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A half century of Holistic Management: what does the evidence reveal?

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Abstract
Holistic Management (HM) is a decision-making framework based on triple bottom line thinking and a proactive approach to managing complexity. Primarily associated with an approach to managing livestock, it has spurred long running and still unresolved debates in rangeland ecology and management. Less studied are the social, cultural, and psychological aspects of HM, which may hold the key to successful ecological outcomes. In this article, we describe the main tenets of HM as conceived by wildlife biologist Allan Savory and address the longstanding and unresolved controversy over its legitimacy. We then provide a meta-analysis that not only provides an up-to-date review of the multidisciplinary evidence and ongoing arguments about HM, but also provides a novel explanation for the controversy—that it is grounded in epistemic differences between disciplines associated with agricultural science that rule out any chance of resolution. We conclude that the way to resolve the controversy over HM is to research, in partnership with ranchers, rangeland social-ecological systems in more holistic, integrated ways. This can account for the full range of human experience, co-produce new knowledge, and contribute to social-ecological transformation.

Keywords Adaptive multi-paddock grazing · Grasslands · Holistic planned grazing · Regenerative agriculture · Rotational grazing · Social learning

Introduction

While Holistic Management (HM) has been the subject of a longstanding debate in the rangeland ecology and management literature regarding its unorthodox approach to grazing (Briske et al. 2008, 2011; Teague et al. 2013), its human dimensions have been understudied in comparison to other alternative agri-food systems, such as biodynamics, organic, or permaculture. Further, when social scientists do turn their attention to HM, they tend not to engage with the ecological research on holistic planned grazing (HPG), an important dimension of HM (Sherren and Kent 2019). What is needed, ironically, is a more holistic look at HM.

The dearth of integrated research is surprising given that, in addition to economic and environmental sustainability, HM places a strong emphasis on social and psychological well-being (McLachlan and Yestrau 2009). In this sense, HM can be thought of as a "triple bottom line" approach to sustainable agriculture (Howell 2009). This research gap has not deterred over 10,000 farmers, ranchers, pastoralists, and other land managers who have adopted HM on an estimated 40 million acres across four continents. Farmers and ranchers point to anecdotal evidence of the effectiveness of HM, and HM practitioners around the world are often recipients of conservation awards. In Australia, for example, nearly all the recipients of the Carbon Farmers of Australia "Carbon Cocky of the Year Award" for innovation and leadership in farming practices that increase carbon sequestration have been HM practitioners; and several have won the more

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mainstream Australian Farmer of the Year award. At the same time, there has been growing interest from the international conservation community, as well as the general public, in HM's potential to restore grasslands, reverse desertification, mitigate climate change and enhance adaptive capacity and resilience, all while maintaining or increasing food and fiber production. As of December 2019, HM founder Allan Savory's 2013 TED Talk, "How to Fight Desertification and Reverse Climate Change," had received just over 6.6 million views on the TED website. Concurrent with this widespread interest among practitioners and in popular culture, there has been an ongoing and heated scientific debate in peer-reviewed journals about the ecological effects of HPG spawned by Savory's claims. Indeed, the scientific debates have escalated with increasing attention and kudos directed at Savory and HM (Sherren and Kent 2019).

The present controversy over the efficacy of HM appears to be irreconcilable, however, due to the incommensurability of competing studies. As the following review shows, critics and advocates appear to be arguing over different things, while failing to articulate core theoretical and methodological assumptions (Sherren and Kent 2019). In this paper, we address longstanding and unresolved controversy over the legitimacy of HM with a meta-analysis that not only provides an up-to-date review of the multidisciplinary evidence and ongoing arguments about HM, but also provides a novel explanation for the controversy—that it is grounded in epistemic differences between disciplines associated with agricultural science. These differences make any effort to resolve the controversy within one scientific discipline invalid as definitive proof within the other, ruling out any chance of resolution. These epistemic differences have proven intractable because they are rooted in ontological differences between the hypothetico-deductive sciences and holistic knowledge practice. Unaddressed, these divides obscure efforts to assess the fundamental challenge that HM is making to conventional agricultural practice. Shining light on these differences offers great potential for developing new, more holistic and participatory approaches to studying HM.

We lay the groundwork for this argument by first offering a comprehensive overview of the philosophy, key principles, and assertions behind the HM decision-making framework as outlined by its founder, Allan Savory. This detailed self-definition provides a means of noting the contrast between the original HM idea and how it has been portrayed (and often mischaracterized) through other perspectives and disciplinary lenses, which we then summarize in a review of the limited body of empirical research on farmers'/ranchers'/pastoralists'/graziers' experiences practicing HM. We conclude by suggesting that the tension between thinking about HM in terms of theory or practice—which is an ontological problem—can be reduced in ways that can benefit both practice and evaluation by adopting a form of embodied knowing, or phronesis, that engages HM practitioners and researchers in the co-production of knowledge. We conclude that this broader frame is essential—that analyses must consider not only the ecological impacts of HM, but also the essential role of the human agent (the rancher) in both distinguishing failure from success and the outcome itself (Sherren and Darnhofer 2018). Through this process, ranchers (and their communities) are part of what is being transformed/improved, and the researcher is part of the research frame. In order to take that perspective, a different kind of science is called for—one that is interdisciplinary and interpretive as well as analytical, performed in partnership with the rancher to co-produce new knowledge about sustainable agriculture.

What is Holistic Management?

In simple terms, HM is a values-based approach to decision making developed in the 1960s by Allan Savory, a Zimbabwean biologist, game ranger, politician, and farmer. Savory was searching for ways to restore the Southern African savannah and its wildlife, which he surmised had been degraded by inappropriate management of grazing.

The HM philosophy and framework were developed in response to Savory's sense that poor decision making driven by reductionist thinking was at the root of most human-made environmental problems. Drawing from Smuts' (1927) views on holism and evolution, Savory recognized that nature is made up of integrated wholes, not parts, and that all things are connected. His goal was (and continues to be) to help ranchers see how their overall quality of life—i.e. their social and economic wellbeing—is intimately connected to the health of the land. As such, their decisions must consider both immediate and long-term effects on ecological, economic, and social/personal well-being, which he saw as "the critical factor missing in conventional decision making, where few decisions prove sound in all these respects" (Savory and Butterfield 1999, p. 267). Because adoption of HM requires a shift from reductionist thinking to a holistic view of the world and a commitment to "right livelihood" where behavior is aligned with values, it generally involves a fundamental paradigm shift in the land steward's approach to land management and in his/her perceptions about humans' place in nature.

In their influential book *Holistic Management: A New Framework for Decision Making*, Savory and Butterfield (1999) outlined three elements in holistic decision making. First, the entity being managed ("the whole") must be broadly defined, in terms of both the people responsible for its management and the resources available to them (e.g. land, money, human labor). Second, those people work together to articulate what they want now and in the future in the form of a ‘holistic goal’. This carefully crafted statement may take a page or more to express—and years to refine. It begins with a ‘quality of life’ (QOL) statement, which expresses how the rancher wants his or her life to be, in terms of desires and aspirations, based on what he/she most values. The holistic goal concept later morphed into a ‘holistic context’ (Savory and Butterfield 2016). In addition to the QOL statement, the holistic context includes a description of the ‘future resource base’ on which the people depend, as it will have to be to sustain what they must produce, which will, in turn, create the quality of life they envision. This involves thinking about what the land will have to be like 100 or 500 years from now in terms of how ecosystem processes including water and mineral cycles, energy flow, and community dynamics function, as well as how the producer needs to behave to get the land to that point. Savory and Butterfield note that articulating one’s holistic context is difficult “because it takes time for people to feel comfortable enough to express more than superficially what they want in terms of QOL—even when people live in the same family—to gain clarity on what needs to be produced, and to fully envision a future resource base” (Savory and Butterfield 1999, p. 86).

After defining the whole and articulating a holistic context, the rancher has the basis for decision-making. The third element of the framework involves ongoing checking of the soundness of every decision made in terms of its potential implications for the environmental, economic, and social aspects of the rancher’s envisioned future and to ensure actions are in context. Decisions are evaluated according to the same criteria the rancher has always used, but in addition, he/she assesses the wisdom of the decision using seven “context checks” (Table 1). If the proposed action fails to pass one or more of the context checks, it can be modified until it passes or is dropped altogether. If it passes and no unintended consequences are perceived, the rancher puts it in the plan. Thus, a key aspect of HM is responsive action, in which ranchers are flexible and change in order to continue striving for their goals and objectives based within their specific holistic context. Savory and Butterfield (1999, p. 8) explain that monitoring biological processes, profit, and social dimensions also informs decisions about necessary changes:

> Any action taken to deal with a problem, to reach an objective, or to meet a basic need, should not only accomplish what is required but also enhance progress toward the future resource base described within their holistic context. To ensure that this happens, a feedback loop is established so that if monitoring shows the decision is not taking you where you want to go, you can act immediately to correct it.

As mentioned above, HM can be thought of as a “triple bottom line” approach to food and fiber production because it explicitly requires attention to ecological, economic, and social/personal factors. In the rest of this section we briefly discuss the role each of these factors plays in HM decision-making.

Ecological dimensions: regenerative farming

For ranchers to manage land sustainably (and restore degraded lands), HM dictates that they understand four ecosystem processes: the water cycle, the mineral cycle, energy flow, and community dynamics. Savory places special emphasis on soil health as the basis of land regeneration, since it is a prerequisite for functional hydrologic processes and reducing bare ground. Healthy soils also sequester carbon, contributing to climate change mitigation. Land managers are taught that when these ecosystem processes are functioning, everything else falls into place and the need for inputs such as fertilizers, pesticides and herbicides is minimized. These are seen as counterproductive to regenerating ecosystem health, and also lead to financial dependence on chemical companies.

Table 1 Context checks used for decision-making in Holistic Management (Savory and Butterfield 2016, Table 24-1, p. 264)

Cause and effect	Does this action address the root cause of the problem?
Weak link	*Social*: Could this action, due to prevailing attitudes and beliefs, create a weak link between us and those whose support we need? *Biological*: Does the action address the weakest link in the life cycle of this organism? *Financial*: Does this action strengthen the weakest link in the chain of production?
Marginal reaction	Which action provides the greatest return toward the goal for each additional unit of time or money invested?
Gross profit analysis	Which enterprises contribute the most to covering the overheads of the business?
Energy/money source and use	Is the energy or money to be used in this action derived from the most appropriate source in terms of our holistic context? Will the way in which the energy or money is used be in line with our holistic context?
Sustainability	If we take this action, will it lead toward or away from the future resource base described in our holistic context?
Gut feel	How do we feel about this action now? Will it lead to the quality of life we desire? Will it adversely affect the lives of others?

Savory identified a suite of tools for managing natural resources including money, labor, human creativity, fire, rest, living organisms (which includes grazing and animal impact), and technology, as well as the less recognized tools of grazing and animal impact. HM is probably most well-known for its emphasis on the latter two tools which have to do with the role of livestock in both the degradation and restoration of grassland systems. Savory argues that grassland health has historically depended on the actions (grazing, defecating, stomping, salivating) of large wild herds of herbivores constantly on the move in response to predators. Those actions, he posits, are what build soil, deepen plant roots, and increase water holding capacity and diversity. As large wild herds have been replaced with relatively small, dispersed numbers of domestic, sedentary livestock living without fear of predators, the cycle of biological decay has been interrupted in many parts of the world and once-rich soils have turned into dry, exposed desert land that is ineffective in absorbing and retaining rainfall.

As such, HM posits that degraded grasslands can be restored by both mimicking wild herds through strategic planned grazing of domestic livestock herds and encouraging the return of deep-rooted perennial plants that soak up carbon, create organic material, and allow soil to hold more water. With this approach, ranchers divide their land into numerous units (e.g. paddocks or pastures) and move the animals as frequently as is necessary for their context, not letting them return to an area until the grasses have recovered. A central HM principle is that the amount of time the plants are exposed to grazing animals and the amount of time between consecutive grazing events is more important than the number of animals, and the timing is highly variable depending on a variety of climatic and other factors (production, stocking rate, stock density, residual cover, etc.). Practitioners use "a feedback loop that includes monitoring for the earliest sign things are not going as planned, making adjustments, and re-planning" (Malmberg 2013, p. 10). It is through biological monitoring that managers determine when cattle should be moved, thereby differentiating them from graziers that practice continuous grazing ("set stocking") and conventional rotational grazing based on a timed schedule (Savory and Butterfield 1999).

Economic dimensions: financial planning

For a livestock operation to be sustainable, it must be solvent. This usually involves eliminating debt and diversifying the enterprise structure to reduce vulnerability to market fluctuations. HM practitioners manage their finances to ensure money earned and spent results from actions that are socially, environmentally, and economically sound in the short and long term and that correspond with the values articulated in their holistic context. By testing decisions, they avoid enterprises that conflict with their values (Butterfield et al. 2006). The financial dimension of HM also calls for frequent monitoring. Use of the seven context checks (Table 1) allows people to recognize whether they need to make changes to their actions to reach their goals and objectives.

Being aware and nimble allows the rancher to make changes based on ecological conditions and can lead to innovative approaches to income diversification. Thus, ranchers increase herd size when ecological conditions permit and decrease it at other times (e.g. in drought) to ensure environmental soundness. This flexibility reduces the risk of running out of forage and having to use expensive supplemental feed and/or sell off cattle at inopportune times (e.g. when everyone else is doing the same thing, bringing down the price). Since reducing herd size results in reduced profit, ranchers must find ways to compensate by reducing costs (e.g. eliminating expensive machinery and chemical inputs); enhancing the ability of the animals to thrive in variable conditions (e.g. through breeding strategies); seeking off-farm investment opportunities; maximizing the amount of revenue each animal produces with marketing strategies (e.g. holding over calves until the spring market when prices are higher); and/or engaging in niche marketing or certification schemes (e.g. predator friendly lamb, grass-finished beef or regeneratively-raised Merino wool).

Importantly, there is a psychological dimension to the adoption of the economic strategies outlined above. Ranchers must change their focus from yield (i.e. number of cattle sold) to net profit, which sets them apart from most conventional ranchers. That is, there may be fewer outputs in an HM enterprise, but with fewer inputs, a healthy profit is possible. Financial security is critical for the third pillar of sustainability, human well-being.

Social dimensions: human and community well-being

While the original impetus behind the development of the HM framework was concern for the ecological health of grasslands, Savory recognized early on that the state of those environments depended on not only the economic well-being of the pastoralists that steward those lands, but also their social and psychological well-being. According to Savory and Butterfield (1999, p. 91), a holistic perspective applies to the whole life of the rancher: "Common sense tells us that making a decision that is not in line with our values is illogical. But that is precisely what humans have done throughout history." This is why there is so much emphasis placed on articulating a quality of life statement as the first step in transitioning to HM. Savory and Butterfield (1999, p. 71) explain that the QOL statement

> expresses the reasons you're doing what you're doing, what you are about, and what you want to become. It is a reflection of what motivates you. It should excite you. It speaks of needs you want to satisfy now, but also of the mission you seek to accomplish in the long run. It is your collective sense of what is important and why.

Critical to this process is HM practitioners' willingness to look at (and be confronted by) what is missing in their lives (e.g. balance between work and personal life). They are asked to think about what will make them flourish (e.g. more time with family and more involvement in their community). The group of producers, including family and staff, defined as the 'whole', envisions desired relationships (i.e. "how you want to behave with each other since this will influence your ability to communicate with one another"); and pathways to "challenge and growth." Savory and Butterfield (1999, p. 73) argue that "human beings have a need to experience challenge; without it we fail to grow and develop." HM educators invite students to think in terms of

> what you find stimulating, what requires all the resourcefulness and creativity you can muster, what kind of atmosphere you might create to ensure that everyone remains enthusiastic, yet no one feels overwhelmed.

After the QOL vision is articulated, the family, group, organization, or community intentionally pursues the activities necessary to realize their vision; they continually monitor outcomes associated with various decisions; and adjust as necessary. Imagining the quality of life desired is critical because it provides the energy needed to transition and maintain a different, potentially more challenging lifestyle (at least initially) and makes it seem justified and tolerable. Savory and Butterfield (1999, p. 68) posit that if you commit to paper what is most important to you, "you gain the personal commitment needed to achieve whatever else you have to achieve."

Finally, HM practitioners must identify their 'purpose and contribution' in relation to the larger society. HM practitioners enjoy strong social networks that involve continual social learning through the exchange of ideas, experiences, and data. Many people who take HM courses continue to meet with their fellow classmates and visit each other's ranches to further the learning process and get support during the challenging process of transitioning their farming systems.

Scholarly literature

Although a growing number of ranchers and farmers around the world have been practicing HM since the 1970s, scholarly literature on the topic is relatively scarce, and mainly focused on the pros and cons of the purported 'grazing system' promoted by Allan Savory. Our goal was to identify all articles written about Holistic Management in agricultural systems around the world, with a particular focus on those examining social, cultural, and economic dimensions given that these components have received less treatment in the literature. First, we used Google Scholar and Web of Science to search for articles using the terms Holistic Management, Holistic Resource Management, holistic planned grazing, and cell grazing. These terms were selected because Holistic Resource Management was the original term used by Savory, but it was later changed to Holistic Management; using the two terms captures a longer time period during which articles were written about the topic. Holistic planned grazing and cell grazing (in Australia) refer to the grazing approach used by HM practitioners. We then searched the citations in these papers and used the "cited by" function in Google Scholar and Web of Science to identify subsequent articles on HM. We continued this process until we were unable to identify new literature. Most of the articles we found dealt with the ecological dimensions of HM, but we also found 36 articles discussing social, cultural, and/or economic dimension of HM, along with 13 additional works that mentioned HM in passing. Articles examining HM included research conducted in North America, Oceania, Africa, and South America, with the majority focused on the US and Australia.

Sherren and Kent (2019) argue that literature on the ecological and social dimensions of HM tend to exist in parallel universes. The authors also identify two discrete and incompatible types of evidence in the HM literature, associated with social sciences/management on one hand and experimental sciences on the other. Notably, studies that focus on the social dimensions of HM tend to endorse the approach and call for broader support of the movement. Stinner et al. (1997, p. 212), for example, concluded that "a decision-making process like [HM] can help empower individual farmers and farm communities" with limited resources who are becoming increasingly vulnerable to foreclosures or buy outs and have decreasing management options. Stinner et al. (1997) claim that their study demonstrates how HM can "support biodiversity, profitability, ecosystem function and quality of life."

In this section, we aim to consider the entirety of the body of scholarly literature on HM, highlighting dominant themes, summarizing key arguments and findings, and reviewing major studies in some detail. We begin with a brief summary of the relatively high-profile ecological debates surrounding HM, then review some of the lesser known scholarly discussions focused on its social dimensions.

Debates about ecological outcomes associated with Holistic Management

As stated above, most references to HM in the scholarly literature are associated with the ecological implications of adopting recommended practices. Literature on environmental outcomes associated with HM is divided, and includes results from both experimental, field-based research, and qualitative research that reports perceptions of HM practitioners. In studies comparing perceptions and experiences of holistic and conventional managers, for example, findings suggest that holistic managers use less herbicide and pesticide (Ferguson et al. 2013; Sherren et al. 2012), burn pastures less (Alfaro-Arguello et al. 2010), and enjoy a higher emergy yield ratio (Alfaro-Arguello et al. 2010) and more on-farm biodiversity (McLachlan and Yestrau 2008; McCosker 2000; Stinner et al. 1997). Experimental research focused specifically on ecological outcomes associated with HPG (also referred to as cell grazing, intensive rotational grazing, multi-paddock adaptive grazing, strategic planned grazing, etc.) has yielded neutral/mixed views, at times leading to acrimonious debate (Sherren and Kent 2019). Most commonly at issue are Savory's assertions that overgrazing relates to time and that animals should be densely contained; in other words, high intensity, short-term rotational grazing is better than dispersed, continuous grazing. Briske et al. (2011) review the history of this debate, which will only be summarized briefly here, as do Sherren and Kent (2019) in an exploration of "the rift around Holistic Management." The latter finds that views of HM in scientific literature differ depending on geographic region (more positive in Oceania and South Africa—'brittle environments' on which Savory's work focuses), time period (increasingly more positive since 2001), and discipline (social science papers present a more positive view, compared with neutral/mixed views of experimental studies).

We suggest that a good deal of the conflict can be explained by miscommunication and inconsistent use of terminology, which is necessary to understand before detailing the ecological debate. Inconsistent use occurs not only with opposing camps, but also among those within the same camp. Critics often equate HPG with rotational grazing and focus their efforts on disproving claims that rotational grazing is superior to continuous grazing, as discussed in more detail below. HM proponents, however, will point out that while HPG involves moving animals, that is where any similarity with rotational and other grazing approaches ends. Proponents of HM critique these experimental studies because they do not account for the focus on managing complexity (social, economic, and environmental) and they neglect the important component of manager decision-making (Sherren and Darnhofer 2018), two aspects of HM that do not lend themselves well to experimental design (Teague and Barnes 2017). Complicating matters even more, HM proponents use differing terminology. For example, HM and HPG are often equated (in a positive way) with adaptive management. Savory objects to this characterization of HM, however, asserting that all human management is adaptive and reductionist; humans only adapt when things do not work out as planned, which does not work because complexity is not adequately addressed. Savory asserts that HM involves a proactive approach where a practitioner is managing for social, economic, and environmental complexity. Similarly, equating HM with a prescriptive management system (e.g. a grazing system) is also problematic, according to Savory, as such a system cannot address complexity. That said, some conceptualizations of HM as adaptive management do seem to capture that proactive sentiment. For example, Hodbod et al. (2016, p. 383) argue that adaptive multi-paddock grazing (another term for HPG):

> is a values-based triple bottom line approach (social, environmental and economic sustainability) to decision-making in grasslands that builds on high-intensity, short-duration grazing to allow adequate recovery of grazed plants within a proactive, flexible, and goal-directed plan.

Therefore, it seems that one may need to look beyond terminology to instead identify the underlying intent of the manager. As Sherren and Kent (2019) observe, Savory is such a polarizing figure that some HM proponents avoid using HM terminology when reporting associated practices. It is important to unpack these variations in terminology (and their underlying agenda) in order to more clearly delineate divergences and convergences of opinion on the merits of HM.

A number of published studies have found that, if practiced appropriately, HPG results in positive ecological outcomes. Specifically, it can improve forage and livestock production (Peterson et al. 1992; McCollum et al. 1994; Earl and Jones 1996; Biondini and Manske 1996; Sparke 2000; Jacobo et al. 2000, 2006; Krausman et al. 2009; Teague et al. 2011, 2013; Ferguson et al. 2013; Barnes and Howell 2013; Grissom and Steffens 2013; Jakoby et al. 2014; Norton et al. 2013; Ortega-S et al. 2013); reduce bare ground (Earl and Jones 1996; Teague et al. 2011); improve stream and riparian health (Sovell et al. 2000); improve soil respiration, topsoil depth, organic matter, and overall soil health (Ferguson et al. 2013; McCosker 2000; Teague et al. 2011; Stinner et al. 1997; Xu et al. 2018); improve soil–water content, water holding capacity and hydrological function (Weber and Gokhale 2011; McCosker 2000; Teague et al. 2011; Earl and Jones 1996); and improve nutrient availability and retention (Teague et al. 2011).

By extension, some studies have argued that the improved soil conditions associated with HPG mean that it is an effective approach to mitigating climate change through increased soil carbon sequestration (Neely et al. 2009; Teague et al. 2016; Rowntree et al. 2016). In his 2013 TED Talk, Savory argues that only livestock management using HPG (or a better process if developed) can address climate change and reverse global desertification. Briske et al. (2013) strongly contested these claims, however, saying that rangelands are weak sinks for atmospheric carbon and citing research that shows that grazing strategy has a minimal effect on carbon sequestration. In a personal communication (March 3, 2019), Savory argued that the studies on which Briske et al. (2013) based their conclusions were conducted on rangelands influenced dominantly by partial rest, which leads to desertification in brittle environments; therefore, it is not surprising that little likelihood of significant carbon sequestration was found. A series of rebuttals and responses to Briske's (2013) critique were published in subsequent issues of *Rangelands* (Teague 2014; Briske et al. 2014a; Cibils et al. 2014; Teague and Borelli 2014; Grissom 2014). Elsewhere, Carter et al. (2014) and Nordborg and Röös (2016) also contest the argument that HPG can mitigate climate change, pointing to the complicating issue of livestock methane production and its resulting impact on climate.

Focusing on adaptation rather than mitigation, Sherren et al. (2012) called for policies and programs that would support grazier adoption of HM, arguing that it is a "particularly promising measure" to adapt agriculture to increasing climate variability in Australia because of its emphasis on increasing biodiversity, water infiltration, and carbon sequestration through perennial grasses. Like Alfaro-Arguello et al. (2010), they provide a policy recommendation that governments support the broad adoption of HM to benefit the public by providing financial support to reduce start-up costs associated with a transition from conventional to HM ranching, and supporting the expansion of instruction of HM principles. Sherren et al.'s (2012) endorsement of HM drew harsh criticism from Briske et al. (2014b), who argued that "the vast majority of experimental evidence does not support claims of enhanced ecological benefits in intensive rotational grazing compared to other grazing strategies" and concluded that endorsement of this approach to grazing is "unjustified and unwarranted." Briske et al. (2014b) did acknowledge that certain aspects of HM (e.g. the focus on enhancing adaptive capacity, sound financial planning and recognition of ecological constraints), are important in achieving sustainable grazing strategies, suggesting the need for a more in-depth inventory of empirical evidence regarding the different aspects of HM.

Numerous rangeland ecologists besides Briske, however, have raised concerns about claims regarding the superiority of HPG over other grazing strategies. Many critics contend that Savory's theories are not based on scientific experiments, but instead on observations and anecdotal evidence. In an attempt to disprove Savory's theories, critics point to the robust body of experimental evidence that intensive rotational grazing does *not* increase plant and animal production or enhance surface soil hydrology or improve plant community composition compared to continuous grazing under otherwise similar conditions (Painter and Belsky 1993; Patten 1993; Oliva et al. 1998; Briske et al. 2008, 2011; Bailey and Brown 2011). Recently, Hawkins (2017) conducted a meta-analysis on studies comparing rotational grazing and continuous, seasonal grazing to retest Briske et al.'s (2008) findings; she found that HPG did not impact production. As mentioned above, the problem with this work is that intensive rotational grazing is not the same as HPG. In addition to pointing to results of rotational grazing studies, critics also reason that there is too much bioclimatic variability among rangelands (i.e. mesic vs. arid/semi-arid) to legitimize across-the-board conclusions and prescriptions regarding the superiority of a given grazing approach, such as with fragile Southwest desert crusts (Briske et al. 2013; Goodloe 2013; Hawkins 2017); but HPG advocates argue that since HPG is context-specific and focused on managing complexity, they do not endorse across-the-board prescriptions, so these criticisms may not be relevant.

There have been several attempts to explain contradictions in experimental research-based and experiential management-based perceptions regarding the ecological benefits of HPG (e.g. McCosker 2000; Briske et al. 2011; Teague et al. 2013; Roche et al. 2015; Wilmer et al. 2017). In a review of studies exploring adaptive multi-paddock grazing, Teague and Barnes (2017) note that many classical grazing studies choose simplicity over complexity and control and replication over realistic context. The scientific experiments cited in the Briske et al. (2008) critique of rotational grazing, generally small paddock studies, can be thought of as inconclusive on the subject of HM, since they occurred on fewer and smaller pastures than a rancher using HPG on a large ranch and, as such, do not reflect the real-life time and space in which HPG occurs (Brunson and Burritt 2009; Budd and Thorpe 2009; Teague et al. 2013; Roche et al. 2015). Moreover, experimental paddock studies use predetermined stocking rates and rotations and are often on a rigid schedule to ensure integrity and repeatability, which removes management of social, economic and environmental complexity that is central to HM (Brunson and Burritt 2009; Budd and Thorpe 2009; Kothmann et al. 2009; Roche et al. 2015).

Therefore, HM proponents believe that studies focusing on limitations of rotational grazing do little to effectively undermine the Savory method, which has at its core a holistic, landscape scale, triple bottom line approach to decision-making (Teague 2014). As Roche et al. (2015, p. 248) observe, "research on grazing strategy has predominantly focused on comparison of biophysical outcomes (e.g. livestock weight gains and annual forage production) between fixed grazing treatments implemented over fine spatial and temporal scales" but "ranchers make decisions and adapt management for multiple outcomes across numerous scales in response to the dynamic social-ecological systems within which their ranch enterprises are embedded." As such, their perceptions of success and failure may be different from those of range scientists. Briske et al. (2011) concede that contradictory findings regarding the ecological benefits of rotational grazing "can be reconciled by evaluation within the context of complex adaptive systems in which human variables such as goal-setting, experiential knowledge, and decision making are given equal importance to biophysical variables" and that most experiments intentionally exclude these human variables. Briske et al. (2008) argue that a well-managed rotational system would have higher production rates than poorly managed continuous grazing, but the converse would also be true; the more productive system would be the one with better management. As such, HM critics argue that the ecological benefits enjoyed by HM practitioners cannot be causally linked with a specific grazing technique; rather, they are more likely the result of adaptive management more generally (Briske et al. 2013; Hawkins 2017). Hawkins (2017) states that given the farm-level benefits, future research on production rangelands should examine social-ecological aspects (see also Brunson et al. 2016).

Thus, there seems to be some agreement that the manager's mindset is one of the most important factors contributing to positive ecological outcomes associated with HM. This mindset is characterized by an appreciation of rangelands as complex social-ecological systems that produce multiple ecosystem services besides forage, and a holistic decision-making approach that includes checking to make sure actions are aligned with the holistic context, planning while assuming one is wrong, controlling within the plan, monitoring frequently, and re-planning. Roche et al. (2015, p. 255) add much needed clarity to the dialogue by pointing out that "considerable agreement—not debate—exists between experiential and experimental perceptions about the success of [intensive rotational strategies] for achieving *primary livestock production goals*."

Social science research on Holistic Management

The above review of ecological dimensions of HM reveals the need to better understand its social, psychological, and economic aspects in order to better inform ongoing debates and identify promising pathways to more sustainable management of complex rangeland social-ecological systems. Stinner et al. (1997) distinguish between "scientia" (controlled, quantitative) and "praxis" (complex, qualitative) approaches to agricultural research, calling for more of the latter, since the former do not emulate complex, real world conditions. As Risbey et al. (1999) observe, the propensity of many studies to classify agricultural adaptations as either economic or physical in nature is problematic as the social dimension is simply underemphasized if not ignored completely. In this section, we review social-psychological research on HM and identify some topics for future research.

Sindelar et al. (1995, p. 45) published one of the first peer-reviewed overviews of HM in the *Journal of Soil and Water Conservation*, noting "growing involvement of universities, government agencies, and private individuals" in HM and endorsing it as a promising approach to sustainable agriculture on Montana's Great Plains. Since then, only a handful of empirical studies have focused exclusively or mostly on human, social and psychological dimensions of HM (e.g. Stinner et al. 1997; Roncoli et al. 2007; McLachlan and Yestrau 2009; Richards and Lawrence 2009; Alfaro-Arguello et al. 2010; Sherren et al. 2012; Ferguson et al. 2013; deVilliers et al. 2014; Hodbod et al. 2016; Cross and Ampt 2016, Mann and Sherren 2018; Gosnell et al. 2019). Others mention HM in passing or lump HM practitioners in with "innovators" (e.g. Duram 1997; Brunson and Burritt 2009; Bohnet et al. 2011) or with rotational grazing (Nerbonne and Lentz 2003) or just describe the adoption of HM in a community (Gadzirayi et al. 2007). Identifying articles in this latter category that include some useful insights into HM can be challenging, since terminology is not always consistent. For example, HM is increasingly used interchangeably with the term *regenerative agriculture* (Gosnell et al. 2019) and even the Savory Institute has embraced this newer terminology.

Most published studies are comparative, examining characteristics, practices and management innovations of HM practitioners vs. conventional farmers, ranchers and graziers; although both Mann and Sherren (2018) and Gosnell et al. (2019) incorporate insights from interviews with HM trainers. Among the comparative studies, McLachlan and Yestrau (2009) note that HM and non-HM farmers in Canada were comparable in age but HM respondents were more financially stable, had higher levels of formal education, were more likely to work off-farm, and more likely to be female. Sherren et al. (2012) and Richards and Lawrence (2009) also found that HM farmers were more likely to be female or part of a couple working as a team than conventional farmers, and that women played a more prominent role in cell grazing. This finding supports Savory and Butterfield's (1999, p. 92) observations about differences between men and women in the ability to articulate a quality of life statement as part of one's holistic context. Mann and Sherren (2018) also discuss the role of gender in HM uptake. Beyond demographics, the studies reviewed below characterize HM people in terms of the way they think, their approach to finances, how they interact with others, their experiences transitioning to HM, and observations about the potential for HM to 'scale up'.

Thinking adaptively and holistically

A number of studies have documented the ways in which HM practitioners think differently due to adherence to the HM decision-making framework described above. Because they think about success differently, they take a different approach to time management and they perceive and value landscapes and natural resources differently due to their deeper understanding of ecological processes.

HM practitioners emphasize quality of life in addition to economic profit (Abel et al. 1998; Bohnet et al. 2011; Mann and Sherren 2018; Gosnell et al. 2019). In a study about knowledge sharing between scientists and Minnesota farmers practicing HM, Nerbonne and Lentz (2003, p. 75) report that "farmers and researchers alike found that the focus on holism and quality of life helped them to focus on bigger goals than just profits or publications." Malmberg (2013) draws on positive psychology theories associated with prospection (Seligman et al. 2013) and flourishing (Seligman 2011) to explain the effects of adopting the HM decision-making framework. She argues that HM ranchers' focus on improving quality of life is a key to their perceived success, because it makes them more resilient, able to respond to difficult circumstances, have perspective, feel confident, be self-determined to make their own way in the world, and constructively engage with other people. She compares links between human well-being and psychological resilience with links between ecological health and ecosystem resilience. The self-reliance that HM practitioners exhibit, she posits, comes from their focus on harnessing the tools they already have and honing their skills to enhance their well-being, rather than looking to the outside (e.g. technology or pharmaceuticals) for quick solutions. Rather, they seek to address the root cause of whatever problem they encounter and address it directly. Richards and Lawrence (2009, p. 633) looked at a spectrum of grazier worldviews ranging from a "productivist paradigm" to an "ecologically integrated" paradigm and found that HM cell graziers were in the middle, representing a "new green kind of productivism" that undermines dominant rural culture associated with primary production: "Cell graziers spoke in more holistic terms than conventional graziers, identifying lifestyle, production, economics and environmental protection as the interrelated components of sustainability." This different way of thinking about success correlates with a more heterogeneous identity common to HM practitioners, who think of themselves not simply as beef farmers or graziers or cattlemen, but in terms of navigating multiple roles including grass farmers, pasture growers, business people, investors, and environmental managers (Richards and Lawrence 2009; Bohnet et al. 2011; Sherren et al. 2012).

Thinking about success differently translates into a different approach to time management. Stinner et al. (1997, p. 199) found that 91% of 25 HM practitioners interviewed "reported improvements in their quality of life because of changes in their time budgets." Indeed, one of the oft-cited benefits of HM's low input approach to agriculture is that it frees up more social and family time (McLachlan and Yestrau 2009). Interviewees reported being more intentional with how they spent their time since adopting HM, saying things like, "we are no longer doing a lot of things we do not like to do" (Stinner et al. 1997, p. 206).

Thinking holistically contributes to practitioners' adaptive capacity related to various kinds of stressors and crises including climate variability and market conditions. Adherence to the HM decision-making framework involves the kind of higher order, systematic thinking necessary for successful adaptation (Sherren et al. 2012; Gosnell et al. 2019). De Villiers et al. (2014) found that HM practitioners in South Africa were aligned with six key traits of adaptive capacity, including personal control, record keeping and monitoring, learning, innovation, leadership and group participation, and diversity of income and land use. Richards and Lawrence (2009, p. 638) found that "cell graziers have exhibited the ability to adapt to both market and climatic conditions by reconfiguring their own identities as producers, re-thinking cattle management techniques, embracing a new, more entrepreneurial business philosophy, and focusing upon the condition of the environment." HM graziers take a longer view and are more open to fundamentally changing their operations to adapt compared to non-HM graziers' more incremental approach to adaptation typically involving plans for supplemental feeding in drought years (Sherren et al. 2012).

Graziers who adopt HM become more accepting of risk and open to experimentation, exhibiting "a change in farming mentality from trying to gain control over the land, for example through engineering solutions that aim to reduce temporal variability, to working within the bounds of natural variability" (Sherren et al. 2012, p. 79). McLachlan and Yestrau (2009, p. 302) make a case for looking at HM as "a grassroots adaptive response to environmental and socioeconomic decline in rural landscapes the world over … that can potentially play an important role in adapting to rural crises." They base this conclusion on empirical research comparing the responses of conventional and HM farmers in Manitoba, Saskatchewan, and Alberta to bovine spongiform encephalopathy (BSE), finding that HM ranchers were more optimistic than conventional ranchers about their ability to adapt not only to BSE, but also to concomitant climate change, reduced commodity prices, and the future of agriculture. They found the HM farmers saw themselves as doing more 'acting' than 'reacting' since adopting HM. Stinner et al. (1997, p. 202) similarly conclude that the HM approach, in which the practitioner assumes his decision is wrong and then monitors outcomes, "creates a different psychology from that in conventional decision-making in which a carefully researched decision is generally assumed to be right." This finding aligns with Savory's contention that HM is not about adapting using hindsight, but rather being proactive and anticipatory.

Understanding sources of adaptive capacity and resilience means that HM practitioners also perceive and value landscape and ecological processes differently than conventional producers, which is not surprising given the paradigm-shifting focus of HM training (Mann and Sherren 2018; Gosnell et al. 2019). Sherren et al. (2012) found that HM graziers evidenced "a different way of seeing and talking about their land" than conventional graziers, while Nerbonne and Lentz (2003, p. 68) describe HM farmers as having "reinvented their relationship with the land." Farmers in their study reported having to be more observant and aware of "the whole picture" in order to implement HPG properly. Roche et al. (2015, p. 255) found that Wyoming ranchers who use an intensive rotational grazing strategy associated with HM ranked livestock production lower than other producers in terms of their operational priorities: "Ranchers adopting this strategy are likely making decisions to meet alternative ecosystem service goals (e.g. forage production, soil health), and their perceptions of success are not based on the traditional livestock production metrics that the scientific community commonly uses to compare grazing systems." Stinner et al. (1997, p. 199) found only only 9% of their interviewees reported thinking about biodiversity in the context of their operations before being exposed to HM; after adopting HM, all of them reported that "biodiversity is important to the sustainability of their farms and ranches." They also reported that "the paradigm that [HM] is based upon, in which humans learn to work consciously with ecological processes to rebuild biodiversity and ecological integrity on their land, is fundamentally and radically different from the paradigm that dominates conventional agriculture, which places relatively little emphasis on ecological processes and biodiversity" (Stinner et al. 1997, p. 212) Sherren et al. (2012) used photo-elicitation (photography and follow-up interviews) to compare the landscape perceptions of HM graziers in New South Wales, Australia with those of more conventional graziers and examined how those perceptions related to their management actions and priorities. HM graziers showed more interest in animals and insects than conventional graziers, were less concerned about weeds, often spoke of links between biodiversity (e.g. a mix of native perennials vs. a monocrop of introduced annuals), and were open to the possibility of integrating biodiversity protection into a working landscape vs. setting aside a separate area of the property for conservation.

Gosnell et al. (2019, pp. 101, 965) found that multisensory and multidimensional satisfaction associated with regular ecological monitoring plays an important role in transformation both in the producer's life and on the land s/he manages. They argue that:

> feedbacks associated with daily monitoring occur in both cognitive and emotional spheres and drive adaptive/proactive management. Over time, self-amplifying positive feedback loops fueled by traction in personal, practical, and political spheres increase regenerative potential, leading to persistence and alignment with one's most deeply held values.

They note that "friction" in these spheres (e.g. derision from neighbors and social isolation, or an inability to control weeds) can impede the growth process.

Economic efficiency and profits

Also common in the scholarly literature on HM are findings related to economic benefits and the possibility that attention to the health of ecosystem processes can be compatible with economic prosperity. Stinner et al. (1997, p. 206) reported that 80% of the farmers they interviewed had perceived increased profits since transitioning to HM and 52% reported decreases of up to 40–60% in labor requirements in their operations in spite of extra planning and monitoring required by HM: "These ranchers believe that their investments of time and money to upgrade their land is netting increased profits in higher carrying capacity and lower production costs." Other studies have similarly found that HM practitioners generate profit due to decreased costs of production and use of inputs (e.g. synthetic fertilizer, artificial weed control, and supplemental feeding of livestock), reduced animal health costs, and improved cattle conditions and product output (e.g. milk, manure) (McCosker 2000; Gadzirayi et al. 2007; Sherren et al. 2012; Ferguson et al. 2013). For example, Gadzirayi et al. (2007) reported that HM's focus on monitoring resulted in reduced cattle losses by reducing theft and detecting disease early for a Zimbabwean community who transitioned to holistic grazing. In their photo elicitation study, Sherren et al. (2012) noted that HM graziers were more likely to document the lightweight temporary fences and portable solar panels used for cell grazing, while non-HM graziers photographed their large equipment and silos used for storing supplemental feed; HM graziers had little need for heavy equipment since most had given up cropping due to the perceived impacts of plowing and fertilizers, and they had no need for silos to store supplemental feed since they believed that stocking rates should be adjusted to respond to available forage. Ferguson et al. (2013) found that HM ranchers purchased less hay and feed and used less herbicides and pesticides than their conventional neighbors and concluded that HM strategies are leading to greater ecological and economic sustainability. Abson et al. (2019) explore similar themes from a resilience perspective, concluding that a mix of approaches to economic prosperity is likely ideal.

Both McLachlan and Yestrau (2009) and Alfaro-Arguello et al. (2010) found that 'holistic technology' allowed HM ranchers to reduce input costs, while the land provided more services. The latter conducted an emergy analysis (i.e., calculation of the available energy used in the work of making something) on the resource use, productivity and sustainability of holistic and conventional ranches in Chiapas, Mexico. They found that holistic ranches had double the emergy sustainability index values of conventional ranches, but that the improved emergy sustainability did not decrease milk or cattle production. They concluded that productivity can be maintained as the sustainability of rural dairy ranches is increased if HM principles are adopted, a finding with important implications for ranchers with low profit margins considering adopting HM.

Becker (2000) profiled a HM ranch in Central California affiliated with Cal Poly University as a model of "sustainable agriculture and habitat management integration." Her objective was to demonstrate how agricultural operations, through innovative practices, can be profitable without compromising ecological values. She noted that the ranch plan "to be profitable in all its operations in five years" was a key to its success. Though she mentions that the ranch "has successfully implemented the Holistic Management program promoted by Allan Savory … with excellent results for both the weight-gain stocker cattle and cow/calf operations," she does not connect the management of other aspects of the ranch or the overall success of the ranch to HM decision-making explicitly. This exemplifies the tendency to associate HM with only livestock grazing systems, and not with the broad approach to managing an operation holistically.

Much research on economic efficiency and profits has focused on ranching practices, however, many HM practitioners also take advantage of non-traditional means of income generation. Richards and Lawrence (2009) found that HM incorporated a broader business management philosophy than conventional ranching and reported that many cell graziers also were involved in off-farm investing, which allowed a reduction of natural resource dependency and decreased reliance on trade and climate. Gosnell et al. (2011a, b) report on the role that HM practices played in western US ranchers' ability to participate in the voluntary carbon market. Chicago Climate Exchange protocols for generating carbon credits through rangeland soil carbon sequestration aligned well with HPG principles and practices. In addition to the profits resulting from increased production and decreased inputs mentioned above, Gadzirayi et al. (2007) reported economic diversification through a bee production scheme and increased maize crop yields due to more labor being available for agricultural activities in the communal scheme.

We did not find any studies reporting declining profits associated with HM adoption. Recurring themes in the scholarly literature had to do with increased profits associated with reduced inputs including labor and novel approaches to income diversification.

Social learning and community engagement

Almost without exception, all of the social science studies we reviewed addressed the distinctive role of community in the HM approach to life, both for support in transition and persistence, and as a source of social learning and ongoing innovation. Stinner et al. (1997, p. 206) found that "networks with other [HM] practitioners were considered critical to the success of most of the interviewees" and this finding has been echoed repeatedly in subsequent studies that discuss HM study groups (de Villiers et al. 2014), management clubs (McLachlan and Yestrau 2009; Alfaro-Arugello et al. 2010), communities of practice (Cross and Ampt 2017), and even microscope clubs (Gosnell et al. 2019) supported by a common knowledge base and common language (Kennedy and Brunson 2007).

HM networks tend to build trust and result in collaborative capacity, though when part of the community has not adopted HM this can also cause tension (Abson et al. 2019; Gosnell et al. 2019). Gadzirayi et al. (2007) described the social benefits the Chikukwa people gained when working together to implement a HM grazing system in a communal area on the border of Zimbabwe and Mozambique. The new system reduced conflict among community members, increased community involvement in all stages of project planning and management, and enhanced social cohesion as families spent more quality time together. The authors attribute the success of the holistic grazing scheme to its "coordinated community management approach to natural resources" which "has helped bring about community ownership of resources." Gadzirayi et al. (2007) found that the planning of the grazing scheme, training, and stakeholder consultation meetings led to institutional benefits including better collaboration between the Chikukwa community, the government, and local NGOs, and among community members. Similarly, in the American West, HM "has been a powerful tool in allowing stakeholders with different visions and values to work together cooperatively" (Paulson 1998, p. 311) and has facilitated good working relationships among permittees, public land managers, extension agents, researchers and other institutions (Kennedy and Brunson 2007).

These networks build resilience by connecting individual decision-makers to collective decision-making (de Villiers et al. 2014), especially in rural areas experiencing depopulation and scant opportunity for community interaction. In the BSE study described above, McLachlan and Yestrau (2009) found that HM social networks led to increased innovation among interviewees. Kennedy and Brunson (2007) similarly found that HM practitioners cultivated a supportive atmosphere that facilitated change (Kennedy and Brunson 2007). Social learning related to HM often leads to innovation, new management techniques, and overall enhanced adaptive capacity (Paulson 1998; de Villiers et al. 2014). In Australia, financial collaboration among cell graziers built social capital and trust, and led to the pioneering of a new form of beef production (Richards and Lawrence 2009). Kennedy and Brunson (2007) attributed a culture of innovation in western Colorado to the large number of ranchers there that had been exposed to HM training. They demonstrated an openness to change and experimentation that the authors attributed to the clarity of their goals. The ranchers reported that as long as new ideas were in line with their overarching holistic goal [now holistic *context*] they were open to considering new ways of doing things. They were also more likely to consult more sources of information in their decision-making because of this openness.

Social learning networks can also fill the role of technical support programs. Alfaro-Arugello et al. (2010) found that in the absence of strong technical support programs, farmer-to-farmer technology transfers as seen among HM club members offered needed solutions for production and sustainability challenges. In their study of carbon sequestration as a way to mitigate climate change, Roncoli et al. (2007) noted that most literature focused on technology and not social and institutional elements. HM is worth studying, they argue, because it "moves beyond purely proposing a technical intervention, and integrates capacity building efforts to enable communities to manage the system" (Roncoli et al. 2007, p. 103).

While there are a number of studies that explore how local and regional HM clubs or communities of practice interact, there have been no comprehensive analyses of larger HM social networks operating at an international scale as part of an emergent agroecological social movement. There are several organizations, networks, and businesses that have been created over the last four decades in the name of promoting HM. Some have come and gone, some have endured, some have evolved, and some are in their infancy. What social dynamics enable and constrain coordinated efforts to scale up the HM movement? How can these social dynamics be monitored in systematic ways that parallel economic and ecological monitoring? Insights from studies of other transformative learning networks (Goldstein et al. 2017) could inform such investigations.

Making the transition

Of interest to a number of researchers has been why ranchers adopt HM. Difficult circumstances such as drought, degraded land, or economic crisis are a major reason, which leads farmers to cross a threshold and transition to another approach (Brunson and Burritt 2009; Kennedy 2005; Kennedy and Brunson 2007; Stinner et al. 1997; Gosnell et al. 2011b; Mann and Sherren 2018; Gosnell et al. 2019). Indeed, Savory has admitted that most ranchers told him that "they were at rock bottom and facing financial ruin and I was their last resort" (McGuire 2010, p. 54). In Zimbabwe, reasons for adoption of HM included environmental degradation as a result of soil erosion, steep slopes and inappropriate farming practices (Gadzirayi et al. 2007). Cattle farmers in Chiapas, Mexico turned to HM because they were dissatisfied with outcomes resulting from conventional approaches to tropical cattle farming on extensive grassland areas in Latin America that included reductions in tree coverage, increase in invasives, compaction and erosion of soil, loss of soil fertility, and decrease in biodiversity (Alfaro-Arguello et al. 2010).

Adoption of HM is motivated not only by push factors and desperation, but also by the potential for a better way. Kennedy and Brunson (2007) found that the primary motivations for changing practices in the American West were values tied to the land base such as forage production, range health, and water quality, as well as a desire to improve profitability, increase efficiency, and maintain a ranching lifestyle. Suggesting triple bottom line thinking, HM ranchers in various studies have explained that they experienced paradigm shifts that led them to adopt HM in order to increase efficiency, improve profits, conserve natural resources, improve family's quality of life, and sustain future generations, often highlighting the connections between these goals (Kennedy and Brunson 2007; Tohill and Dollerschell 1990; Yestrau 2008; Gadzirayi et al. 2007; Richards and Lawrence 2009; Gosnell et al. 2011b). Richards and Lawrence (2009) found that improving profits was not the main motivation of the cell graziers they studied; rather, they tended to be motivated by their family and life circumstances and were not bound to family traditions, in part because most did not have a long history of ranching and farming.

This scholarship reveals that in many cases farmer motivation is not entirely economic or ecological, but rather part of a more complex, embodied narrative. Gosnell et al. (2019) characterize Australian farmers' transition to HM as a type of transformational adaptation, often catalyzed by "induced epiphanies" associated with HM training; social learning; and embodied, multisensory experiences working with the land and their animals. Given the growing interest in the role of interiorities and inner transformation in sustainability transitions (O'Brien 2013; Ives et al. 2020), the HM phenomenon is a promising area for research.

Barriers to change and scaling up

As the previous sections suggest, there has been significant interest in factors influencing farmers' and ranchers' decision to transition to HM. Less studied are the dynamics influencing its adoption at larger scales, or its potential to contribute to a significant transformation in agriculture. McLachlan and Yestrau (2009) portray HM as a "grassroots farmer movement" with a focus on environmental, social and economic sustainability. Cross and Ampt (2017, p. 1) also portray HM as a "movement" and "a strong example of a bottom-up transition toward a sustainable agroecological farming system." Savory and Butterfield (2016, p. 1) go further, calling it a "commonsense revolution to restore our environment." McCosker (2000, p. 207) described the first ten years of cell grazing in Australia and declared a paradigm shift, predicting that "its principles will be considered 'normal science' within another 10 years." While the number of acres under HM has certainly risen in Australia and elsewhere around the world, it cannot yet be argued that it is becoming the dominant paradigm in agriculture. There are a number of factors that make transitioning to HM difficult at the farm level and that stymy efforts to catalyze a broader shift at a societal level (Gosnell et al. 2019).

Some of the literature we reviewed examines the factors that impede farmer/rancher participation in this movement and the diffusion and institutionalization of HM innovations. Gosnell et al. (2019) and Abson et al. (2019) highlight some of the social barriers to transitioning to HM (e.g. peer pressure, fear of stigma, and having to shift social groups). Stinner et al. (1997, p. 212) found the biggest difficulty for individuals transitioning was the paradigm shift required, noting that, for many, forgoing a traditional ranching lifestyle and practicing HM "was mind boggling at first." In a recent interview study with HM trainers, it was clear that the paradigm shift was the most challenging aspect, and one that the trainers hoped most that their trainees would take away, even if they never adopted the specific planned grazing approaches also taught (Mann and Sherren 2018).

There are a number of practical challenges, as well, including the lengthy process involved in transitioning, and significant time and resources needed to learn new techniques, train livestock to behave differently (rotate pastures in groups), and purchase necessary infrastructure (e.g. electric fencing) (Gosnell et al. 2011b). HM involves more planning and monitoring than many farmers and ranchers are accustomed or willing to do, and there can be considerable lag time before benefits become apparent, both of which can be deterrents. Nerbonne and Lentz (2003) found that farmers considering transitioning to HPG in response to the HM training they had received were concerned about associated risks, but the presence of a support network of other farmers who were going through the same process made them more confident about experimenting with the new approach. Sherren et al. (2012) observed that the likelihood of transitioning to HM may be more a function of personal adaptive capacity (aversion/openness to risk and experimentation) than the presence or absence of practical hurdles or enticing incentives.

The influences of other individuals can also be a barrier to transitioning. Disapproval from peers is a factor that many are unable to tolerate (Gosnell et al. 2019). Stinner et al. (1997, p. 206) reported that most of their interviewees "relayed that they were considered odd by their immediate neighbors" in spite of the fact that "many of them are now sought after speakers for national meetings or even internationally." Another factor has to do with the influence of the agrochemical industry, which stands to lose profits with widespread adoption of the low input agriculture associated with HM (Gosnell et al. 2019). The local agrochemical sales representative is often an important member of rural farming communities.

In sum, scholarship suggests that HM is more than a "management system"; it is a paradigm shift, which helps explain barriers to transition. Cross and Ampt (2017, p. 1) characterize HM as "a potent grass-roots example of adaptive farm management that generates optimism in the farming families involved, and challenges existing research and extension paradigms regarding both innovation and practice change." Future research might investigate what forms of environmental governance support farmer transition and how capital is being pooled by HM advocates to reconnect fractured landscape ownership and implement HM at a landscape scale.

Discussion

Allan Savory initially grounded the credibility of HM on its capacity to increase forage, reduce desertification and fix carbon in the soil. As we have just described, these claims have attracted both widespread interest and scientific skepticism. After a half century of research, the results are inconclusive—the most that can be said is that ecological results vary depending on context. These inconclusive results have only fed a sometimes bitter and longstanding controversy over the value of HM.

While it may seem that the way to resolve this controversy is by conducting more science in order to achieve consensus around a series of conclusive tests, achieving consensus this way is unlikely. Scientific disagreements conducted at the research frontier where no consensus exists about what constitutes proper research are often not amenable to resolution through empirical evidence, because of what Collins (1981) called "the experimenters' regress", in which the protagonists in a controversy are unable to agree whether an experiment that provides critical evidence was competently done. This is even more the case when there are opposing interests, when there is controversy about a discovery, when there is distrust over the experimenter's qualifications and reputation, and when experiments are conducted outside of a controlled laboratory setting where experimental conditions are impossible to fully replicate.

Yet, while the controversy over Savory's ecological claims continues to rage, there is little controversy within the social sciences over the potential benefits of HM which, as we have documented, include building relationships and social networks, adaptive capacity, optimism, and resilience. Briske et al. (2013, p. 325) suggest that the rotational grazing debate persists "because the rangeland profession has not yet developed a management and research framework capable of incorporating both the social and biophysical components of complex adaptive systems." In other words, science has a hard time exploring complexity and therefore tends to reduce the questions at hand to a set of complicated variables.

One way to resolve the larger question of whether HM is beneficial might be through aggregate assessment of social-ecological benefits (Briske et al. 2013). Depending on what values inform the weighting of the factors, however, an overall assessment may yield a negative or positive result in a specific context. This would depend on reaching agreement on the relative weighting of different values, and would be made all the more difficult since social and ecological factors may be inter-dependent. For instance, adaptability to changing climate might require longer time scales to realize ecological benefits.

Sherren and Kent (2019) suggest a less cohesive interdisciplinarity that honors the variety of scientific perspectives, noting that "awareness of the incompleteness of any one picture should help to mitigate polarization and smooth the way for integrative, socio-ecological research to address complex problems." This approach maintains the assumptions of a linear relationship in which science informs policy, albeit one that is more ecumenical about scientific frameworks. However, as Sherren and Kent (2019) acknowledge, a linear approach that does not allow for interaction between producers and users of knowledge has limited utility to create usable and useful knowledge (Armitage et al. 2011; Dilling and Lemos 2011).

Joining Briske et al. (2011), Sherren and Kent (2019) advocate for the more participatory approach of engaging stakeholders at different phases of knowledge production about HM, suggesting that the goal of greater scientific participation is not to achieve consensus and closure, but rather to reveal competing understandings, increasing the options available to policymakers. They note that one of the obstacles to operation of this open marketplace of ideas is the insular nature of HM communities, which share the challenges and successes of their practices only among themselves. Sherren and Kent (2019, p. 88) conclude that "scholars may be more likely to engage and partner if the HM community were to share the problem-solving and critical reflection that is happening inside." This is a telling comment for what it reveals about the limitations of this participatory model, since it assumes that the problem lies with distrustful practitioners who will not adopt the open norms of science that would enable them to "reveal challenges encountered with HM principles in action, document iterations of experimentation; and demonstrate the community as a place of critical analysis and support."

However, rather than criticize HM practitioners' defensive posture, we see it as grounded in an essential feature of the theory of knowledge co-production that is often overlooked, which is the inseparable relationship between our understanding of material reality, our knowledge of that reality, the social context of knowledge production, and how we choose to act in the world (Wyborn 2015; Jasanoff 2004). Power flows through these relationships between knowledge, social practices, and institutions, as ideas gain cognitive, moral, and political standing (Miller 2004). The circulation of power is not a sign of bias or poor intentions—rather, it is an inevitable occurrence, as knowledge is embedded within decision making, and institutions perpetuate a particular understanding of the natural world (Jasanoff 2004).

This dynamic—which informs the power relations that undergird conventional agricultural science—is often overlooked in calls for more interaction between scientists and stakeholders. When we highlight the cultural and scientific influences on governance, we become more cautious about considering these influences in isolation. In earlier sections of this paper, we documented how HM is more than mere interdisciplinarity—in its farmer-centeredness, its holism, and its history of challenging conventional agricultural science. This broader picture points us toward solutions that offer a more substantial renegotiation of farmer scientific knowledge production, by supporting alternative knowledge practices, and institutions to manage these practices.

What is required are institutions that can hold space for knowledge co-production outside of the conventional bounds of agricultural science and its associated social order, and enable communication and negotiation with the institutions that sustain the dominant configurations of knowledge and power (Guston 1999; Cash et al. 2003). We need boundary organizations that occupy the space between science and policy and facilitate knowledge co-production through communication, mediation, and translation among stakeholders (Guston 1999; Cash et al. 2003; Wyborn 2015). Boundary organizations build trust by providing accountability to actors on both sides of this boundary, while fostering learning and connecting and coordinating activities (Cash et al. 2003; Hahn et al. 2006).

In light of these concerns, we would like to suggest another way to resolve the controversy, which is to change the way we are asking the question. Far from being a cop-out, redefining the question is the way that these kinds of scientific controversies are often resolved (Collins 1981, 2014). Rather than attempting to isolate the social and ecological effects of HM, we suggest adopting a framework that takes both the social and ecological into account, and engages ranchers as both knowledgeable, active subjects and as part of the system under study (Sherren and Darnhofer 2018). The core question that has to be asked about HM is not just about ecological outcomes related to forage availability, water quality, and soil carbon; it is about how a social-ecological regime like HM can help bring about necessary shifts in the systems, structures, assumptions and worldviews in order to support a sustainable society (Strauch et al. 2009; Fazey et al. 2018). Addressing this kind of "how to" question requires a more democratic, inclusive, and action-oriented relationship between scientist and practitioner, often called 'action research'. Nerbonne and Lentz (2003) anticipated this shift when they called for a move to a "new era" in which farmers and researchers build new knowledge together, "finding new solutions to creating sustainable relationships between human and ecological systems."

These kinds of questions have traditionally been confined to the domain of practice, in part due to the assumption that implementation is political, normative, and therefore not amenable to scientific analysis (Umpleby 2016). While this kind of research may not find a home in traditional agriculture research, its capacity to both generate novel insights and disseminate knowledge can be enhanced when it is conducted within facilitated communities of practice and learning networks, a number of which exist within HM. We anticipate novel results from participatory action research involving the Ranching for Profit Executive Link program, Holistic Management International's management clubs, Grasslands LLC's regional managers model, Savory Institute's Hub program, and other mechanisms supporting fledgling HM practitioners, along with other training mechanisms, e.g. Australia's TAFE, the Savory Center R&R program, and Savory Institute's on-line learning. Cross and Ampt (2017) have begun this promising approach to research with a participatory rural appraisal of HM communities of practice in southeast Australia.

Conclusion

In conclusion, we believe that the controversy over the effectiveness of HM can be traced back to the narrow terms in which HM was initially studied, at a time before social-ecological frameworks were developed. Studying a different agricultural paradigm was inhibited because—within an industrial farming paradigm—the only credible way to establish the value of an agricultural practice was to frame it in narrow, positivistic terms that removed the rancher as a thinking, adaptive agent, instead focusing solely on generic treatment efficacy for increasing forage, reducing desertification, and fixing carbon. Hodbod et al. (2016) attempt to address this issue with a new framework for assessing the performance of agroecosystems from a multifunctional perspective, arguing that Adaptive Multi-Paddock Grazing (a.k.a. HPG) scores high according to their criteria.

Shortly after Savory wrote the first edition of his book on Holistic Management (1988), British sociologist Brian Wynne considered how mainstream science clashed with local knowledge of ranching conditions during a crisis caused by fallout from the Chernobyl nuclear disaster (1992). Wynne describes how a 'one-size fits all' model adopted by government scientists ignored the ability of farmers to cope with ignorance and lack of control. The scientists' need to standardize and aggregate scientific knowledge denied the differences between farms and undermined the status of lay knowledge, a result which Wynne (1992, p. 42) noted was inherent to the "institutional embedding, patronage, organization and control of scientific knowledge."

A more holistic approach to co-producing scientific knowledge about HM, grounded in enhancing the capacity and agency of ranchers, should be seen as part of the system change that HM is attempting to leverage within agriculture. This approach, more radical than participatory, is not only truer to the vision and purpose of HM, it is more coherent with how Savory himself now frames the problem and solution. Quoting from the front page of the Savory Institute's website, the claim is not that adopting HM practices increases forage, reduces desertification and fixes carbon, but rather that "Holistic Management is a process of decision-making and planning that gives people the insights and management tools needed to understand nature; resulting in better, more informed decisions that balance key social, environmental, and financial considerations."

Finally, we suggest that examining the HM phenomenon using a social-ecological systems (SES) lens could result in new contributions to the rangeland science literature. Hruska et al. (2017, p. 266) note that little research has examined rangelands as SESs, and, when it does, "too often, only single cross-system influences are emphasized … such as how changes in resource or social policy affect rangeland ecosystems, without following up to see how altered ecological processes feed back to affect the social system." What is needed are applications of the SES framework to analyze "how social and ecological components of the system interact in iterative cycles" (Hruska et al. 2017, p. 266). Given HM practitioners' explicit commitment to social and ecological monitoring and adjusting behavior as needed (Gosnell et al. 2019), we suggest that studying HM could be a fruitful means to address this gap in order to better understand integrated rangeland SES, as well as processes and mechanics of inner and outer transformation.

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