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SPECIAL FEATURE: ORIGINAL ARTICLE

The "How" of Transformation: Integrative Approaches to Sustainability

Regenerating soil, regenerating soul: an integral approach to understanding agricultural transformation

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Abstract

Understanding what motivates farmers to adopt "climate-smart" regenerative practices is critical for developing the right policies, incentives, outreach, and support mechanisms. This article explores factors that motivated farmers in NSW Australia to transition from conventional to regenerative agriculture (RA), focusing on the role that their perceptions of agrochemicals and the microbiome played. Drawing on integral theory, the article takes a holistic approach to analyzing how farmer interiorities in personal and collective realms interacted with external behavior and the larger social-ecological system in which food and fiber is produced. A key finding is that negative experiences with agrochemicals associated with increasing costs and declining results were an important driver of change. Conversely, positive experiences learning about the microbiome and practicing ecological approaches to fertilization and pest control engendered enthusiasm and commitment to a transition away from high-input agriculture and a transformation in mindset. Further, conviviality associated with communities of practice, e.g. microscope groups, played an important role in the transition process, as farmers solidified new identities and participated in ongoing social learning. Based on these results, I argue that farmers' feelings of kinship with nature (animals, plants, microbes) resulting from learning about and working with soil are underappreciated drivers of behavioral change and powerful leverage points for larger-scale social-ecological transformation. The integral model facilitates recognition of the connections between soil condition, farmers' perceptions of and feelings about its condition, ensuing behavior including participation in new networks, and the creation of new norms, all of which create space for the emergence of institutional and systemic change.

Keywords Regenerative agriculture · Climate-smart agriculture · Agrochemicals · Microbiome · Integral theory · Social-ecological transformation

Introduction

Growing dissatisfaction with modern industrial agriculture and its associated environmental and social harms (Campbell et al. 2017) is creating space for the rise in popularity of an alternative model—regenerative agriculture, which concerns itself with enhancing and restoring resilient systems supported by functional ecosystem processes and healthy, organic soils capable of producing a full suite of ecosystem services, among them soil carbon sequestration and improved soil water retention (Gosnell et al. 2019; Newton et al. 2020). Regenerative agriculture can be thought of as a type of "climate-smart agriculture" (CSA), in that it aims to "transform and reorient agricultural systems" to respond to a changing climate by "sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible" (FAO 2013); but it goes beyond CSA in that it focuses on the functionality of ecosystem processes associated with soil health. Because the transformation in worldview and thinking that is required to succeed in regenerative agriculture after having been a conventional farmer all of one's life is so significant, we conceptualize the change process as a type of transformational adaptation (Gosnell et al. 2019). In contrast

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to a more limited socio-technical "transition" in agricultural practices, a full spectrum social-ecological transformation from conventional to regenerative agriculture would involve significant changes in natural capital, norms, values, beliefs, rules and practices (Holscher et al. 2018; Moore et al. 2015). Given the many systemic, cultural, and personal barriers to change that actors in agriculture face, the realization of this potential is uncertain (Campbell 2020). Scholarship on social-ecological transformation provides insights into the issue but has mostly focused on the ecological, behavioral and institutional aspects of systemic change (Gunderson and Holling 2001). There is growing recognition of the need to integrate other important aspects of transformation with social-ecological systems thinking to more accurately understand and address the phenomenon; but perspectives on subjective, interior phenomena including human experience, consciousness and culture generally receive less attention in sustainability science (Folke et al. 2011; Westley et al. 2013; Brown et al. 2019; Chapin et al. 2011; Masterson et al. 2017; Shrivastava et al. 2020).

Given the growing evidence that the personal sphere of transformation matters (Adger et al. 2011; Masterson et al. 2017; Brown et al. 2019), what is needed is a more synthetic metatheoretical approach. An approach to understanding how social-ecological transformation occurs, e.g., as a result of a socio-technical transition to regenerative agriculture (RA) (Holscher et al. 2018), would allow for consideration of how material and non-material aspects of transformation interact with each other. In the absence of such knowledge, effective interventions and leverage points to reduce ecological, economic, and societal harms caused by modern agriculture and space for the emergence of a more regenerative model remain limited.

With this paper I aim to broaden understanding of the "how" of social-ecological transformations by using integral theory (Wilber 1996; Esbjorn-Hargens and Zimmerman 2009), as interpreted by climate change adaptation and sustainability science scholars (O'Brien and Hochachka 2010; O'Brien 2018; Shrivastava et al. 2020), to examine how transformation occurs in and across four "domains of reality" that include personal experience, culture, behavior, and systems. Integral theory is a "philosophical map" that seeks to describe and explain the relationship among the four domains, which represent singular and plural perspectives on the interior and exterior aspects of reality. "Interiors refer to the subjectivity and intentionality of individuals" in the singular, and to cultural systems in the plural; while exteriors refer to "behaviors and physiological characteristics in the singular and to systems phenomena in the plural" (O'Brien and Hochachka 2010, 92).

Drawing on interviews with sheep and beef farmers in Australia who are long-time practitioners of RA, I argue that the potential for agricultural transformation cannot be understood without examining farmer "interiorities" along with their outward manifestations in behavior and systems. Examining all four dimensions and linkages between them sheds light on how social-ecological transformation in the agricultural system occurs from the bottom up and inside out (Moore et al. 2015). This responds to calls in sustainability science to integrate an understanding of the inner transformation that takes place in personal and cultural realms with behavioral and systemic change in social-ecological transformations (Adger et al. 2013; Brown et al. 2019; Chapin et al. 2011; Gosnell et al. 2019; O'Brien 2018; Shrivastava et al. 2020). Identifying the processes by which these actors are bringing about transformation in agriculture as well as the barriers they face provides knowledge about leverage points, such that interventions can be designed to support the transformation to a more regenerative and equitable agricultural system (Tourangeau and Sherren 2020).

There are a myriad of entry points to a consideration of levers for the agricultural transformation associated with farmer interiorities. This paper focuses on one important aspect of the process which has to do with farmers' experiences with agrochemicals and the microbiome. I argue that negative experiences with chemicals create space for considering other ways of producing food and fiber, and that, conversely, positive experiences learning about the microbiome and seeing the results of new practices that forgo the use of chemicals are a major motivator for starting and continuing on the transformation journey. Giving up chemicals is challenging, however, and support and fellowship are essential ingredients in the transition process. The adoption of new farmer identities, new ideas about "good" farming, and the cultivation of new norms around production are critical but underappreciated aspects of the project of transforming our agricultural systems to be more resilient, regenerative, and climate-smart.

After providing an overview of RA, I describe my conceptual framework and methods, then present research results. I characterize and explain transformational processes and feedbacks associated with (1) the interior lives and experiences of farmers who have undergone the transition; (2) their old and new behaviors; (3) their experiences interacting with their peers and participating in cultural change; and (4) their perceptions of the larger agricultural system (industry, policy, institutions). Persistent barriers to transformation in each of these realms are also considered. The discussion considers the value of applying an integral lens to the study of social-ecological transformation to provide a holistic understanding of how systemic change in the way food and fiber is produced by farmers interacts with cultural transformation, behavioral change, and epiphanies and experiences of meaning-making in the "personal sphere" (O'Brien 2018; Shrivastava et al. 2020). Leverage points for supporting transformation are considered and form the basis

for a broader set of policies and strategies to create space for transformative change in producer identities, relationships, communities, government programs, business models, and institutions associated with modern industrial agriculture.

Background: regenerative agriculture

Regenerative agriculture is a set of ideas and practices that have emerged over the past 3 decades in response to growing societal concern with modern industrial agriculture's role in climate change, soil depletion, and biodiversity loss (Newton et al. 2020; Campbell et al. 2017). A low cost, low-tech natural climate solution that aims to enhance soil and ecosystem health along with the well-being of farmers and the larger society, RA has the potential to help meet a number of Sustainable Development Goals associated with environmental and social justice (Neufeldt et al. 2013; Griscom et al. 2017; Rhodes 2017; Paustian et al. 2016; Lal 2020). Variously identified with practices of ecological agriculture such as permaculture, Holistic Management, and carbon farming, the umbrella term regenerative agriculture was originally coined in the 1980s by Robert Rodale, who saw the need for an approach that would not merely sustain dysfunctional approaches to food production that deplete resources, but rather improve and regenerate the resources it uses (Francis and Harwood 1985). Although the primary focus has been on soil and ecosystem health, RA has also become increasingly concerned with social equity as one and indivisible with ecological health, the ultimate goal being "an ecosystemically vibrant, socially equitable, culturally diverse, and spiritually meaningful global system of regenerative potential" (Soloviev and Landua 2016, 1; Lal 2020; Fullerton 2015).

Practices associated with RA aim to leverage ecosystem processes to increase soil organic matter and soil biodiversity which serves the dual purpose of fostering forage growth and increasing water holding capacity to reduce vulnerability to droughts and floods (Machmuller et al. 2015; LaCanne and Lundgren 2018; Masters 2019; Gosnell et al. 2020a, b). Managing soil carbon is a major focus and is accomplished through a number of techniques including reducing or eliminating tillage; increasing soil organic matter through spreading compost; planting diversified cover crops to reduce bare ground (and tolerating weeds); and diversifying crops to reduce vulnerability to disease and pests (Toensmeier 2016; Montgomery 2017). Regenerative farmers also eliminate, or at least reduce, the use of chemical inputs such as synthetic fertiliser, herbicides, and pesticides to "restore integrity" to the system and "rebuild the soil microbial bridge central to producing foods with the full spectrum of vitamin, minerals and enzymes" (Masters 2019, 239). Those with livestock use strategic or holistic planned grazing or adaptive multi-paddock grazing to increase soil carbon sequestration and perennialization, moving livestock frequently between habitats and across elevational gradients to follow optimal forage conditions as they shift during the growing season and to allow sufficient rest and recovery of grazed pastures (Teague et al. 2016; Teague and Barnes 2017; Scherr et al. 2012; Fynn 2012).

Montgomery (2017) notes that regenerative farmers "see" soil differently, as a biological system rather than a chemical reservoir and this is why they work to support subterranean life rather than kill and replace it, fostering a "subterranean symbiosis" between mycorrhizal fungi and plants to bring soil back to life. They also think differently about water. Drought is not just determined by what falls from the sky, it has to do with what is in the soil and whether the ground can hold water (Montgomery 2017). Rather than reactively depending on precipitation, regenerative farmers proactively manage landscape and soil processes to improve water storage and availability, e.g., through Keyline design, a landscaping technique aimed at maximizing the beneficial use of the water resources on a tract of land, i.e. helping land retain all the rainfall it receives (Yeomans 1954; Doherty and Jeeves 2016). Some regenerative farmers approach decision making using the principles of Holistic Management (Savory and Butterfield 2016; Gosnell et al. 2020a, 2020b), a "deep leverage point" for facilitating "effective and lasting transformations" in farmer behaviour involving fundamental changes in system design, structure, and ways of thinking, e.g. paradigm shifts (Tourangeau and Sherren 2020). Australian farmer Charles Massy (2017, 391) observes that "the leading regenerative farmers work with and not against nature: they seek to enhance her uniquely complex functions, nuances and directions—even when they don't fully understand them." Regenerative farmers enjoy a different relationship with their livestock that involves "low stress" animal husbandry and learning from their "nutritional wisdom" (Provenza 2018).

Despite its many appeals, a number of challenges keep farmers and ranchers from adopting RA: lack of experience and information about regenerative practices, cost of transition, peer pressure, fear of stigma, having to shift social groups (Gosnell et al. 2019; Abson et al. 2019) and, importantly, the need for a paradigm shift to higher-order systems thinking (Stinner et al. 1997; Sherren et al. 2012; Mann et al. 2019; Fazey 2010; Massy 2017). Understanding and learning to manage the system can be challenging and may take years (Gosnell et al. 2020b). Early adopters are often motivated by crisis (e.g. drought, bankruptcy, illness) and have a willingness to try new approaches when able to access mentorship, peer-to-peer learning, and communities of practice (Cross and Ampt 2016; Nerbonne and Lentz 2003; Gosnell et al. 2019). Massy (2017, 413) argues that emotion related to crisis and "the galvanisation of a strong ethical element" is "the critical motivator to

change." He notes that regenerative farmers develop a strong sense of community and compassion for wider society.

The RA movement has grown into a "soil revolution" of sorts in recent years as consumers, producers, retailers, policymakers, and investors have been made aware of the importance of soil health and increasingly support regenerative products and respond to emerging niche markets and certification schemes (Montgomery 2017). Transnational corporations such as McDonalds, General Mills, Cargill and Tyson—understudied but key actors in social-ecological transformation (Folke et al. 2019)—have also expressed interest in "climate-smart" agricultural practices associated with RA and some are investing in research to help farmers/ranchers reduce their carbon footprint (Mercola 2017; Giles 2019), though the potential for regenerative practices to contribute to climate change mitigation remains somewhat controversial (Giller et al. 2021; Fountain 2020; McGuire 2018). In the U.S., Australia, Europe, and elsewhere, policies and programs aimed at incentivizing RA to enhance resilience to climate change and drought are becoming more common and attracting bipartisan support (Evich 2019; Volcovici 2020; Perroni 2019; Fortuna 2020). These are all signs of what Lorimer (2020, ix) refers to as a "probiotic turn" in the management of human and environmental health, characterized by the use of "probiotic approaches" that involve "using life to manage life; and intervening in the ecological dynamics of a system to deliver desired functions and services."

As discussed in previous studies (Massy 2017; Gosnell et al. 2019), crisis is a common precursor to transformation, and, for conventional farmers, it comes in many forms. Climate-related crises are important drivers of change (both adaptation and transformation) and have been written about extensively (Pelling 2010; Moser and Hart 2015). In this paper, I focus on physical and existential crises associated with the use of agrochemicals, and processes leading to the inner and outer transformation that have to do with the discovery of alternative ways to grow food and fiber that forgo chemicals and rely on the microbiome, leading to a new sense of connection, purpose, enthusiasm, and empowerment. This aspect of farmer transformation has broader relevance to other environmental crises and to the sustainability science community since it provides insights into an important leverage point for change—the power of reconnecting individuals to nature which can activate biophilic emotions that fuel new behaviors, including collective actions that contribute to new societal norms that will, ultimately, be reflected in systemic change.

Conceptualizing social-ecological transformation with an integral lens

Recent scholarship on social-ecological system transformation has called for greater attention to the "how" of transformation, and more specifically the ways in which it occurs from the bottom up through deliberate actions, e.g., cross-scale networking and social movements (Moore et al. 2014, 2015; Chaffin et al. 2016) and from the inside out via the inner dimensions of sustainability transformation (Grenni et al. 2019; O'Brien 2013a, b; Adger et al. 2013; Brown et al. 2019; Gosnell et al. 2019; Shrivastava et al. 2020). These interiorities include individual epiphanies, paradigm shifts, new identities and values, empathy, sense of place, and efforts to rectify cognitive dissonance (Tourangeau and Sherren 2020; Brown et al. 2019); as well as collective cultural shifts born of moral psychological reckonings with environmental loss and decline (Callicott 1990; Singh 2015).

One way to address the multidimensional and distinct aspects of social-ecological transformation is to frame research questions and objects of inquiry using integral theory (Wilber 1996), which recognizes that disparate aspects of reality—experiences, behavior, culture, systems—are all critically important to any knowledge quest. There is a growing body of scholarship that demonstrates the value of integral theory to overcome previous deficits and impasses and deliver new kinds of insights into various social-ecological dynamics and challenges (Riedy 2007; O'Brien and Hochachka 2010; Hochachka 2011; O'Brien 2018; Riddell 2011; Tissot 2011; Shrivastava et al. 2020). Gosnell et al. (2019) built on O'Brien's (2018) "spheres of transformation" integral framing, adding an analysis of zones of friction and traction in personal, political, and practical spheres as they relate to RA adoption in Australia, and linkages between the spheres.

Integral theory's four-quadrant model (Fig. 1) highlights four dimensions of reality associated with interior and exterior phenomena relevant to both individuals and collectives (Wilber 1996; Marquis 2007; Esbjörn-Hargens and Zimmerman 2009; Shrivastava et al. 2020). Phenomena on the left side of the diagram, which include individual experience and collective culture, are referred to as interiorities. Exterior phenomena including individual behavior, ecosystems, and institutions—commonly studied in sustainability science—are represented on the right side of the diagram.

In quadrant 1, considerations of farmers' personal experience include mindsets, beliefs, values, motivations, and identity. For example, many farmers associate "good farming" with tidiness and order, an aesthetic which generally relies on agrochemicals (Burton 2004).

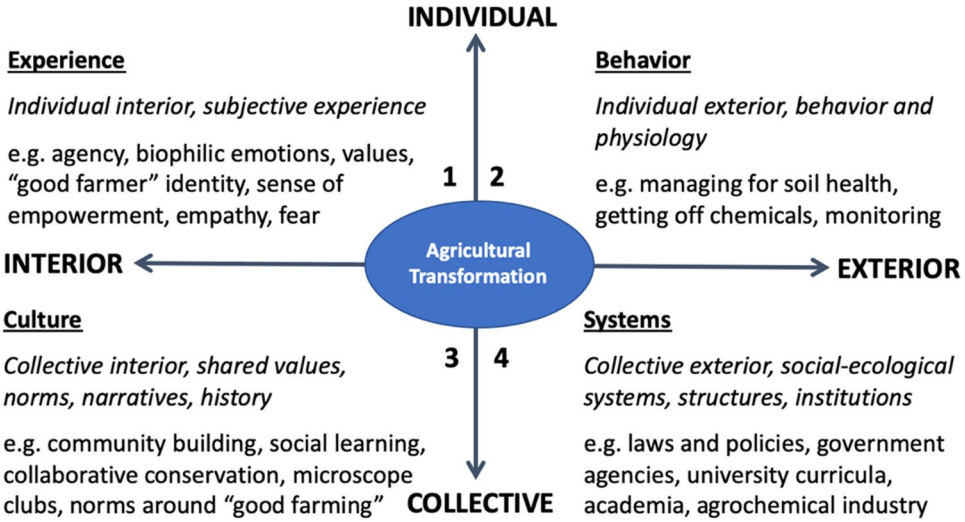

Fig. 1 Integral theory's four-quadrant model recognizes four perspectives/domains of reality that present different types of knowledge about a subject, in this case the role of RA farmers and farmer networks in social-ecological transformation. We examine linkages and feedbacks between phenomena occurring in different quadrants (adapted from Shrivastava et al. 2020 and O'Brien and Hochachka 2013)

A topic of growing interest in sustainability science, this dimension is critical for explaining inside-out transformation towards more regenerative social and ecological practices (O'Brien 2018; Gosnell et al. 2019). Quadrant 2 is where considerations of individual farmer's behavior and practices reside. Quadrant 3 deals with the culture and communities associated with conventional and regenerative agriculture. Shared values, norms, and narratives in this domain both derive from and influence individual ideas in the upper quadrants and can eventually manifest in system change in quadrant 4. System considerations include ecosystems, policies, laws, institutions, markets, and educational systems, for example, which are critical components in a complete transition from non-regenerative to regenerative social-ecological systems, e.g. restoring a landscape, putting a price on carbon, disincentivizing the use of agrochemicals, and ensuring equal access to government programs that support RA.

Phenomena in each of the realms can be degenerative or regenerative; they can be adaptive, involving incremental change within existing social-ecological systems, e.g. reducing the harms of conventional agriculture; or transformative, involving "more fundamental changes that can alter dominant social-ecological relationships and create new systems or futures" (Barnes et al. 2020), e.g. transitioning to RA, which often involves forgoing chemicals, adopting new management strategies, and working closely with soil and animals to produce food and fiber. Analysis of phenomena in each of the four quadrants and cross-quadrant dynamics to determine the ways in which farmers are experiencing and contributing to social-ecological transformation requires insights from scholarship that goes beyond the study of exterior phenomena such as behavior and institutions.

This paper draws on and seeks to integrate exterior phenomena in quadrants 2 and 4 with more specialized, in-depth studies regarding psychological and behavioral well-being and change in farmers associated with individual subjective experiences (quadrant 1) and collective cultural experiences (quadrant 3). The former (quadrant 1 material) includes scholarship on biophilic impulses from ecopsychology (Kellert and Wilson 1995; Kamatsis and Francis 2013; Davis 2011; Mayer et al. 2009), transpersonal agroecology (Cox 2014), affective ecologies (Singh 2015; Hustak and Myers 2012; Lloro-Bidart 2018; O'Brien 2013a, b; Puig de la Bellacasa 2014; Pouliot 2013), multispecies ethnography (Ogden et al. 2013), resilience thinking (Caillon et al. 2017), and horticultural therapy (Adevi and Martensson 2013). Relevant scholarship on the cultural and collective aspects of agriculture, generally, and soil, more specifically (quadrant 3), includes perspectives from environmental philosophy (Callicott 1990) and rural sociology (Beus and Dunlap 1990); ethnopedological studies of farming communities and their soil and land knowledge systems (Barrera Bassols and Zinck 2003; Richelle et al. 2018; Pauli et al. 2016; de Bruyn and Abbey 2003; de Bruyn and Andrews 2016; de Bruyn et al. 2017) and more applied work on social learning, outreach, engagement, and empowerment around soil health (Pincus et al. 2018; Babaian and Twigg 2013).

Results from this research illustrate how experiential, behavioral, cultural, and systemic change create synergistic feedbacks to promote all-quadrant transformation of the agricultural sector and what leverage points and barriers matter in supporting transformation (Meadows 2008; Tourangeau and Sherren 2020). By focusing on the linkages between the four quadrants, and specifically inside out/outside in and bottom up/top down dynamics, I am able to identify unexpected levers for change.

Methods

This research took place in Australia primarily because there is a large community of farmers who subscribe to RA there and a number of government and farmer-led organizations have been set up to support this approach to farming. Methods included semi-structured interviews; participant observation at public meetings about regenerative farming and in a course I audited on Holistic Management; and document analysis, e.g., government policy and program statements and newsletters and websites of farmer organizations promoting RA. Interviewees were selected through purposive sampling (Bernard 2006) informed by suggestions from representatives of various regional and international farmer organizations that work with people who identify as regenerative sheep and beef farmers, e.g., Carbon Farmers of Australia, the Quivira Coalition, and the Savory Institute. I interviewed to the point of saturation, with 28 interviews throughout the "wheat and sheep belt" of NSW in Australia in 2013. In addition to Australian farmers (F), some of whom were also Holistic Management educators (FE) or consultants (FC), I also conducted three supplemental interviews with U.S. soil educators (E) and consultants (C) specializing in biological farming and RA who work with farmers internationally to help them with the transition. These supplemental interviews were conducted to deepen insights into how farmers learn about and experience the microbiome, what excites them, and how they experience "getting off" agrochemicals.

Corresponding with exterior and interior dimensions of the lived experience, interviews covered both objective and subjective aspects of farmer decision making and behavior, and were informed by social-ecological systems theory as well as social theory associated with concepts such as agricultural values, identity, emotion and place attachment, all of which relate to quadrant 1. Questions focused on the nature of the socio-technical transition farmers underwent away from conventional agriculture in quadrants 2 and 4 and the associated cognitive, emotional, and social transformation in quadrants 1 and 3. We also discussed systemic factors influencing their perceptions and behavior to address quadrant 4. Interviews lasted from one to three hours and were recorded and transcribed. Analysis of the interviews was conducted using a thematic analysis approach whereby repeated coding, sorting and categorizing were conducted using NVivo 9 qualitative analysis software (Miles and Huberman 1994; Maxwell 2005; Creswell 2009). The coding was primarily deductive in that I expected to learn about both interior factors (e.g. emotions, identity, values) and exterior factors (e.g. information, markets, incentives) influencing the decision to transition from conventional to regenerative agriculture, and therefore started with codes for those topics; but it was also inductive in that I did not expect to learn that the farmers' antipathy to agrochemicals and connection to the microbiome would be important factors influencing their behavior. The coding resulted in the identification of categories and concepts that emerged from the qualitative data and the linking of concepts together into plausible, substantive conclusions about the findings (Bernard 2006; Patton 2002).

Results

Results are presented in terms of their relevance to each of the four quadrants described in "Conceptualizing social-ecological transformation with an integral lens" and Fig. 1. Figure 2 provides an overview of the four quadrants and includes exemplar quotes for each one.

Farmer interiors: the role of inner experience in agricultural transformation

A common theme in the stories of transformation shared with me had to do with the emotional impact associated with the slow realization that the agrochemicals farmers relied upon were not working as well as they had in the past while becoming increasingly unaffordable. This realization frequently led to feelings of frustration, anxiety and depression.

> *We were highly productive but we were not profitable. In 2003 [before we transitioned], we grossed 1000/acre off the 2500 acres we had here then, but it cost us 1087 to do it per acre. So you do not stay around for too long, doing that. So, one of our friends, a mentor, so he came around and said, "You have got to change." (F6)*
> *That whole philosophy of trying to kill things that want to grow and trying to grow things that want to die, it is incredibly soul destroying and costly. (FC6)*

Since all of the farmers I interviewed were no longer using chemicals, they, and the consultants who work with them, all had a story to tell about the challenge of getting off of them. One consultant likened the experience to recovering from addiction to drugs.

> *You think about certain drugs that people use like cocaine. You use it the first time and you have a great feeling. And then after that you have to use more and more to get the same effect that you got the first time. And at the same time you're deteriorating your body, right? It is the same thing with chemical agriculture. The first time that a farmer uses chemicals or synthetic fertilisers on virgin soil, they have great yields. It is*

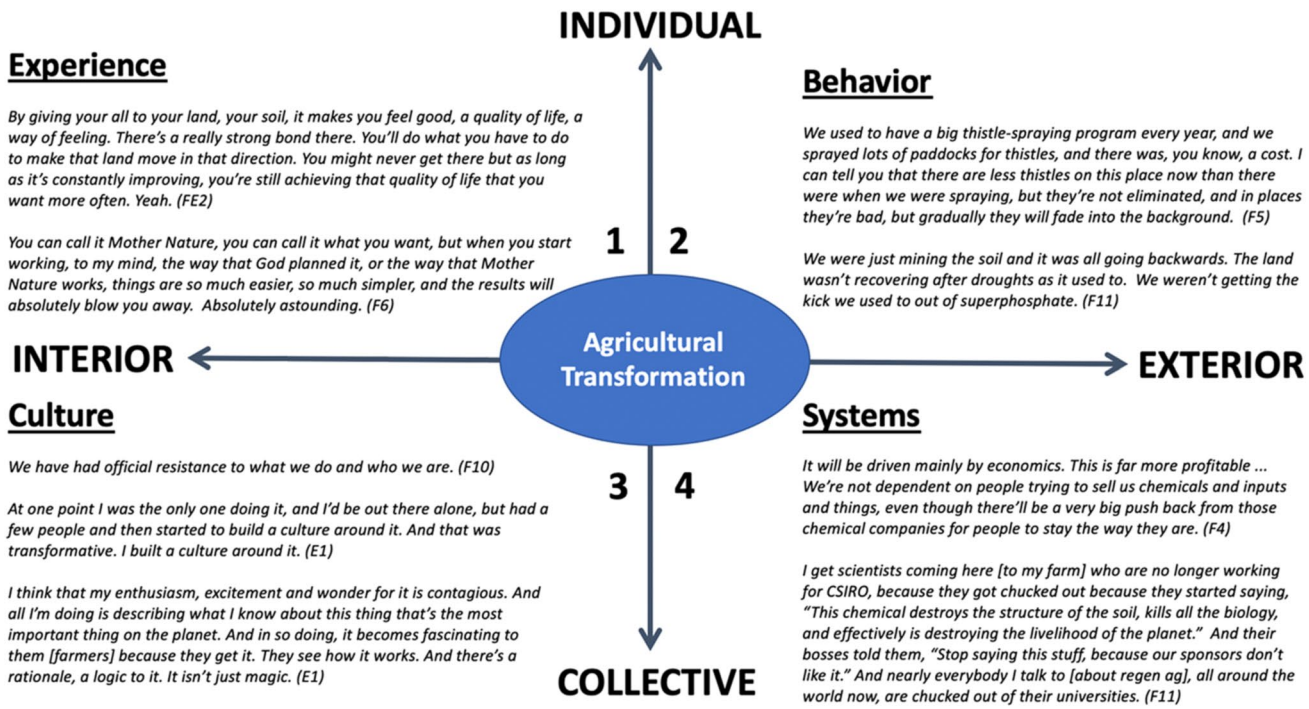

Fig. 2 Exemplar quotes related to different domains of reality in integral theory's four-quadrant model

great, they are hooked. And every year after that, to get the same yields, they have to use more fertiliser than they used the year before. They get to a point where their plant diseases and pests are so great that their yields are greatly impacted or they lose their entire crop. And the reason that the plant begins to suffer after so many years of chemical dependency is that the plant is not getting the nutrients that it needs. So as the years go by these problems compound and get worse and worse until the farmer's like, "Oh my God, what am I going to do? I can't continue on this addiction." Of course, they do not see it that way, but that's how I refer to it. (C1)

A key part of the process for all interviewees was changing their mindset to believe that farming could be possible without chemicals. This required setting aside skepticism and fear, about both crop failure and the opinions of their peers. In all cases, it required the assistance of an educator or consultant. One consultant estimated that the transition from conventional to regenerative agriculture usually takes about three years. The quotes below highlight the role of mindset and how it changes as a result of monitoring and experiential learning, both of which are empowering.

Changing the mindset of the farmers is very difficult. They do not believe that nature can take care of feeding the world. It is just that the [regenerative] system is so different, the concepts are so different that they can not see. We are both looking at the same thing, but from a different perspective. So they can not understand what I am saying, but I understand what they are saying because I have dealt with that mindset, and there is a lot of resistance. (C1)

We were very reliant on phosphate and chemicals to make sure that we could maintain our production. So what we have found since stopping the superphosphate and changing to rotational grazing is, we are encouraging more productive native grasses, like the Warregos and the Microlaenas in the summer, and in the winter the Wallabies and the common wheat grass, so we are getting a change in species composition, which is helping us maintain that production without superphosphate. (F12)

The shift in thinking is made possible as farmers undertake the formidable task of learning about fundamental ecosystem processes like energy flows and nutrient cycling. This happens through encounters with the microbiome, looking through a microscope, and by witnessing improved soil health. This educator reflected on the level of commitment required to undertake this journey and the need to "grow up" and be more responsible.

[I tell the students] you really do not need that stuff [chemicals] if you are really paying attention. This kind of farming requires you to know everything, so you need to go to school and you need to learn eve-

rything. This is not just calling up the Simplot guy and saying, "When do I spray?" You have got to be there and you have got to notice everything and you have to understand about insects, about biology and chemistry and physics. And you need to know it all, if you really want to do this. And all the other stuff has been kind of a shortcut for not knowing. And we did not know 50–100 years ago. We did not know how it worked so those solutions did not seem like shortcuts, they seemed like answers. (E1)

The "short cuts" associated with industrial agriculture are becoming less enticing to farmers as they come to understand the tradeoffs. But doing it "right" is hard, and, at least initially, more time consuming.

All trainings in RA include encounters with the microbiome, which also contribute to change in mindset, along with feelings of humility, awe, curiosity, enthusiasm, and a desire to continue learning.

One of the biggest aha moments is when they start to see the soil structure change on their property. For example, they will see that before they could not stick their finger into the soil deeper than half an inch, and now they can go in all the way to their palm. They start seeing the mycelium forming, the soil aggregation happening, the moisture in the soil from the water seeping in and not running off. And they are like, "Wow, it is possible. It's amazing." They look at [the improved soil] with disbelief, and then they get happy, they get excited. (C1)
The fact that it [soil] is a living thing, that it is alive, I think, is the thing that makes it interesting because then you can identify with it in a way that seemed very external before. The same functions that happen in the soil are happening in you, and that is why you are alive. (E1)

This new awareness and understanding provides confidence to experiment with replacing high cost, conventional tools (large machinery, chemicals and agronomists) with low-cost tools involving monitoring and working with nature, e.g. brewing and applying compost tea, to solve problems on their own. Seeing the possibility of a new way of doing things, with newfound independence, is motivating and empowering.

You get this hard soil going on, so you jump on large tractors with big pieces of machinery behind them and rip it up to break this hardness. Well we don't need to do that anymore because the plants do it for us. And you get lots of bugs and things that are also working for nothing. (F5)
Most people have never really understood nutrient cycling, as if the only way to grow a plant is for a human being to put an inorganic fertiliser in the soil. The plants have been around on this planet for the last billion years and didn't need any fertiliser salesman, so how did they survive before? And they are clueless. So they're all like, "I knew it! I knew that would be the way it worked! So thank you for telling me and now I can go and tell my fertiliser salesman, 'You're an idiot. I don't need your stuff, get out of my life!' And I get to keep this money in my pocket too!" (C2)
The average everyday person can join in the observations and collect data and they can look for themselves at what's happening in their soil, and that is of huge interest to them. (F11)

Another educator highlighted the difference between having a "*deeper understanding*" of what's happening on the ground and relying on "*what somebody tells you on a piece of paper. 'Oh, here's the report back on the soil, here are the numbers, and you are low on this…'" (E1)*

In addition to new perspectives on synthetic fertilisers, regenerative farmers begin to see weeds differently, as inputs, and as potential forage and nutritional supplements for their livestock. They come to realize that weeds are actually exacerbated by synthetic fertiliser, which kills the very soil biology that is capable of preventing weeds; and that herbicides can be counterproductive, as well as expensive.

And I grew up where we burnt every dead tree off the place, we burnt the tussocks. A good paddock was clean and bare, whereas now I see weeds as a friend. Biodiversity is my goal, and so whatever's growing, let it grow and trust nature that, as I build my soil, succession will head me towards a higher species. (F11)
I think the other thing is what used to be seen as a weed is now seen as an input to healthy soils and healthy animals. It becomes, the animals will graze it. You know, some of the dandelions and things that we would think of weeding, as unhealthy plants, are very good for animals. They concentrate copper and zinc and that's good. So, instead of having a supplement of copper and zinc that costs us lots of money we've got a natural way of doing it. And the animals benefit. (FC6)

Regenerative farmers also perceive "pests" differently, seeing less of a need to kill things with herbicides and insecticides, and trusting that other parts of a functioning ecosystem will take care of any imbalance.

There's a whole reframing about bugs and critters … as just part of a healthy ecosystem. So things that perhaps we used to spray for become an input to something else. Red legged earth mites and some other pests that we used to spray the most noxious, toxic chemicals around, well we don't need to do that now because we

have birds that control them. And they've become a food source for the birds so, bingo! (FC6)

With the freedom from chemicals and with the realization that they can be successful by working with nature, comes relief, happiness, a greater sense of control, and, for many, greater prosperity.

We have farmers that have [reduced] $100,000 - $150,000 a year of expenditure every year and their land is healthier, they're happier and they're more profitable. And it's not rocket science and it's not me. It's by really just understanding the principles about how things grow and how you can grow more of them, growing three leaves where there were two, covering the soil surface, better water cycles, better grazing management and stop doing things that are bad for the land and the people, and substituting other things for those high inputs. (FC6)

Many interviewees expressed their excitement about learning about compost (as an alternative to synthetic fertiliser) and perfecting their brewing and application techniques.

We make our own fertilizer with a biodynamic aerating system. I put the worm juice in the spray thing. So I've got compost tea, worm juice, some minerals...a whole lot of things, and I just mix them all up. The sprayer is on the back of a thousand-litre trailer, and it's just got two big jets. When I used to spray to kill, I had to cover everything. Now I actually want big droplets to go out, because I get my stuff and look at it under a microscope. You can see all the bugs in there. Fungi, bacteria, and all the little goodies. You don't want to bash them around. So you spray them out through about a 3 mm nozzle, and it goes out in droplets, and that's why you spray at night, because this is a live product and you want it to land on the soil and go into the soil. (F11)

Another source of farmer satisfaction is in daily ecological monitoring, which leads to a stronger connection with nature and an embodied joy. One farmer exclaimed, "*I just love walking on covered soil! I'm looking at my different grasses all the time, and I just…yeah, I just like doing it!" (F7)*

You'd walk around this farm and the soil would…you know, almost ring under your feet… but the soil here, because we've got cover all the time, it feels spongy to walk on now. (F5)

There's nothing more rewarding for farmers than knowing that they're doing a good job when they understand that ecosystem framework. They'll get most excitable about fungi. They see strands of fungi you know, and that's brilliant because they know that's a really good thing. They'll see spiders spinning webs between tall plants. Now spiders are a top order predator. If they get lots of spiders they know that there's lot of things happening that feed the spiders through that soil food web. They get very excited about digging around and finding worms for the first time. Not seeing runoff from their land after a heavy storm, or the runoff that happens is clear, doesn't have soil in it. They see huge benefits from seeing different types of birds coming in. (FC6)

For many, their new understanding of how they can work with nature results in a new identity, characterized by a focus on the soil, the microbiome, plants, and the larger landscape, rather than animal units and farm machinery.

I've shifted from being the quintessential Australian wool-grower who loves to be in his wool shed all the time to someone who's really more a custodian of the soil surface, managing the natural functions. If we do that well, then the animal enterprises and production and prosperity will follow. Before, the land was there to provide me with an income, and the animals were my means of production, whereas now I see the animals as the tool to modify the natural processes. (FE4)

Several of the consultant/educators I interviewed reflected on the process of change, highlighting the important role of the farmer's inner experience, including sensations, feelings, emotions, virtues, and drives/motivation.

The process of change has to start with an emotional response. "I'm either happy with what I'm doing or I'm not happy." It has to start with some discontent and part of the process is not just working out where your discontents are but working out where you want to move towards that would make you content. People need to either move away from something or towards something or both. And that's the process of getting in control. And a lot of folks feel out of control. (FC6)

I think, what makes people change is creating a good picture. That creates sustainable change. And the environmental groups are probably hugely at fault because they use fear to create change. It's all apocalyptic and what is going to happen at the end to us… That doesn't create sustainable change. But creating a picture of health and vitality and happy families, that keeps people moving in a [good] direction. (FE2)

One consultant observed that a formidable barrier to behavioral change in conventional farmers is the disconnection to nature and self that modern chemical application methods involving tractors and sprayers seem to foster.

When you are sitting in a tractor, all you have to do is fill up the big drums on your tractor, now you're just driving back and forth, back and forth… And they're not coming into contact with that toxic stuff that they're spraying out. It's a wonder how it is they can drive down the field and look in their rearview mirror and watch all of the birds and insects dying behind them. It's … (long pause) … heart rending really. To have people saying "I was driving along and you know, there was a flock of something or other came and landed and all the dead bodies are out there now." So there's some sort of disconnection with the mechanization of that application. Even though they are visualizing it happening and they can talk about it, it's somehow not emotionally affecting them. Because they are not actually involved with feeling the soil, touching the soil. (C2)

From an integral perspective, these results suggest that technologies that arise from capitalist agrochemical industry in quadrant 4 influence behavior in quadrant 2. Culture grows up around the use of chemicals, and chemical salesmen become part of the community in quadrant 3. The behaviors in quadrant 2 are subject to change with powerful influences from quadrant 1 associated with reconnecting to nature and a part of themselves that had been lost as a result of modern industrial agriculture. Growing awareness of how they feel about the chemicals, and growing support from like-minded individuals – communities of practice – create space for social-ecological transformation.

Behavioral change in agricultural transformation

Cognitive and emotional changes associated with quadrant 1 went hand-in-hand with behavioral change in quadrant 2 as farmers transitioned from conventional to regenerative agriculture. As described in Sect. 2, behavioral aspects of RA as practiced by the farmers I interviewed included adopting holistic planned grazing, forgoing agrochemicals, increasing soil organic matter through spreading compost, and encouraging the growth of deep-rooted native perennials to reduce bare ground, practices which require tolerance for weeds as the transition from conventional to regenerative agriculture plays out. Driving all of these activities was a focus on managing for soil health and ecosystem health.

Many farmers spoke about the role that the personal reckoning with chemicals described above played in their decision to transition to RA.

Most farmers are interested in what's above ground, grass and livestock. And they are slowly becoming interested in what's actually driving it, which is soil, especially now that the cost of synthetic fertiliser has gone up so dramatically in the last 5-10 years that a lot of them can no longer afford to use it. And because the land has become so degraded it no longer works like it used to. (FC3)

In their former lives as conventional farmers, they went along with the dominant paradigm in modern industrial agriculture, which held that chemicals such as superphosphate (fertiliser) and glyphosate (herbicide) were needed to both grow plants and control pests, and that a monocrop of introduced species such as lucerne (alfalfa) was superior to a "mishmash" of native perennial species. These ideas were handed down from parents, taught in university, and reinforced by government agencies, chemical salesmen and agronomist/consultants who were part of their communities and upon whom they depended for advice. One farmer described this dynamic as follows:

[The farmers] are used to sending off the sample to the soil chemistry lab and three weeks later the data comes back, they look at the soil chemistry sheet and go "Hmm.." They hand it off to their agronomist and the agronomist goes "Hmm, well, you need three tons of lime and a heavy ton of gypsum and you need to put out some phosphate fertiliser and we are gonna put out some nitrogen fertiliser." (F11)

Many interviewees saw this dependence on the agronomist resulting in a loss of knowledge and a disconnection between farmers and the plants they grow, negating the possibility of an integral approach to agriculture.

Some of the guys on my course, fourth and fifth generation farmers, they knew their cattle, every single one. "That cow had a beautiful calf last year, and her mother had a good calf..." everything about them. But you took them out to a paddock, they didn't know a single grass species. They knew to ring up the agents and say, "Yeah, get me some rye grass," but they didn't know what it looked like when it grew! (F11)

All of the farmers I interviewed reported that after adopting RA they developed a greater understanding of and appreciation for plant diversity and the microbiome, especially fungi, and changed their approach to monitoring to include attention to this aspect of their operation.

We do some monitoring and one of the things we look for is evidence of other forms of life. But I think a lot of the things that are doing most of the work are, you know, microscopic. But there are a few indicators. When you're doing a lot of disturbance farming and throwing around a lot of inorganic fertilisers, [the fungi] fade out quite a lot. They're not disappeared totally, but it's very hard on them, and we've found that since we haven't been using any of that stuff we see the

evidence of lots of fruiting bodies of fungi all over the place, so that's quite good. (F5)

These individual interior and exterior changes, associated with quadrants 1 and 2, manifested in collective interior and exterior realms (quadrants 3 and 4) as well.

The role of community and culture in agricultural transformation

Many interviewees spoke of the cultural barriers they encountered during their transition from conventional to regenerative agriculture. Cultural norms regarding "good farming" (Burton 2004) are closely aligned with the ideals of modern industrial agriculture, including a tidy landscape, the use of agrochemicals and the absence of weeds. A recurring conversation in my interviews had to do with perceptions of neighbors and family members regarding their approach to farming.

As far as society's concerned… there's an element of, because we've stepped outside the box, we're regarded as being rather quirky in the district. And that has its downsides. (FE4)
I remember being hassled by people, my father-in-law, because I had thistles growing in my paddock and I better get on to them...and at that time, I knew enough to say, "No, no. I'm happy." And sure enough, the following year there wasn't a thistle in sight. (FE5)

Because regenerative farming is so different from conventional farming, abandoning old practices can lead to loss of community.

There was a lot of peer pressure on you to toe the line in what they were doing in that district. "You need to be doing the same things we're all doing, because we don't like what you're doing," is pretty well what you get. "We're uncomfortable that you're grazing that way." And anger. Like, I had farmers who were angry. What I was doing had nothing to do with their property, but they were angry that I was doing a certain thing. (FE7)

Finding new peers and a new support system is part of the transformation process. One consultant noted that regenerative farmers could not rely on government agencies and extension personnel for support, since agrochemical companies influence what they teach farmers. Frequent turnover in the government agencies set up to help farmers exacerbates the problem.

Change happens through relationships and these government departments are anti-relationships. Farmers like to trust people and get to know them first and if you've got churn, people just turning up and blowing through the system, that's a problem. (FC6)

Regenerative farmers are often forced to seek out new kinds of fellowship outside of government for support as they navigate their new life path. Often these new connections are made in Holistic Management or Grazing for Profit classes or trainings. Graduates often decide to continue their informal learning by creating or joining "management groups" or bootcamps or other communities of practice (Cross and Ampt 2016).

You've got to learn new skills. Our group is still getting together seven years later, and we go out in each other's paddocks, and we're still identifying grasses and looking at them and discussing, and it's an exciting process. (F11)

Because one of the hallmarks of regenerative farming is an increased appreciation for the microbiome accompanied by curiosity and enthusiasm, it is not surprising that new forms of fellowship around this topic have emerged in the form of microscope groups (Watershed Landcare Inc. 2013).

I'm part of a microscope group, and their focus is on soil health, and I mean, 10-15 years ago there weren't groups like that around. They do field trips to different properties, going out into the paddock and digging some soil and pulling it apart, and seeing how the roots are structured, and can we see any organisms in there with the eye. I've now got a microscope! (laughs). [The leader] talks about soil and has explained it in the most easy way to understand. It makes you realise that you have to think [about] a lot more than what you see on top of the ground. (F14)

Participants also spend time with microscopes, discussing what they are seeing in each other's soil samples, sometimes over wine, supporting each other's efforts to improve their soil. They learn how to use a microscope, why they should care about "*bacteria, fungi, protozoa, nematodes, microarthropods, mycorrhizae, fungi, all the critters down there, what's their role and what's their function" (EI),* the benefits of getting them back into their soil, how to make compost ("*thermal compost, worm compost, static compost" (E1))* and then how to turn that compost into a liquid application. Presenters strive for a fun learning environment that results in practical skill-building. This soil educator described the sense of wonder students experience when looking through a microscope, suggesting that learning about the microbiome leads to more self-awareness.

And it's like holy s##, in that little pile of stuff there really are a lot of living things. They can see it and they just can't believe what they look like up close and they've never thought about it before in that way. They are see-*

ing mites and really ancient ancestral forms of centipedes and spiders, and they're all in there by the gazillions. They're crawling all over each other, something on top of something that's rotting away and it's endlessly wondrous and fascinating. That's the cool thing. It's not just like observing some other culture, it's like, we are looking at ourselves when we look at the soil. (E1)

Over time, these communities of regenerative farmers are cultivating new cultural norms around the concept of "good" farming, talking about different kinds of fungi instead of different kinds of chemicals.

They get a little high off of knowing that their peers respect what they're doing. And sharing techniques and information, how do I achieve better results. That's always been the way, I think, with farmers. It's just that when it was about chemicals, they would get together and talk about which chemicals are we using. But it's kind of a dead end, I mean … knowing a lot about chemicals doesn't bring you to the mirror, you know, it's just kind of the machine. Servicing the machine. And you're just detached from it forever. Whereas this kind of thinking, it brings you into it personally, physically, really in a reality way, you are actually one with it. (E1)

Commenting on why learning about the microbiome is a leverage point for transformation in thinking, this educator explained,

Because you've never thought of it before. And what's interesting is they are invisible, and what are they doing, and why are they there? And why have I looked at soil my entire life and never known that? Why didn't I learn that in grade school? You know, it almost seems like a crime to people. I get that a lot. They're like "Why didn't we learn this when we were in grade school?" (E1)

The value of the collective interior experience is in the shared foundation of principles and ethics that keep the farmer on this challenging but rewarding path. Farmers feel a need to be around people who have been where they have been and have undergone the shift in consciousness and outward practices they are cultivating. Membership in the group solidifies the commitment and prevents backsliding to chemicals when challenges arise. Conviviality and camaraderie help farmers feel reconnected with nature, community, and self.

The role of systems in agricultural transformation

Interviewees identified a number of systemic barriers to widespread adoption of RA. A consistent concern was the omnipresence of the agrochemical industry and its influence on the activities of government agencies, government-funded research, and university curricula, as well as cultural norms in agricultural communities.

One farmer lamented the influence of "*the ads on TV*" which suggest that the "*good farmer*" kills weeds. *"They want you to kill everything and then you need their synthetic fertiliser"* (F11). He went on to reflect on the resulting lack of awareness among farmers about the downside of chemicals, and the role that chemical salesmen and government-funded extension officers play in perpetuating that ignorance.

"Well, Dad was successful, so I'll do the same." But what they never saw was what was happening below the soil surface. It's never mentioned by any extension officers, any of the guys selling you chemicals and fertiliser – that "our chemicals, our fertilisers, are giving you a process of mining the last bit of life out of your soil." The contractor turns up, he's not going to tell you, "This is going to destroy the structure and create a pan, and if it doesn't rain, it's going to blow away." (F11)

This farmer also shared his perception that government researchers' dependence on funding from agrochemical companies constrains the kind of research that can be done on RA.

Sadly, in Australia, we've now got a system where the CSIRO [Commonwealth Scientific and Industrial Research Organisation, Australia's national science research agency] has to be self-funded, so they get sponsored by [major agrochemical company].. You know? It's a deadly cycle. (F11)

Universities were also implicated by this farmer. He claimed that faculty who do research that threatens the industry do not get tenure. Interestingly, one of the consultants I interviewed shared her story of that very experience. This influence in universities not only affects research, it also affects what is taught to the next generation of farmers in classrooms.

They're churning out students that are perfectly equipped to the 1970s, but it's the 2010s. What about the 2040s which will be these students' careers? They're poorly equipped to be able to lead and manage their industries. (FC6)

Several interviewees predicted that in spite of these powerful forces, large-scale systemic change will happen eventually because it makes sense from both economic and environmental perspectives.

There's resistance to everything I've been talking about. I mean, this is not the prevailing mindset in

agriculture by any means. But it certainly is an emerging mindset and it's too large to ignore. (FC6)
It'll get to a critical mass one day. It'll take off one day. It has to, just because it's so logical, and common-sense, and it works. They haven't found anywhere that it doesn't work yet. (F8)

One consultant predicted that as scientists learn more about the soil microbiome and its ability to do what synthetic fertilisers do, but better and more economically, farmers will become more interested in RA. One way to accelerate their engagement is to include farmers in the discovery process.

We have only begun this adventure into the soil, the adventure into understanding human nutrition and plant nutrition, and how do plants actually take up nutrients. There's a lot yet to be learned, and I think that energizes people. [They say] "I need to be involved, I can do some of the discovery." (C2)

This consultant envisioned a future where farmers are competent with a microscope and knowledgeable enough about their own soil to challenge an agronomist advising the use of chemicals. In such a future, a farmer might say,

"What data on that soil chemistry test did you use to come to that decision that I have to go out and spend $1000 per acre putting those nutrients out? Where on this soil chemistry test does it say that I am lacking nitrogen?" (C2)

One practical challenge to the scaling up of RA has to do with the need to replace synthetic fertiliser with large amounts of organic fertiliser.

It's gonna take a whole boatload of organic matter but, we keep producing all of this organic matter in our waste materials and our sewage treatment plants. Why aren't we putting that back out into the desert and making use of that organic matter? No, we put it in landfills so that we destroy all of the water quality downstream from the landfill. We don't close the loop. (C2)

Several interviewees referenced the need for a circular system that mimics nutrient cycling in nature, rather than the current "unsustainable linear" system.

Human beings don't understand nutrient cycling. It's supposed to go around and around and around. When you start talking about composting, somebody will say, "Do you have to make compost with manure? Manure is so icky." Well we need to recycle that stuff. "Do you realize that every carbon cell in your body was once upon a time manure?" And they're like "Eww, that's disgusting!" It's the wonder, the joy of transformation and biology does that for you. It converts it from something that's awful into bacterial and fungal biomass which is great stuff. So nutrient cycling, preventing erosion, preventing leaching, all that stuff. And as you go through each one you can see the little lights, the "aha" moments and there are hundreds of them in the talks that I give. (C2)

In answer to the question of how RA could be scaled up and incorporated into the system, several interviewees saw the need for recognition and appreciation of the natural cycles described above in consumers, who could then encourage farmers to adopt regenerative practices with a price signal.

Getting people more interested in or understanding about the whole cycle. People in the city need to know more about the soil and the complexity and how that affects what they're eating. We need to go out there and say, "This food is coming from an aware farmer. A carbon farmer." (F14)
What we call ourselves now is, we're an ecologically regenerative farming practice. And there's no herbicides and chemicals used. The niche marketing has now developed into a health food marketing, and most of our customers are coming from naturopaths and have major health issues, with Crohn's disease, bowel cancer, food allergies. And they're saying, "We can actually handle your food!" which has been really interesting. (F6)

In sum, the future of RA depends on policy makers, universities, and research institutions providing farmers with the tools they need to be successful as the effects of climate change intensify. Such tools include outreach and engagement programs, funding mechanisms, incentives and tax breaks to support adoption, and support for collaborative research on RA. Such systemic support will contribute to the development of new cultural norms, new behaviors, and new farmer identities, all of which will, in turn, reinforce the new system through self-amplifying positive feedbacks.

Discussion: the importance of integrative approaches to agricultural transformations

Results from this research contribute to knowledge about the *how* of social-ecological transformation in several ways. Thinking holistically, an integral framing makes clear how systems of power embedded in capitalism (e.g. those associated with agrochemical companies in quadrant 4) influence individual farmer and rancher decision-making and behavior (quadrants 1 and 2); how culture, shared values, and communities of practice (e.g. "good farmer" norms or those associated with microscope clubs in quadrant 3) interact with

system dynamics (quadrant 4); and how positive and negative embodied experiences in nature and in communion with nonhuman beings (quadrant 1) and kindred human spirits (quadrant 3) contribute to social-ecological dynamics at different scales. Importantly, dominant worldviews and frames of meaning making (quadrant 1) often exert considerable power and influence on politics (quadrant 4), evidenced in the entanglement of modernist worldviews and the political power of "Big Ag". These cross-quadrant dynamics can contribute to entrenchment in modern industrial agriculture or, with growth in the regenerative agriculture social movement, they can cultivate paradigm shifts that make space for new power dynamics and new approaches to farming.

The integral framework also sheds light on the "inside out" and "bottom up" dynamics of social-ecological transformation (Moore et al. 2015) by pointing to how inner experience and outer behavior interact to cultivate new producer identities that challenge the dominant paradigm via collective action, creation of new cultural norms about "good farming", and demands for institutional change and corporate accountability. Farmers repeatedly contrasted their current regenerative, anti-chemical mindsets with former, more conformist worldviews, and told stories of finding kindred spirits and becoming more aware of the need for systemic change. These insights suggest that an integral framing improves our understanding of social-ecological transformation and is a useful alternative to approaches that focus on the systemic, behavioral, cultural, or individual perspectives alone.

A key finding from this research is the power of both negative feelings of disconnection and positive biophilic emotions associated with reconnecting to nature and one's own self for catalyzing transformational change. Farmers explained how the realization that chemicals were creating declining ecological conditions made them feel, and how it motivated them to seek an alternative more in line with their values. They all expressed enthusiasm and delight and a sense of empowerment about their newfound ability to improve soil conditions, biodiversity, productivity, and their overall quality of life by engaging directly with subterranean life. As such, for many farmers, regenerating soil goes hand in hand with the regeneration of their dignity; sense of purpose; and sense of connection to their land, animals, and community, i.e. regeneration of their soul. The despair associated with dependence on chemicals and the sense of well-being and enthusiasm that comes from discovering new competency in regenerative practices both constitute underappreciated leverage points in the project of agricultural transformation. While crisis and transformation are often related (Gosnell et al. 2019), I do not see them as necessarily interdependent in transitions to regenerative agriculture. The evidence and current trends suggest that over time, regenerative practices will continue to make more sense to farmers, independent of pitfalls and crises associated with modern industrial agriculture.

In terms of implications of these findings, as the impacts of climate change become increasingly unavoidable and the imperative for healthy fertile soils becomes undeniable, growing numbers of farmers are likely to become interested in "climate-smart" practices that help them adapt to drought, floods, and other unexpected disturbances. Not all will undertake the kind of wholesale transformation described by the farmers in this study, including "recovery" from "addiction" to agrochemicals, but those who do will need a different kind of support than has been made available to date by dominant institutions in modern industrial agriculture. Designers of interventions aimed at individuals may find useful insights from scholarship on addiction recovery, such as the social identity model of recovery (SIMOR) which suggests that "recovery is best understood as a personal journey of socially negotiated identity transition that occurs through changes in social networks and related meaningful activities" involving social learning (Best et al. 2015, 111). Central to the journey is user empowerment and self-determination as the addict identity is supplanted with a new identity. Drawing on a case study of Alcoholics Anonymous, Best et al. (2015) propose that recovery can be transmitted in social networks through a process of social influence. Notably, this framing highlights the role of individual and collective interiorities in the recovery process. De Bruyn and Abbey (2003) also point to the importance of empowering farmers to understand soil so they are not dependent on laboratories and agronomists connected to the agrochemical industry. They also highlight the role of the collective interior, calling for cultural change to create system change and dismantle powerful agrochemical interests.

Findings from addiction research align with the integral framing described in this study. With support from communities of interest, e.g. HM classes and microscope groups, farmers who transitioned to RA took on new identities as stewards of soil and the subterranean and subsequently enjoyed a sense of right livelihood. Studying soil, alone and in community, has the potential to change the way people see the world and induce epiphanies about the interconnectedness of all life. These insights have relevance for sustainability science associated with natural climate solutions since most of the attention to date has been on creating the right economic incentives and the right soil health metrics. These objectives are important and probably necessary for systemic change, but may not be sufficient to understand, let alone catalyze, system transformation, given that any progress in soil regeneration and sustainable circular economies hinges on a large-scale change in the behavior of individual farmers.

Conclusion

This paper has addressed the need for a holistic understanding of how to catalyze social-ecological transformation in the agricultural space. Drawing on the experiences of veteran regenerative sheep and beef farmers in Australia, I have demonstrated the utility of an integral framework for organizing thinking about how farmer interiorities relate to behavioral and systemic change. I showed that farmers' negative experiences with agrochemicals create space for consideration of alternatives, and that learning about the microbiome and practicing working with it to co-produce food and fiber without chemicals is an empowering and transformative experience. As one farmer put it, "*I've actually been a very reserved person all my life. I've actually been very shy, but this whole world has absolutely electrified me. My being*." (FE4) Communing with like-minded students of RA facilitates the emergence and solidification of new farmer identities and new cultural norms around what "makes sense" given the changing climate and the increasing cost of agrochemicals. Collective entities like microscope groups represent a promising pattern that can be replicated around the world in different contexts. Universities, government agencies, and extension personnel can help facilitate system transformation by making training in soil science, use of microscopes, and home soil testing methods widely available and by providing the necessary technical and emotional support for those undergoing a transition from conventional to regenerative agriculture. Funding for research on strategies for food and fiber production that enhance soil health rather than degrading it, from entities that do not have a vested interest in the sale of their products, needs to be more available to accelerate scientific innovation in RA. A broadened approach to sustainability science that involves consideration of interiorities and takes seriously the agency of farmers and farmer collectives can play an important role in increasing knowledge to support social-ecological transformation in agricultural systems.

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