Draft chapter 14: The resilience of Australian agricultural landscapes characterized by land sparing versus land sharing

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Introduction

The notion of resilience has extended beyond its original application—describing ecological systems (Holling, 1973)—to one useful for understanding social-ecological interactions and interdependencies (Holling, 2001). A social-ecological system consists of a biophysical unit and its associated (tied) social actors and institutions. Social-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding a particular ecosystem (Redman et al., 2004); in practical terms, they often span landscapes or regions. We define the resilience of a social-ecological system as the ability to maintain its 'identity'—key functions, structures and roles within society that define the system—in the face of exogenous perturbations (Walker et al., 2004). A resilient social-ecological system should have the adaptive capacity to maintain its identity, if not all its original processes (Folke et al., 2004), where adaptive capacity describes the ability of social-ecological systems to change in response to changing circumstances.

This chapter combines conceptual reasoning with evidence gathered during several years of extensive empirical research in the livestock grazing landscapes of the upper Lachlan River catchment of New South Wales (NSW), Australia. Specifically, we consider how two agricultural landscape management approaches—holistic management (land sharing) and conventional livestock management with protected patches (land sparing)—create different social-ecological system properties that influence the resilience of each farming system.

Social-ecological resilience

Following Walker and Salt (2006) we differentiate between two types of resilience—general resilience and specified resilience. General resilience describes "the general capacity of a social-ecological system … to absorb unforeseen disturbances" (Walker and Salt, 2006, p121). Three system properties have been suggested as playing important roles in ensuring general resilience, namely diversity, modularity and the tightness of feedbacks (Levin, 1998, Walker and Salt, 2006, see Box 1 for details).

Box 1. System properties associated with general resilience in social-ecological systems.

Three general system properties typically associated with greater resilience are diversity, modularity and tightness of feedbacks. Diversity refers to the range of different structures, functions, people and institutions in the social-ecological system. Such diversity is assumed to aid general resilience by increasing flexibility and response options in the face of disturbances (Walker and Salt, 2006). Modularity relates to "the manner in which the components that make up the system are linked" (Walker and Salt, 2006, p. 121). Shocks tend to travel rapidly throughout highly connected systems. In contrast, systems that have clearly identifiable subgroups with strong internal links, which are only loosely connected to each other, are more likely to withstand shocks. Such modular systems can keep functioning when a particular module fails, particularly if there is a diversity of modules providing similar functions within the system (i.e. functional redundancies). Finally, the tightness of feedbacks relates to how quickly and strongly the changes in one part of the system are felt and responded to in other parts of the system. Tight feedbacks enable rapid adaptive changes to system perturbations.

In addition to these three general system properties—diversity, modularity and feedbacks—we also consider access to capital asset bundles as important determinants of general resilience in our case study (e.g. Carney and Britain, 2003). Capital assets are stocks of tangible and intangible assets that can be accessed to provide and improve human livelihoods (Scoones, 1998). In our case study, we specifically focus on three key capital asset types—natural capital (the elements of nature that produce value to people), financial capital and social capital (the institutions, relationships, and norms that enable societies to function effectively)—that can help buffer shocks in different farming systems. We acknowledge that other capital types, such as human capital (the collective skills, knowledge, and intangible assets of individuals that can be used to create economic value), may also be important determinants of social-ecological resilience. However, we suggest that natural, financial and social capital assets are more clearly linked to the choice of land sparing or land sharing land management strategies than other capital asset types. Therefore, these three capital asset types are the most important determinants of differentiated general resilience in our case study.

In contrast to general resilience, specified resilience is premised on understanding specific threats to a system and identifying the key variables related to those threats that may change the system's identity. Specified resilience is the resilience "of what, to what" (Carpenter et al., 2001, p765). Regarding resilience "to what", in this chapter we focus on two major exogenous perturbations relevant to our case study area, namely fluctuations in (1) climate (e.g. drought), and (2) agricultural input prices (we set aside the issue of output price fluctuations as we assume that both holistic and conventional farmers are equally impacted by such perturbations). Regarding the resilience "of what" we consider both maintenance of system identity (i.e. economically viable, family-owned livestock farms within functioning ecosystems), and also the resilience of valued native species within the case study area.

Land sparing and land sharing

Green et al.'s 2005 paper "Farming and the fate of wild nature" introduced the notions of land sparing versus land sharing (originally termed "wildlife-friendly farming") as two alternative land use options for managing the trade-offs between biodiversity and food production within agricultural landscapes. Land sparing involves intensive (high yield), specialized agricultural production on existing lands, thus (in theory) sparing land for non-agricultural activities such as biodiversity conservation (Lambin and Meyfroidt, 2011). We assume that spared land must be within the same ecosystem as the intensively farmed land. This is necessary both in order to make meaningful comparisons between land sparing and land sharing, and because the assumption that intensive land use in one place necessarily leads to protection of land elsewhere is largely untenable (Lambin and Meyfroidt, 2011). In contrast, land sharing involves lower intensity (low yield), but more extensive, agricultural production that promotes 'wildlife-friendly' agricultural landscapes (Fischer et al., 2008). Land sharing approaches favour minimizing agrochemical inputs and support the notion of multifunctional landscapes, in which economic and non-economic goods are co-produced (Fry, 2001, Altieri, 2000).

While the notions of sparing land for nature (e.g. Waggoner, 1996) and wildlife-friendly agriculture (e.g. Krebs et al., 1999) predate the work of Green et al., the idea of 'land sparing versus land sharing' as contrasting options within a conceptual framework for assessing the co-production of biodiversity and agricultural goods has sparked considerable interest and debate. Support for sparing (e.g. Egan and Mortensen, 2012, Grau et al., 2008, Phalan et al., 2011) or sharing (e.g. Dorrough et al., 2007, Mastrangelo and Gavin, 2012, Perfecto and Vandermeer, 2010) land use strategies is driven to some extent by the underlying scientific research approaches, paradigms and worldviews of individual researchers (Fischer et al., 2008). Similarly the type of system studied may favour either a sparing or sharing approach (von Wehrden et al. 2014). For example, intact primary habitat may lend itself to sparing strategies, while land sharing may be more suitable in secondary habitats (Ramankutty and Rhemtulla, 2013). In addition to the context-dependent nature of the findings, the sparing/sharing framework has been criticized for implying that static optimization is possible or desirable in dynamic, multifunctional systems and for assuming commensurability between the different types of 'goods' being traded-off (Fischer et al., 2014).

Despite these limitations, the sparing/sharing framework has provided a useful way of thinking about contrasting types of land use patterns and management approaches in agricultural landscapes. Here, rather than engaging in the contentious debate regarding which strategy (sparing or sharing) provides better outcomes for biodiversity and food provision, we apply the useful conceptualization of landscapes as gradients from sparing to sharing in order to investigate how the system properties associated with starkly different land use patterns and management approaches in agricultural landscapes influence social-ecological resilience.

Table 1 provides a list of typical characteristics of social-ecological systems under land sparing and land sharing. We recognize that for some species or purposes, a different characterization of landscapes would be more suitable. Our 'archetypes' serve a conceptual purpose, to delineate the ends of the land sparing/land sharing gradient, and must, therefore, be considered as stereotypes that over-extend the differences observable in the real-world; many hybrid systems sit on the continuum between these two extremes.

Table 1. Typical characteristics of 'archetypal' land sparing versus sharing systems as assumed in this chapter. Note that many real-world farming systems exist between these two archetypal extremes.

Land sparing	Land sharing
Clear delineation between protected and productive components within the landscape (beyond the mere presence of field margins)	No clear delineation, but a diversity of "wildlife-friendly" elements throughout the landscape (e.g. scattered trees, shrubs, field margins, streamside vegetation)
Intensive agricultural land use (typically including the use of agrochemicals)	Extensive agricultural land use (typically low use of agrochemicals)
Yield/profit maximization, often in conjunction with agricultural specialization	Minimization of agrochemicals, often in conjunction with on-farm business diversification
Landscape homogenization within intensively used areas is tolerated to capture economies of scale in agricultural production	Landscape heterogeneity is encouraged to maintain natural capital for agricultural production
Separate production of biodiversity and agricultural goods (binary view of landscapes with an emphasis on efficient allocation of resources between biodiversity and agricultural commodity production)	Co-production of biodiversity and agricultural goods (holistic view of landscapes with an emphasis on interdependencies between commodity production and biodiversity)
Natural capital conceptualized as a resource conserved for reasons other than its benefits for agricultural production	Natural capital conceptualized as a resource used for agricultural production

Methods overview

The methods used in the various pieces of previously published research are explained in detail in the cited references – for convenience, we provide a brief summary here. Our research combined ecology, social science and policy research components via 33 shared case study farms and collaborative workshops in the study area (Sherren et al. 2010; Fischer et al. 2014), and two large-scale landholder surveys to test our observations at a broader scale (Schirmer et al. 2012a; Schirmer et al. 2012b; Sherren et al. 2012b).

We mapped case study farms and their woody vegetation, and established grazing practices such as stocking rates and total annual grazing days for each paddock through discussion with each farmer. Ecological surveys targeted two-hectare plots in grazed woodlands, open paddocks and scattered tree sites, as well as ungrazed woodlands, to inventory trees, seedlings, birds and bats. These data allowed grazing practices to be linked to tree cover and seedling recruitment, and the resulting woody vegetation to be associated with biodiversity (Fischer et al, 2009; Fischer et al, 2010a).

Twenty five farmers participated in interviews that used their own photographs of 'significant' landscapes as prompts for discussion. Those photo-elicitation interviews allowed us to understand how farmers valued various aspects of their landscapes, including how their perceptions drove management practices and outcomes (Sherren et al, 2010; Sherren et al, 2011b, Sherren et al, 2012a). More detailed interviews followed with a subset of farmers to explore their financial management, such as farm gate receipts and costs associated with specific management regimes. Three annual workshops held with local graziers, farm consultants, catchment managers and government representatives helped us interpret our observations and their implications.

Throughout the remainder of this chapter, we draw on the findings of this previous work, as well on the conceptual understanding of the study system we developed throughout the research process.

The case study area

The study area (approximately one million hectares) is within the grassy-box woodland ecosystems of the upper Lachlan river catchment of New South Wales (NSW), Australia, in which livestock grazing is the dominant agricultural activity (Figure 1). The eastern side of the study area is hilly and rocky in parts and livestock grazing is the only viable agricultural activity. Further west, slopes are gentler and the amount of cropping increases. Large patches of trees are largely confined to the hilltops, but scattered paddock trees are common throughout the region, and account for approximately one-third of the remnant tree cover on farms (Fischer et al., 2010b). Grazing covers approximately three quarters of the study area, while 10-15% is under crop production; much of the remainder is covered by patches of woodlands and dry forests thus is broadly reflective of the wider temperate grazing zone or 'sheep-wheat belt' (Sherren et al., 2012a). The study area is characterized by old, fragile, and sometimes degraded soils containing relatively low levels of organic matter. Average annual precipitation is typically between 600 and 850 mm and is distributed relatively evenly during the year (van der Beek and Bishop, 2003). Inter-annual variability in precipitation is relatively high with both droughts (e.g. the 'Big Dry' that prevailed for most of the last decade (Cai et al., 2009)) and floods (e.g. 2010-2012 (McClusky et al., 2012)) over the past two decades.

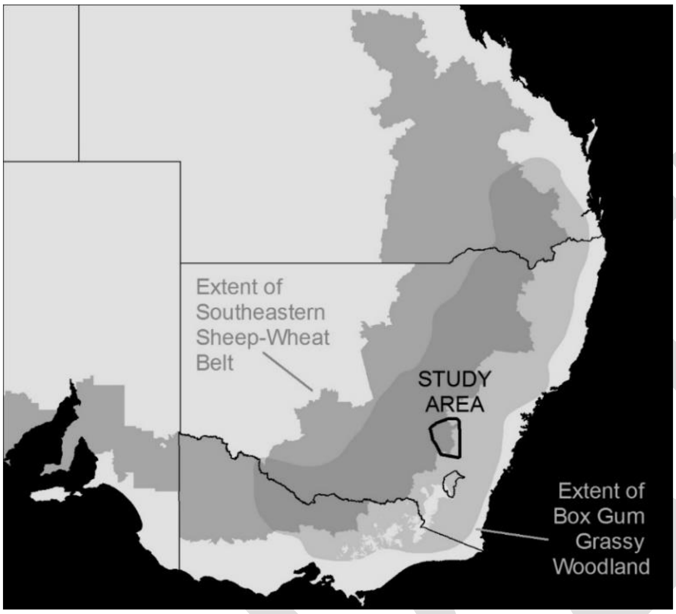

Figure 1. Case study area, upper Lachlan river catchment of New South Wales (NSW), Australia (Source: Sherren et al., 2012a)

Conventional management (land sparing approach)

Conventional livestock management in Australia's temperate grazing zone involves keeping livestock in paddocks for extended periods, or even year-round. The average annual stocking rates used by holistic versus conventional farmers do not necessarily differ (Fischer et al. 2009); the primary difference thus lies in the application of rotational grazing with long rest periods used by holistic managers versus more continuous grazing by conventional managers. Moreover, conventional practices typically involve the use of exotic or annual pastures, and regular applications of chemical fertilizers to maintain pasture productivity (Sherren et al., 2012a). External inputs such as fodder and fertilizers are used to bolster farms' carrying capacities when the natural variability in the climate, particularly lack of precipitation, reduces natural biomass production.

Conventional farmers seek to conserve biodiversity typically by creating clearly demarked 'fenced off' protected patches (typically measuring at least 5 ha, and often more) based on the assumption that the best way to protect native vegetation (especially trees and shrubs) is to completely exclude livestock (land sparing, Figure 2a). For biodiversity conservation, 'sparing' farmers typically prioritize large patches because these are known to have the greatest value to biodiversity (e.g. exhibiting higher bird species richness than small patches (Watson et al., 2001). Many of these protected patches tend to be on relatively steep slopes and hilltops, which are not productive for livestock or cropping (Fischer et al., 2010b). Alternatively, they include riparian strips and fencelines. In both cases, the costs of protection have often been shared with local governments or catchment management authorities, with farmers providing labour, and the materials needed for fencing often being subsidized by the state. Many conventional farmers are proud of their stewardship work of 'fencing off'; and protected woodland patches were twice as frequently captured by non-holistic than holistic farmers when they were asked to photograph significant elements of their farms (Figure 3b; Sherren et al., 2011b). Figure 2 shows the distribution of woody vegetation in subsets of archetypal conventional (Figure 2a) and holistically managed (Figure 2b) properties in the case study area.

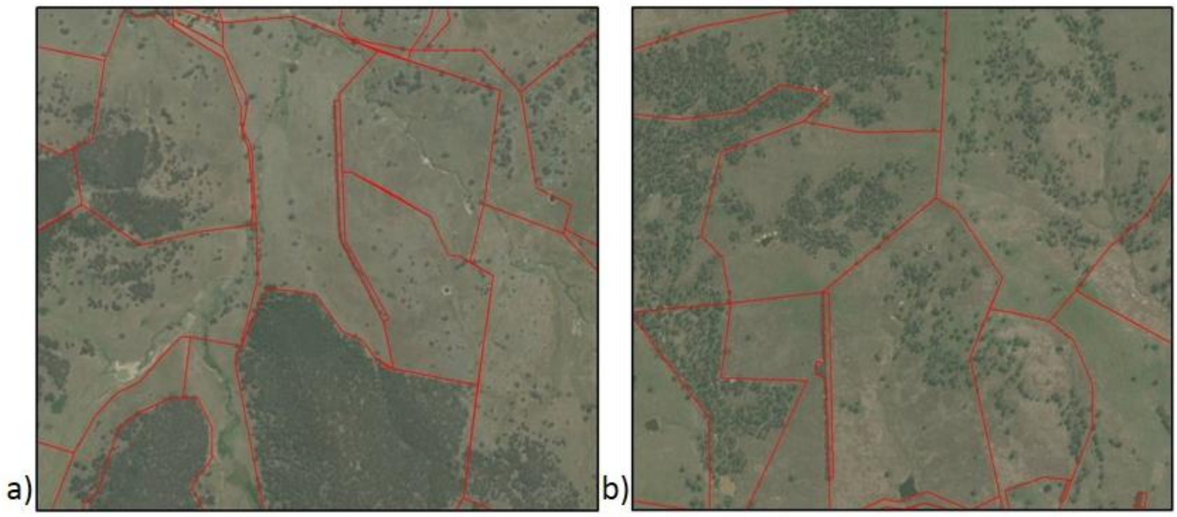

Figure 2. Examples of woody vegetation cover for subsets of an archetypal a) conventional (spared) farm and b) holistic (shared) farm from the study area. Red lines represent fencelines (fencelines do not necessarily represent spared land).

Holistic management (land sharing approach)

In contrast to conventional management approaches, livestock-based holistic management usually involves intense bursts of grazing pressure within a given grazing location, followed by extended recovery time (Savory and Butterfield, 1999, Stinner et al., 1997). Grazing occurs at very high stocking densities in a single paddock, with the livestock moved after a few days and the 'hard hit' paddocks given a long period of rest—often weeks or even months, informed by careful monitoring of feed levels—between grazing events. Rather than rely on protected patches of native vegetation, holistic management is intended to provide conservation benefits throughout the farm as the intensive grazing events are believed to be too infrequent to permanently damage native vegetation.

The holistic approach to grazing requires practitioners to experiment, manage adaptively and develop and monitor holistic goals related to the forms of production needed to support quality of life. Holistic management also includes landscape planning that protects and enhances biodiversity and supports ecosystem processes, such as succession, energy flows and hydrological and nutrient cycling (Savory and Butterfield, 1999, Stinner et al., 1997). In our study area, the implementation of holistic practices varied between individual farmers, but generally involved high-intensity short-duration grazing, the reduction or elimination of artificial fertilizers, and an emphasis on pastures with native plant species (Sherren et al., 2012a). Within the holistic management philosophy, the health of the land and the natural resource base of the farmed landscape are considered fundamentally important for maintaining a profitable farm enterprise. The emphasis on supporting and building biodiversity and wildlife-friendly structures throughout the farmed landscape, and the relatively lower priority given to clearly delineated, protected patches, clearly mark holistic farming as an example of the land sharing paradigm (Figure 2b, Figure 3b).

We note that while holistic management aspires to create landscape-wide biodiversity benefits, there is controversy as to the actual effectiveness of this approach. Nevertheless, there is some evidence of landscape-level benefits (e.g. for tree regeneration) in our case study area (Fischer et al. 2009).

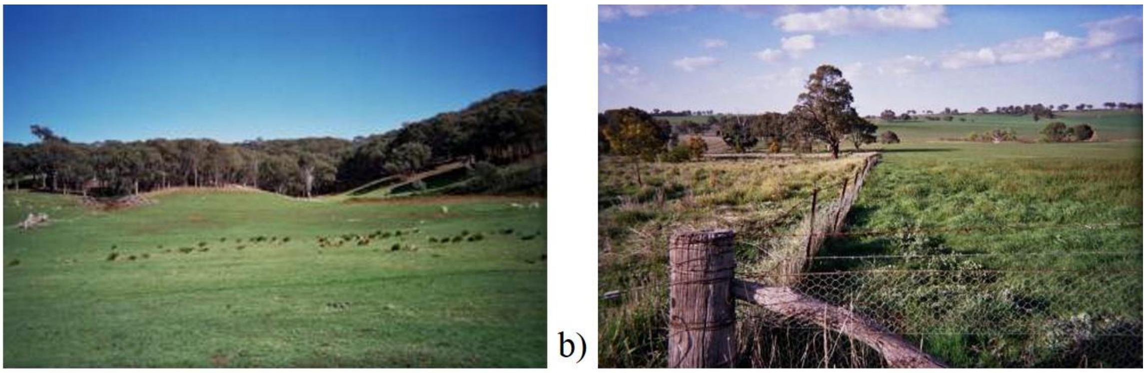
a) b)

Figure 3. Examples of a) a spared patch of trees and; b) a 'shared', holistically grazed landscape to the left of the fence, compared with conventional grazing to the right. Both photos were captured by Lachlan catchment farmers when asked to photograph significant elements of their farm landscape (method explained in, for example, Sherren et al. 2012a).

Historical, environmental, socio-economic and institutional setting

Prior to European settlement, our study area was dominated by grassy box woodland in the valleys and, to a lesser extent, dry sclerophyll forest on the hills. Both of these vegetation associations have an overstorey dominated by Eucalyptus trees. In grassy box woodlands, trees are spaced widely and the crowns of individual trees often do not touch. The understorey of box woodland is dominated by grasses and forbs, and to a lesser extent by shrubs. Dry sclerophyll forest is denser and typically contains more shrubs in the understorey. In both cases, trees, and to a lesser extent other types of woody vegetation, are the structural elements with which other native biota have co-evolved. While a comprehensive assessment of biodiversity would need to consider a wide range of variables, the structure and spatial arrangement of woody vegetation have been shown to be particularly important (Law et al. 2000), including for birds (Watson, et al. 2001; Hanspach et al. 2011), reptiles (Fischer et al. 2005; Brown et al. 2008) and bats (Hanspach et al. 2012; Law and Chidel, 2006). Over the last 150 years of European settlement and land clearing, approximately 80–95% of original tree cover has been lost, and the remaining cover occurs as small patches and as scattered trees (Fischer et al., 2009).

In 2006, farming of sheep, beef cattle and grain in the Cowra and Boorowa census districts (core to the study area) employed 11.7% and 36.6% respectively of the workforce, compared with 1.5% Australia-wide (Sherren et al., 2010). In 2006, 55% of the region's AUD$130.6 million worth of production came from livestock. Farming within the Lachlan catchment persists in the face of volatile agricultural input and commodity prices, both within Australia (O'Donnell, 2010) and on global markets (e.g. Headey and Fan, 2008).

While the case study area is large, its farming community is small and interconnected through family and marriage; Cowra is the largest urban centre, at around 8,000 people in 2011 (Australian Bureau of Statistics, 2013). Practices that are judged to be acceptable by trusted and well-connected members of the farming community are more likely to be taken up by the majority (Pannell et al., 2006). Thus by far the most dominant strategy is that of conventional grazing, which is seen across many of Australia's farming regions (Sherren et al., 2011b). Courses teaching relatively novel practices such as holistic management can be expensive, and do not necessarily involve ongoing technical or social support, making change difficult in the first instance, and difficult to maintain (Box 2; Sherren et al., 2012a). Such systemic practices are also difficult to trial on small areas of a farm, which presents a risk to farmers (Pannell et al., 2006). Holistic management is thus still a marginal activity in much of Australia, estimated to be practiced by less than 10% of farmers (Sherren et al., 2012a). Finally, extended drought relief and investment in technological 'fixes' such as silage facilities for climate-related challenges have historically buffered conventional farmers from the need to reconsider their management practices.

In the case study area, as elsewhere in Australia, relatively large patches of native vegetation have typically been the priority for public-supported protection initiatives. Fencing costs can be reimbursed to protect compositionally and structurally intact woodlands. Many farmers have taken up such funding opportunities, thereby providing important core habitat for a wide range of species (Sherren et al., 2011a). Riparian fencing is also often supported, as well as the fences and seed to plant and protect vegetated strips along existing fencelines (Sherren et al., 2011a). More recently, however, some stewardship programs have begun to include land sharing principles: defining 'high-quality' habitat to include scattered tree cover and native grasses, instead of just woodlands; and including payments for a range of habitat enhancements, including retaining coarse woody debris, ceasing chemical fertilization, weed control, understory plantings, as well as allowing occasional grazing or requiring only short-term stock exclusion (Sherren et al., 2012b). Several holistic managers tended to already do many of the things in this list (Sherren et al., 2012a) and some participated in the pilots of more recent 'land sharing' stewardship schemes.

Box 2. Examples of the social difficulties facing graziers adopting holistic management practices in the case study area (unpublished data from photo-elicitation interviews in 2008, discussed, for example, in Sherren et al. (2012a)).

"There's some BBQ's that we go to that I'll actually go there thinking "right, what are some topics that I can open up with?" You know, like at the moment it would be protein, screenings, the number of small grains yield per hectare, how late they've been working every night, that'd be the conversation. In January it'll be the amount of chemical, what rate per hectare and then what chemicals they're using to kill all the weeds in January because it's rained. Then all the way through autumn that would more or less be the same. Oh, and then, the cost of fertilizer prices and diesel. Then in May it's sowing, what are you sowing, how dry is it or how wet is it, what depth are you putting it all in. I don't do any of this anymore. I used to do all this stuff so I know what they're [conventional graziers] talking about, I just think it's futile." (Husband, Farm 5)

"I came back [from the holistic management course] all enthused and everyone thought I'd lost the plot I think. I didn't say too much to a few because they were just - I mean most of them aren't open to the idea at all. Generally most graziers in Australia aren't open to the idea I don't think. It's too far out there for a lot of them. So I don't talk about it much. My brother, he went and did the course on my advice but he'd be one of the few I'd mention it to. ... I don't think the majority [that take the course] go on and do it. Even I found it difficult because when you come back no one else thinks like you're thinking. Unless you've got some support from somewhere you sort of just go… There's so much push from everyone else around you, you gradually just sort of tend to go like a sheep and follow the rest and end up going back to your old ways. (Husband, Farm 17)

Assessing resilience in our study area

Having provided an overview of the study area and archetypes of farms managed holistically or conventionally, here we discuss which properties of these archetypal systems convey general or specific resilience to the system.

Comparing general resilience between farming systems

In our case study, the holistic management approach builds general resilience via dynamic adaptation to changing environmental conditions based on conserving natural capital. In contrast, the conventional management approach builds resilience by accumulating financial capital to mitigate the negative impacts of environmental perturbations (Table 2). These two general strategies might loosely be characterized as *internalized* (natural capital; holistic management) versus *externalized* (financial capital; conventional management). One potential advantage of the conventional (land sparing) approach is that financial capital stocks can be converted more easily into other resources to deal with unexpected shocks than the natural capital stocks on which holistic (land sharing) depends.

The land management options in our case study derive general resilience from different sources. The holistic management option relies on diversity, redundancy and adaptation as means of coping with shocks, building natural capital and increasing the adaptive capacity of the social-ecological system. By contrast, the conventional approach builds financial capital (perhaps at the expense of natural capital) to compensate for shocks to the system, effectively using financial capital accrued during good years to draw external resources into the social-ecological system to bolster resilience during perturbations.

One important difference in general resilience between the holistic management and conventional approaches in our case study area relates to the challenge of maintaining biodiversity (an important component of system identity). The conventional (land sparing) approach tends to lead to relatively high species diversity and intact vegetation condition within the protected patches (e.g. Fischer et al. 2010). This relatively intact state, combined with the removal of economic pressure on the protected patches, may infer greater resilience of the ecological "identity" of the landscapes (Fischer et al. 2010).

Table 2. Conceptual matrix to assess general resilience of the grazing regimes.

Social-ecological system property	Holistic management (land sharing)	Conventional management with protected patches (land sparing)
Diversity	Biological diversity at farm level is intermediate, but spread across the landscape providing more adaptability to shocks. Income diversity can be on-farm (e.g. tourism; native plant sales) Experimentation as a key component of the management strategy Income diversification through on-farm income less resilient to some natural shocks (i.e. flood, fire, etc.)	Biological diversity at farm level potentially higher than for the holistic management approach. The isolation of biodiversity from production may be both a source of vulnerability (lack of redundancy) and resilience (lower connectivity to shocks). Income diversity often off-farm through secondary employment, or spousal incomes. Uniformity and control of the environment as key management strategies Off-farm income diversification increases resilience to on farm natural shocks (i.e. flood, fire, etc.)
Modularity (redundancies)	Potentially high levels of redundancy in resource use (i.e. rested pastures and the use of diverse native grasses)	Relatively low level of redundancies in resource use (continued occupation of pastures)
Modularity (system connectivity)	Less reliance on imported fodder supplements and artificial fertilizers – reducing connectivity to markets	More reliance on imported fodder supplements and artificial fertilizers – increasing connectivity to markets. Dependency on inputs subject to price volatility reduces general resilience
Social-ecological feedbacks	Adaptive management that is sensitive to changes in ecological condition. Management approach premised on anticipation of/ adaptation to shocks, and constant monitoring. Limiting factor: available resources within the system, labour to monitor and move stock.	Compensatory/buffering management that seeks to "dampen" shocks by importing resources from outside the physical boundaries of the social-ecological system. Limiting factor: the ability to command resources from outside the system
Financial capital assets	Financial capital not the primary means to buffer shocks	Financial capital the major source of buffering capacity within the system
Natural capital assets	The maintenance and enhancement of natural capital is a key concern, economic activity is kept within ecological carrying capacity, and natural capital is used as a substitute for financial capital as a buffer against shocks.	Natural capital within the farmed areas is at risk of being degraded, with substitutions from financial capital used to maintain productivity. Protected areas are largely protected from economic shocks because they are separated from the economically productive components of the system.
Social capital assets	Holistic management farms were more frequently partnerships of married couples, collaborating on monitoring and stock rotation, and prioritizing family time during goal-setting. The relationship within the couple might supplement the lack of support in the community for practices, especially with the dearth of formal ongoing supports for holistic practices/transitions.	Conventional practices are strongly supported within social and community networks, giving a sense of legitimacy and validity. Such practices are likely to be perpetuated/replicated.

However, other (i.e. grazed) locations within conventional farms may be more susceptible to degradation through continuous livestock grazing, resulting, for example, in the loss of scattered trees (Fischer et al. 2009). The loss of scattered trees, in turn, would create a binary landscape with relatively intact patches becoming isolated within an increasingly hostile landscape context. If overgrazing is severe in a land sparing system, there may be negative flow-on effects that could permeate throughout the landscape, also affecting the protected patches (e.g. reduced water infiltration capacity or soil erosion).

In contrast, biodiversity within a holistic management (land sharing) landscape should be expected to be more evenly distributed, but may be lower in total. Such lower landscape-level species diversity may reduce ecological resilience due to a lower number of functional redundancies among species – for example, if a given pollinator goes extinct, in the absence of functional redundancy pollination services would be lost entirely (Walker, 1992, Walker, 1995). However, the more even distribution of woody vegetation throughout the landscape may afford greater landscape connectivity for some species, thereby facilitating better population viability in the face of disturbances. Both types of landscape therefore have advantages and disadvantages for ecological resilience. Highly sensitive species such as specialized woodland birds probably benefit particularly from structurally complex, large patches being fenced off (Watson et al., 2001). Many generalist species, however, can persist throughout landscapes of scattered trees (Fischer et al. 2010b).

Comparing specified resilience between farming systems

The internalized, dynamic adaptation approach to resilience (holistic management) and the externalized, dynamic control or buffering approach (conventional management with protected areas) in our study systems have different consequences for the specified resilience to climate variability and agricultural input price shocks.

In the face of climate variability—especially droughts—holistic (land sharing) farmers adapt by matching their stocking rates with the climate (and therefore the productivity of their pastures). Holistic farmers rarely use supplementary feed to get through a drought (other than occasionally on small parcels of specifically 'sacrificed' land). Instead, they strongly rely on grazing charts and constant monitoring of pastures to anticipate livestock feed availability and match stocking levels to carrying capacity (Earl and Jones, 1996, Sherren et al., 2012a). Precautionary de-stocking—the sale of livestock when fodder requirements exceed the farm's current production capacity—is used to avoid the requirement to buy expensive supplementary animal feed, and to ensure that stocking levels do not exceed the land's current carrying capacity. Moreover, soil management and high levels of ground cover in the pastures also help to retain moisture in the soils and thus lessen the impact of potential droughts on biomass production within the pastures. Lower incomes during droughts are offset by keeping input costs low, although the need to destock may leave Holistic farmers exposed to market price fluctuations when selling livestock. Similarly, occasional de-stocking may prevent holistic farmers from developing breeding stock, and thus participating in markets where breeding is critical, such as super-fine merino wool; some go so far as to specialise in agistment (i.e. they do not keep any of their own breeding stock). There is some evidence that holistic management practices improve outcomes in dryland grazing systems in terms of higher mean income, lower variance and preserving pasture quality (Jakoby et al 2014).

Conventional management (land sparing) approaches to coping with drought are very different. The key strategy used here is to make high profits in good years, thereby building a buffering stock of financial capital. High profits are achieved in part via the application of fertilizers to maximize pasture productivity when there is sufficient rainfall. When there is a rainfall deficit, conventional farmers typically bring in feed for their livestock from external sources (paid for via the profits from better years), so that they do not have to destock (or not as much). While constant stock maintenance has the advantage of reducing a given farmer's exposure to market price fluctations (she or he can retain livestock when prices are low), if stocking rates are not adapted to climatic conditions natural capital stocks can be degraded and their renewable flow of benefits reduced. Long droughts especially may force conventional farmers to invest ever-increasing amounts of financial capital to replace the resource flows from the degraded landscape – causing expenses for the acquisition of supplementary feed as well as for its storage (e.g. silos).

With regard to agricultural input price fluctuations, many holistic farmers in our study area limit their exposure by minimising the use of external inputs, instead seeking to draw as much of their resource use as possible from within their farms. Moreover, incomes on holistic farms are sometimes bolstered via on-farm activities such as farm tours, farm stays, or native plant sales. In contrast, conventional farmers relying on external (agrochemical) inputs are more exposed to input price fluctuations: in our study area, there appeared to be a greater prevalence of off-farm jobs as 'backup income' among the spouses of conventional farmers.

In this case study, conventional farmers practicing the more locally accepted landscape management approach can draw on a wider range of institutional resources, and the knowledge and social capital of the wider farming community, to bolster resilience in the face of perturbations. Holistic management farmers, in contrast, rely more strongly on less extensive, but potentially more tightly connnected social capital assets (because they are 'outsiders', they often connect strongly to the relatively small number of peers who are also 'outsiders'). However, these differences in social capital are to some extent an artifact of the relative popularity of the two aproaches in our case study area, and in Australia more generally, rather than resulting from inherent system properties relating to land sparing versus land sharing.

Other potentially incidental issues, rather than inherent factors, may also affect the resilence of the two contrasting approaches in our case study. For example, older farmers tended to farm more conventionally, compared with holistic farmers who more often had young families. However, younger farmers were less likely to invest in measures to protect biodiversity than older farmers, even though young farmers were more likely to recognise this as a source of resilience, perhaps because they were busier and less financially secure than older farmers (Sherren et al., 2012b).

Conclusion

Although regional and farm-level idiosyncrasies are likely, our case study suggests that the two archetypal approaches to land management—conventional grazing with protected patches (land sparing) and holistic management (land sharing)—do differ in their primary means of how farmers manage for social-ecological resilience. The holistic management approach appears to primarily rely on dynamic adaptative management in the face of perturbations, often via experimentation and maintaining tight feedback loops between ecological conditions and livestock stocking density. The primary source of resilience in the conventional grazing approach lies in the careful use and management of diverse natural capital assets (maintaining redundancy and modularity). The holistic land sharing approach of graziers in the Lachlan catchment therefore provides a social-ecological approach to resilience that relies primarily on on-farm resources. In contrast, the land sparing approach to resilience in the case study area is typifed by the use stocks of financial capital (accumulated during stable periods) to buffer shocks, and maintain productivity and income via the application of external inputs to system. Here we should note that additional income might be obtained from the spared areas themselves (e.g. via recreation, wood fuel, conservation grants) which would provide additional financial buffers within this system. In the sparing approach, biodiversity conservation is much more separated from economic activity, and is not managed as the primary safeguard for maintaining the farming system in times of perturbation., such as the drought events experienced in the study regions over the last decade.

Our findings suggest that it is difficult to say whether archetypal land sparing or land sharing is the inherently more resilient social-ecological management approach at the farm level. Notably, the shared landscapes appear more resilient in a social-ecological sense, in that the famers in such landscapes place greater emphasis on building general resilience via redundancy, modularity and tight social-ecological feedbacks. Moreover, they recognize the fundamental dependence of human livelihoods on natural capital as a productive input for resilient agricultural practices. However, the relative lack of financial buffers may lead holistic management approaches more vulnerability to intense system perturbations. In contrast, the buffering approach used in the conventional, spared landscapes may lead to greater short-term resilience due to access to more institutional support and a greater reliance on more 'convertible' financial capital stock. However, the relative lack of emphasis on natural capital within the agriculturally productive land in the spared landscapes potentially leaves the social-ecological system exposed to long-term declines in natural capital (erosion, soil health and biodiversity on productive lands), and exhibits a potentially dangerous reliance on external inputs that are based on non-renewable resources.

One important point to note is that there may be profound effects in the transition from one archetypal approach to the other. In particular a move from land sharing to land sparing may be problematic in that the sharing approach is less likely to accrue the financial and infrastructure capital over years necessary to convert to intensified farming, meaning that such transitioning systems are likely to be less resilient, at least in the short term. Similarly, holistic management aspires to be – as its name suggests – a system-wide management practice, and is difficult to trial on small areas of the farm. Moreover, the time required to build the natural capital on which this farming approach depends may leave farmers in transition to such practices vulnerable. In the context of building social-ecological resilience, institutional support to ease the transitions between these two archetypal approaches (as well as potential hybrid practices) may be preferable to attempting to institutionalize a 'winner' in the sparing versus sharing debate. At the regional scale, the differing strengths and weaknesses of the sparing and sharing approaches may be complementary in maintaining overall system identity in the face of multiple system shocks. It may thus be that, at the regional scale, a mixture of land sparing and land sharing might provide the highest level of social-ecological resilience. A heterogeneous social-ecological region would provide a diversity of commodity options, as well as ecological structures, mixing continuous well-connected and evenly distributed 'shared' biodiversity with high value, species-rich 'spared' patches. Similarly, having a mixture of conventional and holistic farms within the Upper Lachlan River catchment provides a diversity of socio-economic management strategies to cope with perturbations, drawing on differing capital asset bundles and adaptive mechanisms—buffering (sparing) and dynamic management (sharing)—that may confer greater resilience for the region than if only a single approach was favoured.

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