From Landscape Rehydration to water resilient farming:

Supporting practice change

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Acknowledgement of Country

I acknowledge the Gathang speaking people whose land I write from, and all Australia's First Peoples, the traditional custodians of Country who have much to teach us about regenerative land and water management.

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The Mulloon Institute, the Kandos School of Cultural Adaptation, Peter Andrews and the farmers on the Manning River Estuary Community Reference group have inspired and nurtured my interest in regenerative farming and landscape rehydration. In my role as Catchment Manager with MidCoast Council I have met many local farmers and NRM practitioners who "get it" and are doing great work across numerous fronts to support a more sustainable and resilient food system. Buying regeneratively produced meat from local farmers I know has to be the most pleasurable way to reduce my carbon footprint. Upper Mooki Landcare and Wallabadah Landcare are doing tremendous work leading catchment-scale landscape rehydration projects and kindly introduced me to local farmers.

I had an excellent time travelling around western New South Wales in my VW campervan meeting with innovative farmers and NRM practitioners, learning about their landscape rehydration practices first-hand and asking endless questions about how they transition from traditional farming. Thank you for your generosity and patience. Not everything I learnt has surfaced in this thesis, but rest assured I will be drawing on this knowledge for years to come.

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Executive Summary

Agriculture accounts for 55% of landuse in Australia (ABARES 2022). While many farmers make concerted efforts to protect the ecosystem services which support production, agriculture continues to put significant pressure on water quality and ecosystem health for rivers and their catchments. A whole-of-catchment approach in partnership with farmers is required to improve land management and address these pressures.

For farmers, Australia's naturally low and variable rainfall coupled with weathered soils and a legacy of land degradation put stress on the water resources required for agriculture (Anderson et al. 2016; Eldridge et al. 2018; McKenzie et al. 2004). Climate change will exacerbate these challenges. Conventional farming methods that lead to high on-farm losses in water balance will be a significant liability (Falkenmark and Rockstrom 2006).

Integrated Water Resource Management (IWRM), a participatory approach to managing water in the landscape for environmental, social and economic values, provides a framework to improve water management for environmental and agricultural outcomes (GWP 2002).

This thesis has been developed within the IWRM discipline. It investigates the case for Landscape Rehydration (LR), a land management approach affiliated with Natural Sequence Farming that aims to improve on-farm water balance by slowing surface flows and improving infiltration and retention of rainwater in the soil. The result is a recoupling of the hydrological and carbon cycles that drive productivity (Norris and Andrews 2010).

The thesis reviews the literature and farmers' experience to understand the suite of management practices involved in LR, their efficacy for production and catchment outcomes and the drivers, enablers and barriers for practice change. It is organised into six chapters:

Chapter 1: Introduction, rationale, objectives, description of landscape rehydration

Chapter 2: Literature review – project evaluations, the diffusion of LR; theories of change

Chapter 3: Social science research method – qualitative thematic analysis

Chapter 4: Results – farmer characteristics and drivers, characteristics of the practices, the barriers and enablers for diffusion

Chapter 5: Discussion bringing together social science research and the literature

Chapter 6: Conclusion and recommendations

Key findings include:

- The innovators and early adopters of LR have diverse aspirations across social, economic and environmental dimensions;
- Farmers are using LR to solve a range of problems including drought resilience, land degradation and wet and dry extremes;
- They are using site-specific, holistic programs of integrated practices to improve hydrology, native vegetation, soil, grazing and pasture management from top to bottom of their farms;

- LR has good trial-ability with small-scale, low risk interventions achieving observable relative advantage across production and environmental indicators; cost-benefit is more difficult to quantify;
- For farming to transition to more nature-based, regenerative and water resilient practices, an enabling environment and removal of barriers will need to happen at multiple scales.

My thesis concludes with recommendations to help government and non-government agencies and other actors to support more widespread uptake for production and catchment management outcomes.

Recommendations

Principles

- **Re-frame *landscape rehydration* as *water resilient farming***
- **Promote a broad and holistic toolkit of integrated LR interventions from top to bottom of catchments/properties**
- **Align LR with the growing movement for Nature-Based Solutions**
- **Match the scale of the intervention to the scale of the degradation process**
- **Promote small-scale, low-cost, "light touch" interventions first**
- **For more complex projects use specialist site assessment and design**

Activities

- **Broker multidisciplinary scientific research** to fill knowledge gaps
- **Provide farmers with education opportunities to build ecological literacy**
- **Develop on-line hub of information** on LR practices with factsheets and videos
- **Provide online training courses with mentoring support and study groups**
- **Establish more demonstration sites** with field days and case studies
- **Invest in long-term project monitoring and evaluation** of LR projects
- **Undertake cost-benefit analysis** to alleviate uncertainty for "early majority" farmers.
- **Facilitate catchment scale projects that** bring neighbours together.
- **Contribute to communities of practice** for cross-sectoral learning.
- **Host cross sectoral networking and learning opportunities**
- **Support direct marketing opportunities** between farmers and customers.
- **Review the regulatory framework** for environmental restoration projects.

Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
DPI	NSW Department of Primary Industries
DPIE	NSW Department of Planning, Industry and Environment
ECAF	European Conservation Agriculture Federation
FAO	Food and Agriculture Organisation of the United Nations
IWRM	Integrated Water Resource Management
LLS	NSW Local Land Services
LR	Landscape Rehydration
NGO	Non-government Organisation
NRM	Natural Resource Management
NbS	Nature-based Solutions
NSF	Natural Sequence Farming
TMI	The Mulloon Institute
TNC	The Nature Conservancy
TPT	Tarwyn Park Training
UN	United Nations

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1. Introduction

My intention with this thesis is to critically evaluate the case for Landscape Rehydration, drawing on the literature and direct primary social science research with practitioners. Landscape rehydration (LR) is an approach to land management defined by the NSW Department of Planning, Infrastructure and Environment as “the process of restoring the natural movement of water through rural landscapes” (DPIE 2021 a, p.13). LR is a farmer-led innovation that sits within the broader field of regenerative or ecological agriculture. It aims to repair land degradation, restore ecological function and improve the water balance for agricultural production, biodiversity and catchment outcomes (Andrews 2006, 2008; CSIRO 2002; Hurditch 2015; Williams 2010).

My interest in LR was sparked when I was engaged as the Catchment Management Coordinator for MidCoast Council in NSW. I worked with a Council-appointed community reference group to prepare a Catchment Management Program (CMP) to protect water quality and ecosystem health in the Manning River and its estuary (MCC 2021).

Farmers were a key stakeholder group in this mission, with four represented on the reference group. Agriculture, (predominantly beef and dairy), is the Mid-Coast’s biggest industry and helps to define the Manning valley’s cultural identity and way of life (Saphere Group 2018).

It is crucial that agricultural land is well-managed to maintain the catchment’s environmental values and the ecosystem services that underpin production. While many farmers make concerted efforts to reduce their impacts, agriculture continues to be a significant pressure on ecosystem health, biodiversity and water quality (MCC 2021).

When I was working on the CMP from 2019-2022, the Manning was in the midst of the worst drought on instrumental records (Figure 1), followed by a major flood (Figure 2) and two wet “la Nina” summers. These extremes impacted farmers and the environment and were a catalyst to prepare for climate change. Several farmers on my reference committee advocated for a transition to regenerative agriculture[1], and more specifically LR, which promises to address both water resilience for farmers and agricultural impacts on the catchment.

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[1] Regenerative agriculture can be defined as a conservation and rehabilitation approach to food and farming systems. It focuses on topsoil regeneration, increasing biodiversity, improving the water cycle, enhancing ecosystem services, supporting biosequestration, increasing resilience to climate change, and strengthening the health and vitality of farm soil. (Reference: Regenerative agriculture - Wikipedia)

Figure 1: Drought conditions in the Manning catchment, August 2019

Figure 2: The Manning River in flood, March 2021

This thesis will review the literature and farmers' experience to understand the suite of management practices involved in LR and the drivers, enablers and barriers for practice change. The centrepiece of the thesis is primary social science research featuring interviews with innovators and early adopters of LR. The resulting recommendations aim to help NRM facilitators and agricultural extension officers in the government, non-government and commercial sectors to support more widespread uptake of LR for production and environmental outcomes.

The thesis sits within the framework of Integrated Water Resource Management (IWRM), an approach to water management endorsed by world leaders at the United Nations' Rio Earth Summit in 1992. IWRM is a coordinated approach to managing water in the landscape that protects the sustainability of ecosystem services while maximising economic and social welfare in an equitable manner *(*GWP 2002, p. 22). IWRM has three core principles: social equity, economic efficiency and environmental sustainability (IWA 2022).

LR is a practical, local, "micro" example of IWRM. In keeping with IWRM's core principles, LR seeks to make the most efficient use of rainfall for production and ecosystem health. LR proponents engage farmers at the catchment scale, taking the participatory approach at the heart of IWRM.

1.1 Project objectives

My project has five objectives:

1. To identify the suite of practices gathered under the banner of LR;
2. To report on the stock of literature on LR, its efficacy and the diffusion of knowledge;
3. To research agricultural practice change and establish a conceptual framework for my social science research;
4. To undertake primary social science research on the knowledge and experience of farmers leading LR practice change;
5. To make recommendations to promote further development and dissemination of LR.

My research questions are:

- What are the characteristics and drivers for farmers practicing LR?
- What are the characteristics of LR interventions being practiced by farmers?
- What are the barriers and enablers influencing practice change towards LR?

1.2 Project rationale

Despite the efforts of many farmers to manage their environmental impacts, land degradation from farming continues to impact water quality and ecosystem health for rivers and their catchments. In New South Wales (NSW), agricultural diffuse-source run-off is ranked in the top three threats to estuaries; impacting environmental, social and economic values (BMT 2017). Agricultural activities such as land-clearing and set-stock grazing cause compaction, loss of soil carbon and degradation of riparian (riverbank) vegetation, reducing rainwater infiltration into the soil and accelerating the rate of runoff and erosion. Sediments, nutrients, pathogens and agricultural chemicals are transported into rivers and their estuaries (NSW Government 2009).

Australian agriculture is also threatened by land degradation. Australia is the second driest continent on earth, with lower mean rainfall and higher rainfall variability than most other nations (CofA 2022). Its ancient soils are strongly weathered, acidic and nutrient-depleted (Eldridge et al. 2018). Stocks of the soil organic carbon critical for water infiltration and retention are naturally low (Anderson et al. 2016; Eldridge et al. 2018; McKenzie et al. 2004). A legacy of agricultural practices poorly adapted to these conditions has degraded the fragile ecological functions that support production and exacerbated the water scarcity faced by Australian farmers, who experience "greater volatility in yield than most other farmers in the world" (Anderson et al. 2016 p.299)

Climate change is adding to these challenges (ABARES 2022; Anderson et al. 2016; Ferrier et al. 2020; Iles 2021). According to Australia's bi-annual State of the Climate Report (CofA 2020), the southeast and southwest are becoming drier while the intensity of heavy rainfall events is increasing in many regions. More frequent and prolonged drought will put pressure on the availability of soil water during the growing season (ABARES 2022). Extreme rainfall events will increasingly impact on production and catchment values through flood damage, run-off, loss of topsoil and nutrients (CofA 2020).

> *"There are business advantages and resilience benefits that come from good management. If fertiliser is running off into the river, its money lost to the farmer.*
>
> *We could manage soil better to hold water in the landscape for resilience from drought, flood and climate change."*
>
> Kirsty Hughes, member, Manning CMP Community Reference Group

Conventional farming methods[1] lead to high on-farm losses in water balance with only a small proportion of rainfall used effectively for production (Falkenmark and Rockstrom 2006 p. 130). Clearly there is a case for improved water management in our agricultural sector, which will need to adapt to a "new norm where climate resilience becomes a significant factor" (Ferrier et al. 2020 p. 6). Falkenmark and Rockstrom (2006

[[2]] Conventional farming used here refers to farming systems established in the 1950s-60s, which include the use of synthetic chemical fertilizers, pesticides, herbicides and other continual inputs, genetically modified organisms and high yielding varieties, concentrated animal feeding operations, heavy irrigation, intensive tillage, or concentrated monoculture production. Thus conventional agriculture is typically highly resource-demanding and energy-intensive, but also highly productive (Reference: Conventional farming - Appropedia. See also Green Revolution - Wikipedia).

p. 131) propose that the opportunity to improve water management “lies in tapping the potential of…ineffectively used on-farm water balance” using “innovative strategies to manage sudden excesses of water and…dry spells.” Rather than acquiring additional water resources to meet agricultural demand, Ferrier and Jenkins (2020) call for improvements to the way soil water is managed.

LR meets this call, benefitting the public good while meeting the needs of farmers. LR is part of a broader movement towards agroecological or regenerative practices that work *with* rather than *against* nature, sustaining the biophysical processes that support both production and environmental values (Hurditch 2015; Ogilvy et al. 2015). Scientific evidence on the efficacy of Landscape Rehydration practices is an emerging field of study, with research projects underway to evaluate outcomes. However, there is a strong body of research to demonstrate the impact of Eurocentric agricultural practices on the ecosystem services that influence water infiltration and retention in the landscape. This research provides sufficient confidence that the LR interventions designed to reverse degradation processes and restore ecosystem services will have outcomes for both catchment health and agricultural productivity (**Appendix 1**).

LR is gaining traction with farmers, having been popularised by mainstream media coverage such as ABC Television’s Australia Story (2005; 2012) and books such as Peter Andrews’ “Back from the Brink” (2006) and Charles Massy’s “Call of the Reed Warbler” (2018).

LR is also starting to receive attention from the NRM sector looking to promote farming methods compatible with environmental protection. Government funds are being directed to LR demonstration projects such as the Mulloon Rehydration Initiative (Peel et al. 2022). In NSW, changes are being proposed to the State Environmental Planning Policy (Infrastructure) to streamline the approval process for leaky weirs (DPIE 2021 a).

Growing awareness, a more robust approach towards project evaluation (Peel et al. 2021), policy change (DPIE 2021) and investment are setting the stage for a more considered approach to dissemination of LR practices.

Understanding farmer perspectives through social science research is an important part of this process. Engaging farmers directly in the design and roll-out of research, development and extension programs has a long history and leads to more effective and sustainable outcomes (Coutts 2022; Famuyiwa et al. 2017; Botha et. al. 2017). Grassroots input into program design is aligned with the principles of IWRM, which encompass “local scale, bottom-up” approaches (Jonsch-Clausen & Fugl, 2001 p. 501) with “an appreciation for local ideas and demand management” (MacDonnell 2008 p. 132).

1.3 What is Landscape Rehydration?

LR "the process of restoring the natural movement of water through rural landscapes" (DPIE 2021 a, p.13). A core practice is the construction of "permeable bed control structures made from natural materials such as logs and rocks" (DPIE 2021 p. iii). These "leaky weirs" contribute to "rebuilding the natural flow patterns and ecological function of any given landscape" (p. iii).

LR is affiliated with Natural Sequence Farming (NSF). The "natural sequence" in NSF is described by Andrews and Norris (2010 p. 394):

> *"The basic factors that control this landscape are the carbon-processing green surface area of plants and the water cycle, operating together in an interrelated sequence of processes. The event that sets the sequence in motion is rain. The key principle is re-coupling of the carbon cycle with the hydrological cycle, which together have the capacity to promote landscape fertility…"*

LR was developed for the low-energy "swampy meadow" and "chain-of-ponds" fluvial landscapes in southeast Australia (Callow and Bell 2021; Hurditch 2015; Peel et al. 2021; Williams 2010). It aims to improve water infiltration, retention and more natural hydrology, for agriculture, biodiversity and catchment outcomes (DPIE 2021; Hurditch 2015; TMI 2022; Williams 2010).

To this end, LR involves tailored, site-specific interventions to restore the three biophysical systems that support water balance: hydrology, soil and vegetation (Andrews and Norris 2010; Williams 2010). Each of these systems are interrelated. LR therefore takes a holistic, integrated approach to achieve "careful optimisation of all these domains within the farming complex" (Hurditch 2015).

While there are parallels with other eco-engineering approaches (Dobes et al. 2013), LR is led in Australia by two proponents:

- Peter Andrews (2006, 2008), farmer and founder of Natural Sequence Farming (NSF) now trading with his son Stuart as Tarwyn Park Training (TPT); and
- The Mulloon Institute (TMI), an NGO established to build on Andrews' work under the banner of Landscape Rehydration (Peel et al. 2022).

Figure 3: A "leaky weir" Mulloon Creek NSW

The key practices of each proponent are set out in Table 1.

Table 1: Key LR practices of the two major proponents

Proponent	Program	Key practices
Peter Andrews/TPT	Natural Sequence Farming (NSF)	Five pillars of NSF: • Slow the Flow: repairing eroded streams with leaky weirs to slow the flow of surface water and reconnect it with the alluvial aquifer. Installing grade control structures on-contour to slow run-off and promote water infiltration. • Let all Plants grow: pioneer weeds used to increase fertility and biomass. Planting willows and reeds to stabilise the riparian zone. • Careful where the animals go: excluding stock from sensitive areas (riparian zones, wetlands); rotational grazing and strategic pasture management. • Filtration is a must know: reinstating wetlands for nutrient filtration. • Return to the top to recycle the lot: “cut and cart” method used to bring hay and mulch from production and filtration areas to accumulation areas at the top of the system. (From TPT 2022)
TMI	Landscape Rehydration	• Leaky weirs installed in series: In-stream permeable grade-control structures made from natural material such as logs and rocks and stabilised with reeds and sedges (e.g. *Phragmites australes*) • Contour banks on the floodplain and at the break-of-slope and contour channels to slow surface flows, reduce erosion and spread water across the floodplain • Revegetation: riparian, aquatic, hilltop, contour berms • Soil erosion control such as brush-packs and other sieve structures • Holistic/strategic grazing to maintain 100% groundcover and water cycling (Peel et al. 2022; pers. Comm. Peter Hazell, TMI, 26/7/2022’ www.themullooninstitute.org)

Depending on their scale and scope, LR projects are preceded by "close observation and respectful interaction with the landscape (Norris and Andrews 2010 p.389); or by detailed analysis including "catchment-scale scoping studies, hydraulic and flood modelling, biodiversity and cultural heritage assessments, full site descriptions, detailed site designs, monitoring plans and vegetation management plans" (TMI 2022). The geomorphic setting is key to this analysis and projects must be designed to fit the fluvial context (For example see Appendix 4).

Rather than favouring any one program or "brand", as a catchment manager in local government I am seeking to understand the full range of interventions and provide landholders with options best fitted to their site and fluvial landscape. For the purpose of this project, I have therefore used *landscape rehydration* (LR) as a generic term to cover the suite of interventions promoted by these organisations, not restricted to the more well-known "leaky weir" stream-bed grade control structures.

Synthesising information from each of the proponents, I have categorised LR practices into four interrelated domains: hydrology, vegetation, soil and grazing/pasture management (Table 2). This scheme will be used to classify the LR practices implemented by farmers participating in my study.

Table 2 Landscape rehydration practices across four critical dimensions

Hydrology
– Permeable streambed flow-control structures (leaky weirs) made with natural materials (rocks, logs, vegetation) in incised streams and drainage lines – Floodwater diversion structures such as contour swales with spillways
Vegetation
– Reinstatement and management of riparian, instream and terrestrial vegetation
Soil health
– Erosion control including sieve structures, grade control structures, incised gully repair – Introduction of organic matter (manures, mulch) to restore soil carbon
Grazing and Pasture Management
– Holistic or strategic grazing management to maintain 100% groundcover

Figure 4: A contour swale with small water storage and native planting on the downslope berm, Mulloon Rehydration Initiative

Figure 5: Hilltop vegetation, windbreaks, biodiversity corridors and native grasses, Jillamatong, NSW

Figure 6: Brush-pack sieve erosion control on contour, Capertee Valley NSW

Figure 7: Instream macrophytes slow flows and stabilise the bed

2. Literature Review

Having addressed *Objective 1* by identifying the suite of practices gathered under the banner of LR; this literature review addresses *Objectives 2 and 3* of my thesis:

2. To report on the stock of literature on LR, its efficacy and the diffusion of practice change;
3. To research agricultural practice change and establish a conceptual framework for my social science research.

The results will provide the foundation for my primary social science research and inform my recommendations.

2.1 What is the stock of literature on Landscape Rehydration?

The stock of literature on LR is still developing, as would be expected for this emerging, farmer-led approach to land management. While there is a through-line from P.A. Yeomans' "Water on Every Farm" (1964) and permaculture methods of water management (Mollison and Holmgren 1978), LR remains a "niche" practice.

To investigate the LR literature I used three key-word searches: "landscape rehydration," "Natural Sequence Farming" and "The Natural Farming Sequence." My methods for locating literature included:

- Using the Scopus and Google Scholar search engines filtered for the key words;
- Asking my supervisor at The Mulloon Institute to recommend and provide references;
- Mining the reference lists of all papers identified.

I developed criteria to sort the references into three categories, each of which add value to the stock of knowledge on LR (Table 3). The full catalogue is provided in **Appendix 2**. Key themes included:

- Principles and practices of LR (Norris and Andrews 2010; Williams 20210)
- Project evaluation to demonstrate efficacy of LR (Peel et al. 2022; Pringle et al. 2006; Streeton et al. 2013);
- The diffusion of practice change (Hall 2021; Mactaggart et al. 2006; Hurditch 2015).

A brief report on this literature is provided below.

Table 3: The stock of literature on landscape rehydration

Category	Criteria	Number of documents
Academic literature	Published, peer reviewed journal articles with multiple reference citations	8
Grey literature - published	Government reports, books, conference proceedings, journal articles not available through academic search engines	31
Grey literature - unpublished	Unpublished documents including student theses, consultant's reports, papers with unknown author or unknown publisher	10

2.2 Landscape Rehydration Project Evaluation

Evaluations of LR projects include:

- Two qualitative evaluations (Callow and Bell 2021; CSIRO 2002)
- Four quantitative evaluations (Bush et al. 2010; Keene et al. 2007; Streeton et al. 2013; Weber and Field 2010).

A summary of the methods and results are provided in Table 7, **Appendix 3**. Key findings for LR management at various study sites in NSW include:

<u>Tarwyn Park</u>: Streambed erosion replaced with net deposition; increased water storage in the aquifer; "effective sub-surface pasture irrigation…and increased pasture productivity"; overall water balance restored to a more natural condition (CSIRO 2002 pp. 1, 6). Elevated levels of total phosphorous and soil biota at NSF sites (Weber and Field 2010).

<u>Widden Brook</u>: Instream structure had localised effect on water exchange between the channel and hyporheic zone and effectively reduced erosion (Keene et al. 2007).

<u>Spring Creek</u>: Leaky weirs resulted in sediment aggradation and improved streambed complexity and riparian vegetation (Streeton et al. 2013).

<u>Baramul</u>: bed control structures correlated with increased stream-pool volumes in cease-to-flow periods; strong hydrological linkages between streamwater and groundwater in coarse channel deposits; localised effect on water exchange between the hyporheic zone and the channel. (Keene et al. 2007; Keene et al. 2008). Improved soil organics (Rogers & Bauer 2006)

While the CSIRO panel postulated that some of the interventions practiced at Tarwyn Park could be applied to other fluvial settings (**Appendix 4**), there is agreement that the landscape context must be carefully assessed for suitability of hydrological interventions (CSIRO 2002; Weber and Field 2010). Weber and Field cautioned that the effectiveness of NSF techniques for soil improvement would be debatable in clay dominated floodplain systems. Streeton (2013) noted that leaky weirs in sodic soils must be monitored and maintained regularly. These points highlight the significance of the landscape context including geomorphic characteristics and soil type.

In sum, the evaluation study results provide sufficient probability that an integrated program of LR interventions will have a positive influence on water balance and ecosystem health in the riparian zone and floodplain. As we shall see, farmer's observations in this study further support the positive outcomes of LR practices.

2.3 The diffusion of LR practice change

Several papers in the LR literature provide perspectives on the diffusion of practice change, which have informed my project. Barriers canvassed include stakeholder concerns (Dobes et al. 2013; Mactaggart 2006; CSIRO 2002; Peel et al. 2022); lack of cost-benefit data (Dobes et al 2013) and regulations (Hall 2021; Mactaggart et al. 2006). The authors advocate for enablers including catchment-scale community engagement (Hall 2021; Peel 2022), cross-sectoral networks and education (Hall 2021; Mactaggart et al. 2006); information and training (Hall 2021); multidisciplinary research across a range of landscape types (Dobes et al. 2013) and policy reform (Hurditch 2015; Hall 2021).

Collectively these authors call for a considered approach to promote more widespread uptake of LR practices to reverse land degradation, support regenerative agriculture and foster climate resilience (Dobes 2013; Hall 2021; Hurditch 2015; Mactaggart et al. 2006; CSIRO 2002; Peel et al. 2022)

2.4 Theoretical frameworks for practice change

This section investigates a sample of the extensive research literature on factors influencing decision-making and practice change by farmers. These theories were used to guide my social science research and recommendations.

To state the obvious, for a farmer to change their practice they must have a problem that needs solving and feel confident that the innovation will allow them to "better achieve their goals" (Pannell et al. 2006 p. 1408). Adoption is based on "subjective perceptions or expectations" (p. 1408). These perceptions are influenced by multiple factors that I have classified into four key themes:

1. Farmer characteristics and drivers (Kaine et al. 2003; Rogers 2003; Pannell et al. 2006);
2. Characteristics of the innovation (Rogers 2003; Guerin and Guerin 1994; Pannell et al. 2006);
3. Effectiveness of the learning and diffusion process (Kuehne et. al. 2017; Rogers 2003; Rockwell and Bennett 2004);
4. External factors: social, cultural, environmental, political and economic (Ajzen 1991; Geels 2002; Iles 2021; Pannell et al. 2006).

2.4.1 Farmer characteristics and drivers

Farmer characteristics influencing practice change include:

- Perception of a problem that needs to be addressed (Guerin and Guerin 1994);
- Locus of control (i.e. sense of personal agency) (Kaine et al. 2003);
- Goals and planning horizon (Pannell et al. 2006);
- Current skills and knowledge (Kaine et al. 2008; Bennett 1976; Kuehne 2021; Rogers 2003);
- Willingness to seek information (Rogers 2003; Pannell et al. 2006);
- Attitudes towards profit, risk, and change (Rogers 2003);
- Environmental values (Greiner and Gregg 2011);

2.4.2 Characteristics of the innovation

When choosing to adopt an innovation, Rogers (2003) proposes that farmers consider:

- Complexity – how easy or difficult is it to understand and apply the new practice/s?
- Compatibility with the farmer's values and experiences.
- Trial-ability – are small field trails possible before making larger commitments?
- Observability – does the innovation provide tangible results?
- Relative advantage over the previous practices – for example social, financial, environmental and management benefits.

These characteristics are reinforced across multiple studies (e.g. Guerin and Guerin 1994; Pannell et al. 2006). Critically, farmers must see that a practice has a relative advantage in relation to their own values and needs which could include financial, environmental and personal benefits.

2.4.3 The learning and diffusion process

When considering a new practice, farmers will actively seek information to build understanding and reduce risk. The typical next step is small-scale trials and evaluation, followed by scaling up of the practice if the results are positive (Pannell 2006).

Bennett (1976) defined the agricultural practice change as a hierarchy of steps (Figure 8). Changes in Knowledge, Attitudes, Skills and Aspirations (KASA) are the critical step, and include the knowledge required for change to occur; attitudes that influence the decision to change; practical skills to implement the new practice and aspirations that will be met by the change (Rockwell and Bennett, 2004, p. 36).

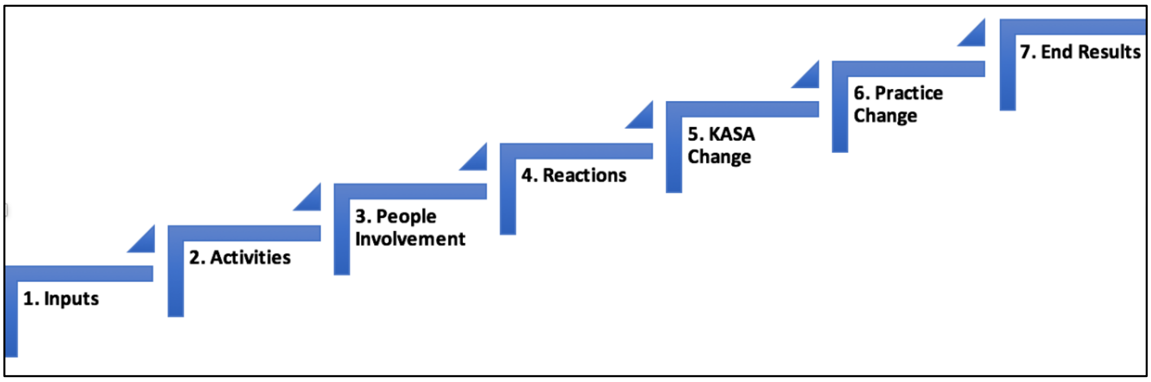

Figure 8: Bennett's Hierarchy for design and evaluation of agricultural extension (from Agrifutures Australia)

Agricultural extension is a service that supports these steps and can positively influence adoption (Pannell et al. 2006; Kuehne et al. (2017 p. 116). Extension officers assist farmers to analyse problems; develop leadership; disseminate research information and mobilise resources (Famuyiwa et al. 2017). Participatory methods of extension that take a "farmer-first, bottom-up" approach include Participatory Action Research (Guerin and Guerin 1994 p. 562) and the Agricultural Knowledge and Innovation System (Long et al. 2016).

Farmers' learning modes must be considered when designing extension activities. Farmers tend to be independent and practical, and prefer to learn techniques that have obvious advantages and can be immediately applied to solve real problems (Kilpatrick and Rosenblatt 1998; Davey 1987).

In his seminal Diffusion of Innovation model, Rogers (2003) classifies the population into five categories: early adopters, early majority, late majority, and laggards (Figure 9).

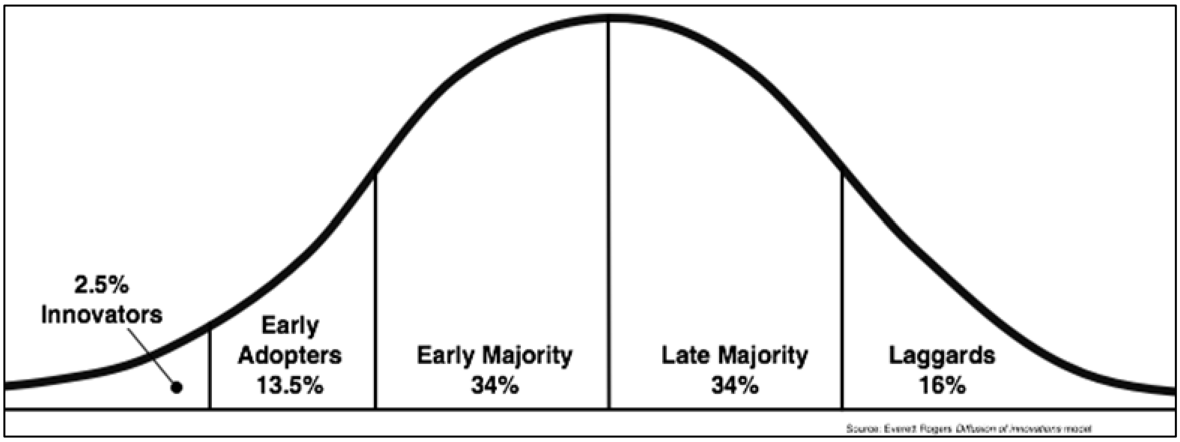

Figure 9: The Diffusion of Innovation Model (from Rogers 2003)

The role of change agents is to promote diffusion from innovators to majority uptake when critical mass is reached. Methods include creating an enabling environment, identifying and supporting the innovators and facilitating two-way communication channels that meet the needs of the target population (BUSPH, 2019).

Decision-making is a social process and social participation is an important enabler in the diffusion process (Kancans et al. 2014; Vanclay 2004; Iles 2021; Feola et al. 2015; Pannell et al. 2006). Peer support and encouragement will “reinforce commitment and provide a buffer against setbacks” (Pannell et al. 2006 p. 1411).

2.4.4 External factors

Farmers are subject to multiple external pressures and opportunities, which they must weigh up when making decisions. External factors can either support or inhibit transitions and are difficult to influence at the personal level (Iles 2021).

Geels proposes that transitions occur at niche, regime and landscape scales. Landscape scale encompasses population demographics, the economy and political context. The regime is the dominant paradigm, such as industrial agriculture. Niches are where alternative practices such as LR can develop. They allow “social learning to take place, support networks to coalesce, and different norms to develop” (Iles 2021, p. 3).

Transitions start within niches and can expand into the dominant agricultural system if changes in the regime and landscape provide an opening. Iles (2022) proposes external factors driving this transition include climate disruption; growing demand for sustainably produced food; coalescing social organization (such as the regenerative agriculture and food sovereignty movements); and favourable government policies.

2.4.5 Barriers

As with enablers for practice change, numerous authors have studied constraints and barriers that prevent the diffusion of innovations in agriculture (e.g. Anderson 1982; Guerin and Guerin 1994; Vanclay 1982). Barriers identified by Guerin and Guerin (1994) include the level of complexity of the innovation; the level of risk involved (financial, social, environmental); lack of peer support; attachment to conventional methods; unfavourable government policy and lack of subsidies and incentives.

Iles (2021) examines the role of lock-ins: “technological, institutional, economic, and political constraints on the ability of existing systems to change.” In the case of agroecological practices, lock-ins he investigates include market and political incentives that favour industrial farming; concentration of industry power; a market dominated by exports and consumer demand for cheap food. Farmers’ and NRM practitioners’ perspectives on barriers and ways to overcome them will be considered in my recommendations.

2.5 A conceptual framework

As we have seen, the causal mechanisms for behaviour change are complex (Pawson and Tilley, 1995). In an effort to bring together the key factors identified in the literature review, I have organised them into a conceptual framework to guide my social science research (Figure 10).

Characteristics of the farmer	Knowledge, attitudes, skills, aspirations
	Perception of a problem
Characteristics of the practice	Compatibility with farmer's values, skills, management practices
	Trial-ability (complexity, ease of implementation, risk)
	Observable relative advantage – financial, environmental, social
Learning and diffusion	Access to information and training
	Social participation
	Two-way communication channels and peer-to-peer learning
	Influential champions and allies
External factors	Socio-cultural
	Environmental
	Political (policy and regulation)
	Economic (subsidies and incentives; market opportunities)

Figure 10: A conceptual model of factors leading to practice change

3. Social Science Research Method

So far, I have reported on the research literature on the efficacy and adoption of LR; discussed theories of change and developed a conceptual framework for my research. I will now present my primary social science research with farmers and NRM practitioners.

I used qualitative social science methods with interviews of key actors and thematic analysis to explore the research questions. Qualitative methods are an important alternative to quantitative research, providing "valuable insights into the local perspectives of study populations" (Mack et al. 2005 p. iv). They enable the researcher to respond to the study participants' own understanding and perceptions to arrive at a more complex, contextual insight into their experience without pre-empting the findings (Mack et al. 2005; Crow et al. 2015). The methodology followed the steps shown in Figure 11.

Figure 11: Steps in my social science research project

3.1 Participant selection

The primary study population is farmers who are innovators and early adopters of LR practices. A secondary group of NRM practitioners was included to compare and contrast with the landholders, adding depth to the research.

The participants were identified using purposive sampling. I selected eight farmers: three from my networks on the MidCoast; three introduced by my project supervisor at the Mulloon Institute; and two introduced by the coordinator of the Upper Mooki Landcare Group. Of the three NRM practitioners specialising in LR, two were introduced by my supervisor and one from my professional network.

According to Galvin (2015), the probability (P) of detecting an attitude or theme that is held by a proportion of the target population (R) in a given number of interviews (n) can be calculated using the following formula:

$P = 1 – (1 – R)^n$

Table 4: Probability of detecting an attitude or theme held by the target population when 8 farmers are interviewed

R	0.1	0.2	0.3	0.4	0.5
P	56%	83%	94%	98%	99%

By this method, interviewing 8 landholders gives a 99% probability of detecting an opinion held by 50% of the target group, and is therefore an appropriate number of subjects to assess dominant attitudes. Each interview subject was ascribed a code as shown in Table 5.

Table 5: Interview participant sectors and codes

Sector	Enterprise	Codes
Farmers	Sheep	F1
	Beef	F2, F5, F8
	Vermiculture	F3
	Mixed (beef ++)	F4, F6
	Biodiversity offset	F7
NRM	Consultant	NRM 1
	NGO	NRM 2, NRM 3

3.2 Research questions and interview process

Each interviewee was provided with an explanation of the research project, how data would be used, assurance they would remain anonymous and the opportunity to opt-out of the study at any time. A consent form was signed by all participants. Names were removed from the transcripts to preserve anonymity. These protocols met the Griffith University's ethics standards and ensured that "a basis for trust is established between researchers and study participants" (Mack et al. 2005 p. 8).

Technical advice on how to conduct in-depth interviews was gained from the manual *Qualitative Research Methods: A Data Collector's Field Guide* ((Mack et al. 2005)**.** In-depth, semi-structured interviews were conducted with participants. In-depth interviews are optimal for collecting data on participant's "personal histories, perspectives, and experiences" (p.2). The interviews were semi-structured around a series of questions, to provide direction and elicit comparable data from each participant (**Appendix 5**). Open-ended questions were used, allowing participants to answer in their own words. This enabled me to evoke responses that are "meaningful and culturally salient to the participant, unanticipated by the researcher, and rich and exploratory in nature" (p. 4).

The research questions were derived from the literature review and refined after the first two interviews. They were designed to allow the interviews to unfold in a logical narrative while addressing the overarching themes of 1) characteristics of the farmers; 2) characteristics of the innovation; 3) the learning and change process and 4) external factors. Participants were asked what they would do to help promote LR and how they would remove barriers, as direct input to the recommendations.

Farmer interviews commenced with a one-to-one conversation in their home then moved outside for a farm tour. I used the survey instrument but allowed the interviews to unfold naturally, so the order of questions varied and sometimes questions were missed and followed-up later via email. The NRM facilitators were interviewed either face-to-face in the field (1) or via Zoom video conference calls (2), with one providing written follow up using the survey instrument. I wrote responses onto a hard copy of the survey instrument and made a voice recording. Notes were transcribed verbatim, and the recordings were used to cross-check and add direct quotes.

3.3 Thematic Analysis

Once transcribed, the interview data was interpreted using Thematic Analysis (TA), a foundational method in social science used for “identifying, analysing and reporting patterns (themes) within data” (Braun and Clarke 2006 p. 79). It follows the steps shown in Figure 12 (Braun and Clarke 2006). TA enables researchers to “create a narrative understanding that brings together the commonalities and differences in participants’ descriptions of their subjective experiences” (Crow et al. 2015 p, 216).

I transferred the interview data to an excel spreadsheet, and assigned codes to common themes. The factors in the conceptual framework were used as both a schema to organise the material, and codes to capture common understanding and perspectives (Braun and Clarke 2006). Additional codes were assigned that were not in the concept framework, reflecting the complex factors involved in transitions. TA may be “data driven”, identifying themes from an open analysis of the data, or “theory driven” based on pre-existing research questions. My approach was a hybrid, using questions based on the literature review while not constraining the responses and remaining open to the participants perspectives.

Figure 12: Steps undertaken for thematic analysis

3.4 Strengths and limitations

Purposive sampling is useful when the researcher has a specific purpose in mind (Trochim undated), in my case understanding landholders who have adopted LR practices. But it is non-probabilistic and can therefore introduce bias (ibid). The small sample size is appropriate to understand the range of viewpoints held (Galvin 2015) but is not statistically valid and cannot be extrapolated quantitatively. However, at times I have presented the number of respondents selecting a particular response to show the relative strength of a viewpoint within the cohort. If time allowed, more interviews would have been valuable, especially from other bioregions such as the Great Barrier Reef catchments.

A limitation of qualitative research is that it is "specific to a particular context, time and group of participants," and cannot be generalised across other populations (Thomas and Harden 2008 p. 2). The recommendations will need piloting and refinement to allow for this limitation.

The wide range of factors influencing practice change cited in the literature led me to write up a very long list of questions, hoping to cover all bases when it came to analysis. This made for some very long conversations, and I thank the farmers for their generosity and patience! It also made it difficult to present the full range of insight provided by the farmers. By using my conceptual framework to categorise the questions and responses I have attempted to organise and interpret the wealth of material.

Farmers gave generously of their time and my farm tours helped me see and understand the practices first-hand. However, the indoor/outdoor format and time constraints sometimes made it difficult to consistently record responses for every question from every farmer. A written survey instrument to complement the interviews would have been good to get more accurate quantitative responses e.g. information sources, observed outcomes.

Despite these limitations, I feel I recorded a strong body of perspectives to inform the recommendations.

4. Results

4.1 Farmer characteristics and drivers

The survey opened with a series of questions to get some basic details on the participants and their enterprise (**Appendix 6**).

The eight farms were clustered in three districts of New South Wales: The Southern Tablelands, the North West around Quirindi and the MidCoast region. The largest property was 740 hectares (ha) and the smallest 4 ha with a median size of 372 ha. Enterprises included beef (3); sheep (1); beef plus mixed enterprises (2); vermiculture (1) and a beef farm converted to a biodiversity offset/native plant nursery (1).

Ages ranged from 40-81 and the median age was 61. Five were first generation farmers and three were fifth generation farmers. Median number of years on the farm was 17.5. All but one of the farmers had off-farm income and all had worked in other professions. Three had freshwater stream frontage and four had incised gullies running through the property that had dehydrated the landscape.

The NRM practitioners were from an NGO (2) and the commercial sector (1).

4.1.1 Knowledge and skills

Farmers were asked three questions to identify their knowledge and skills before and after implementing LR.

Five of the farmers considered they had useful pre-existing knowledge and skills prior to commencement, including earthmoving and construction, land management and an innovation mindset:

"I had a lot of time in the landscape observing imbalances and figuring out how to address them" (F3).

One farmer noted that he had to question and overcome traditional farming practices:

"Some of my previous traditional farming skills were a hindrance – I had to overcome existing knowledge" (F6)[3].

Interventions could be done within their existing skill set.

"We work with what we've got. 90% of our LR work has been done with our own very small tractor" (F1)

Four farmers brought in consultants to design and install bigger projects.

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[3] For example, using chemical herbicides, sowing annual pastures with limited plant species, set-stock grazing.

4.1.2 Attitudes and orientation

Profit orientation: farmers were asked to rate themselves from 1(not very important) to 5 (very Important) on the importance of profit in their management decisions. Most (7/8) considered profit to be important or very important.

"If we are going to make a difference we need to be seen as serious operators. Economics is a good framework for making decisions about the investment of capital" (F7).

Environmental management: All farmers nominated protecting the environment as an important (2) or very important (6) factor in farm management decisions.

"I'm after triple bottom-line sustainability. Environmental outcomes are as important as financial profit" (F5).

Managed Risk: 7/8 farmers considered they had high to very high-risk tolerance, but they aren't reckless, weighing up risks across multiple dimensions before they commit.

"Primary production is inherently risky because of the variation in conditions. We do a lot of research, weigh up our options and take managed risks" (F8).

"I consider social standing, reputational risk, financial risk" (F1)

Innovation mindset: 6/8 of the farmers identified themselves as innovators while F6 saw himself as an early adopter.

"It's my mission to innovate. I research everything I do" (F4).

"I find the most brilliant minds and put their ideas into practice" (F6).

As a group they were independent with a strong sense of agency:

"Farmers are very powerful people. Once they make a decision, they have the resources to make things happen" (F5).

4.1.3 Aspirations

Farmers were asked about their planning horizon and goals for their property. The most common planning horizon was 5-10 years, with five farmers reporting a long-term vision of 20 years or more. Several themes emerged.

Production was mentioned by seven farmers, with goals for producing beef or breeding stock.

"We are interested in high intensity grazing, producing grass finished beef" (F8).

Biodiversity was a goal for seven farmers aimed for environmental and production benefits:

"My goal is to build the biodiversity of the whole system – soil, pastures, stock and wildlife" (F6).

Creating a closed-loop ecological farming system that was regenerative and self-sustaining with low inputs (chemical, labour, costs) was a goal for five of the farmers.

"My vision is a closed-loop, naturally fertile system that operates into perpetuity – a stable agro-ecosystem" (F1).

Other goals and their frequency in the dataset are shown in Figure 13.

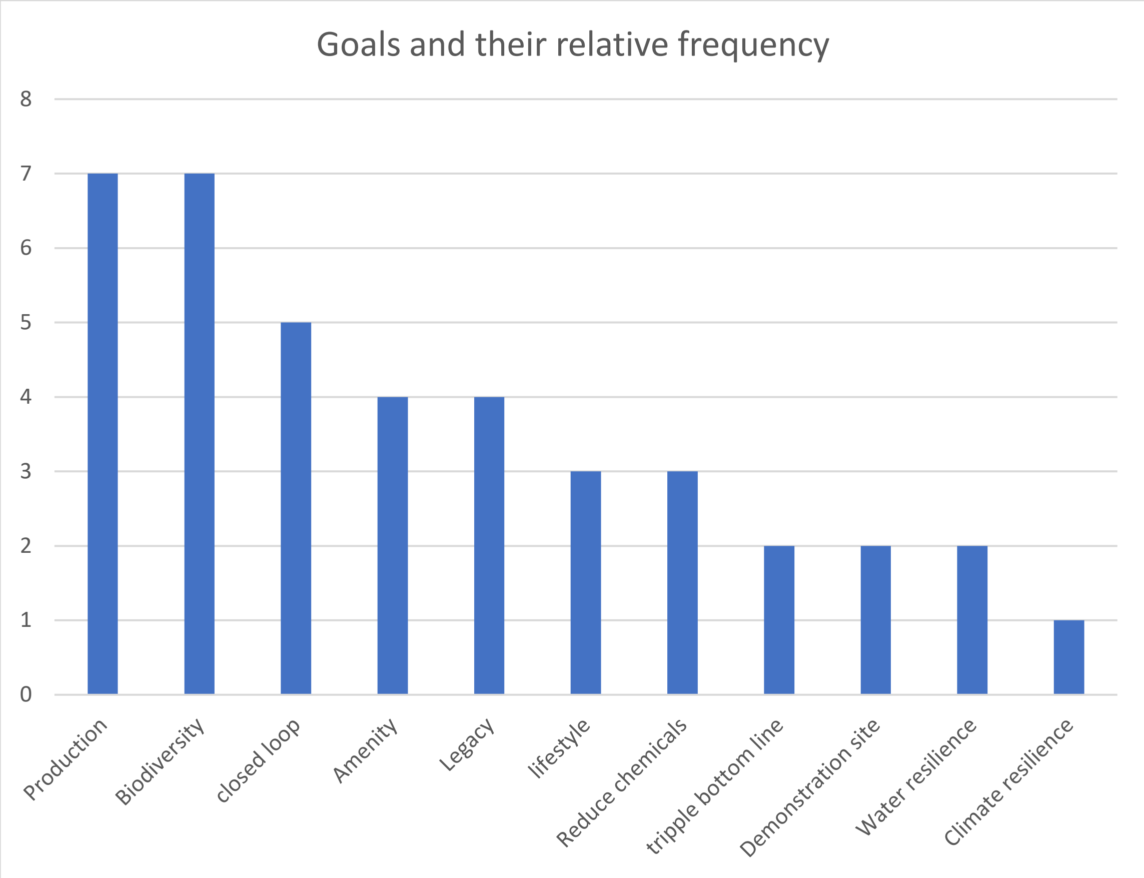

Figure 13: Goals nominated by the farmers and their relative frequency

4.1.4 Perception of a problem

Farmers were asked about their key concerns, management issues and what motivated them to implement landscape rehydration practices.

Water was the most commonly cited management issue and driver for practice change, mentioned by every farmer and NRM practitioner.

"Everything needs water. I see hydration as the critical point that drives everything else on the farm. It will be a deal breaker if it's not factored into your design and processes" (F1).

Drought, most recently in 2019, was recalled as a major stress by seven participants, with farmers having to cart water for livestock or de-stock completely:

"Drought taught me how important it is to manage and conserve water" (F2).

Using LR to buffer both wet and dry extremes was mentioned by four farmers and one of the NRM practitioners:

"We have really variable rainfall. There's either way too much or not enough. The capacity to mitigate those extremes is imperative to your property design. We are trying to achieve even hydration so we're not going from extreme wet to extreme dry" (F1).

A legacy of land degradation and its impact on sustainable production is driving practice change, as discussed by three farmers and one of the NRM practitioners:

"Europeans have only been here for a couple of hundred years and we've had a massive impact. We've engineered a drying environment through farming practices" (F8).

"There's so much land degradation from agriculture that has dried out the land and caused a loss in productivity. Landscape rehydration – in its broadest sense – is a way to reverse this" (NRM1).

Climate change is another external driver for innovation, with four farmers and two NRM practitioners discussing the LR benefits to climate resilience:

"*This landscape was a basket case during the drought. If climate change is what we think it is land like that is a big liability"* (F5).

"Properly implemented, LR will rebuild landscape function and resilience to climate change" (NRM3).

4.2 LR Practices implemented by the farmers

4.2.1 What does landscape rehydration/ NSF mean to you?

Holistic management was the strongest theme (6). Farmers saw LR as a broad, integrated approach that requires attention to vegetation, soil and animal management, as well as hydrology. The farmers don't distinguish between LR and regenerative agriculture[3]. They discussed the interactions between the various ecosystem services pertaining to water balance and fertility on the farm. This holistic approach was also captured well by one of the NRM practitioners.

"It's a holistic approach – identify and work on your weakest links. I think about what tools I have available at different stages in the journey" (F1).

Water retention was the second strongest theme mentioned by 5 farmers and NRM practitioners:

"It's about retaining water where it falls: rain soaking into absorbent soils rather than draining away in gullies" (F4).

Land management to buffer both wet and dry extremes was discussed by two of the farmers and two of the NRM practitioners:

"It's about evening out the extremities of rainfall and trying to maintain consistent soil moisture" (F1).

NSF was seen as being best suited to the low energy, swampy meadow alluvial landscapes where it originated by the three farmers on the MidCoast, all of whom were farming hillslopes without watercourses:

"Landscape rehydration is definitely the primary focus here, mainly because of my conceived notion that NSF has more to do with wider, sandy valleys" (F1).

Two of the farmers took issue with the label "landscape rehydration."

"I see rehydration as a reactionary move which follows a loss of moisture. It is important to work toward maintaining hydration not to rehydrate after drying out" (F2).

"Talking about landscape rehydration alienates people. Its water resilience – looking after our water" (F7).

4.2.2 What LR interventions have you implemented on your farm?

Farmers showed me their LR practices via site tours and I tabulated the practice type based on my own observations. Later I cross-checked my results against the interview data. In line with their understanding discussed above, the farmers took a holistic, integrated approach. The most common practices are shown in Figure 14.

A detailed tabulation of practices is provided in **Appendix 7** with narrative on farmer responses in **Appendix 8**. In summary:

Strategic animal management was seen as a critical tool by every farmer that ran stock (6/8), aiming to achieve 100% groundcover and improve soil carbon, nutrients (via manure), water infiltration and retention. Many cited Alan Savory as an influence.

Riparian zone revegetation was implemented by fiver farmers;

Stream grade-control structures were installed by five farmers (F3, F4, F5, F6, F7) with up to 14 in series to create a chain of weir-pools.

Contour swales with small ponds were installed by four farmers to hold water high in the landscape and distribute it across the paddocks (F1, F2, F6, F7).

Hilltop vegetation (4/8) and windbreaks (4/8) are part of the integrated farm system contributing to landscape hydration.

Biodiversity was seen as a whole-farm proposition to harbour birds, microbes and insects, improving resilience.

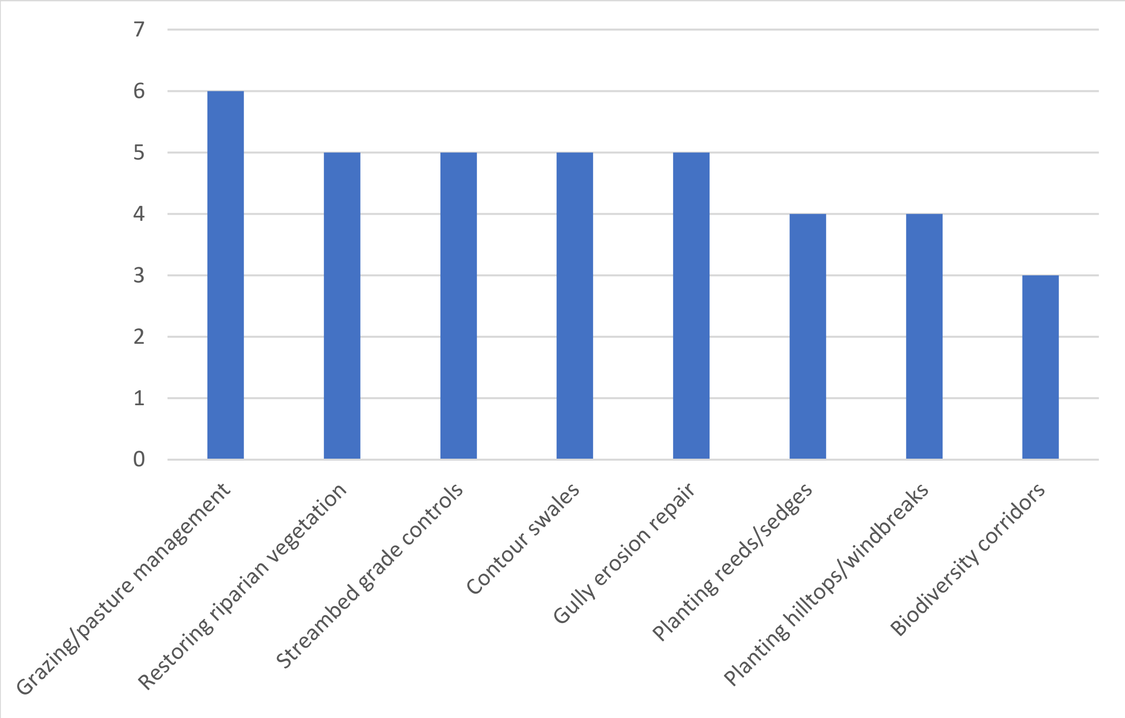

Figure 14: The most common LR interventions practiced by participating farmers

4.3 Trial-ability

Key factors influencing trial-ability are complexity, ease of implementation, cost and risk.

- 5/8 of the farmers had seen LR being trialled on other properties
- 5/8 said that doing small trials had helped them adopt LR practices
- 5/8 rated LR interventions as low or very low risk
- 5/8 of the farmers thought the upfront costs were low or very low
- 5/8 of the farmers had most or all of the skills they needed to implement the practices, although 5 brought in consultants for tasks such as design and installation of leaky weirs.

"I do small trials then apply and regulate feedback" (F3).

4.3.1 How would you rate the complexity of LR?

Five farmers rated LR as "very complex" because it involves understanding ecosystem services across multiple dimensions.

"Conventional farms are all about simplification. We need to embrace complexity. Once you start integrating everything there's a lot of moving parts" (F3)

On the other hand, once farmers adopt a mindset of working with nature and develop ecological literacy, LR can be simple:

"It's complex, but not complicated" (F4).

"It's a concept that farmers can easily understand and get behind" (NRM1).

4.3.2 How would you rate the upfront costs?

Four farmers reported the cost of adopting LR as "very low", while two found the costs "very high."

"I use resources to hand. My goal was to keep inputs low right from the start" (F4).

One of the NRM practitioners agreed:

"Farmers can have a positive impact doing small scale interventions within their skill base and with their own machinery" (NRM1).

4.3.3 How would you rate the level of risk involved for you in adopting LR practices?

Farmers reported a range of risk ratings from "high" (1) and "moderate" (1) to "low" (2) and "very low" (3).

"Subtle, low risk intervention was a principle" (F4).

The NRM practitioners were cautious:

"The bigger the interventions, such as earthworks, the bigger the risk of something going wrong" (NRM1).

"Water can have a big impact; it needs to be treated with respect. Farmers need to know what they don't know" (NRM2).

4.3.4 Trialability as an enabler for practice change

Promoting small-scale, "light-touch," low-risk, low-cost trials was seen as an important way to achieve more widespread uptake:

"To be replicable it needs to be approachable for the right people e.g. smaller, low cost interventions you can do yourself" (F1).

"Promote the smaller scale interventions that farmers can do within existing resources to have an impact" (NRM1).

Both farmers and NRM practitioners believe LR can be scaled-up:

"Yes, absolutely it can be scaled up. Big corporate commercial farms are investing in LR. They are seeing the relevance to different landscapes" (F5).

"They are improving water retention on some huge properties in Queensland" (NRM1).

"The larger the scale of implementation, the more resilient the outcome." (NRM3)

4.4 Observed results

Farmers were asked if they undertook monitoring and evaluation of their results.

Monitoring methods reported included direct observation, drone monitoring of vegetation growth; sensor monitoring for soil moisture; testing of soil nutrients and microbes; pasture observation. One farmer (F6) had joined the *Land-to-Market Ecological Outcome Verification Scheme*.

Records kept included photos, grazing records, transect monitoring for biodiversity, cattle numbers, growth rate, and sales value.

4.4.1 Environmental relative advantage

Anecdotally, farmers are observing environmental improvement to water balance, native vegetation, pasture cover, soil health and stability. Farmers were asked to self-report ratings for a range of parameters before and after adoption of LR practices, based on their own anecdotal perception. A five-point scale of conditions was provided: poor/moderate/good/very good/excellent. Farmers sometimes declined to offer a rating due to the absence of monitoring data and the wide range of variables. Qualitative perceptions of environmental advantage are provided in **Appendix 9**.

Farm water balance: all eight farmers reported improvement from “poor” before to “very good” (1) or excellent (7) after LR interventions.

“My farm is more resilient to wet and dry conditions” (F5).

“The swales have significantly reduced run-off. Overland flow has reduced by 75-100%. Instead of a peak flow, there’s slow flow for longer” (F8).

Water storage: four farmers reported improvement from “poor” before to “excellent” after interventions.

“We were the only place with water during the drought – the fire-fighting helicopters were pulling water from my weir pools” (F6).

Native vegetation: four farmers observed change from “poor” before LR, to moderate (1), good (1), very good (1) and excellent (2) after interventions.

“Some locally extinct or endangered species are returning naturally” (F4).

Soil water: four farmers reported an improvement from “poor” before LR; to “very good” (1) and “excellent” (3) after LR interventions.

Soil biological health: four farmers went from “poor” before to “very good” (1) and “excellent” (3) after LR interventions.

“Before the soil was sloppy clay. Now it is healthy productive biologically active soil requiring minimal fertilizers” (F2).

Soil stability: four farmers went from “Poor” before to “very good” (2) and “excellent” (2) after LR interventions.

“My place was highly erosive before, stable now. I don’t have any erosion on site” (F4)

Pasture cover: five farmers went from “poor” (4) and “moderate” (1) to “good” (1) and “excellent” (4) after LR interventions.

"There's green pasture all year round, we can keep fattening cattle right through winter" (F6).

Climate resilience: All eight farmers believed their LR management program was "*highly likely"* to make their farm more resilient to climate change.

"Does it improve climate resilience? 110%!" (F4).

4.4.2 Financial relative advantage

Financial advantage was explored through a question on cost-effectiveness, with 5/8 rating the practices as having either "excellent" (4) or "very good" (1) cost effectiveness. F2 and F6 had recorded increased profits through improvements in the growth rates and market price of their cattle.

"The benefits outweigh the costs. I've seen a big improvement in profitability despite the drought and La Nina. There's less work required and lower input costs. My cattle are 30-70 kilos heavier than ten years ago. I get top dollar now, compared to 80% of market price before. The herd is healthier" (F2).

"One year's super bill paid for all the structures – about $14K – and I haven't supered for 20+ years" (F6).

4.4.3 Social relative advantage

Farmers reported social benefits from their innovative approach including social connections formed with like-minded farmers; spiritual benefits from connecting with nature; social approval from friends and family and a sense of agency and optimism:

"I'm enjoying watching the land regenerate rather than labouring over it. I thank the Lord every day - it's nourishing" (F4).

"I spent 35 years searching for meaning and found it very quickly when I came back [to the family farm]" (F7)

"You can see hope when young people come here [on internships] and they realise they can be part of the solution" (F6).

NRM practitioners also reported social dimensions to LR programs:

"It's incredibly empowering when people realise they can prepare for climate extremes. That sense of agency is positive for their mental health and it creates a more positive mindset for their community" (NRM2).

4.4.4 Observed relative advantage supports more widespread dissemination

All eight farmers agreed that the benefits of the practices warranted more widespread promotion and uptake, based on their personal experience.

"It gives free production from the land. Every farmer could be very successful using these principles" (F4).

"I've seen a phenomenal flip in the health of my farm… Inputs have been dramatically reduced. Production has increased 230 % based on an independent analysis of my farm records" (F6).

4.5 Barriers

4.5.1 Socio-cultural barriers

The industrial agricultural mindset in which agriculture is extractive rather than regenerative is seen as a barrier to more widespread uptake by 5/8 of the farmers:

"The industrial concepts and corporate mindset of commercial agriculture which is disconnected from nature are a barrier" (F5)

"To create change people need to reassess the <u>why</u> and shift away from the us versus nature mindset" (F1)

Adherence to tradition is also seen as a barrier:

"Aversion to change is a barrier… Intergenerational farmers can tend to adhere to traditions, and not notice that the landscape and conditions have changed" (F5).

Oppositional attitudes were identified as a barrier to LR uptake by three farmers and two NRM practitioners. Institutional support varies from district to district, with Landcare and Local Land Services being sources of information and support in some districts such as the northwest, and not interested or oppositional in others.

"Bureaucratic institutions are against LR. Once they commit to a point of view they won't change their mind. Everyone believes what they say because they hold the power. They will fight to defend their position. I've had lots of opposition from other farmers…Landcare people don't believe in my methods." (F4)

"A lot of people are taking a polarized position. The NSF and LR people are pushing their perspective and not considering when [a leaky weir] is not appropriate and what other practices are available. And the government and scientific people are dismissing it out of hand. There needs to be an effort to listen to each other and find common ground" (NRM1).

Some participants felt that NSF and LR could suffer from taking an ideological approach.

"If you try to have a one-sided ideological approach it can be a bottleneck that hinders the process of change" (F3)

Maintaining the broad scope of LR interventions was recommended by NRM1:

"If you make it all about leaky weirs and earth works it will have limited application. Avoid branded programs with a limited set of options. Farmers need a broad range of tools to use depending on their situation" (NRM1).

4.5.2 Lack of scientific evidence

The need for more robust scientific data and the difficulty or cost involved in evaluating results was mentioned by four farmers (F2, F5, F7, F8).

"We're terrible at monitoring" (F7).

"There's scepticism and a lack of science behind LR. People are saying show us the evidence" F8.

4.5.3 Lack of cost-benefit data

While the participating farmers were confident of their environmental and social benefits, there was more uncertainty around the profitability of LR.

"*We need cost benefit analysis. Does it stack up? Profitability as a key outcome needs to be demonstrated. Otherwise it doesn't matter rich you are coming into it, if it's a net loss it's not sustainable*" (F1).

"Farmers need help understanding the financials – how are they going to pay for it, how's it going to affect income – how do they manage the transition financially" (NRM2)

4.5.4 Regulation

Regulation is seen as a major barrier to LR by both farmers and NRM practitioners (F2, F3, F5, F6, NRM2). Concerns include the number of regulatory authorities, the complexity of navigating multiple regulations, lack of consistency and biased personnel. A key concern is that regulations using computer-based numeric assessments designed to manage the impacts of development don't make sense when applied to restoration projects.

"There's too much red tape – regulation is complicated and difficult to find and understand. We need a flow chart to explain the regulatory framework" (F3).

"The complexity of the regulatory framework is baffling for farmers. How did it get so complicated? Farmers and TMI are trying to repair the environment but we're treated like developers. We are subject to the same controls as if we were building a 10-storey building. The regulatory framework is not fit-for-purpose and the officers working within those frameworks are completely captured by the law as it stands. The costs, the amount of information you need to supply, the modelling of the outcomes is very expensive and time consuming" (NRM2).

However, some farmers (F1) and NRM practitioners were more accepting of the status quo:

"Regulation is the context we operate in. I used a consultant [to help me comply]" (F1).

"I'm cautious about changing regulation to avoid Review of Environmental Factors for instream structures – they can do a lot of damage if they're not designed well or located inappropriately" (NRM1).

4.5.5 Market barriers

Regulations that block direct marketing of produce from farmer to consumer and an inability for consumers to identify regenerative produce are seen as barriers.

"There's regulations every step of the way for direct sales – at the abattoir, the butcher; there's issues with verification that the meat is from your animal" (F6).

"Farmers need policy support to sell their [regeneratively farmed] produce at a premium… they need a system in place" (NRM2).

4.6 Enablers

4.6.1 Information, education and training

The participating farmers actively seek information, have good access and draw on a wide range of resources to inform their decision-making (Table 18, Appendix 10).

Improving information resources was the number one action proposed by eight of the study participants to enable more widespread uptake of LR. Ideas included training more people in the technical skills; funding NGOs such as The Mulloon Institute (TMI) to offer training services; writing case studies; training programs and online resources.

Formal training had been undertaken by half the farmers. Courses undertaken included Natural Sequence Farming (NSF) at Tarwyn Park Training (TPT), Alan Savory's Holistic Grazing Management, RCS, broadscale permaculture biodynamics and DPI's ProGraze.

YouTube videos were an accessible format that suited four farmers:

"Funds are well-spent on videos and online content. Online you can reach more people and have more in-depth content" (F3).

The farmers are discerning and assess information in relation to their individual sites and problems:

"I'm cautious about taking other people's ideas and shoe-horning them into my site" (F1).

4.6.2 Demonstration sites

Demonstration projects were the second most highly recommended enabler for practice change, suggested by seven of the study participants. Some participants said it was difficult to find demonstration projects and see the practices first-hand. Others noted the need to monitor and evaluate results at demonstration sites to generate data on efficacy. Government funding was needed to support this.

"Going to field days [at demonstration sites] helped me understand and adopt LR- seeing farmers doing their own small trials with small interventions and positive results" (F5).

"We need government funding for a proper independent program of monitoring and evaluation studies. Setup trial sites, monitor, report and publicise" (F2).

4.6.3 Social participation

Participation in social networks is an important influence for all of the farmers, usually at the local and district levels (Table 6).

"There's always been a connection between a rural property and the village. I still have those connections. There's a depth and breadth of community for me here." (F7).

"LR is bringing people together with a lot of enthusiasm to repair degradation and improve resilience" (NRM1)

"You have to go back to the family/community/individual level. Bringing neigbours together to relate communally on shared projects will bring us together in connection with our land" (F5)

Table 6: Farmer participation in networks

	Local	District	State	National	International
F1	✓	✓			
F2	✓	✓			
F3	✓				
F4					✓
F5	✓	✓		✓	
F6	✓	✓	✓	✓	✓
F7	✓	✓			
F8	✓				
Total	7	5	1	2	2

Landcare groups are an important source of information and social support, hosting farm field days and leading catchment scale projects (e.g. Upper Mooki and Wallabadah Landcare).

"Our Landcare group and other Landcare groups have been helpful (F7).

The regenerative agriculture movement, which LR is a part of, is a niche practice creating a wave of interest and support for LR innovation, with champions, mainstream media stories, large conferences and interest from government agencies and consumers:

"Most people in the regenerative agriculture movement are "givers." When you take your end up you create a regenerative cycle of support and change. We are excited about finding solutions to land degradation" (F6).

4.6.4 Allies and champions

Allies are a trusted source of information. Building support from allies was seen as a way to promote the benefits of LR:

"If agency people in leadership roles support LR it will happen" (F4)

Enabling allies mentioned included consultants, LLS, Local Government Agencies, individual scientists and The Mulloon Institute (TMI).

"Fund NGOs like TMI and Landcare to work with graziers" (F3).

"TMI is such an important part of it. They say we're here; we want to work with you. We can provide a bit of money. We're having a talk tomorrow if you want to come" (F5).

"LLS has been especially helpful" (F7).

Charismatic champions are also playing an important role as enablers. Peter Andrews OAM is a champion of Natural Sequence Farming and maintained relationships with three of the participating farmers. His advocacy and networking have created a significant profile for NSF and more broadly, LR.

Other champions mentioned included the late Tony Cootes AM, Martin Royds (Jillamatong) and Craig Carter (Tallawang).

4.6.5 Market opportunities

Market opportunities are growing, with direct access to connect with customers on-line:

"There's a growing desire amongst customers to buy local. We're selling a story not a product. The internet allows us to connect with our customers" (F1).

One farmer (F6) participated in the Land-to-market accreditation program to sell accredited regenerative agriculture products at a premium.

4.6.6 Grass Roots Leadership

Farmers unanimously agreed that the diffusion of innovation for LR is led by the grassroots rather than top-down through government policy support. Apart from problems with regulation, government policy and incentives such as grant funding did not feature in their responses.

"As an innovator I've never looked to government to take the lead. I'd try to grow TMI long before I'd be trying to grow government involvement." (F5).

5. Discussion

In this section I bring together the results of my social science research and literature review, addressing my research questions:

- What are the characteristics and drivers for farmers practicing LR?
- What are the characteristics of LR interventions being practiced by farmers?
- What are the barriers and enablers influencing practice change towards LR?

5.1 Farmer characteristics and drivers

As discussed in my literature review and conceptual framework, the primary characteristics of farmers that influence practice change are KASA (knowledge, attitudes, skills and aspirations); and perception of a problem.

Key findings:

- The participating farmers demonstrate the characteristics of innovators and early adopters;
- Their aspirations were diverse, covering financial, environmental and social dimensions;
- The problems they were solving included wet and dry extremes as well as land degradation and drought resilience.

5.1.1 Knowledge and skills

In general, the farmers reported a good level of existing knowledge and skill to implement the interventions they desired (Section 4.1.1). The majority also used consultants to assist with design and construction of leaky weirs and contour swales.

This aligns with a comprehensive review of practice change theory by Kuehne et al. (2017 p. 117) who found that the effectiveness of learning depends on farmers' "existing skills and knowledge, their involvement in farmer groups, and their usage of farm advisors."

5.1.2 Attitudes

The participants' attitudes were pro-innovation, with a high level of tolerance for managed risk, and an orientation towards both profit and environmental protection (Section 4.1.2). They demonstrated the characteristics of innovators and early adopters identified by Rogers (2003). Innovators are risk-takers who are quick to adopt new ideas and technologies. They play a key role introducing innovations to a wider group. Early adopters are respected leaders with social standing who share and promote the innovation with their peers.

Change agents can promote diffusion of LR by supporting this cohort and facilitating two-way communication channels to share their successes with "early majority" farmers

– the next group in the diffusion process (Rogers 2003; BUSPH 2019). "The early majority" are more deliberate in their approach to change and require more evidence and exposure to the practice before they adopt it (Rogers 2003).

Case studies, demonstration sites, field days and mentoring programs could meet these needs and will be discussed further in section 5.4.2.

5.1.3 Aspirations and perceptions of a problem

The participating farmers had diverse aspirations covering production, biodiversity, closed loop ecological farm systems, triple-bottom-line profitability and sustainable lifestyles (Section 4.1.3).

The importance of appealing to a range of aspirations was noted in a study on practice change by Kancans et al. (2014 p. 2) for the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES):

> *"While communicating production and financial benefits is important, communicating environmental and personal benefits is likely to also play an important role in encouraging uptake of sustainable farm management practices. Extension that promotes the multiple benefits of adoption…have a greater influence on a wider audience than extension that fails to recognise these multiple benefits and motivations."*

The participating farmers had clear perceptions of a problem that could be resolved through the LR approach. Problems included drought and water scarcity; extremes of wet and dry conditions; the legacy of land degradation, particularly incised gullies that were draining the landscape; and climate change (Section 4.1.5). Acknowledging the gravity of a problem and searching for solutions are key drivers for practice change (Guerin and Guerin 1994; Pannell 2006).

LR practices are currently framed around resolving land degradation and addressing water scarcity. Opportunity exists to broaden the scope of problems addressed by the practices involved, which could appeal to both catchment managers concerned with diffuse source run-off and farmers trying to maintain productivity, prevent soil erosion and retain nutrients during wet periods.

Re-framing *landscape rehydration* to *water resilient farming* for environmental, social and financial benefits will meet the needs of more farmers and help tell this story.

5.2 Characteristics of the LR practices

The characteristics of an innovation that influence adoption in my conceptual framework are compatibility with farmers values, skills and management practices; trial-ability and observable relative advantage.

Key findings:

- LR practices are compatible with farmers who are turning away from industrial agriculture and seeking nature-based solutions.
- Farmers choose a site-specific, holistic, integrated suite of practices.
- LR practices have good trialability with a program of small scale, light touch interventions achieving observable results.
- The complexity lies in understanding the agro-ecological principles across multiple ecosystem dimensions.
- Relative advantage is readily observed across environmental and social dimensions. Cost benefit analysis would help address uncertainty.
- LR practices in their broadest sense meet the objectives of NRM practitioners to improve catchment management and biodiversity.

5.2.1 A holistic suite of integrated practices for multiple landscape types

Six of the eight farmers described LR as a *holistic* suite of integrated practices to solve site-specific problems. They are not limiting their LR practices to hydrological interventions or a specific program. Strategic grazing for pasture management was the most common intervention, along with riparian restoration, erosion control and hydrological interventions (which F7 described as a “last resort”). Interventions were practiced from hilltop (contour swales, revegetation) to valley floor (riparian restoration, streambed grade control). This approach offers tools for multiple landscape types.

This contrasts with a perception that NSF and LR target the bottom of catchments by installing leaky weirs to repair swampy meadows. Although both programs use a broad range of tools to achieve results, the “optics” on LR perpetuate this perception. For example, literature on the Mulloon Rehydration Initiative focusses exclusively on leaky weirs and riparian restoration (Hall, 2021; Peel 2022), despite a wider range of tools being applied. Similarly, the evaluation studies in the stock of literature on LR primarily monitor and report on the performance of leaky weirs, (Weber and Field 2010; Keen et al. 2007; Streeton et al. 2013).

Significantly, the more holistic suite of LR practices being implemented by farmers are strongly compatible with the goals of NRM managers, who are seeking to slow surface flows, reduce erosion and diffuse source run-off and improve biodiversity. Land management approaches that meet the needs of farmers while benefitting the public good are a key to promoting agricultural practice change for environmental outcomes (Pannell 2006). LR meets these criteria.

Articulating and promoting the full toolkit of LR interventions from top to bottom of catchments for multiple landscape types and benefits will diversify its application, win over NRM practitioners and build the credibility of the approach.

5.2.2 Trial-ability

Trial-ability promotes adoption by “reducing uncertainty about the relative advantage of the practice” (Pannell et al. 2006 p. 1416). Farmers reported a range of risk ratings and up-front costs which depended on the scale of the intervention being trialled.

Significantly, effective LR improvements can be observed from small-scale interventions within existing resources (F1, F4, F5). This aligns with the practice change literature which agrees that small scale interventions with relatively low costs and low risks positively influence trialability (Rogers 2003; Guerin and Guerin 1994; Pannell et al. 2006).

Promoting small-scale “light touch” interventions that farmers can do themselves within their existing skillset was seen as an approachable way to spread the practices (Section 4.1.1).

LR was described by F4 as *“complex but not complicated*” because it requires an understanding of multiple ecological functions. However once these core principles were grasped and farmers adopted a mindset of working *with* rather than *against* nature, it became easy to understand and get behind (Section 4.4.1).

Complexity is negatively correlated with trialability (Pannell et al. 2006).

Education programs that build ecological literacy will help farmers understand the principles underpinning LR, enabling them to apply their critical thinking and problem-solving skills to design and trial nature-based solutions to improve water balance.

5.2.3 Observable relative advantage

Based on anecdotal observation of their LR interventions, all farmers were satisfied with relative advantage across environmental and social dimensions (Section 4.3). While F2 and F6 maintained records to demonstrate increased profitability for their grazing enterprises, financial profitability of LR was less certain for others. Farmers anticipated lower inputs over time but were unable to quantify improved financial outcomes (F1, F3, F5, F8).

Observing a relative advantage in relation to the farmer’s own needs is a key factor in diffusion of innovation (Guerin and Guerin 1994; Pannell et al. 2006; Rogers 2003). While multiple dimensions are important, profitability is a key driver. Several farmers called for cost-benefit analysis to demonstrate profitability.

The need to undertake scientifically valid monitoring and evaluation programs to demonstrate the environmental and production relative advantage, and difficulty meeting the associated costs, was noted by both farmers and NRM practitioners ((F2, F5, NRM3).

Investing in long-term project monitoring and evaluation will provide evidence to the risk averse “early majority” farmers as well as NRM practitioners and agricultural extension officers in government and non-government agencies, building credibility for the practices. Demonstration projects and case studies will help promote the results.

Undertaking cost-benefit analysis will help alleviate uncertainty for “early majority” farmers who are more risk-averse. The comprehensive case studies prepared by NGO Soil for Life are a good example. This data will also be important to inform government policy and investment (Dobes et al. 2013).

Figure 15: monitoring results across a range of indicators will help build evidence

5.4 What are the barriers and enablers influencing practice change towards LR?

5.4.1 Barriers

Barriers to uptake of innovation by farmers are multi-factorial and create “disabling dynamics” that inhibit the emergence of new approaches (Iles 2022 p. 6).

Key findings

Comparing barriers discussed in the stock of literature on LR, the literature on theories of change and my direct social science research, I found that:

- Stakeholder concerns, lack of peer support and polarised, oppositional attitudes were common to all three sources
- Lack of scientific evidence and cost-benefit analysis were identified in the LR literature (Dobes et al 2013) and my study results (section 4.4.2; 4.4.5)
- The industrial mindset and attachment to conventional methods and was common to the theory of change literature and my research results (Section 4.5.1)
- The regulatory framework was discussed in the LR literature (Hall 2021; Mactaggart et al. 2006) and the study results (Section 4.5.4)
- Unfavourable policy and lack of incentives was discussed in both the LR literature (Hurditch 2015; Mactaggart et al. 2006; Hall 2021) and theory of change literature (Guerin and Guerin 1994) but was not a key issue discussed by the farmers.

Stakeholder concerns and opposition

Stakeholder concerns and oppositional attitudes were seen as a significant barrier to LR (Dobes et al. 2013; Mactaggart et al. 2006; Guerin and Guerin 1994; Iles 2021; results sections 4.5.1, 4.5.2). The need for scientific research was mentioned by numerous study participants as a way to address this, by helping to demonstrate efficacy and establish credibility (Section 4.5.2). Farmers such as F7 are collaborating with university scientists to evaluate the efficacy of their practices at the property-scale.

Sponsoring multidisciplinary scientific research to fill knowledge gaps and build a stronger evidence base is utilised in practice-change programs to improve credibility and help address stakeholder concerns and opposition (IFRC-WWW 2022 p. 11; Iles 2022).

Stakeholder concerns to be investigated include negative impacts to catchment hydrology (Mactaggart et al. 2013 p. 72); the role of native vegetation as an alternative to exotic plants used in NSF (Mactaggart et al. 2013); impact on water quantity and quality for downstream properties (Dobes et al. 2013); and impacts on fish dispersal (Dobes et al. 2013; Mactaggart et al. 2006).

Regulation

The complicated and confusing regulatory framework is seen as a significant barrier to LR, (Section 4.5.4). NRM2 held the view that the approval regulations applying to LR interventions such as leaky weirs and contour swales are designed to assess and manage environmental impacts for development and not “fit-for-purpose” to manage risk for restoration projects.

Regulations are part of the socio-ecological context for farmer decision-making and reform can be used as a tool for “enhancing adaptive capacity and promoting sustainable agriculture” (Feola et al. 2015 p. 75).

Reviewing the regulatory framework and establishing a fast-track for environmental restoration projects would provide a more enabling environment for LR interventions. This could include a one-stop portal for approval applications and streamlining the interagency referrals. Triggers could be applied to ensure significant earthworks and hydrological interventions have a suitable Review of Environmental Factors. A flow-chart to clearly explain the regulatory process would help landholders and NRM practitioners to navigate approvals.

The Industrial Mindset

The industrial mindset was seen as a barrier by 5/8 of the participating farmers (Section 4.5.1) and was also noted as a barrier in the literature (Guerin and Guerin 1994; Iles 2022). Iles (p. 7) argues that “strong beliefs among scientists, industry, and government elites in the power of science and technology to overcome climate constraints are leading to agroecology being ignored.” He suggests that “widely shared public consensus on the need for a transition could undermine institutional lock-ins” (p. 6).

Aligning LR with the growing movement for Nature-Based Solutions (NbS) could help proponents to establish legitimacy. NbS are actions that “protect, sustainably manage and restore natural or modified ecosystems to address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (IFRC-WWW 2022 p. 9).

Nature-Based Solutions are an Action Area for the United Nations (UN) Global Compact, which is the world’s largest corporate sustainability initiative (www.ungolbalcompact.org). They underpin the UN’s Sustainable Development Goals by supporting ecosystem services for biodiversity, access to fresh water and sustainable food systems. Global NGO The Nature Conservancy (TNC) partnered with the UN Food and Agriculture Organisation to release three reports on NbS and agriculture in 2021 (see Nature-Based Solutions for Agriculture | The Nature Conservancy). Restoring habitats crucial to watershed health is one of the first examples used to explain NbS on this web page. Leveraging these efforts will help LR challenge the dominant paradigm of industrial agriculture and gain credibility.

5.4.2 Enablers

Key Findings:

Three enablers are common to all three information sources for my thesis: the LR literature, the literature on practice change and my study results:

- Improving access to information and training;
- Demonstration projects;
- Social participation and community engagement.

Market opportunities are discussed in the practice change literature and study results.

Access to information and training

The participating farmers actively seek information, have good access and draw on a wide range of resources to inform their decision-making, with F6 using 14 of the 20 reference types identified. When asked to identify enablers that would help other farmers to adopt LR, the most frequently nominated activity was improving training and information resources (4.5.1).

This aligns with the importance of gathering information and building new knowledge and skills in order to adopt new practices cited in the literature review (Pannell 2006; Bennett 1976). In the literature on LR, Hall (2021 p. 26) called for more "skills-based learning for landholders."

An on-line hub of LR information such as fact-sheets and videos will enable farmers to research solutions to their land and water management problems in their own time. Referencing the fact-sheets with footnotes will give them credibility for NRM practitioners and agricultural extension officers.

Online training courses with mentoring support and study groups could be offered to farmers who want to pursue LR principles and practice in more depth.

Demonstration projects, field days and case studies

Demonstration sites with quantitative monitoring and evaluation were the second most popular enabler selected by the farmers (Section 4.6.2). Field days and case-studies can be used to showcase demonstration sites, build credibility and share success stories. In the LR literature, Hall (2021 p. 25) noted that "demonstration of practice is key to sharing knowledge and building understanding." Guerin and Guerin (1994) provide evidence that farmers prefer oral sources including extension personnel, other farmers and demonstration days. Iles (2022, p. 29-30) points out that it is farmers, not agronomists, who are inventing landscape rehydration. He argues that "scientists and policy-makers must recognize farmers and pastoralists as being legitimate producers of knowledge in their own right."

Establishing more demonstration sites and using field days and case studies to showcase the broad range of LR interventions across a range of landscape types and regions would provide a platform for farmer-to-farmer skill-based learning and education for NRM practitioners. Study tours to demonstration sites can be used to present farmer's results to scientists, policy-makers and politicians.

Figure 16: Demonstration sites and farm field days help disseminate innovations

Social participation and community engagement

The respondents had strong participation rates in local and district networks (Section 4.1.5). Social groups noted as valuable enablers included neighbours and NRM facilitators involved in catchment scale projects, Landcare groups and the regenerative agriculture movement more broadly.

Iles (2022) and Massy (2018) observed that Landcare members were more likely than non-members to adopt regenerative practices. The Landcare movement provides a platform for social participation, a “repository of experience and local knowledge” and could support the spread of regenerative practices such as LR (Iles 2021 p. 21).

Facilitating catchment scale projects brings neighbours together to trial innovations with expert advice and peer support (Peel et al. 2022). TMI’s Mulloon Rehydration Initiative and catchment-scale rehydration projects led by Wallabadah Landcare and Upper Mooki Landcare are good examples of community-based projects achieving social and environmental outcomes at the catchment scale.

Joining in communities of practice will help drive practice change. Not-for-profit organisations such as The Mulloon Institute, regional Landcare networks and commercial training providers such as RCS, Maia Grazing and the Savory Institute support communities of practice for ecological or regenerative agriculture. Actively contributing to these communities of practice will support the transition to more water-resilient farming for agricultural production, biodiversity and catchment management.

Hosting cross sectoral networking and learning opportunities was recommended by Hall (2021) and Mactaggart et al. (2006). Scientists, politicians, policy makers, NRM facilitators and agricultural extension officers in the government and non-government are all important allies in the transition to LR. Events such as forums, study tours and webinars foster “cognitive and cultural change” and a more “broad-based, inclusive social movement” to overcome lock-ins (Iles 2021 p. 6). Cross-sectoral education should be egalitarian and avoid ideology and narrow, brand-based definitions of LR (F3, NRM1).

Market opportunities

Several farmers discussed the importance of new direct marketing opportunities and the barriers that inhibit premium sales of regeneratively produced meat (Sections 4.5.3 and 4.6.5).

Monopolies by Woolworths and Coles dominate food supply in Australia and drive expectations for low-cost food served by industrial agriculture (Iles 2022). To support a more sustainable food system, Gliessman (2016 p. 188) recommends re-establishing “a more direct connection between those who grow our food and those who consume it.”

Supporting shorter food supply chains with more direct links between farmers and customers and promoting the value of local, regeneratively produced foods will help regenerative farmers practicing LR to sell their produce at a premium price. Mechanisms include online “farm-to-fridge” services, food trails, selling to restaurants who champion local produce and farmers markets.

6. Conclusion & recommendations

Agriculture accounts for 55% of landuse in Australia (ABARES 2022). Our naturally low and variable rainfall coupled with a legacy of land degradation puts pressure on soil and surface water for catchment health and agriculture (Anderson et al. 2016; Eldridge et al. 2018; McKenzie et al. 2004). Climate change will exacerbate these pressures.

Land degradation has impacts on water quality and ecosystem health for rivers and their catchments, with agricultural diffuse-source run-off ranking in the top three threats to estuaries; impacting environmental, social and economic values (BMT 2017).

Along with degrading catchment values, conventional farming methods that lead to high on-farm losses in water balance will be a significant liability (Falkenmark and Rockstrom 2006). Already facing the highest price and yield volatility in the world, smart farmers will continue seeking ways to adapt and improve their water resilience (Anderson et al. 2016). They will need well-designed and resourced support to make this transition.

Integrated Water Resource Management (IWRM), a participatory approach to managing water in the landscape for environmental, social and economic values, provides a framework to address this challenge (GWP 2002, p. 22).

My research for this thesis, both through the literature and direct interviews with farmers and NRM practitioners, shows that LR methods are aligned to IWRM and offer Nature-Based Solutions for water resilient farming. The practices will achieve outcomes for production while improving biodiversity and catchment values in both water quality and quantity.

The suite of LR practices is holistic and improves the availability of surface and soil water through interventions targeting hydrology, native vegetation, soil and the grazing-pasture system. These methods can be tailored to suit any site and are best applied from top to the bottom of the property or better still the catchment.

For farming to transition to more nature-based, regenerative and water resilient practices, an enabling environment and removal of barriers will need to happen at multiple scales. As Iles (2022 p. 20) points out, “individual farmers, local communities, rural regions, urban centres, states, and the nation are all part of the agri-food system.” Leadership, expertise and social support at all levels will be needed to help drive the transition. Based on analysis of my interview results in relation to the literature, I offer the following recommendations for NRM facilitators and agricultural extension officers in the government, non-government and commercial sectors seeking to support more widespread uptake of LR for production and environmental outcomes.

6.1 Recommendations

6.1.1 Principles

- **Re-frame the practice from *landscape rehydration* to *water-resilient farming*** for agricultural, environmental, social and financial outcomes.
- **Promote a broad and holistic toolkit of integrated *water-resilient farming* interventions** from top to bottom of catchments across multiple landscape types.
- **Align LR with the growing movement for agricultural Nature-Based Solutions** to establish legitimacy.
- **Match the scale of the intervention to the scale of the degradation** ensuring the project design is fit for purpose**.**
- **Promote small-scale, low-cost, "light touch" interventions** that farmers can do themselves at low-cost within their existing skillset.
- **For more complex projects use specialist site assessment and design**

6.1.2 Activities

- **Broker multidisciplinary scientific research** to fill knowledge gaps and investigate the evidence base. Disseminate the results widely.
- **Provide farmers with education opportunities to build ecological literacy** and understanding of the ecosystem interactions underpinning LR**.**
- **Develop on-line hub of information** on *water-resilient farming* practices with factsheets and videos to enable farmers to research solutions to their land and water management problems in their own time.
- **Provide online training courses with mentoring support and study groups** for in-depth knowledge-building.
- **Establish more demonstration sites** and use field days and case studies to showcase LR projects to farmers, NRM practitioners, politicians and policy makers.
- **Invest in long-term project monitoring and evaluation** of productivity, cost-benefit, social and environmental indicators to provide evidence for the risk averse "early majority," opponents and policy makers.
- **Undertake cost-benefit analysis** to alleviate uncertainty for "early majority" farmers who are more risk-averse.
- **Facilitate catchment scale projects that** bring neighbours together to trial innovations with expert advice and peer support.
- **Contribute to communities of practice** hosted by Landcare, The Mulloon Institute, other NGOs and commercial education providers.

- **Host cross sectoral networking and learning opportunities** for farmers, scientists, agronomists, consultants, politicians, policy makers, NRM facilitators and agricultural extension officers to establish a broader base of allies and change agents.
- **Support** "farm-to-fridge" services and farmers markets to provide local, premium-price retail opportunities for regenerative farmers.
- **Review the regulatory framework** and establish clear and transparent fast-track for environmental restoration projects.

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Appendix 1: The efficacy of Landscape Rehydration for catchment health and agricultural outcomes

Alignment with global land and water management agendas

In principle, the LR approach of restoring the connection between surface and soil water is aligned with the seminal work of Falkenmark and Rockstrom (2006, p. 129), who conceptualise water in agricultural settings as 'blue' and 'green' (Figure 17):

- Blue water is the water in rivers, lakes, dams, wetlands and groundwater aquifers.
- Green water is moisture held in the unsaturated zone of soil which flows through plants to the atmosphere via evapotranspiration.

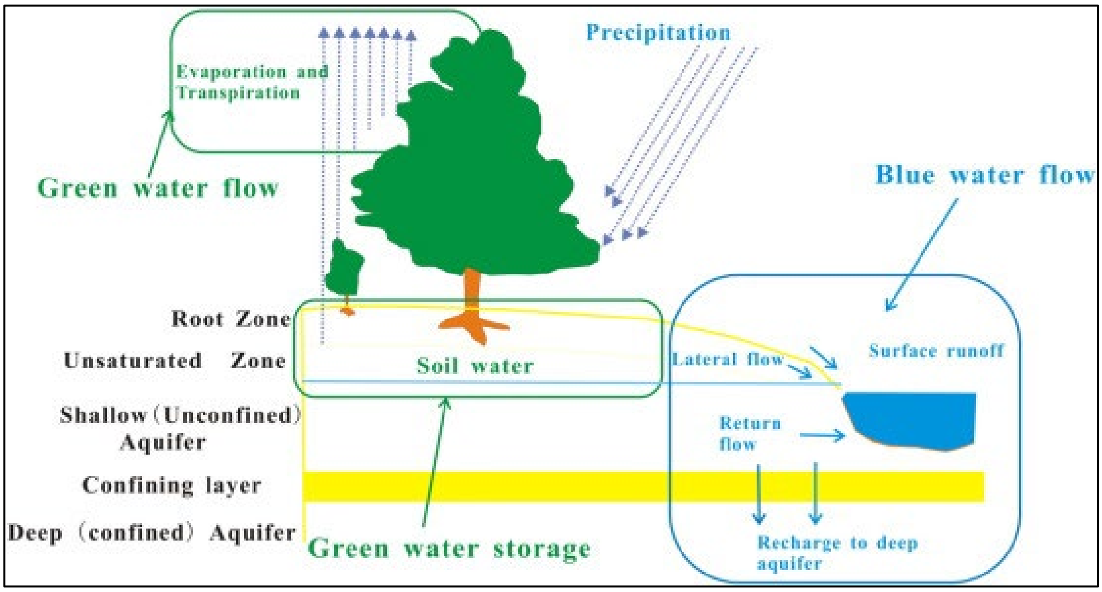

Figure 17: The blue and green water cycles, showing circular exchange between the two systems. **From: Zhao et al. 2016 p. 319)**

Green water, essential for plant growth, is the most important water source for agriculture (Lundquist et al. 1999), and sustainable agricultural systems need to manage both blue and green water resources (Falkenmark and Rockstrom 2006). LR meets this brief.

LR's manipulation of hydrology is further supported by the Millennium Ecosystem Assessment's synthesis of research on desertification, which notes that improved water management practices that restore hydrology, recharge groundwater and spread floodwater can prevent desertification and provide water reserves during drought (MEA 2005 p. 14).

Restoring Hydrology

The central thesis of LR is that swampy meadows, *Phragmites* reed-beds and chain-of-ponds landscapes were once widespread, have been drained and desiccated by agriculture and can be repaired through LR practices (Norris and Andrews 2010; Williams 2010).

This premise is supported by the literature. Mould and Brierley (2017) describe swampy meadows as low-gradient valley floors with cut-and-fill fluvial landscapes, sometimes featuring discontinuous watercourses presenting as chains of ponds (Figure 18). These wetlands were "common in the pre-European record" (Mould and Brierley 2017 p. 349) and found in a "wide range of environmental settings…from tropical through temperate to arid conditions" (Fryirs and Brierly 2013 p. 189-190).

Broadscale degradation of swampy meadows through agricultural impacts is well established (Eyles 1977; Mactaggart et al. 2006). Vegetation clearing and high intensity set-stock grazing reduced surface roughness and flow resistance, diverting rainfall from evapotranspiration to surface-flows (An and Verhoeven 2019; Streeton et al. 2013). High-energy flows incised the swampy meadows. Floodplains were left perched above their rivers, limiting overbank flooding and recharge of alluvial soils, wetlands and aquifers to extreme rainfall events (Boulton, 2007; Brierly et al. 1999; Dobes et al. 2013; Eyles 1977; Keene et al. 2007; Mactaggart et al. 2007; Mould and Brierly 2017). The result is depicted in Figure 19.

It is widely understood that longitudinal, vertical and lateral hydrological connectivity between a stream and its floodplain sustains the ecosystem processes of river systems (Boulton et al. 2007; Keene et al. 2007). When incision occurs, “the channelling of flood waters along incised streams prevents flood waters from spreading across the width of the valley floors” (Streeton et al. 2013 p. 72). As a result, the “probability and frequency of overbank flows and transfer of water, sediments and nutrients between these two landforms” is reduced, drying out the landscape. Impacts include biodiversity loss, increased diffuse-source run-off and declining agricultural productivity (Mactaggart et al. 2006).

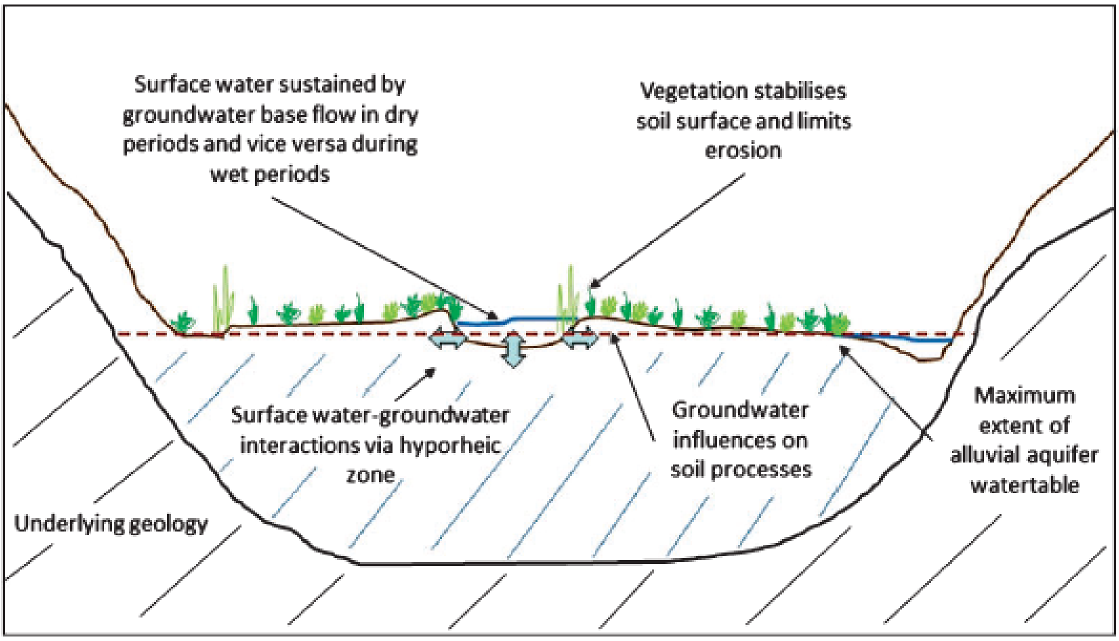

Figure 18: Lateral cross-section showing common functional attributes of a cut-and-fill swampy meadow landscape in SE Australia

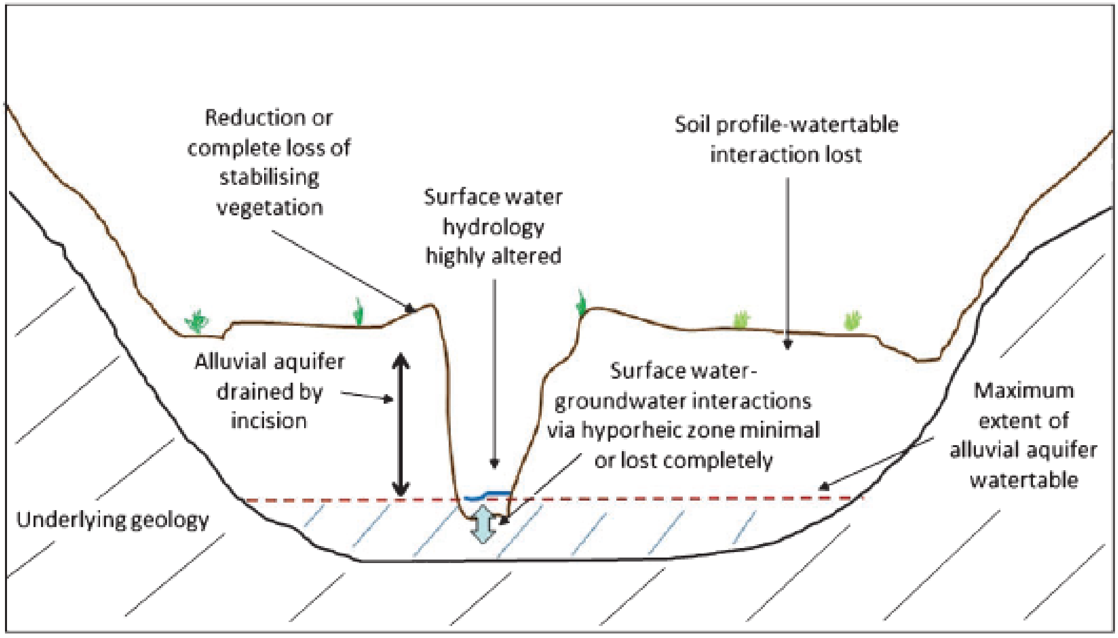

Figure 19: Lateral cross section showing an incised floodplain, associated impacts on an upper floodplain of SE Australia (from Dobes et al. 2013 p. 341)

LR practitioners hypothesize that repairing stream incisions, accumulating sediment to raise the streambed and restoring in-stream and riparian vegetation will reverse the incision process and successfully drive lateral diffusion across the floodplain (CSIRO 2002; Dobes et al. 2013; DPIE 2021 b; Norris and Andrews 2010; Peel et al. 2022; Williams 2010). Hurditch (2015 p. 332) writes that "the resulting re-connection of surface and alluvial water flows converts degraded watershed landscapes from a "drainage mode" to a "natural storage mode", with streamside floodplains effectively becoming grass-covered water reservoirs (Figure 20).

Several of the monitoring and evaluation studies in the LR literature support the hypothesis that lateral diffusion to rehydrate the floodplain is achieved through leaky weirs (Bush et al. 2010; CSIRO 2002; Keene et al. 2007; Streeton 2013; Weber and Field 2010).

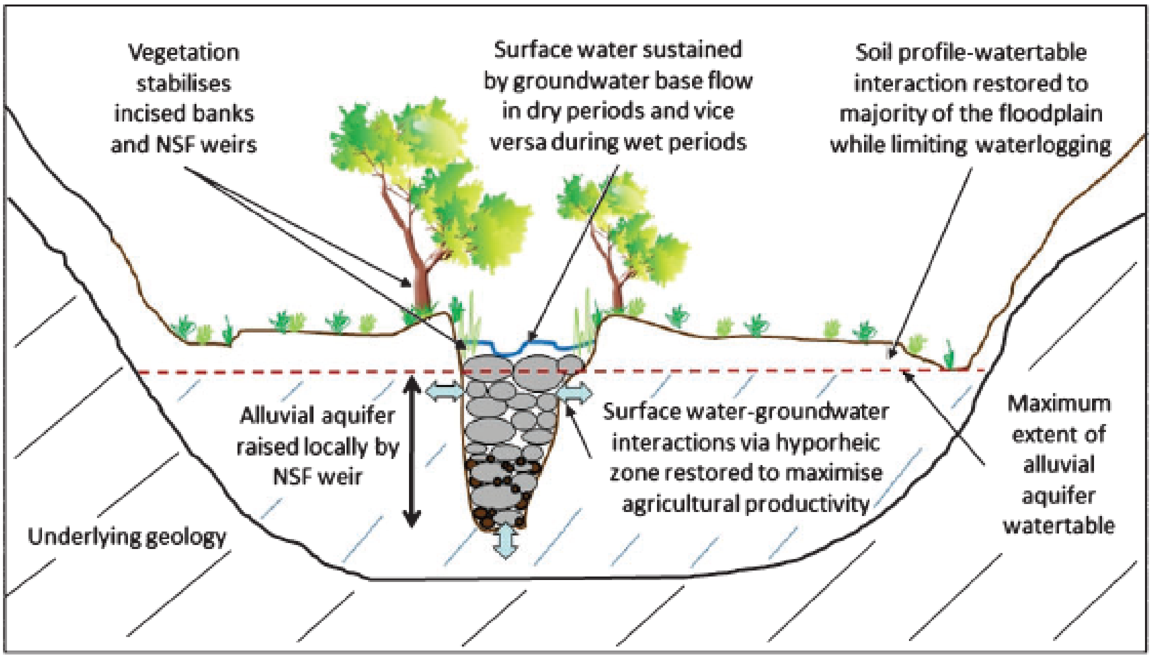

Figure 20: Lateral cross section showing hypothesised result of remediation with a leaky weir (From Dobes 2013 page 342)

Restoring Vegetation

Along with hydrological interventions, restoring riparian vegetation is a key focus for LR programs (Peel et al 2022). This intervention is well-supported by the literature (Burrows et al. 2000; Hansen et al. 2010; Pietsch 2019; Kemp et al. 2017; Carvalho et al. 2020; Tabacchi et al. 1998). Pietsch (2019 p. 4) asserts that “managing riparian vegetation is the principle tool available to natural resource managers to effect catchment-scale improvements in the river environment.” Riparian vegetation mediates the flow of matter, biota and energy between the stream and its floodplain (Hansen et al 2010) and buffers waterways from the impacts of landuse (Burrows 2000). Belsky et. al. (1999) note that “healthy riparian areas act as giant sponges during flood events, raising water tables and maintaining a source of streamwater during dry seasons. The result is a more stable streamflow throughout the year.” Restoring riparian vegetation is a “no-regrets” practice that slows surface water run-off, takes up nutrients, reduces diffuse source water pollution and promotes stability and biodiversity in river systems (Kemp et al. 2017; Swanson 2020b; Pietsch et al. 2019 p. 13).

Similarly, the LR practice of installing instream reeds and sedges (Peel et al 2022) is known to dissipate energy, stabilise banks, improve water quality and provide habitat for birds, macroinvertebrates and aquatic fauna (Rejmankova 2011, 2016).

TMI’s Mulloon Rehydration Initiative includes revegetation of hilltops and the berms of contour swales (Hazell pers. Comm. 26 July 2022). Terrestrial tree cover promotes deep infiltration and maintenance of the water table (Harris 2001; Beale and Dalby 2007). It plays a role in green water management by providing shade and wind protection to reduce surface temperatures, dissipating solar radiation and mitigating atmospheric temperature extremes via evapotranspiration and condensation of water vapour (An and Verhoeven 2019; Pugh 2017).

The importance of restoring hilltop vegetation is noted by Mould and Fryirs (2017) whose research at Crisps Creek in the southern tablelands of NSW found that revegetation of the hillslopes to increase rainfall infiltration and de-stocking the riparian zone initiated a recovery phase in a degraded chain-of-ponds system without structural interventions to the stream-bed. A study by Filoso (2017, in IFRC undated p. 2) found that “upland forest restoration can slow water run off and reduce river flooding by up to 80%.”

Another claim of LR proponents is that trees support hydration of the landscape by driving the “small water cycle,” promoting rain at the regional scale (Norris and Andrews 2010). This hypothesis is also supported in the literature (An and Verhoeven 2019). Evapotranspiration increases humidity; creating updrafts that facilitate condensation and pressure gradients, drawing moist air inland from the coast. The volatile organic compounds released by trees oxidise to form cloud condensation nuclei which seed raindrops (An and Verhoeven 2019; Pugh 2017).

Grazing management and pasture cover

Holistic or rotational grazing is used in LR programs to maintain groundcover (TMI 2022; TPT 2005). CSIRO’s evaluation of the NSF regime at Tarwyn Park found that pasture management including minimal tillage encouraged a mix of annual and perennial plant species (including legumes) to achieve year-round cover (CSIRO 2002).

The LR emphasis on holistic grazing methods to maintain pasture cover is supported by the NSW Department of Primary Industries, which asserts that “managing pastures to maintain adequate levels of groundcover is the most effective way to minimise run-off and erosion,” (DPI 2005p. 1). Tactical grazing to conserve pasture benefits the catchment by reducing sediment and nutrient loading, and maintains soil water and biology for production.

Pasture cover improves water infiltration and retention by protecting soil from compaction, dispersing surface flows and building SOC (Beale and Dalby 2007 p17; Schwartz 2019; DPIE 2022; Tinley and Pringle 2013). Through the process of photosynthesis, groundcover plants create the simple sugars that provide energy for the microbial biome, a crucial ingredient in the soil aggregation and carbon sequestration to promote water infiltration and retention (Schwartz 2019; Zhang et al. 2021).

Restoring soil health

Soil Organic Carbon and the microbial biome

Restoring soil health by improving Soil Organic Carbon, biology and nutrient availability is a key principle of NSF (Williams 2010). CSIRO (2002) found that the net deposition of sediment at Tarwyn Park brought an accumulation of nutrients and SOC. Andrews also actively increased soil organics by redistributing animal manure and harvested aquatic plant mulch to the head of the floodplain and onto hillslopes (CSIRO 2002).

A working group reporting to the IPCC noted that improving SOC has benefits for both climate mitigation (by sequestering carbon) and adaptation. Organic carbon stores increase soil's capacity to hold moisture and resist erosion, helping it to "withstand droughts and floods, both of which are projected to increase in frequency and severity under a future warmer climate" (Smith et al 2014 p. 846).

Soil is composed of mineral particles which form aggregates with SOC and living micro-organisms. Soil aggregation is influenced by plant community composition, the soil biome, clay and organic content, and management regimes (Zhang et al 2021). Microbial activity drives the process of soil aggregation. Aggregates are bound together by sticky compounds produced by microorganisms, fungal mycelium and a substance called glomalin exuded by mycorrhizal fungi (Zhang et al 2021).

The soil aggregate, particularly SOC, plays a key role in regulating green water (Schwartz 2019). In well-aggregated soil, pores facilitate the movement of air, water and nutrients, enhancing plant production (Donovan in Schwartz 2019 p. 51; Jones 2018). By helping form water-stable aggregates, SOC increases rain infiltration and reduces surface water run-off. SOC also improves soil water retention, holding up to twenty times its own weight in water (Jones 2018; Itsukushima 2016; Homolak 2017).

The retention of water in healthy soil provides a positive feedback loop, supporting further accumulation of SOC, cooling the soil and surrounding atmosphere and reducing soil mineralization and acidification (An and Verhoeven 2019).

Controlling erosion

Erosion control is part of the LR suite of activities. Methods include sieve structures, gully stabilisation and contour berms to reduce surface flows and loss of topsoil and improve water infiltration and retention (TMI 2020).

Tinley and Pringle (2013) note that stopping gully nickpoints and spreading flows out of erosion channels serves to improve soil water retention times, reverse rangeland dehydration and improve cattle carrying capacity.

Erosion control aligns with the MEA's research (2005 p:14), which found that "all measures that protect soils from erosion… and other forms of soil degradation effectively prevent desertification."

Appendix 2: Catalogue of LR literature

Academic documents (published, peer reviewed/refereed journal articles with multiple reference citations)
1. Dobes, L., Weber, N., Bennett, J., Ogilvy, S. (2013). *Stream-bed and flood-plain rehabilitation at Mulloon Creek, Australia: A financial and economic perspective*. Rangeland Journal 35(3), pp. 339-348
2. Hurditch, W. J. (2015). *Sustainable water and energy management in Australia's farming landscapes*. WIT Transactions on Ecology and the Environment; Southampton Vol. 200, 329-341. Southampton: W I T Press. (2015) DOI:10.2495/WS150281
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Appendix 3: Summary of LR evaluation studies

Table 7: Summary of LR evaluation study results

Author	Method	Findings
Bush et al. 2010	Quantitative study comparing soil health at three sites; one adjacent to a leaky weir, one adjacent to a constructed pool, and the third a control site with comparable geomorphology and land-use but no NSF interventions. Tested physical and chemical properties in 15 pooled soil samples and 15 whole shoot pasture samples across the three sites. Tested Electical Conductivity (EC) in 3 water samples from above and below the weir.	• Soil moisture, soil organic matter and cation exchange capacity was higher at both the NSF sites compared to the control site. • Nitrate levels were higher in pasture soil at the control site compared to the NSF sites, but pasture shoot N concentration was in the normal range for all 3 sites. • Increased soil moisture and microbial activity at the NSF sites was driving more efficient utilisation of nutrients by pasture plants.
Callow and Bell 2021	Qualitative review of NSF's applicability to dryland grain and sheep farming in Western Australia by a geographer and PhD candidate	• Chain of ponds fluvial landscapes are not present in SW WA. • Surface water management structures (i.e. contour swales) are inefficient on grain farms using GPS guided equipment. • Surface water management structures are superfluous in arid landscapes. • Recharge of alluvial aquifers could exacerbate dryland salinity. • Revegetation of the landscape has a range of benefits.

CSIRO 2022	Qualitative assessment of NSF at Tarwyn Park by an interdisciplinary panel of scientists.	• Net deposition rather than erosion of soil. • Overall water balance restored to a more natural condition. • Reconnection of the stream with its floodplain assumed to recharge the hydrophytic zone, promoting natural regeneration of riparian vegetation • Grade-controlled stream promoted natural regeneration of instream reeds and sedges • Increased water storage in the aquifer improved the availability of soil water for pasture growth • Net primary production and profitability increased • Resilience to climate fluctuations improved • Pasture management was expected to increase SOC • Nutrients and SOC accumulated on the floodplain
Keene et al. 2007	Quantitative year-long field study to ascertain if a leaky weir at Widden Brook successfully improved lateral connectivity between surface water and the aquifer Monitored lateral and longitudinal variations in Electrical Conductivity (EC), redox, DO, Ca, K and Mg	• Streamwater and groundwater levels reflected strong hydrological linkages in coarse channel deposits • In-stream structure had a localised effect on water exchange between the hyporheic zone and the channel.
Streeton et al. 2013	Quantitative 5-year study of sediment aggradation at Spring Creek NSW. LR interventions included stock exclusion fencing, riparian revegetation, and the installation of 13 leaky weirs.	• Condition of riparian vegetation had improved • Leaky weirs resulted in a significant increase of sediment aggradation restoring complexity to the streambed. • Sediment aggradation requires an upstream sediment source • Weirs constructed in sodic soils require frequent monitoring

Weber and Field 2010	Quantitative study of the effects of NSF on physical, chemical and biological properties relating to agricultural productivity. 3 paired sampling sites based on comparable positions on the floodplain 31 soil samples along bisecting transects at each site Standard tests for total and available Phosphorous, Total Nitrogen, Electrical Conductivity, SOC and macro-biota abundance and diversity Statistical significance of variation determined using T-tests	• NSF sites had elevated levels of total P, soil effective cation exchange capacity, soil-biota diversity and abundance • Leaky weir appeared to have major positive influences on soil chemical and biological properties

Appendix 4: Application of NSF practices in a range of fluvial settings

Table 8: Matrix indicating which practices employed at Tarwyn Park (shaded) are applicable in different fluvial settings

	Water balance control	Erosion control	Salt export control	Productivity control	Nutrient retention control	Pasture functional diversity control
Headwater streams		•stream grade control structures •ground cover				•encourage broad-leaf annuals •avoid herbicide use
Confined floodplains – naturally chain of ponds	•floodwater diversion •aquifer recharge and storage •hillslope runoff trapping	•stream and floodplain grade control structures •contour collection and diversion channels •ground cover	•aquifer salt storage •reduction in hillslope salt delivery	•effected by water and nutrient management	•mulching •nutrient redistribution	•encourage broad-leaf annuals •avoid herbicide use
Confined floodplains – naturally incised channel	•hillslope runoff trapping	•floodplain grade control structures •contour collection and diversion channels •ground cover	•reduction in hillslope salt delivery		•mulching •nutrient redistribution	•encourage broad-leaf annuals •avoid herbicide use
Unconfined floodplains		•floodplain grade control structures •ground cover			•mulching •nutrient redistribution	•encourage broad-leaf annuals •avoid herbicide use

(From CSIRO 2002 p. 11)

Appendix 5: The interview questions

Interview Questions

Basic Details		
Hectares		
Enterprise		
Is it your primary occupation?	Other sources of income	Yes No
How many head of stock do you usually run?		
Your Age		
Years on the farm		
Previous career (if any)		
Waterway frontage		Yes No
TELL ME ABOUT YOURSELF (DRIVERS)		
How many years is your planning horizon?		
What are your goals for the property?		
What are your key concerns/management issues?		
Is water an issue for you?		
What motivated you to try Landscape rehydration?		☐ Recognition of crisis
How important is maximizing profit in your decisions about farm management?		☐ Very important ☐ Important ☐ Moderately important ☐ Not very important ☐ Not important
How important is protecting the environment in your farm management decisions		☐ Very important ☐ Important ☐ Moderately important ☐ Not very important ☐ Not important

How would you rate your **tolerance of risk**		☐ Very high ☐ High ☐ Medium ☐ Low ☐ Very low
Do you see yourself as an innovator?		
What connections do you have with your community?		Networks: ☐ Local ☐ District ☐ State ☐ National

TELL ME ABOUT YOUR LR PRACTICES

Is Landscape Rehydration or Natural Sequence Farming an approach you are implementing on your farm?	
What does landscape rehydration/ NSF mean to you?	
What do you see as the top 3 most effective LR practices?	
Is this a solo project or are you working with multiple properties? Who?	

WHAT LR INTERVENTIONS HAVE YOU IMPLEMENTED ON YOUR FARM?

Water management		☐ In-stream grade control structures ☐ Floodwater diversion ☐ Water storage
Vegetation management – riparian		☐ Riparian revegetation ☐ Stock exclusion fencing ☐ Weed control
Vegetation management – in-stream/wetlands		☐ Instream macrophytes ☐ Wetland restoration ☐ Stock exclusion from wetland
Vegetation Management – Terrestrial		☐ Hilltops ☐ Windbreaks

		☐ Corridors ☐ Native or introduced?
Stock management		☐ Stock exclusion fencing ☐ Off-stream waterpoints ☐ Set stock ☐ Rotational
Pasture plants		☐ Diverse types ☐ Deep rooted species ☐ Perennial grasses ☐ Native pasture
Erosion control		☐ Sieve structures ☐ Gully incision ☐ On contour grade control
Soil amendment		☐ Manures ☐ Compost ☐ Mulch ☐ Microbial inoculants ☐ Inorganic minerals ☐ Chemical fertiliser

WHAT RESULTS HAVE YOU OBSERVED?

Have you done anything to monitor and evaluate the results of these activities? What?			
OBSERVED RESULTS		**BEFORE**	**AFTER**
Waterways – flow, instream condition Has the water balance on your farm improved?		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent
Water storage e.g. dams		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent
native vegetation		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent

		☐	☐
Groundcover		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent
Soil water		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent
Soil health		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent
Soil stability		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent
How would you rate its cost effectiveness?		☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐ Excellent	
Has there been any social/cultural/spiritual benefits?			
How likely are do you think LR will make you more resilient to climate change?			☐ Very likely ☐ likely ☐ Medium ☐ Low ☐ Not likely
Do you think it would be beneficial for LR practices to be more widespread? Why?			
Can it be scaled up?			

TRIALABILITY

How would you rate the complexity of your LR approach?		☐ Very complex ☐ Complex ☐ Not very complex ☐ Simple
Do you have the skills you need, or do you bring in consultants?		

Relative upfront costs – how would you rate the upfront costs compared to the benefits from using these practices?		☐ Very high ☐ high ☐ moderate ☐ low ☐ very low
How would you rate the level of risk involved for you in adopting LR practices?		☐ Very high ☐ High ☐ Medium ☐ Low ☐ Very low

ENABLERS

How did you find out about Landscape Rehydration/NSF?		
Had you seen anyone you know trialling it?		
Before you got into LR did you already have existing skills and knowledge that helped you adopt it?		
Where do you get information about LR?		☐ Local Land Services ☐ Consultants ☐ Landcare ☐ Other farmers ☐ Industry associations ☐ TMI ☐ Tarwyn Park ☐ EMU ☐ On-Line ☐ Books ☐ Web sites ☐ Magazines/newspapers ☐ podcasts
Have you done any training in LR/NSF? Who with? What sort?		☐ Field Days ☐ Formal training
How important are your networks in supporting new practices?		☐ Very important ☐ Important

		☐ Don't know ☐ Not very important
What do you think about the level of acceptance of LR practices by mainstream farming?		
Have you had support or opposition?		
Do you think LR is spreading from the grassroots, bottom up? Or top down led by industry/government/NGOs? Or both?		
What helped you to adopt new LR practices?		☐ Farmer to farmer learning ☐ Landcare ☐ External allies e.g. scientists, NGOs, governments, businesses ☐ Access to Technology/Equipment ☐ Successful trials ☐ Effective practices ☐ Favourable Government policy ☐ Grants and incentives ☐ Regulation ☐ Favourable Marketing opportunities e.g. direct marketing, farmers markets
What do you think could be done to help promote and support Landscape Rehydration practices?		
BARRIERS		
What challenges or barriers have you come across when implementing LR practices?		☐ Government policy aligned to industrial farming ☐ Regulation ☐ Finance ☐ Lack of knowledge ☐ Lack of social support ☐ Market support

		☐ European agricultural model ☐ Geography/conditions ☐ Climate impacts ☐ Lack of farmer subsidies/financial support
What do you think should be done to remove these barriers?		
Is there anything else you'd like to talk about?		
Would you like a copy of the report?		

Thank you

Appendix 6: Farmers' basic details

#	M/F	Age	yrs on farm	generations farming?	Ha	stream?	Enterprise	How many head of stock?	Off-farm income	Other job (current or past)
F1	M	41	5	5	40	No	Sheep	200	Yes	Yes
F2	M	80	22	1	140	Yes	Beef	100	Yes	Yes
F3	M	40	8	1	4	No*	Worms,	NA	No	Yes
F4	M	81	30	1	223	Yes	Beef, sheep	200	Yes	Yes
F5	M	71	25	1	740	Yes	Beef	100	Yes	Yes
F6	M	63	27	5	423	No*	Cattle + mixed enterprise	350	Yes	Yes
F7	M	62	5	5	70	No*	Biodiversity offset, native plant nursery	NA	Yes	Yes
F8	M/F**	59	15	1	387	Yes	Beef	220	Yes	Yes
MEDIAN		60.6	17.5	3	372			225		
AVGE		62.1	17	2.5	253			195		

** F8 invited his wife who takes an active interest in farm management to join us for a join interview

Appendix 7: Practices used by participating farmers to manage water in their landscape

Table 9: Hydrology management practices by participating farmers

	HYDROLOGY MANAGEMENT PRACTICES		
	Stream bed grade control	**Contour swales**	**Dams**
F1		1	1
F2		1	1
F3	1		1
F4	1		
F5	1		
F6	1	1	
F7	1		
F8		1	
Total	**5**	**4**	**3**

Table 10: Vegetation management practices by participating farmers

	VEGETATION MANAGEMENT PRACTICES								
	Riparian zone Reveg.	**Riparian Zone Stock exclusion**	**Install Instream macrophytes**	**Weed control**	**Protect/ Restore Wetland**	**Hilltop veg**	**Windbreaks**	**Biodiversity Corridors**	**Native plants used?**
F1						1	1		1
F2	1	1				1	1	1	1
F3									
F4	1		1			1			
F5	1	1	1				1	1	1
F6			1			1	1	1	1
F7	1	1	1						1
F8	1	1							
Tot	**5**	**4**	**4**	**0**	**0**	**4**	**4**	**3**	**5**

Table 11: Stock and pasture management

	STOCK AND PASTURE MANAGEMENT					
	Rotational/holistic/strategic grazing	**Off-stream water points**	**Diverse**	**Deep rooted species**	**perennial pasture**	**native grasses**
F1	1	1	1	1		
F2	1	1	1	1	1	
F3						
F4	1		1		1	1
F5	1					
F6	1		1		1	1
F7			1			1
F8	1		1	1	1	1
Total	**6**	**2**	**6**	**3**	**4**	**4**

Table 12: Erosion control and soil amendment

	EROSION CONTROL			AMENDMENT					
	Sieve structures	**Gully repair**	**on-contour grade control**	**Manures (via animals)**	**compost**	**mulch**	**Microbe inoculant s**	**mineral**	**chemical fertiliser**
F1		1		1		1			1
F2		1	1	1	1	1	1	1	
F3		1	1						
F4	1			1	1	1			
F5	1								
F6		1		1	1		1	1	
F7		1							
F8		1							
Total	**2**	**5**	**2**	**4**	**3**	**3**	**2**	**2**	**1**

Appendix 8: Interview narrative on LR interventions

Strategic animal management was seen as a critical tool by every farmer that ran stock (6/8), aiming to achieve 100% groundcover and improve soil carbon, water infiltration and retention. Many cited Alan Savory as an influence:

"Alan Savory's holistic grazing method is a key to the whole thing – short term disturbance, long-term rest" (F4).

Riparian zone revegetation was implemented at 6/8 farms;

"We have planted hundreds of trees and shrubs of mixed native species in our riparian zone" (F5).

Stock were excluded from the riparian zone at 4 of the farms, but all farmers grazed the creek paddock on occasion (e.g. twice a year):

"The fenced-out riparian area is the best pasture on the farm" (F8).

Weed control in the riparian zone wasn't seen as an issue:

"There's no need for weed control– nature will sort it out" (F2).

Hydrological interventions including stream grade control and contour swales were installed by 5/8 farmers.

Stream grade-control structures were installed by five farmers (F3, F4, F5, F6, F7) with up to 14 in series to create a chain of weir-pools. They were supplemented with instream macrophytes, re-snagging and sieve structures such as Phragmites, logs, tyres and bricks to slow water movement in incised ephemeral streams.

"I've installed 14 leaky weirs into pinch points of a deeply incised gully. The walls are impervious, but the ponds are not lined with clay, so water continues to flow slowly downstream through the system. Weirs are constructed in "top-to-tail" series – each weir backs up water in a pond to the next weir" (F6).

Some farmers noted that in-stream structures were a last resort, including F7 who has installed five leaky weirs:

"Interventions in the creek and erosion channels are a last resort when you can't do anything else" (F7)

"I don't do major earthworks. I look for riffle benches, natural shallow choke points and bars in the stream and eroding gullies on the hillslope and build them up with soils and rhizomous plants" (F4).

Contour swales with small ponds were installed by farmers to hold water high in the landscape and distribute it across the paddocks (F1, F2, F6, F7).

"I use Yeoman's keyline ploughing, redirecting water across the landscape, and strategically placed dams up high. Water is redistributed by channels and pipes" (F1).

Dams aren't generally considered part of LR schemes but are sometimes constructed with specific purposes:

"The dam at the bottom is for bioremediation to clean water before it spills into the ephemeral creek…" (F3).

Instream macrophytes (reeds and sedges) were installed by some farmers:

"Planting phragmites in the riffle benches during drought created ponding and slowed water down, generating lateral diffusion into the floodplain" (F4).

Others found instream aquatic vegetation regenerates naturally once water is present:

"We observed excellent recruitment of water ribbon in the water column around our leaky weirs" (NRM3).

Hilltop vegetation (4/8) and windbreaks (4/8) are all seen as part of the integrated farm system contributing to landscape hydration.

"We've planted 1000 trees in 5-years. Retaining and increasing native vegetation on the hilltops contributes to rehydration by intercepting water, dropping leaf-litter and slowing run-off. Windbreaks protect our soil moisture and add nutrients to the system" (F1).

Soft and hard soil erosion control techniques were used to slow the movement of surface water:

"I use light-touch methods to slow run-off – small-scale erosion control on the hillslopes and plugging riffle benches with phragmites in the stream" (F4).

Soil amendment to improve biology was primarily via manures introduced through high intensity rotational stocking and diverse animal species (F4 – cattle followed by sheep; F6 chickens and dogs). F6 used an innovative method of introducing home-made compost into a contour swale to promote nutrient dispersal downslope across his paddock.

"Soil is not dirt, its biology. Our farming system destroyed the biology. If your soils are lifeless, they can't hold water. If you've only got dirt the water runs off. When you've got soil biology the rain soaks into the paddock and stays there" (F8).

"I've seen a big build-up of healthy soil from bare, sodic stony ground. Manure plus pasture gives microbes, aggregates and water retention" (F4).

Biodiversity was seen as a whole-farm proposition to harbour healthy microbes and insects improving resilience. Two farmers (F5, F6) had undertaken plantings for bird habitat. One farmer (F7) had de-stocked and converted his landuse to a biodiversity offset which was yielding more income than sheep or cattle.

"I'm introducing biodiversity across every aspect of the system, from soil to vegetation and stock" (F6).

Chemical weed control was not a priority. Instead, cattle and holistic management were used to manage weeds.

Protecting freshwater wetlands also had low attention, with no farmers mentioning them.

Appendix 9: Environmental relative advantage - qualitative perceptions

Table 13: Perceived improvements to water balance

	BEFORE					AFTER				
	Poor	moderate	good	very good	excellent	Poor	moderate	good	very good	excellent
F1	1									1
F2	1									1
F3	1									1
F4	1									1
F5	1								1	
F6	1									1
F7	1									1
F8	1									1
Total	**8**								**1**	**7**

Table 14: Perceived improvements to water storage

	BEFORE					AFTER				
	Poor	moderate	good	very good	excellent	Poor	moderate	good	very good	excellent
F1	1									1
F2	1									1
F3	1									1
F4										
F5										
F6	1									1
F7										
F8										
Total	**4**									**4**

Table 15: Perceived improvements to vegetation

	BEFORE					AFTER				
	Poor	moderate	good	very good	excellent	Poor	moderate	good	very good	excellent
F1	1							1		
F2		1							1	
F3										
F4	1									1
F5	1						1			
F6	1									1
F7										
F8										
Total	4	1	0	0	0	0	1	1	1	2

Table 16: Perceived improvements to soil water, health and stability

SOIL WATER	BEFORE					AFTER				
	Poor	moderate	good	very good	excellent	Poor	moderate	good	very good	excellent
F1	1									1
F2	1								1	
F3										1
F4	1									
F5										
F6	1									1
F7										
F8										
Total	4	0	0	0	0	0	0	0	1	3

SOIL HEALTH	BEFORE					AFTER				
	Poor	moderate	good	very good	excellent	Poor	moderate	good	very good	excellent
F1	1								1	
F2	1								1	
F3										
F4	1								1	
F5										
F6	1									1
F7										
F8										
Total	4	0	0	0	0	0	0	0	3	1

	BEFORE	AFTER

SOIL STABILITY	Poor	moderate	good	very good	excellent	Poor	moderate	good	very good	excellent
F1	1								1	
F2	1								1	
F3										
F4	1									1
F5	1									1
F6										
F7										
F8										
Total	4	0	0	0	0	0	0	0	2	2

Table 17: Perceived improvement in pasture cover

	BEFORE					**AFTER**				
	Poor	**moderate**	**good**	**very good**	**excellent**	**Poor**	**moderate**	**good**	**very good**	**excellent**
F1	1									
F2	1									1
F3										
F4	1									1
F5	1									1
F6		1								1
F7										
F8										
Total	**4**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**4**

Appendix 10: The most commonly used sources of information

Table 18: The most commonly used sources of information for LR

Theme	Source	F1	F2	F3	F4	F5	F6	F7	F8	Total
Learning by doing	Observation trial & error	✓	✓		✓		✓		1	5
Reading material	Books		✓	✓	✓		✓	✓	✓	9
	Scientific papers				✓			✓	✓	
Peer-to-peer	Other farmers			✓		✓	✓	✓		11
	Field days	✓	✓	✓		✓	✓	✓	✓	
Allies	LLS	✓					✓	✓	✓	20
	Consultants			✓		✓	✓	✓		
	P. A. Andrews			✓	✓		✓			
	TMI		✓	✓		✓	✓			
	Scientists	✓	✓		✓		✓	✓		
Social networks	Landcare	✓	✓	✓			✓	✓	✓	6
	Industry groups									
Online resources	Web sites	✓	✓	✓			✓	✓	✓	13
	YouTube Videos	✓		✓	✓				✓	
	Podcasts			✓				✓	✓	
Training courses	Holistic grazing		✓				✓			8
	permaculture	✓	✓	✓						
	Biodynamics		✓				✓			
	TPT						✓			
Conferences	Conferences						✓			1
	Total	8	10	11	6	4	14	10	9	