary from dozens to hundreds of acres). Annual farm revenue may be a better qualifying factor. Following the United States Department of Agriculture, AOTM scholars take midsize farms to be those with an annual revenue between 100,000 to 250,000 USD (ibid). Along with others (Janssen, 2018), our consideration of AOTM moves beyond metrics of acreage and annual revenue to focus on farming practices.

Just as farms tend to bifurcate into the industrial and cottage, we see a similar split in how mycorrhizal fungi, keystone mutualists of the vast majority of plants, are dealt with in agriculture. Products and techniques to optimize arbuscular mycorrhizal fungal (AMF) communities are too often designed for either large- or small-scale farming operations. The lack of mycorrhizal technologies suited for AOTM, we argue, owes to a lackluster research vision for plant–microbe interactions as they exist in midsize farms. To investigate this tendency, we employ the conceptual framework of sociotechnical imaginaries, or "collectively held and performed visions of desirable futures" (Jasanoff & Kim, 2015, p. 19). These carefully and continually constructed visions for the future involve research agendas, government policy, corporate investments, activism (environmental or otherwise), and public relation campaigns. Mycorrhizal technologies have become bound up in the sharply contrasting sociotechnical imaginaries of industrial and cottage agriculture. We show how mycorrhizal technologies tend to follow these two extremes of agriculture, and argue that emergent mycorrhizal research is well-poised to support a third vision for sustainable agriculture, an agriculture of the middle. Unlike industrial or cottage forms of agriculture, AOTM does not yet have a well-developed sociotechnical imaginary. An applied AMF research agenda, which caters to AOTM, is instrumental in developing such a future vision. While we do not oppose mycorrhizal technologies that adhere to industrial or cottage forms of agriculture, we argue for the socio-ecological good that can come from the development of mycorrhizal technologies for an agriculture of the middle.

This opinion piece was written for a diverse array of academics and practitioners. We hope to encourage those who work within AOTM to take seriously the need for research agendas and sociotechnical imaginaries that deal with plant–microbe interactions (in general) and AMF (in specific). We also turn to natural scientists who work with soil symbionts, with the hope of pushing them to connect their research with potential technologies for AOTM. Given our expertise (and the topic of this special issue) our discussion is limited to AMF research and technologies. However, mycorrhizal technologies cannot effect change in agrarian economies and ecologies on their own. In order to foster greater plant health and crop productivity, mycorrhizal applications must be used in tandem with technologies that target other microbial communities.

2 | THE INDUSTRIAL IMAGINARY

An extensive literature covers the antecedents (Melillo, 2012) and watershed moments in the creation of industrial agriculture. Many of these technologies came with the conversion of wartime technologies to civilian use (Light, 2003). In the first few decades of the 20th century, the key pieces that now constitute industrial agriculture came into place: the Haber-Bosch method, a novel way to produce cheap and abundant synthetic nitrogen fertilizers (Smil, 2001); high-performance hybrid seed (Kloppenburg, 1988); synthetic pesticides such as DDT (Nash, 2006); the mass production of tractors and other farm machinery to apply these inputs and work vast tracts of land (Fitzgerald, 2003); the construction of extensive irrigation systems to bring water to what, in many cases, was once desert (Fiege, 2015).

With the end of the Second World War, these technologies were pushed by intergovernmental bodies such as the Bretton Woods institutions and the United Nations. Working in tandem with large-scale industry, these multinational institutions created a narrative in which the world was starving, and industrialization was *the* way to relieve the suffering (Cornu et al., 2018). By the 1960s, the "Green Revolution" was the global extension of this initiative: homogenization, mechanization and reliance on industrially produced inputs grew even greater.

Measures of success for industrial agriculture are often limited to yields, with consideration given to sheer caloric output of crops rather than nutritional levels (cf. Bourn & Prescott, 2002; Zinati et al., 2019). With little concern for agro-biodiversity or nutritional and socio-environmental quality, the aim of industrial agriculture is straightforward: continually produce the largest quantities of a few staple crops (corn, wheat, soy) in as concentrated a space as possible. Beyond the farmgate, industrialization has brought impressive global distribution channels, mass-scale canning (Zeide, 2018), refrigerated freight, and new forms of financialization, such as future markets for wheat (Cronon, 1992).

Commercial AMF inoculants were designed within this context, with the aims of production standardization and context-independent application. AMF inoculants were directly inspired by the successful commercialization of another soil symbiont found in agricultural systems: in 1895 patents were awarded to famed agronomists Lorenz Hiltner and Friedrich Nobbe for the production of inoculants of rhizobia, a group of bacteria that form root nodules on leguminous plants and can fix nitrogen (Oviatt, 2020). By the early 20th century, the use of a handful of rhizobial inoculants became commonplace in industrial agriculture, and researchers sought to similarly commodify AMF.

To be profitable, agricultural companies need an AMF inoculant that can be produced in mass, and work across agrarian contexts. It took a particular species of AMF, *Rhizophagus irregularis*, to achieve this goal. *R. irregularis* is an incredibly resilient (adaptable) pioneering species of AMF, one with global distribution and the ability to withstand the harsh conditions of industrial agriculture. Unlike other AMF species, *R. irregularis* is amenable to large-scale inoculant production: it will readily produce a prodigious amount of spores, and will consistently sporulate under scaled-up in vitro conditions (e.g. large bio-reactors) (Declerck et al., 2005). Thanks to these same features, *R. irregularis* can be used in tandem with many of the pesticides and synthetic fertilizers that farmers have come to rely upon; the species is able to live in a wide array of climates, and persist amidst the harsh conditions of industrial agriculture (Hijri, 2016).

Agricultural conglomerates now produce AMF inoculants alongside synthetic (chemical-based) products. They market AMF inoculants as a complement to their existing catalog of products. Rather than the reform of industrial agricultural practice, this is an "input substitution approach" (Altieri & Farrell, 2018). *R. irregularis* inoculants grown in massive bioreactors have become the dominant mycorrhizal technology in agriculture.

Depending on whom you ask, commercial AMF inoculants are either the forerunner of a new green revolution (Fortin et al., 2016) or a nascent technology with environmental risks and a dubious track record in enhancing yields or plant health (Hart et al., 2017; Schwartz et al., 2006). The greatest success of commercial AMF inoculants may be their ability to fit into status-quo industrial agriculture. Sold as part of a seed coating or as a powder to be mixed in with seed before sowing, a farmer can avoid the expense of specialized equipment or added labor and easily apply AMF inoculants to their crops.

That these inoculants do more to uphold a form of agriculture in need of fundamental change has led critics to deride AMF inoculants—as currently sold and used—as a form of "maintenance repair" in a time when industrial agriculture is in need of "transformational repair" (Henke, 2008). Maintenance repairs have been shown to distract from necessary transformational repair, which almost always comes at a higher political cost (ibid.). Even proponents of commercial inoculants admit that the technology is a "stepping stone" to the greater change that most farmers now agree is needed (Amaranthus & Allyn, 2013).

3 | AN ALTERNATIVE IMAGINARY

The majority of farmers in the world follow non-industrial methods. They have found ways to supply nutritious food to their communities without harming local ecologies or socioeconomic conditions (Mazoyer & Roudart, 2006). Where industrial agriculture has taken hold, it has rendered these forms of farming "alternative." Well-known examples include organic, regenerative and biodynamic agriculture. To be sure, there are plenty of cases in which these agricultural systems have reached what we describe as AOTM (see, Gliessman, 2014). But this ability to expand acreage is far from the norm. Most non-industrial operations rely on practices that are difficult to conduct on larger parcels of land and are not amenable to the continuous production of a few commodity crops. Instead, small-scale farms are celebrated as "beautiful" (Schumacher, 1989), a quality that is now central to the sociotechnical imaginary that we refer to as cottage agriculture.

Ever since the onset of industrialization in agriculture, an adamant and consistent group of researchers and practitioners have realized the environmental and social harm of industrial agriculture: the degradation of soil, homogenization of crops and the growing reliance on inputs and machinery (Jackson, 2010; Rodale Institute, 2014; Shiva, 1993). These critics point out the environmental costs of the mass production of farm inputs, as well as the "afterlife" of these products that concentrate in soils and human bodies, and run off into downstream environments (Murphy, 2017; Myers et al., 2016).

Mycorrhizal fungi have long been part of this conversation. In the early 20th century, a prominent figure of what is now called organic agriculture, Sir Albert Howard, erroneously turned to mycorrhizal fungi when seeking to explain why compost is better for plant health than chemical fertilizers (Gieryn, 1999). In 1946, commenting on the predominant trend in agriculture, Howard wrote of a "failure to realize that the problems of the farm and garden are biological rather than chemical" (Howard, 2006; p. XXV). Such criticism arose with the advent of synthetic and chemical forms of plant fertilization. In 1893, the English physician G. Vivian Poore wrote about "the living earth," and called chemical fertilizers a "speculation" (Poore, 1893; p. 163). In 1898, the English farmer Robert Elliot lamented the rise of "chemistry" in agriculture, noting that the "chemist really knows nothing of agriculture" (Elliot, 1908; p. 117).

Today, the nebulous concepts of "soil health" and "soil biology" remain inseparable and of central concern for those farmers who follow methods that oppose industrial agriculture (Ingham et al., 2000). Farmers in this group insist that plant health and sustainable yields rely on the added labor that supports soil biology—namely, sophisticated crop rotations, the use of cover crops instead of fallow periods, and the regular addition of soil amendments rich in organic matter, such as manure. There is evidence that these practices lead to thriving communities of AMF (Mäder et al., 2002).

If those who conduct research with industrial systems are too confident in their ability to simplify mycorrhizal ecosystem services, researchers and growers who work with cottage farming systems err in the other direction: when asked *how* certain farming practices aid certain plant–microbe interactions, they too often take refuge in the complexity of soil biology. They are too accepting of what is often called the "indeterminacy" of mycorrhizal functioning, and plant–microbe interactions more generally. In this way, soil biology remains a "black box."

Indeterminacy and unknowable complexity has become a hallmark of a sociotechnical imaginary that expands far beyond agricultural practice. In the past decade, a diverse array of popular and academic figures have characterized the mycorrhizal symbiosis as intrinsically wild, the antithesis of efforts to "harness" nature (for plant production or otherwise) (Matsutake Worlds Research Group, 2009). Instead of a well-defined tool, the symbiosis has become a trope for indeterminacy and complexity beyond traditional scientific ways of knowing (cf. Taylor, 2005). In this interpretation, mycorrhiza is a harmonious relationship that exists in the wild, not on managed arable lands (Simard, 2017; Wohlleben, 2016).

To make future agriculture more sustainable, a focus on soil biology is certainly a step in the right direction. Small-scale farmers can operate while black-boxing the specific functions and components of soil biology. However, this approach precludes midsize farmers from taking advantage of the specified "ecosystem services" offered by soil microbes and plant–microbe interactions (Gianinazzi et al., 2010). Mycorrhizal technologies for AOTM offer a way to move beyond the ambiguous concept of "soil biology," they hold promise in joining environmental sustainability with enhanced yields on mid-sized farms.

4 | MYCORRHIZAL TECHNOLOGIES FOR MIDDLE AGRICULTURE

We see mycorrhizal technologies designed for middle agriculture as more integrated into agro-ecologies than a handful of mass-produced inoculants, and more definite than general guidelines to enhance soil health writ large. While these technologies have the potential to bring more than maintenance repairs to industrial-style agriculture, they will not always fit the mandates of organic (or cottage) agriculture. We could consider them "integrated mycorrhizal technologies" (Rillig et al., 2016), designed for mid-sized farms. Rather than resort to indeterminacy, AOTM mycorrhizal technologies would respect and take advantage of the *variability* within AMF, in particular their array of functional diversity (see below). We outline the differences between mycorrhizal technologies for cottage, middle, and industrial agriculture in Table 1.

The lack of specificity with mycorrhizal technologies for AOTM is sure to frustrate some of our readers. However, rather than offering dubious predictions on what form these technologies will take, our intent is to stimulate research and dialogue on mycorrhizal technologies for AOTM. We hope that experts in varied fields of mycorrhizal research will take the lead in developing and implementing the new class of mycorrhizal technologies.

5 | MYCORRHIZAL SCIENCE FOR MIDDLE AGRICULTURE

Why argue for these technologies now? Mycorrhizal science has reached a point in which farmers no longer need to treat soil biology as a black box; nor does the dominant mycorrhizal technology need to consist of inoculants amenable to in vitro (standardized, mass) production. Simply put, the ways AMF are dealt with in arable soils do not reflect recent mycorrhizal science. We see a great need to create a more immediate and responsive connection (feedback loop) between emergent mycorrhizal science and the development of vanguard mycorrhizal technologies for middle agriculture.

During the last few decades, mycorrhizal science has expanded in disciplinary and methodological scope (Ferlian et al., 2018), having moved well beyond the individual plant level on the one hand, and having tackled many molecular intricacies of symbiotic interactions and exchanges on the other. Research designs with AMF now look beyond a limited array of plants and fungi (model symbionts) that grow well in labs and under in vitro conditions. Technologies such as high-throughput sequencing have led to a diverse array of researchers who now work with AMF, a community that spans taxonomic specialists to diverse networks of molecular ecologists. A focus on ecosystems (Powell & Rillig, 2018) has led researchers to more fully embrace the intricacies of the symbiosis in natural ecosystems, and explore the array of changes in AMF functionality with differing biotic and abiotic conditions. In fact, research has moved to the global scale, highlighting regional, and biogeographical variability of AM fungal communities (e.g. Davison et al., 2015).

This new wave of research has altered how AMF, as a group, is characterized. The context-dependent nature and spatial variability of AMF (at multiple levels) has recently become a significant subject of mycorrhizal research. As the spatial variable of AMF more clearly comes into view, descriptions of the symbiosis as indeterminate in its complexity diminish. Sophisticated tools and adventurous research designs (e.g. Johnson et al., 2002; Kiers et al., 2011) have enabled researchers to find new patterns in the functional diversity of AMF. The ability to read these patterns holds potential for the management and optimization of AMF in arable soils.

Emergent findings in AMF functional diversity (variable ecological functions) hold new potential for mycorrhizal technologies. One example is the realization that subsoils may harbor AMF communities that are distinct from those in the more thoroughly researched topsoils; these subsoil communities could be separately managed via agricultural practices (Sosa-Hernández et al., 2019). Researchers are also discovering fungal traits that are critical for agro-ecologies, which mycorrhizal technologies could potentially target—for example the promotion of soil aggregation (Lehmann et al., 2020).

TABLE 1 Characteristics of industrial, middle, and cottage agriculture, exemplified for a number of inputs, management practices and socio-economic benefits and costs

	Industrial	Cottage	AOTM
AMF inoculant production	Limited to strains cheaply produced in global centers of production (in vitro)	Laborious on-farm production (see, Douds et al., 2005)	Wide array of species produced regionally (in vitro & in vivo)
AMF inoculant use	Use of AMF strains best able to supplement or substitute P fertilizers	Used to boost native AMF communities	Used to boost specific microbial communities (native or not), for particular growth parameters of crops, and during transitional periods
Pesticide use	Liberal (few limitations)	Avoided, except in extreme cases	Used strategically, not regularly
Tillage	Liberal (few limitations)	Minimal, most often done for weed control	Depth, style, and frequency done with consideration for specific AMF communities
Crop rotation	Maximize planting of a few cash crops (high-performance hybrids)	Maximize diversity of cash and cover crops, which often reduces short-term farm revenue	Tailored to enhance specific microbial communities, at specific times
Soil amendments (bulk)	Often infeasible with large acreage. Soil deficiencies are corrected with synthetic (less voluminous) inputs	Heavy reliance on compost, manure, and other substances that hinder efforts to scale production	More refined use of bulk soil amendments and synthetic inputs, informed by closer attention to plant-microbe interactions
Plant breeding	High-yield varieties designed to be as context independent as possible	Heritage varieties that are often more difficult to grow and regionally specific, yet fetch higher market values	Breeding done with consideration for effects on microbial communities, and regional economies and societies
Agro-biodiversity (macro and micro)	Limited, to the extent possible	Greater diversity equals healthier agricultural system	Targeted ranges of plants and microbes for specific growth parameters
Economic benefit	Maximized for global commodity markets, often at the cost of regional communities	Local production & consumption (but struggles to fulfill local demand)	Focus on regional economies, potential to fulfill the needs of regional buyers & consumers
Mycorrhizal research (focus and need)	Mass production of commercial inoculum; technologies for field application	Management practices that favor soil biodiversity and AMF abundance in general; local and on-farm production of AMF inoculum	Design of AMF communities to maximize certain functions; integrate AMF in the timing of interventions; locally sourced inoculum for soil restoration; companion technologies to manage other aspects of soil biodiversity

AMF do not function in isolation, and thus companion technologies are needed. Mycorrhizal science must be connected with allied disciplines, such as crop breeding, the use of other microbial inoculants (Rillig et al., 2016) and agronomic research more generally (Shennan et al., 2017). The AMF research community does not currently fully understand how dependent AMF establishment, diversity, and functions are on other soil microbes (e.g., Frey-Klett et al., 2007), or how farming practices may affect these wider community dependencies and interaction networks (van der Heijden & Hartmann, 2016); these are clear future research needs.

To be sure, concepts that take on the complexity and functional diversity of AMF have long been explored, but until recently they have remained at the margins of the research community. For example, as early as the 1980s a small group of researchers were talking about the "mycorrhizosphere" (Linderman, 1988), a theoretical framework that helps researchers investigate the variability and context-specificity of the mycorrhizal symbiosis. There is now a strong will in the mycorrhizal research community to take on the difficult questions of functional diversity of the mycorrhizosphere (e.g. Koller et al., 2013), as it exists in complex environments such as arable or unmanaged lands.

6 | MIDDLE AGRICULTURE NEEDS A SOCIOTECHNICAL IMAGINARY

As described above, a significant amount of work has gone into sociotechnical imaginaries for industrial and cottage forms of agriculture. Research agendas, environmental activism, political lobbying and government policies, and charismatic leaders have worked in unison to ensure that both forms of agriculture would have a place in modern societies. There is, however, far less certainty about what constitutes AOTM, and what it aims to be. AOTM has no well-defined sociotechnical imaginary.

The popular, epistemic and political-economic narrative of AOTM (one that stretches back in time and forward in the future) needs to be written. This will not require a reinventing of the wheel: ample evidence shows that mid-sized farming operations carry many of the same social and ecological benefits as small-scale agriculture. Studies have shown that midsize farms tend to be owner-operated and family-centered, with land passed down to younger generations—qualities that foster long-term commitments for soil health, and encourage investment in the local community (Lyson, 2008). Still, it may be difficult to convince growers to enter into or remain within AOTM. Owing to familial traditions, economic incentives, or political ideologies, many growers are entrenched within industrial or cottage forms of agriculture. This is when a strong sociotechnical imaginary becomes important.

Agriculture of the middle is also a critical way to build regional systems of food production and consumption, what scholars have called "food sheds" (Kloppenburg et al., 1996). Buying local has long been a slogan of organic or cottage farming. However, it can be difficult for smaller farms to meet the needs of local businesses: Local grocery stores may need more consistent orders than cottage producers can fulfill; regional schools or low-income food programs may need quantities that small-scale farmers cannot meet (McAdams, 2015).

All three forms of agriculture may share an aim for environmental "sustainability." But they differ in what sustainability means (Huutoniemi & Tapio, 2014), how to achieve it, and at what political and economic cost. Proponents of cottage agriculture, who want their preferred form of plant production to replace industrial systems, face seemingly insurmountable political hurdles. The rise of AOTM will inevitably disrupt a certain degree of status-quo corporate revenue flows. But compared to organic/cottage agriculture, it is not nearly as tough a sell to politicians beholden to corporate agricultural interests, and to the agricultural conglomerates themselves. In sum, the time is right to make the case for reform in agro-food systems—and vanguard research agendas in plant–microbe interactions, which are directly informed by the needs of midsized farmers, hold great promise in the creation of ecologically sound food systems that can meet regional demands.

7 | A TIMELY PROPOSAL

Ever since industrialization took place, middle agriculture has had an established role. Its decline over the past few decades is a novel phenomenon (Barlett, 1993). This decline has come with the rise of industrial agriculture. While this trade off may have once been acceptable, today, with industrial agriculture causing increasingly apparent destruction of rural communities and environmental quality, along with decreases in the nutritional value of food, its pervasive supplanting of middle agriculture can no longer be justified.

The world's largest food and agricultural companies are not blind to the dire need for agricultural change in industrial societies. Chemical agricultural conglomerates have recently created "biological" divisions, and food companies such as General Mills are investing in "regenerative" agriculture. More recently, the COVID-19 pandemic has revealed the vulnerability of global food distribution networks, invigorating calls to strengthen regional foodsheds. AOTM is necessary if regional farmers are to supply enough food for local buyers, especially schools, hospitals and the like.

In short, the political will to disrupt the entrenched economic interests of industrial agro-food systems is now high. Mycorrhizal researchers, who seek funding and public support for the research agendas we describe above are well-positioned to take advantage of the current socio-political climate. A political climate ripe for agricultural reform now dovetails with a technoscientific climate that offers more nuanced views of plant-microbe interactions, and the tools to manage them. The timing is thus right to push for mycorrhizal technologies for an agriculture of the middle.

8 | CONCLUSION

We have sketched two sociotechnical imaginaries so as to exemplify extreme versions of incorporating mycorrhizal knowledge and technologies into future agricultural systems. We believe that both of these extremes will be difficult to fully realize, especially as far as mycorrhizal science and technology are concerned. Moreover, we are convinced that a future of sustainable agriculture will need more than small-scale farmers who take refuge in complexity, and industrial farmers who seek to homogenize this biology (if not replace it with synthetic, mass-produced technologies). We see "agriculture of the middle" as a potentially workable compromise, and we believe that better integrated (and more sophisticated) AMF technologies will help rekindle this mode of agriculture for the 21st century. The compromise between the industrial and the cottage will be challenging. It will likely fall short of idealized goals in either imaginary; finding compromises for a wide range of parameters will be a contested process. However, it is our hope that making explicit these contrasting visions of agriculture—each with their own set of mycorrhizal applications—will open a productive dialog among stakeholders, including farmers, policy makers, scientists, and industry insiders. Highlighting extremes, we hope, will also stimulate ideas for building bridges among seemingly irreconcilable and contradictory approaches.

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AUTHOR CONTRIBUTIONS

P.O. and M.C.R. planned and designed the article. P.O. wrote the manuscript.

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