Cost effective and practical ways to regenerate layer hen ranges

Final Project Report | **JANUARY 2024**

A report for Australian Eggs Limited

by C. T. de Koning, S. Clarke, E. McGahan, M. Copley and S. Wiedemann

Australian Eggs Limited Publication No. 31RS101SA

ISBN 978-1-920835-69-9

Project Title: Cost effective and practical ways to regenerate layer hen ranges

Australian Eggs Limited Project Number 31RS101SA

Researcher/Author Contact Details
Name: Carolyn de Koning
Address: SARDI, PPPI building, The University of Adelaide, Roseworthy Campus
Mudla Wirra Road, Roseworthy, SA, 5371
Phone: 08 8313 7781
Fax: No fax
Email: Carolyn.dekoning@sa.gov.au

In submitting this report, the researcher has agreed to Australian Eggs Limited publishing this material in its edited form.

Australian Eggs Limited Contact Details:

Australian Eggs Limited
A.B.N: 66 102 859 585
Suite 6.02, Level 6, 132 Arthur St
North Sydney NSW 2060

Phone: 02 9409 6999
Fax: 02 9954 3133
Email: research@australianeggs.org.au
Website: www.australianeggs.org.au

Published in January 2024

Foreword

This project focused on the strategies used by free range egg farmers for dealing with the heavily utilised areas on the range that are problematic due to high nutrient loads, and the ways they encouraged hens to range further from the shed. Firstly, a literature review was conducted to gather results from around the world on strategies used to maintain range areas. Secondly, an online survey was undertaken to gain insight from Australian free range egg farmers as to what range regeneration strategies worked, those that were unsuccessful, and some of the cost involved. Thirdly, targeted interviews were conducted with free range farmers of different production systems (e.g. fixed shed/ fixed range vs. mobile caravan/shed), flock sizes, and outdoor stocking densities. This enabled the research team to gather information from across Australia's diverse climatic zones and soil types. Finally, soil samples and plant tissue samples were collected from three farms to measure the impact of high nutrient loads on the permanent vegetation planted on the range. The main output from this project was a Guideline Package, outlining successful range regeneration strategies and the costs involved with their implementation.

This project was funded from industry revenue, which is matched by funds provided by the Australian Government.

This report is an addition to Australian Eggs Limited's range of peer reviewed research publications and an output of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

Most of our publications are available for viewing or downloading through our website:

www.australianeggs.org.au

Printed copies of this report are available for a nominal postage and handling fee and can be requested by phoning (02) 9409 6999 or emailing research@australianeggs.org.au.

Acknowledgments

The research team would like to thank all the participant farmers for taking the time out of their busy schedules to take part in the online survey, to speak with us, allowing us to visit your farms, and sharing invaluable insights about range regeneration practices on your farms.

Australian Eggs Limited provided the funds that supported this project.

About the Authors

Dr. Carolyn de Koning: Carolyn has over 25 years' experience in pasture variety development, ecology, and agronomy. In the last decade, Carolyn has redirected her skills and experience into free range poultry research with an emphasis on the outdoor range environment. The focus has been on using plants and other enrichments to encourage ranging behaviour by layer hens and meat chickens.

Dr Simon Clarke: Simon is an agricultural scientist with a research background in the applied plant sciences and the tracing of elemental flows through ecosystems.

Eugene McGahan: Eugene works as a private agricultural/environmental engineering consultant. He has spent the last 30 years working predominantly on environmental and resource management issues related to agricultural and agro-industrial industries, with a particular focus on the intensive animal industries.

Mary-Frances Copley: Mary-Frances is an agricultural consultant with a background in economics and a primary focus on life cycle assessment and environmental performance in egg, chicken meat, and pork production.

Dr Stephen Wiedemann: Stephen Wiedemann is the principal research scientist and owner of Integrity Ag & Environment. Stephen has spent his professional career working in agri-environmental research, development and extension in areas including nutrient management, environmental guideline development, and many others. He is a long-term environmental researcher in the livestock industries and is a co-author of the egg industry Environmental Guidelines.

Table of Contents

List of Tables

List of Figures

Abbreviations

F	Fixed shed with a fixed range
FSD	Fixed shed with subdivided range
M	Mobile caravan or shed
SEM	Standard error of the mean
ANOVA	Analysis of variance

Executive Summary

Free range layer hens can be damaging while they are foraging on the outdoor range. Their scratching and pecking behaviour causes physical damage to tree roots and groundcover plants. In addition, nutrients (e.g. nitrates and phosphorus) from hen excreta build up in soils where hens congregate close to the shed and under shelters and trees. As a result, the functionality of the range can be diminished, with the increase of weed plant species, soil compaction in heavily utilised areas and parasite build up in soils. Cost effective and practical strategies and design features are needed to mitigate the impacts caused by hen activities on the range. This project had four components that enabled the collection of information on successful range regeneration strategies from different sources that considered the diverse climate and soils of Australia. The four components of the project were: 1. Literature review; 2. Online survey; 3. Targeted case study interviews; and 4. The impact of high soil nutrient levels on trees and shrubs growing on the range.

1. Literature review

The literature review collected information from around the world on strategies used to maintain range areas from a variety of free range systems. Pros and cons of the strategies were outlined. Although many of the references were from Europe and the UK, valuable insights were found that could have relevance to Australian free range systems. Vegetation was the primary focus of the review because of the multifunctional role of vegetation on the range, in that it provides shelter, shade, enrichment, intercepts nutrients, reduces erosion, buffers odour and improves the attractiveness of the farm. The main strategies examined were rotation systems whereby a section of the range could be rested, the use of enrichments on the range to encourage hens to disperse more evenly across the range, the use of vegetation to entice hens further onto the range, wintergardens, and managing the area immediately outside the shed.

2. Online survey

An online survey was conducted to gain the perspectives of Australian free range egg farmers on their regeneration strategies. Several design features were utilised by fixed shed/fixed range (F) respondents to manage nutrients on the range – they included hard compacted surface immediately outside the shed, vegetative filter strips, pipes to redirect shed runoff water outside the range, wintergardens, and runoff diversions such as contour banks and interception banks. Fixed shed with subdivided ranges respondents (FSD) used hard compacted surfaces outside the shed, vegetative filter strips and pipes to divert water away from the range. Mobile caravan/shed respondents (M) used hard compacted surfaces and vegetative filter strips. Trees were used extensively by F respondents as an enrichment strategy to entice hens further onto the range, but not so by M respondents. Another common enrichment used by F respondents were hay bales. Mobile caravan respondents did not see the need for enrichments as the hens would follow the caravan.

3. Targeted case study interviews

Fourteen targeted case study interviews were conducted with free range farmers with different production systems (F, FSD and M), flock sizes, and outdoor stocking densities. This enabled the research team to capture information from across Australia’s diverse climatic zones and soil types. Most comments from F producers were about the trees and shrubs on the range. Whereas M producers wanted to maintain production without hens diluting their formulated diets by eating too much grass. Yet, grasses are an important component of the groundcover on M farms and required management to control excessive growth.

4. The impact of high soil nutrient levels on trees and shrubs growing on the range

Soil samples were collected from three case study farms to measure the impact of high nutrient loads on trees and shrubs planted on the range. The main permanent vegetation types on the farms were Oldman saltbush, olive trees and grapevines. Nutrient gradients across the range were found on two of the three farms, whereby soil nitrate and phosphorus levels were highest close to the shed and decreased further from the shed. Furthermore, nitrate and phosphorus levels were higher under saltbush, and higher nitrate levels were found under olive trees but not phosphorus. Both nitrate and phosphorus accumulated in the top 10 cm of soil. Despite high levels of nitrate and phosphorus found in soils closest to the shed, plant tissue analysis did not reflect high nitrate, nitrogen % and phosphorus % in olives, saltbush, or vines.

The main output from this project was to develop the Guideline Package for free range egg farmers which incorporated information from all four project components.

Overall Conclusions

Fixed shed producers were using many different strategies and design features to maintain and regenerate the range. The main strategy for M producers was to move the hens frequently. The area immediately outside the shed and the inner range was the biggest concern for F producers. This is where most strategies were being implemented at the greatest cost. Shorter term strategies involved the placement of rocks and bark chips, although bark chips were seen as a fire hazard in some states and territories. Rocks needed frequent topping up or replacement after every flock or every second flock. Longer term solutions were the use of wire or plastic mesh immediately outside the shed. The initial cost is much higher than rocks, but the mesh should last for at least 10 years. The most expensive and the longest-term option was to build a veranda or wintergarden on the shed.

Trees and shrubs were seen as very important by F producers to create shade, shelter, and a natural environment for hens. Their placement on the range was carefully considered and used to help encourage hens to range further from the shed. Most of the survey respondents and interviewed producers were happy with their tree and shrub survival. Tree survival problems arose when hens had scratched around the tree roots, where high water demanding species had been planted, and where dry seasonal conditions at planting and during establishment resulted in high tree deaths. A combination of fast growing and slow growing species of trees and shrubs was used to great effect. Biosecurity concerns about trees attracting wild birds was not overlooked. Many F producers planted trees no closer than 25 m from the shed so wild birds were not encouraged to be near the shed. Furthermore, this provided a fire break. Mobile caravan producers were not so interested in trees on the range. Treed areas were seen as potential refuges for vermin such as foxes, yet some M producers did use trees to provide sheds with extra shade when raising pullets in warmer weather.

Maintaining groundcover close to the shed on F farms was difficult, however straw bales were used to cover bare areas and give hens foraging material. Straw reduced the erosion risk and mopped up excess rain, which minimised muddy conditions on the range. Some farms used a rotation system to rest portions of their ranges. Another strategy was to design range areas 30% larger than required. This enabled F farms to renovate or resow 30% of the range at a time while still maintaining stocking density requirements. Too much grass on the range was an issue for some M producers. Particularly in spring, excess grass growth could result in hens consuming too much grass, thereby diluting their formulated diets, and potentially resulting in crop impaction and reduced production. This issue was tackled by mowing the range and opening the pop holes to the range after the hens had a chance to eat their formulated diet in the caravan/shed.

Nutrient levels (phosphorus and nitrate) in free range soils need to be monitored, especially in those areas close to the shed and under nearby trees. The case study farms demonstrated that nutrient gradients developed in soils across the range with the highest levels found closest to the shed. In addition, nitrate and phosphorus had increased in soils under trees and shrubs when compared to adjacent open areas of the range. Even though soil levels were high for nitrate and phosphorus close to the shed and under nearby trees/shrubs, the plant tissue results had shown the trees and shrubs only took up the nutrients they needed. There were no toxic levels found in the plant tissues in this study. Olive trees and saltbush had maintained healthy growth. Protecting the surface soil layer (0–10 cm) close to the shed from erosion is especially important as this is the layer with the greatest nitrate and phosphorus accumulation.

1 Background

Layer hens have sharp claws and beaks, and through pecking and scratching can damage or destroy non-woody plants and the root systems of trees and shrubs found in range areas. Elevated nutrient levels, which accumulate close to shade shelters, can also create conditions unsuitable for some grasses, trees and shrubs. This destruction and change in range soil conditions reduces the ability of the range to provide birds with suitable groundcover and shelter, increases runoff (by decreasing surface roughness and reducing infiltration), reduces the ability of nutrients to be sequestered by on-site vegetation, and reduces the aesthetic qualities of the range environment. The reduction in biological productivity may also reduce soil microbial activity. This may have unexpected consequences in the form of longer pathogen residence times within the range. These problems are exacerbated by high bird densities on parts of the range and poorly designed ranges. The latter may be common where former cage or shed production systems are converted into free range systems without considering the sustainability of range land resources. As the modern, large-scale free range sector is relatively new, long-term problems and their costs may not have been fully considered with respect to range design or management.

Re-sowing range areas on free range farms is an expensive process due to costly inputs such as seed, fertiliser, soil ameliorants and labour. Efforts to regenerate the range become very costly if plant establishment fails. However, regeneration of the range is required to meet free range standards of ground coverage and the provision of palatable vegetation on the range at all times (FREPA 2015, RSPCA 2015). Fixed shed farms stocked at 10,000 hens/ha need frequent regeneration because a large proportion if not all of the range is denuded of groundcover by the end of a flock's production cycle. Even those farms stocked up to 1,500 hens/ha need to renovate their ranges, particularly in heavily utilised sections of the range.

The objective of this project was to provide tailored solutions to cost-effectively maintain a range that improves productivity and satisfies animal welfare standards, without compromising other concerns, such as nutrient accumulation/runoff and fire risk. There were four components to this project to gather information on range regeneration strategies.

1. A literature review was undertaken to collect results from around the world on strategies used to maintain range areas.

2. An online survey was undertaken to gain insight from Australian free range egg farmers as to what range regeneration strategies worked, those that were unsuccessful, and some of the cost involved.

3. Targeted interviews were conducted with free range farmers of different production systems (e.g. F, FSD and M), flock sizes, and outdoor stocking densities. This enabled the research team to capture information from across Australia's diverse climatic zones and soil types.

4. Soil samples and plant tissue samples were collected from three case study farms to measure the impact of high nutrient loads on the permanent vegetation (trees and shrubs) planted on the range.

A Guideline Package was developed as the main output from this research project, incorporating information from the four components.

2 Literature review – strategies used to regenerate the range

2.1 Introduction

The specific aim of the literature review was to identify the pros and cons of pasture, shrub and tree regeneration options, and their application to modern free range egg farming. Emphasis was placed on groundcover vegetation and trees/shrubs, largely because on the range vegetation performs multiple functions. It creates a natural environment for hens to explore and forage, intercepts nutrient runoff, reduces erosion risks, provides shade/shelter, buffers odours, increases biodiversity, possibly provides an alternative income, and overall improves the aesthetics of the farm. The review identified that range pasture, shrub and tree regeneration strategies fall into two broad categories: the management of range usage, and range design.

Range use management strategies were those requiring decisions and actions over the timescale of a production cycle or shorter. These strategies included rotating through range areas and reducing hen activity in typical high-traffic areas (i.e. close to sheds and under shelter). The latter strategies included the use of objects and vegetation to encourage dispersal, and reducing stocking density. These strategies have been shown to aid hen dispersal across the range, yet deterioration of range resources can lead to fewer hens on the range. Strategies related to range design were potentially one-off decisions requiring a long-term (i.e. longer than a production cycle) modification of the range area.

Tables were used to clearly summarise the results of the literature review. Peer-reviewed and non-traditional literature were reviewed and sourced using Google Scholar and Google Search. For each relevant information source, this review notes the system type (fixed shed, mobile shed, organic) and outdoor stocking density, as well as the experimental design (control, treatment). Pros and cons are then identified, along with any comments that help frame the importance or relevance of the information reviewed.

Strategies not covered in this literature review are training birds to range (e.g. a stock person's skills to entice birds to follow), claw trimming (e.g. the blunting of toenails with abrasive materials to make them less damaging to vegetation) and understanding nesting behaviour (e.g. to reduce the number of birds moving or nest building close to the shed by checking for overused nest boxes).

2.2 The management of range usage

The management of range usage involves rotating range areas to regenerate vegetation in range areas (Table 1); enrichment to encourage dispersion across the range (Table 2); using vegetation to encourage dispersion (Table 3); and reducing stocking density (Table 4). Plants with potential beneficial properties are also discussed (Section 2.2.1).

Table 1 Literature review of pros and cons of rotating ranges to regenerate vegetation in range areas

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Maurer et al. (2013)	O	< 2,500	Access to full range.	Access to ¼ of range for 3 to 4 weeks.	Bare soil 18 m from shed decreased from 90% to 22%.	Despite increased groundcover, N supply > demand. Narrow range difficult to mow.	Had a wintergarden
Fürmetz et al. (2005)	M	< 1,500	Mobile shed fixed for 12 weeks.	Mobile shed moved after 2 weeks in summer, 6 weeks in winter.	Moving the mobile shed avoided destruction of groundcover despite 75% of hens staying within 20 m.		German research
Elkhoraibi et al. (2017)	M	Not specified	NA – survey.	NA	96% of respondents rotated their flocks on ‘pasture’. 28% said ‘managing soil and vegetation’ was their most important challenge, and 62% were interested in maintaining year-round optimum vegetation cover, but ranked the need for this information low.	Managing manure under the mobile shed can be problematic, including a food safety hazard. Producers may be more concerned with issues relating to short-term operating costs than long-term sustainability.	USA research
Spencer (2013)	Not specified	Not specified	NA – review.	NA	The key to healthy pasture is to monitor its condition, including damage by hens and the amount of manure deposited. Use sacrificial paddocks when groundcover is vulnerable, such as when groundcover is dormant or soil is wet.	None listed	USA perspective

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Sossidou et al. (2008)	F	< 2,500	Topsoil, cultivated, sown with grass mix.	Sterilised topsoil compost, compost + sand; all sown with grass mix.	Grasses sown on other (non-compost) treatments declined to 50% cover in one to two months.	Grasses sown on compost (the treatment preferred by hens) declined to 50% cover in about 3 weeks.	Study didn't examine rotations but presented useful information on groundcover loss over time.

[1] F – Fixed sheds; M – Mobile sheds; O – Organic.

Table 2 Literature review of pros and cons of using enrichment to encourage dispersion

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
De Koning et al. (2018)	F	1,500 & 10,000	No enrichments	Continuum of objects on the range included shelters, hay bales, dust baths & traffic cones.	Shelters, dust baths & hay bales were well utilised.	Hay bales & dust baths can attract egg laying.	At least twice the number of hens used the enriched range compared with the non-enriched range.
Zeltner and Hirt (2003)	O/F	< 2,500	Barren range, no trees or shrubs.	Dust bath structures with roof.	Structure influenced distribution of hens, higher percentage of hens found in the furthest part of the range with dust bath structure.	Structure did not increase the use of the range.	More hens may have used the range if they had more time to become familiar with the structure.
Zeltner and Hirt (2008)	O/F	< 1,500	Minimal enrichments – shelters and/or trees. No perches & no pecking objects. Some farms had dust baths.	Variety of enrichments to cater for shelter/shade, perching, dust bathing, scratching & pecking. Shade was a combination of constructed structures and trees.	A variety of different structures attracted more hens to use the range, and across a greater proportion of the range.	Narrow tunnel structures possibly prevented the movement of hens further onto the range when these were the only structures available.	Presence of different structures more important than % cover. Placement of attractive structures should not be too close to the hen house. A variety of structures should be evenly distributed across the range.
Nagle and Glatz (2012)	F	< 2,500	No access to shade cloth shelters, extra forage & shelterbelts.	Access to shade cloth shelters, extra forage, hay bales & shelterbelts.	Forage and hay bales attracted the greatest number of hens onto the range.	Number of hens using the forage & hay bale areas decreased with time, probably because those resources were being depleted.	When pasture is unavailable, the provision of shade cloth shelters, shelterbelts & hay bales was an excellent alternative to entice hens onto the range.

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Bright et al. (2011)	F	< 1,500	No canopy cover.	Up to 100% canopy cover within tree planted areas.	High percentage canopy cover within tree planted areas; hens had reduced plumage damage.	End of lay plumage damage not correlated to proportion of tree cover (5–90%).	Providing a minimum of 5% tree cover with high canopy cover close to the house may be a strategy to reduce feather pecking damage. Could use trees to entice hens further away.

[1] F – Fixed sheds; M – Mobile sheds; O – Organic.

Table 3 Literature review of pros and cons of using vegetation to encourage dispersion

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Borland et al. (2010)	F	< 1,500 (outdoor stocking density 275 hens/ha)	No shelterbelt	Shelterbelts	67.4% of hens went outdoors when provided shelterbelt compared to 58.5% without shelterbelts.	Small experimental flocks.	Hens ranged further with shelterbelts, with more foraging and running behaviours.
Basset (2009)	Not specified	2,000 hen flock, outdoor stocking density not specified.		Case study – sown seasonal cover crops in strips (sunflower & maize), at 3 locations on the range.	Improvement in ranging behaviour. Helped maintain vegetation on the range. Provided cover for hens and later provided seed for foraging hens.	Need to fence off cover crop areas to protect young plants from hens until plants are at least above hen height. Cover crop can also hide predators, therefore sow inside predator proof fence. Seed may attract wild birds.	Hens eager to get into cover crop and moved across range to get there.
Nagle and Glatz (2012)	F	< 2,500	No access to shade cloth shelters, extra forage & shelterbelts.	Access to shade cloth shelters, extra forage, hay bales & shelterbelts.	Shelterbelts encouraged hens further from the house.		17 times more hens used the shelterbelt areas compared to control areas.
De Koning et al. (2018)	F	10,000	No control – observational study.	Small pine forest area located 40 m from shed.	Natural cover provided by trees attracted the greatest number of hen visits, with foraging and dust bathing behaviours.	No resting and/or perching behaviour observed in pine forest, probably due to no understory of low growing shrubs.	Hens travelled across open ground to reach pine forest.
De Koning et al. (2018)	F	< 1,500	No control – observational study.	Only 1 flock out of 4 flocks studied had access to 1 ha olive plantation; trees evenly spaced.	Of the 4 flocks studied, hens with access to olive trees had the best plumage.		Olive trees provided 30% overhead cover. Postulated even distribution of overhead cover enticed large numbers of hens outdoors and

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
							contributed to low plumage damage.
de Koning (2020a)	F	10,000	No saltbush.	Oldman saltbush (*Atriplex nummularia*) planted in rows beginning > 50 m from the house.	Saltbush encouraged dust bathing, foraging and resting behaviour > 50 m from the house.	Drought conditions prevented the sowing of groundcover such as lucerne and annual *Medicago* species between saltbush rows.	Saltbush provided shade and shelter. Hens utilised the range area with saltbush even though annual groundcover species had died off.
Boosten and Penninkhof (2018)	F/O	No flock size or stocking density specified.		Pilot trial – short rotation willow coppice.	Hens were seen to range 250 m from house. Over 75% of the flock outside with even dispersion across range.		Netherlands, demonstration across 4 farms.

[1] F – Fixed sheds; M – Mobile sheds; O – Organic.

Table 4 Literature review of pros and cons of reducing stocking density to regenerate vegetation in range areas

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Campbell et al. (2017a); Campbell et al. (2017b)	F	2,000 10,000 20,000	10,000 hens/ha	2,000 and 20,000 hens/ha	Groundcover dropped to 0% within 5 weeks, and to 20% at 8 weeks, in the highest and lowest stocking densities, respectively.	Egg quality attributes may change with stocking density, reflecting the proportion of commercial feed in the diet.	At low stocking densities, hens made fewer but longer visits to the range.
Gilani et al. (2014)	F, O	40,000 – 120,000	NA	Survey of producers	Proportion of flock on the range at lay was greater at lower stocking densities.	No correlation between feather pecking and ranging.	Range usage was also increased by minimising the difference in light intensity in/outside the shed, and by pop hole availability.

[1] F – Fixed sheds; M – Mobile sheds; O – Organic.

2.2.1 Potential added benefits from plants grown on the range

In addition to plants providing shade, shelter and forage on the range, there could be added benefits from some plants to enhance flock production, improve hen health and remediate soil by utilising excess nutrients deposited on the range. The feasibility of using plants *in situ* on the range for these purposes is discussed.

Plants contain numerous and a wide variety of bioactive compounds. Mostly, they are utilised in the feed ration or drinking water, and come in various forms such as dried plant parts, extracts, seeds and essential oils. Bioactive compounds from plants are being researched for a broad range of beneficial properties (e.g. anti-worm, anti-inflammatory, antioxidant and anti-microbial) to reduce the reliance on synthetic anthelminthics and antibodies. Resistance of microorganisms and worms to synthetic antibodies and anthelminthics is a great concern for animal production including poultry. Many reviews have been written in the last decade examining the potential of plant bioactive compounds in poultry diets (Wallace et al. 2010; Hashemi & Davoodi 2011; Abbas et al. 2012; Christaki et al. 2012; Diarra 2014; Adil et al. 2015; Diaz-Sanchez et al. 2015; Yitbarek 2015; Zeng et al. 2015; Acamovic & Brooker 2005; Akyildiz & Denli 2016; Ezzat Abd El-Hack et al. 2016; Yadav et al. 2016; Madhupriya et al. 2018; Pliego et al. 2020). Although many bioactive compounds are found to be effective, there is acknowledgement that it is difficult to have a consistent product due to the varied ways plants grow and widely different concentrations of the bioactive compounds produced (Yadav et al. 2016). It is also acknowledged that some plant bioactive compounds can have adverse effects (Pliego et al. 2020). Furthermore, there is more to understand about their modes of action (Zeng et al. 2015).

Given some plants have reputed bioactive compounds, is there scope to grow such plants *in situ* on the range of free range layer farms? However, there are very few examples of plants being grown *in situ* on the range of commercial farms for their medicinal or production enhancement properties (Kosmidou et al. 2004). This is because it would be difficult to ensure all birds in a flock self-medicate and some birds will consume less than others. Planting medicinal plants on the range would be more feasible for small flocks at low outdoor stocking densities (e.g. organic and pastured poultry enterprises) as a high proportion of small flocks have been shown to use the range (Gilani et al. 2014; Bestman et al. 2019). Yet, some medicinal plants are not palatable to hens and are considered weeds (e.g. stinging nettle – *Urtica dioica*). Therefore, their use on the range as a medicinal forage plant is limited. A list of plants with medicinal properties that maybe planted on the outdoor range was suggested by Groot et al. (2011) (Table 5). These plants have no products developed as feed or water additives. Nevertheless, some plant species listed are considered weeds in Australia. In addition, Groot et al. (2011) have listed 45 plant species for which plant-based products have been formulated. A higher level of efficacy is more likely to be achieved with plant-based products rather than relying on plants grown *in situ*.

Green plants can remediate soils containing organic and inorganic contaminants, this is through absorption, sequestration and metabolic transformation and is referred to as phytoremediation (Cunningham & Berti 1993). Through natural physiological processes, plants have the ability to pump large volumes of water, solutes, and organic matter. This ability can be utilised in phytoremediation, but there are physiological limitations to phytoremediation (Robinson et al. 2003). However, phytoremediation could be a strategy for dealing with excess nutrients deposited on the range. It has been shown that lucerne and chicory can sequester excess nutrients found in soil (Russelle et al. 2011; Alloush et al. 2003), both species are suitable for growing on the free range farms in Australia. Forage needs to be cut and taken away from the affected site for the benefit to be fully effective. Another strategy is to plant buffer strips of vegetation that can intercept nutrient runoff. These areas will need to be fenced off from hens. Bamboo and false bamboo (*Arundo donax*) have been used in the past on chicken runs (Anon. 2014) to provide fast growing shelter/windbreaks, and utilise high nutrient levels (especially N, P & K – Anon. 2014). Careful consideration is needed if bamboo is to be used on the range as some species are declared weeds in some states of Australia (*Arundinaria simonii f. variegata* and *Phyllostachys* spp. – Weeds Australia website, www.weeds.org.au). There is a need to assess the efficacy of plants to remove nutrients from soils on free range farms.

Figure 1 Stinging nettles (*Urtica dioica*)

Figure 2 Wormwood (*Artemisia absinthium*)

Table 5 Plants that may be grown on outdoor ranges for their medicinal properties and known weed status in Australia

Common name	Botanical name	Plant part used	Bioactive compound	Application	Weed status in Australia (Yes/No)
Willow	*Salix* species	Leaves & bark	1% to 11% salicylates, tannins & flavonoids	Against pain, fever & infection	Yes and No (some species are considered Weeds Of National Significance)*
Yarrow	*Achillea milefolium*	Herb	Essential oil 0.2%, up to 40% is chamazulene, bitter substance	Improves digestion, metabolism & circulation	No
Wormwood	*Artemisia absinthium*	Herb	Bitter substances (artemisinin), essential oil (mainly thuyon and azulene)	Digestion, increase appetite, against parasites	No
Dandelion	*Taraxacum officinale*	Root or herb	Inulin – the root contains up to 40% in autumn, bitter substances, flavonoids, several vitamins and minerals	Digestion, liver, prebiotic, vitamins & minerals	Yes+
Elder	*Sambucus nigra*	Flowers & berries	Essential oil 0.02% to 0.15% & flavonoids	Resistance, metabolism, circulation	No
Meadowsweet	*Filipendula ulmaria*	Flowers & leaves	Salicylates, flavonoids (5%) & tannins	Against pain, infection & fever	No
Stinging nettle	*Urtica dioica*	Leaves	Folic acid, acetic acid, histamine, choline, silicium, many vitamins and minerals (mainly iron) & tannins	Improves calcium metabolism, improves bone development, protects intestines, vitalises, adds minerals and trace elements, supports respiratory tract & general health	Yes+
Plantain	*Plantago* species	Herb	Silicic acid & tannins	Against diarrhoea, optimising metabolism	Yes and No (some species have been developed as pasture varieties)+
Wireweed	*Polygonum aviculare*	Herb	Strengthens plumage during moulting	Silicic acid, tannins & flavonoids	Yes+

Table modified from Groot et al. (2011).

* Weeds Australia website https://weeds.org.au (accessed 25/11/2020).

\+ J.L. Wilding, A.G. Barnett and R.L. Amor (1998) In: "Crop Weeds", published Australia, 154 pages.

2.3 Range design

There are four range design features covered in this section: resistant groundcover (Table 6); agroforestry and silvopoultry systems (Table 7); wintergardens (Table 8); and alternative surfaces immediately outside the shed (Table 9).

Table 6 Literature review of pros and cons of resistant groundcover

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Breitsameter et al. (2013)	F	Equivalent of 40,000 hens/ha	No control	14 species of pasture plants (grasses, legumes, herbs), three stocking durations.	Grasses more resilient to hen activity.	Legumes and herbs less resilient than grasses to hen activity.	The use of disturbance-tolerant grassland species would be suited to outdoor ranges.
Breitsameter et al. (2014)	F	Equivalent of 40,000 hens/ha	No control	14 species of pasture plants (grasses, legumes, herbs), three stocking durations.	*Festuca arundinacea* & *Poa supina* showed resilience to hen activities.	Hens are attracted to and readily peck at soft leaf plants (e.g. legumes & herbs).	Choice of plants, some that offer pecking incentive and others resilient groundcover.
de Koning (2020b)	F	≤ 1,500	No control	Green groundcover percentage measured at 10 m, 20 m & 40 m from shed.	Lucerne (*Medicago sativa*) and Lagoon saltbush (*Atriplex suberecta*) provided some green groundcover under drought conditions.		Green groundcover percentage and pasture height increased further away from shed.

[1] F = fixed sheds; M = mobile sheds; O = organic.

Table 7 Literature review of pros and cons of agroforestry or silvopoultry systems

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Boosten and Penninkhof (2018)	F/O	Not specified		Pilot trial – short rotation willow coppice.	Possible income from willow as woody biomass. Willow fast growing.	Newly planted willows needed protection from hens for 3 months.	Study from Netherlands.
Philipps et al. (2002)	M/O	Broilers		Tree rows with understory shrubs.	Trees and shrubs planted in hedge rows 50 m apart. Diversity of plants in rows.	No perches or dust baths. Birds are not exploring away from the shed.	UK study. Hedge planting to enable the mobile house to move between, also allow space for cropping.
Hermansen et al. (2017)	O	Not specified		Apple orchard & mixed broadleaf trees.	Alternative income from fruit, fruit juice and wood chips for biofuel. Hens may provide control of apple scab.	Trees can compete with the understory grasses and other groundcover plants. Young trees and shrubs need protection from hens.	Extension document based on a farm in Netherlands & in the UK.
Smith et al. (2017); Westaway et al. (2018)	M/O	≤ 1,500	Unsown control	Three pasture mixtures sown under trees. In addition, high chicken pressure plots = pasture mixtures sown 25 m & low chicken pressure plots sown = 50 m from house.	All three pasture mixtures suppressed unpalatable weeds. Possible to establish pasture under trees.	Difficulty maintaining pasture under trees due to chicken activity. Unpalatable weeds replaced sown species when chickens were reintroduced after the rest phase. Sown species almost disappeared from the high-pressure swards sown closest to the shed.	UK study. System best suited to small organic flocks at low stocking density. Possibility of using alley cropping system.
Woodland Trust (2014)	O	Not specified		Tree planting for Woodland Standards for poultry products in the UK.	Trees to provide cover to encourage ranging and facilitate a repertoire of behaviours. Reduce nutrient load around sheds.		Extension document from UK

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Stadig et al. (2018)	O	Not specified		Economic risk analysis of short rotation coppice production scenarios with free range poultry. Interviews with free range farmers and their attitudes to short rotation coppice.	Risk analysis revealed most modelled scenarios had a positive net present value, although low. Price premiums for poultry products, especially for those farms selling directly to the consumer.	Farmers interviewed perceived the short rotation coppice to be labour intensive and not likely to make a profitable return on investment. Biomass used on farm for heating had the highest risk of negative net present values based on the risk analysis.	Netherlands

[1] F – Fixed sheds; M – Mobile sheds; O – Organic.

Table 8 Literature review of pros and cons of using wintergardens as a strategy to regenerate vegetation in range areas

Reference	Context		Control	Treatment	Pros	Cons	Comments
	System [1]	Density (hens/ha)					
Rault et al. (2016); Thuy Diep et al. (2018)	F	< 1,500	NA – one site	NA	Wintergarden promoted similar behaviours to those observed in the range proper, promoted by litter to forage amongst. Hens spent half their time in the wintergarden.	Current literature and regulatory policies are contradictory when referring to the wintergarden as it is both an indoor and outdoor environment.	The range lacked canopy cover or artificial shelter.
Elson (2015)	F	Not specified	NA	NA	A hybrid between an indoor and outdoor could allow natural behaviours and protect hens from predators.	Wintergarden may not be recognised as part of the range for labelling purposes.	
Knierim (2006)	F	Not specified	NA – review	NA	Welfare benefits of the range can be realised by using a covered outside run. Wintergardens can reduce mud trafficking into the shed.		

[1] F – Fixed sheds; M – Mobile sheds; O – Organic.

Table 9 Literature review of pros and cons of using alternative surfaces to manage areas immediately outside sheds

Reference	Context [1]		Control	Treatment	Pros	Cons	Comments
	System	Density (hens/ha)					
Maurer et al. (2013)	O	< 2,500	Untreated	Woodchips over first 10 m of range.	Bare soil 36 m from shed decreased slightly – from 33% to 23%. *Heterakis* and *Ascaridia* fecal egg counts significantly reduced in first 10 m of range.	No change in severe denudation of first 18 m. No difference in worm burdens.	Had a wintergarden.
Wiedemann and Zadow (2010)	F	Not specified	NA - survey	NA – survey	A compacted or concrete pad in the first 10–20 m around sheds could assist collection of nutrient-rich soil and manure.	Strategies to contain runoff should be used in conjunction with these surfaces. Costs of labour and infrastructure. Lack of information indicating whether efforts made a difference on nutrient levels.	

[1] F – Fixed sheds; M – Mobile sheds; O – Organic.

2.4 Conclusions

The literature review identified a diverse range of strategies for regenerating the function of range areas. The key findings associated with these strategies are summarised below.

Rotate range areas – Because this strategy requires taking land out of production it may be unacceptable for financial reasons. There is a need for further information on this strategy from higher density, F operations. The available evidence shows this may be a viable strategy for maintaining groundcover using low stocking densities.

Use enrichment to encourage dispersion – A variety and combination of enrichment structures were found to be the most effective, such as shade from trees, constructed shelters, dust baths, hay bales and pecking objects. Structures need to be maintained to continue being effective.

Use vegetation to encourage dispersion – Trees and shrubs were instrumental in attracting more hens onto the range. Trees need to have high percentage canopy coverage to offer the most overhead security and protection to hens.

Potential added benefits from plants grown on the range – Plants with production enhancement and/or health properties are best utilised in product form. Only small flocks with low outdoor stocking densities may benefit from plants with bioactive compounds grown *in situ* on the range. Some plants can sequester excess nutrients in the soil (e.g. bamboo). This ability needs to be explored on free range farms in terms of efficacy, but with consideration given to weediness risk.

Reduce stocking density – This practice may be effective at avoiding (but not eliminating) a reduction in groundcover over a production cycle. Like rotating ranges, this treatment may be economically unviable because it directly affects farm productivity.

Establish resistant groundcover – Grasses tend to be the most resistant to hen activity when compared to legumes and herbs, partly because hens prefer soft leafed plants such as legumes and herbs. Groundcover is a function of distance from the shed with increased groundcover moving further from the shed.

Agroforestry or silvopoultry systems – Examples were from organic systems in the Netherlands and the UK. Trees enticed hens out to use the range, however, there were issues with maintaining groundcover under trees. High pressure areas close to the shed would become weed dominated. Australian systems would require development, and for the economics of the systems to be evaluated.

Wintergardens – The welfare benefits of the range can be realised by using a covered outside run but current labelling standards do not recognise this practice.

Alternative surfaces immediately outside shed – Treatments identified included covering the inner range area with wood chips, rolled rubble or with a surface that could be scraped to remove manure. However, evidence indicating such treatments are effective or economically viable is needed.

In addition, other strategies may be helpful, for example training birds to move further out onto the range, claw trimming (e.g. using abrasive material in the shed), and bird management around the period of pre-laying.

3 Online survey of Australian free range egg farmers

3.1 Introduction

Human ethics approval for the online survey was granted through the University of Adelaide Human Ethics Committee (Approval number H-2021-023). The online survey was created on SurveyMonkey® and the invitation to take part in the survey was sent out via email on 29/03/2021 and 8/04/2021 by Australian Eggs Limited to 140 free range producers. The survey closed 12/04/2021. In total there were 17 respondents of which 12 respondents fully completed the survey. Nine respondents indicated they were willing to have a researcher contact them to further discuss their regeneration strategies. The first questions of the survey determined the type of free range system egg producers were running (F, FSD & M), along with the farm's soil type and rainfall. Remaining questions were related to the plants that are growing on the range, the strategies used to regenerate the range areas, bird husbandry practices that may influence ranging behaviour, and producer attitudes to free range farming. Initially, responses to all questions were compiled without using any filters. A filter for farming systems was then applied. Only responses that showed a trend were graphed and categorised on the type of free range farm system – mobile caravan/shed, fixed shed with subdivided range areas, and fixed shed with fixed range. Other filters tried were outdoor stocking density and average flock size, but due to the low responses in each category these did not show trends and are not reported. The number of respondents for each section of the survey is noted. Even though respondent numbers were low, information collected from the survey provided insights into regeneration of layer ranges in Australia. Several strategies are used by free range producers to regenerate range areas, after taking into consideration the level of cost involved.

3.2 Key survey results

Key results from the survey have been highlighted in this section. They include design features to manage nutrients on the range, plants sown/planted on the range, strategies to regenerate range areas with groundcover, and enrichment strategies to encourage hens to disperse across the range. More details on farm demographics, real and potential problems, and farmer attitudes to free range poultry can be found in Appendix A.

3.2.1 Design features to manage nutrients on the range

Design features to manage nutrients on the range are shown in Figure 3. The most common design feature used by all three production systems was hard/compacted surfaces in the first 0–10 m from shed and vegetative filter strips. One respondent commented that their sandy soil managed nutrients well. Respondents with F ranges had the greatest number of different design features (Figure 3). This contrasts with M producers who used two design features: hard compacted surfaces, and vegetative filter strips. However, this is based on only two responses. Producers with fixed shed/ subdivided range (FSD) used the same design features as M producers in this survey, although one respondent also used roof guttering and pipes to divert water off the range.

Rocks were commonly utilised to manage the area immediately outside sheds (4 respondents). Other surface types used were compacted hard surfaces (2 respondents), rubber matting (1 respondent), wire mesh (1 respondent), and wood chips (1 respondent). Only one respondent indicated that nothing had been done in the first 0–10 m. Mobile caravan/shed producers specified they move often so it is not a problem.

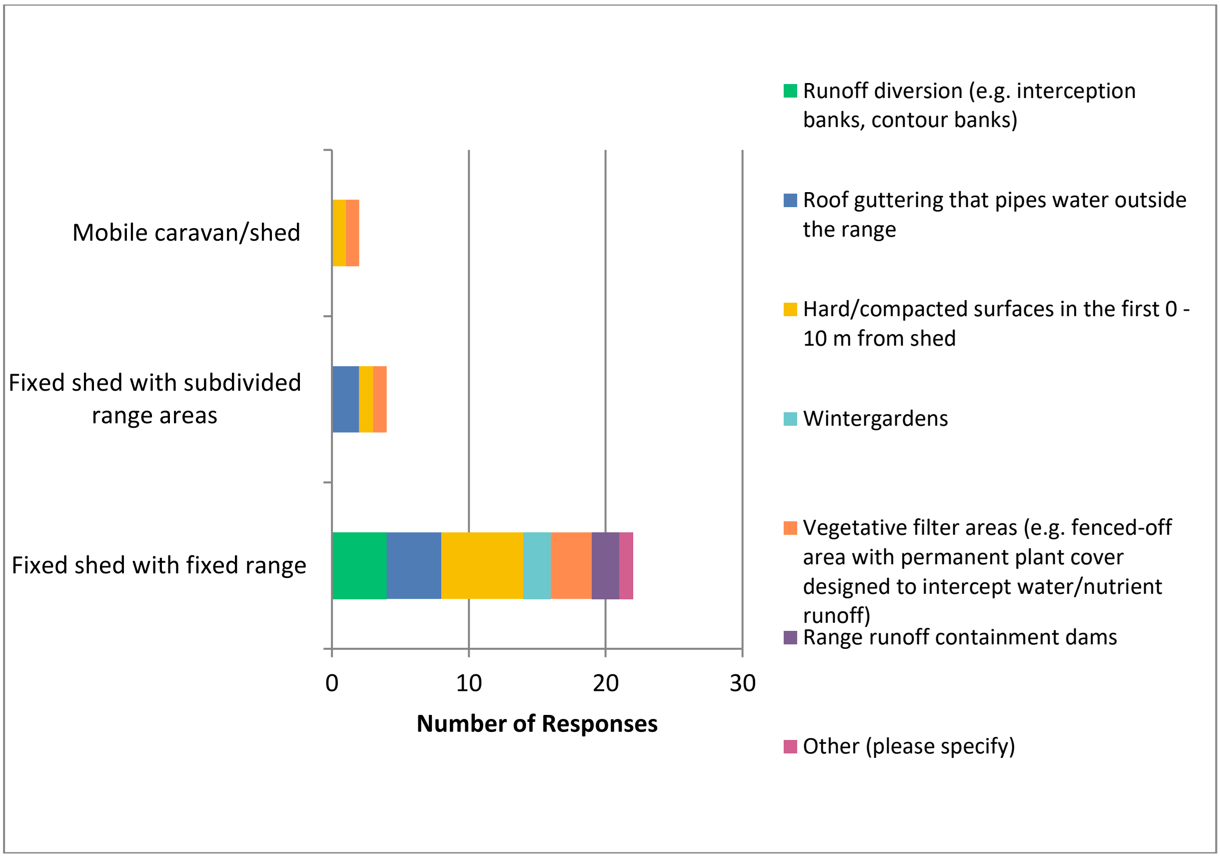

Figure 3 The question was asked of free range producers "Do you have any design features to manage nutrients on the range?" Producers could select more than one answer (response)

The cost to implement design features to manage nutrients varied from less than $50/ha to greater than $200/ha, although five respondents were not sure or didn't know the cost. Most respondents with F (7 respondents) had indicated a cost for implementing design features for nutrient control, only one respondent in this group indicated they were not sure, don't know. In contrast, M respondents replied not sure, don't know (2 respondents), and two FSD respondents were not sure, don't know. Soil samples to monitor soil nutrient levels (e.g. nitrogen and phosphorus) were only taken by half the respondents (8 from 16), with only one respondent sampling yearly. Four respondents sampled soil every 2 years, two respondents every 3 years, and another respondent sampled five years ago.

Fourteen respondents answered the question "How much it cost them to repair damage to the range surface such as dustbathing holes and exposed tree roots?" Unlike the question about design feature costs, more respondents indicated a repair cost, and there was only response "not sure, don't know" response. Repairs cost mostly $100/ha through to > $200/ha, with only one respondent spending less than $50/ha. Repairs to the range were made frequently, with the majority of respondents making repairs after every flock (11 respondents from 16). One respondent would repair the damage after every second flock, and another after every third flock. Two respondents never had to make repairs, and were M producers, although another M producer made repairs after every flock. One respondent indicated that the need to repair the range: "Depended on the season. A good year equated to good groundcover, therefore less need to repair. Also, good growth of grasses with runners." For those respondents who had never made any repairs, they were asked how many years the area had been used for free range production? The responses were 4, 5 and 6 years.

3.2.2 Plants sown/planted on the range

Over half of respondents (9 from 15) had indicated the survival of trees and shrubs on their ranges was 'very good' and 'good' ('Very good' survival with a loss of less than 5%/yr, and 'good' survival a loss of between 5% and 10%/yr). For those respondents with poor tree/shrub survival (loss of > 50%), the main reasons were attributed to exposed roots from hens scratching (2 respondents), tree/shrub species with high water use requirements with a need for too much ongoing watering once established (1 respondent), and low rainfall (1 respondent).

The type of free range farm system influenced the choice of plants, respondents with F had many reasons for their plant choices, Figure 2. The most common reasons were: plants reputed to be resistant to hen activity; advice from local agronomist; and ease of establishment. Mobile caravan/shed respondents also used advice from local agronomist to make plant choices, along with reliance on what is already growing on the range, and nutritional pasture species ('other' category, Figure 4). Respondents with FSD chose plants reputed to have resistance to hen activity, drought tolerance, and ease of establishment.

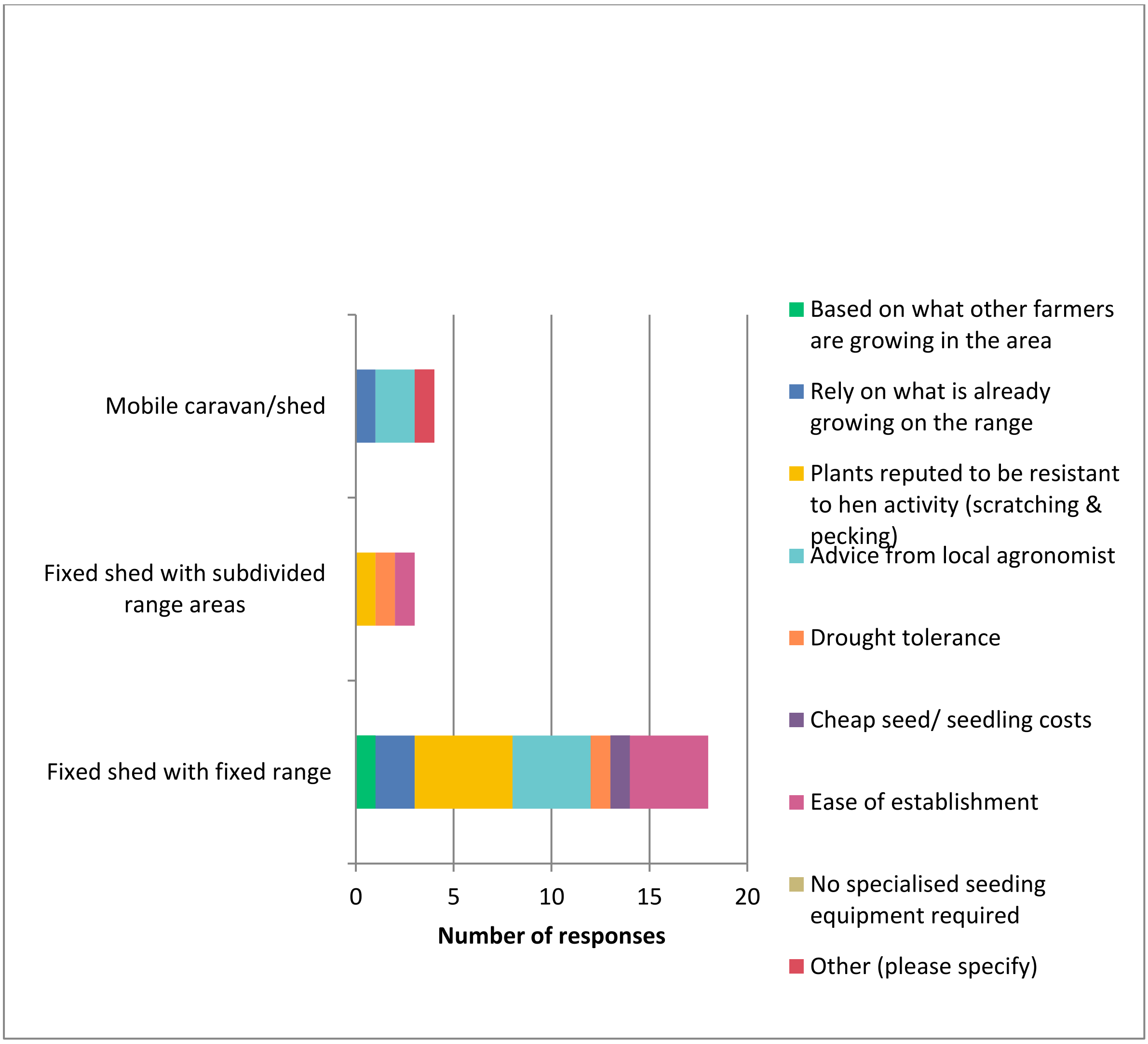

Figure 4 The question was asked of free range producers "If you have planted/sown your range – What influenced your choice of plants to use on the range?" Producers could select more than one answer (response)

3.2.3 Strategies used to regenerate range areas with groundcover

A rotation system is a strategy to regenerate groundcover, whereby hens are excluded from an area of the range for a period to allow the groundcover to regrow (rest period). Rotation systems require additional land and subdivisional fencing while still maintaining the outdoor stocking density accreditation. Twelve respondents answered the questions on rotation systems. Four respondents had never used a rotation system, three respondents had a rotational system as part of their original range management (which continues to be practiced), another three respondents had used a rotational system, but it is no longer a part of their current range management, and two respondents used an M system. A three-paddock rotation is being used by a respondent with FSD, while a respondent with an M system uses a 4-paddock rotation. One respondent with an F system has a 12–14 week resting period during shed turnarounds. The rest period within a rotation system varied from < 3 months (2 respondents), to between 3 and 6 months (1 respondent), and > 12 months (1 respondent). The cost to set up the rotation system was > $800/ha (2 respondents). Mobile caravan/shed producers moved to a new area of the range every 2–7 days (2 respondents), and greater than every 14 days (1 respondent). The time M producers allowed an area to rest before they returned to the area was 20–30 weeks (1 respondent), and greater than > 40 weeks (1 respondent). Although one M respondent indicated it depended on the season and rainfall, generally 10–20 weeks.

At the start of a rotation or flock, six respondents had 80–100%% groundcover, five had between 60% and 80%, and two respondents had less than 25%. Furthermore, the two respondents with less than 25% had F systems. The three M respondents had 80–100% groundcover at the start of a rotation. All three farm systems (F, FSD and M) had reduced groundcover at the end of the rotation or flock. Only three respondents maintained 80–100% at the end of a rotation or flock (2 respondents with F and 1 M respondent). The cost to re-sow groundcover varied from less than $50/ha up to $200/ha.

3.2.4 Enrichment strategies to encourage hens to disperse across the range

Enrichment strategies used by 13 respondents to encourage hens to disperse across the range are shown in Figure 5. In addition, Figure 5 also shows the difference between farming systems. Fixed sheds/fixed range respondents use the most diverse range of enrichment strategies. Whereas M respondents hadn't needed to use enrichments, with one respondent using separate sleeping and nesting trailers, with up to 4 trailers per flock that provide shade/shelter areas. Respondents with FSD used similar strategies to those respondents with F, except hay bales were not used.

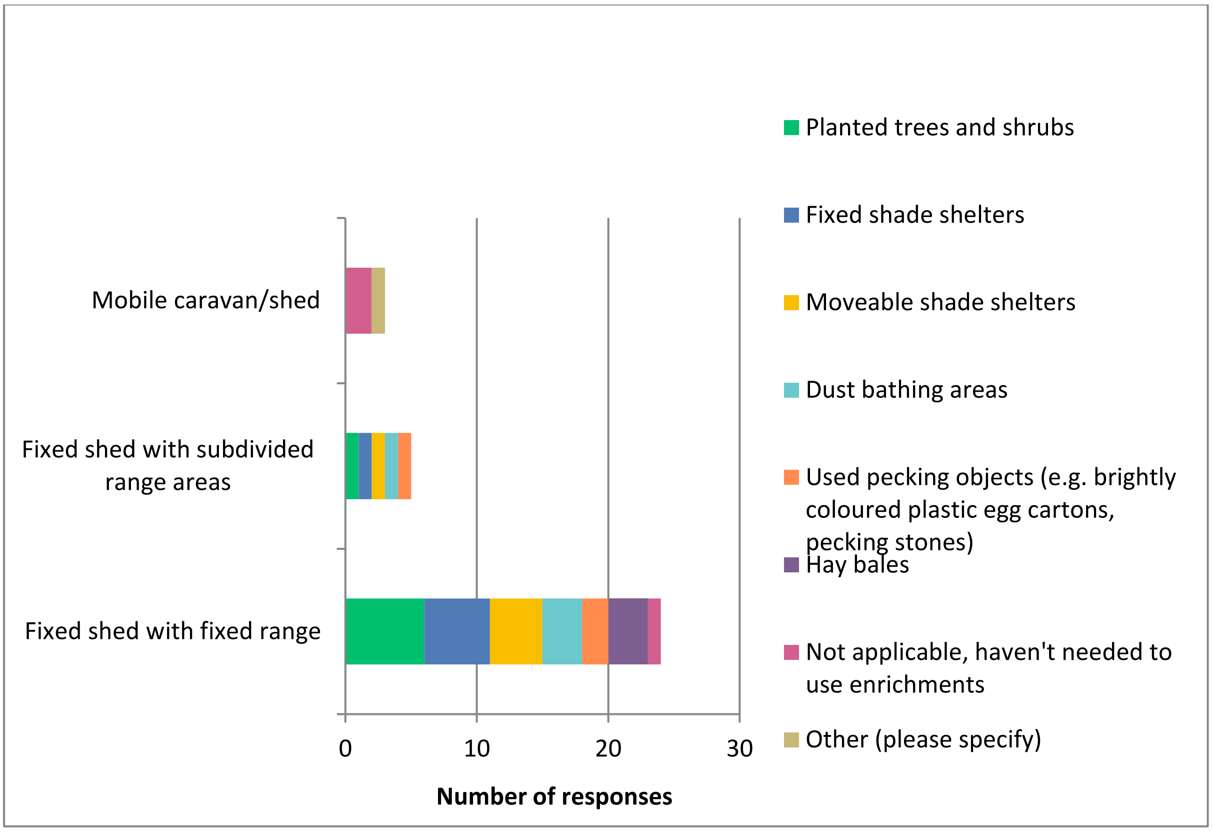

Figure 5 The question was asked of free range producers "Which enrichment strategies have you used to encourage hens to disperse across the range?"

The cost of implementing enrichment strategies was only answered by six F producers. Cost ranged from less than $50/ha up to $200/ha. One producer was not sure of their cost.

Vegetation on the range was planted in different configurations to encourage hens to range, (8 respondents, Figure 6). Commonly trees/shrubs were planted in shelter belts across the range, in rows radiating out from the shed, and in groves. Fixed shed/fixed range producers were also sowing specialty crops to encourage the hens to go onto the range (e.g. sunflowers, cereal crops). The M respondent also described how the hens will follow the feed, water, and shelter, with the sheds moved often. Notably, no one indicated that they used alleys of trees. In addition, bird husbandry practices were used to train birds to forage further onto the range (5 respondents). Nest boxes were checked for overcrowding (6 respondents), as overcrowded nest boxes can lead to eggs being laid on the range.

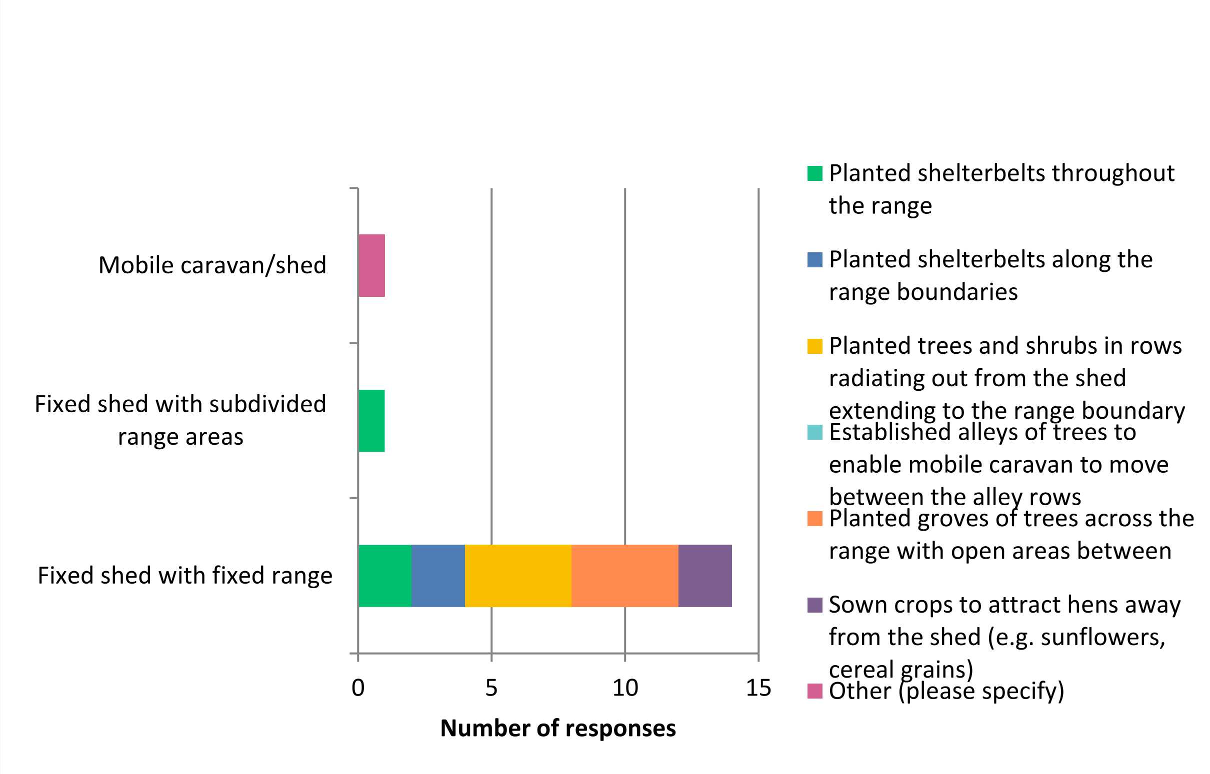

Figure 6 The question was asked of free range producers "How have you planted vegetation to encourage hens to disperse across the range?"

3.3 Survey conclusions

Free range producers are using many design features to manage nutrients on the range. To implement these design features was costing less than $50/ha to over $200/ha. Similarly, to repair damage to the range surface caused by dustbathing and exposed tree roots was costing less than $50/ha to over $200/ha, and was required after each flock for many producers. Enrichment strategies to encourage hens onto the range were used extensively by F producers whilst M producers did not have the need to use enrichment strategies. Nobody indicated they had spent more than $200/ha to implement enrichment strategies. Many varied reasons for plant choices on the range were provided, particularly by F producers with the main reasons being plants with reputed resilience to hens, advice from a local agronomist, and ease of establishment. Plants used specifically for the benefit of the flock were largely based on providing shade, shelter, and visual amenity for F producers, whereas M producers used plants for crops, hay, grazing (for livestock) and providing protein. Set up costs for agroforestry was between $200/ha to over $800/ha, and over $800/ha for setting up ranges for rotation. No producers with agroforestry in their free range system indicated that they harvested tree products (e.g. timber, fruits, and nuts). Possibly trees had not matured to a stage whereby they can yield tree products. Expenses to re-sow groundcover ranged from less than $50/ha up to $200/ha; no one had spent more than $200/ha. Although many respondents acknowledged free range birds are difficult to manage, most agreed range vegetation benefits bird welfare, yet only a third of respondents perceived a marketing advantage by having good groundcover and vegetation regeneration systems on farm (see Appendix A).

4 Case studies – targeted farmer interviews

4.1 Introduction

Human ethics approval for the phone interviews was granted through the University of Adelaide Human Ethics Committee (Approval number H-2021-023). Phone interviews were conducted with F producers and M producers (Table 10). Many of these interviews have led to insightful conversations about range regeneration issues that small- to medium-sized producers are facing and working to overcome. These case studies concisely highlight key challenges and prospects. More detail on case studies can be found in the Guideline Package.

Table 10 A summary of the free range producers who have been contacted

Type of system	Stocking density (hens/hectare)	Climate (Köppen classification)
Mobile sheds	<1,500	Temperate
Mobile sheds	<1,500	Temperate
Mobile sheds	<1,500	Temperate
Mobile sheds	1,500 – 5,000	Temperate
Fixed sheds	<1,500	Temperate
Fixed sheds	<1,500	Temperate
Fixed sheds	1,500 – 5,000	Temperate
Fixed sheds	1,500 – 5,000	Temperate
Fixed sheds	5,000 – 10,000	Temperate
Fixed sheds	5,000 – 10,000	Temperate
Fixed sheds	5,000 – 10,000	Cool - Temperate
Fixed sheds	5,000 – 10,000	Cool - Temperate
Fixed sheds	5,000 – 10,000	Subtropical
Fixed sheds	5,000 – 10,000	Subtropical

4.2 Fixed shed producers

Most of the comments received related to trees and shrubs – where to plant them (i.e. what design), plant choice, and how to promote successful plant establishment. In terms of vegetative groundcover, almost all producers found this difficult to maintain in inner range areas, but ideas to optimise sowing and to prolong groundcover were captured. For surfaces in the inner range area, producers have trialled rocks, mesh (plastic and metal), and organic materials (including bark). Common maintenance activities included repairing holes and controlling weeds. The most popular form of range enrichment was the use of straw bales. Artificial shelter used on ranges included shade huts and structures made of pallets, but these may not be as cheap or long-lasting as trees and shrubs. A small number of comments were obtained on modifying hen behaviour and on shed design.

Some examples of insights from interviews include:

- One producer (temperate climate, < 1500 hens/ha) explained that the initial investment on a shed-long veranda, coupled with protection of the inner range with a rocky base layer underlying chicken mesh and soil/mulch, were vital to minimising ongoing time and money spent maintaining the range.
- New range areas were designed to be 30% larger than required, this enabled renovation or resowing 30% of the range area at a time without affecting stocking density requirements.

- Another producer found success in using Bana grass (a drought tolerant variety of *Pennisetum*, growing over 4 m tall) planted in four 44-gallon drums and packed onto pallets; an effective way to create mobile, living structures that offer shade in the mornings and afternoons. They are cheaply made, available for use as wind breaks, are attractive to native insects, and encourage hens to use the outer range area. Unlike other shade structures, they do not encourage the nesting of wild birds.

To assess how well trees and shrubs were coping with high nutrient levels, soil samples and plant tissue samples were taken from three case study farms, and a fourth farm had only plant tissues taken. All farms were fixed sheds. Results are summarised in Chapter 5.

4.3 Mobile shed producers

Maintaining groundcover on the range was mostly achieved through frequently moving the caravan/shed to a fresh section of range. Another reason for moving frequently was to avoid manure build-up under the caravan/shed. Enrichments were not used by M producers interviewed as the hens would readily follow the caravan/shed to the new location on the range. In spring, too much groundcover was an issue as the hens would fill up on grass and dilute their formulated feed intake, which increased the risk of crop impaction and reduced egg production. Excessive grass growth was managed by mowing the range and adjusting pop hole opening times to a little later in the morning, allowing hens to eat their formulated diet before going out to range. Some M producers manage excessive grass growth by using other livestock (e.g. cattle and sheep) to graze pasture areas before hens have access. Biosecurity protocols need to be followed when ranging hens in rotation with other livestock classes. Provision of shade on the range was largely via the mobile caravan/shed, which was elevated and allowed the hens to go underneath.

Some examples of insights from interviews include:

- The sustainability of mobile caravans was demonstrated by one producer who has had them in rotation for 30 years. The mobile sheds are labour intensive, which poses a problem when trying to scale up production in a family-run business. However, the economic viability of the system comes from greater returns associated with labelling – not just 'mobile' but also pastured and animal welfare-accreditation.
- A mobile caravan producer was making their own sheds so they could easily fit through the farm gateways.

4.4 Case study conclusions

The interviewed F producers expressed how difficult it was to maintain the inner range, as such a variety of strategies was being implemented. This wasn't an issue for the interviewed M producers as they moved the caravan or shed often. Enrichments were provided on F farms to entice the hens to range further, but this was not seen as necessary by M producers as the hens followed the caravan/shed to the new location. Too much grass groundcover growth was seen as a problem by M producers because it could lead to reduced production when hens consumed excessive quantities of grass. Nevertheless, grasses are a desirable component of the ground vegetation on both F and M farms, and grass growth needs to be managed. Usually, F producers don't have issues with too much grass growth on the range, particularly closest to the shed. The importance of grass was highlighted in the Australian Animal Welfare Standards and Guidelines for Poultry (Australian Government, DAFF 2022). Section GA 5.4: "Vegetation should be provided on the range, including mature trees, shrubs and forage such as grasses and ground vegetation." Trees and shrubs were viewed by most F producers as valuable structural elements on the range but their placement on the range had to be well considered.

Figure 7 Fixed shed range with a combination of trees and moveable shelters at least 25 m from shed to encourage hens away from the shed

Figure 8 Elevated mobile caravan that also provides shade and shelter

5 Nutrient levels found in soils and plant tissues on case study free range layer farms

5.1 Introduction

Free range layer hens deposit nutrients onto the range via their excreta, in particular nitrate and phosphorus. Over time, gradients of nutrients develop across free range soils with higher concentrations found closest to the shed and under shelters and trees (Wiedemann et al. 2018). Hens congregate underneath trees and shrubs seeking shade and shelter, but little is known about how well trees/shrubs handle the additional nutrient loads. Nitrate and phosphorus are the main nutrients of concern due to their negative impacts on the environment, especially when they leach into waterways. Three farms with contrasting permanent vegetation on the range had their soils sampled at increased distances from the shed. Samples were taken underneath trees/shrubs and from the adjacent areas in the open range areas. In addition, the permanent vegetation on these farms had plant tissue samples taken from increased distances from the shed. We hypothesised that the plant tissue nutrient levels will reflect the high nutrient levels found in the soil, notably nitrate, total nitrogen and phosphorus.

5.2 Methods

Animal ethics approval was granted through Primary Industries and Regions South Australia (PIRSA # 21/20). During farm visits notes were made on the ranging behaviour of hens.

5.2.1 Soil samples

Soil samples were taken across the ranges of three southern Australian free range layer farms. All farms had fixed sheds with fixed ranges. Farms 1 and 2 had similar soil textures with silty loam and silty clay loam respectively, and flat topography. Farm 3 had deep sand, and a SE facing slope (5–10%). Control soil samples were taken outside the farms on the road verge (at least 3 m away from the road edge). No suitable control sites could be found on the farms – either they were highly disturbed sites due to the construction of buildings/roadways or had hen activity. Farm 1 had an outdoor stocking density of 10,000 hens/ha, while Farms 2 and 3 were stocked at 1,500 hens/ha.

The closest permanent vegetation from the shed on Farm 1 was Oldman saltbush (*Atriplex nummularia var. De Kock*) planted 10 m on the south range. On Farm 2, the first row of olive trees (*Olea europaea var. Kalamata*) was 15 m from the shed, while the first row of wine grape vines (*Vitis vinifera var. Grenache*) on Farm 3 was 23 m from the shed (upslope from the shed). Soil was sampled under the first row of permanent vegetation closest to the shed on each farm, at 50 m and 100 m from the shed. In addition, soil was taken from open range areas adjacent to the permanent vegetation at the same distances from the shed. Only nitrate and phosphorus were measured at the depths of 0–10 cm, 10–30 cm and 30–60 cm. Due to soil constraints (hard clay layer), Farms 1 and 2 were only sampled at two depths (0–10 cm and 10–30 cm). Farm 3 was sampled at all three depth levels. Soil samples were analysed by the Eurofins/APAL laboratory (Adelaide, South Australia).

5.2.2 Plant tissue samples

Farm 1 saltbush plant tissue samples were taken in early summer when saltbush had new active growth. The first fully expanded leaf on a new growing tip was taken (100 leaves x 3 replicates x 3 distances from the shed). Olive trees on Farm 2 were sampled when trees were at the late flowering/early fruit set stage. The first fully expanded olive leaf was sampled on fresh new growing tips without flowers/fruit (100 leaves x 3 replicates x 3 distances from the shed). Grape vines were sampled on Farm 3 during veraison (onset of fruit ripening). Only the leaf blade (no petiole) was taken opposite a bunch of grapes (30 leaf blades x 3 replicates x 3 distances from the shed).

Plant tissue samples were taken on a fourth farm from a variety of native plant species, some planted at the time of farm establishment (no soil samples were taken on Farm 4). Farm 4 had an outdoor stocking density of 10,000 hens/ha and a flock size of 30,000 hens. On Farm 4, two eucalypt species (unidentified) were sampled as a combination. They were planted 25 m from the shed on the north and south range in 2015. Oldman saltbush (planted in 2016 & 2017) was sampled at 50 m and 100 m from the shed, and naturalised small-leaf bluebush (*Maireana brevifolia*) was sampled at 50 m from the shed. Farm 4 plant tissue samples were taken mid-summer. The eucalypts had its new growth sampled (first fully expanded leaf on growing tip, 100 leaves x 3 replicates), and bluebush had all the small leaflets removed from a growing tip 3–4 cm long (30 growing tips x 3 replicates). Saltbush on Farm 4 was sampled using the same protocol as Farm 1. All plant tissue samples were analysed by the Eurofins/APAL laboratory (Adelaide, South Australia).

General ANOVA was conducted on soil nitrate and phosphorus data (Genstat v 21, VSN International, UK). Each farm was analysed separately. The main effects in the model were open range versus tree/shrub, distance from the shed, and soil depth. Means and SEM were calculated for plant tissue results.

5.3 Nutrient testing results

For the purposes of this report the results for nitrate and phosphorus in soils are presented, along with nitrate, total nitrogen and phosphorus for plant tissues. Other elements and minerals were also measured in the top 10 cm of soil, and in plant tissues. Results for plant tissues are tabulated in Appendix B, Table 13. Nitrate levels were significantly higher in soils under saltbush and olive trees (108.6 mg/kg & 83.9 mg/kg, respectively) compared to the adjacent open areas of the range (saltbush open areas = 43.1 mg/kg & olive open areas = 40.0 mg/kg, $P = 0.002$ & $P= 0.004$, respectively). Only Farms 1 and 2 had significant nitrate gradients across the range ($P = 0.003$ & $P < 0.001$, respectively), whereby levels were highest close to the shed and lowest furthest from the shed (Figure 9). Nitrate levels close to the shed exceeded those of the controls on Farms 1 and 2 and the desired level for pasture, olives, and vines. Yet, on distant areas of the range nitrate levels were comparable with the controls (Farm 1 at 100 m, and Farm 2 at < 50m). Farm 3 had very low nitrate levels. On all farms the top 10 cm of soil had approximately double the nitrate levels of those found at 10–30 cm (Figure 10).

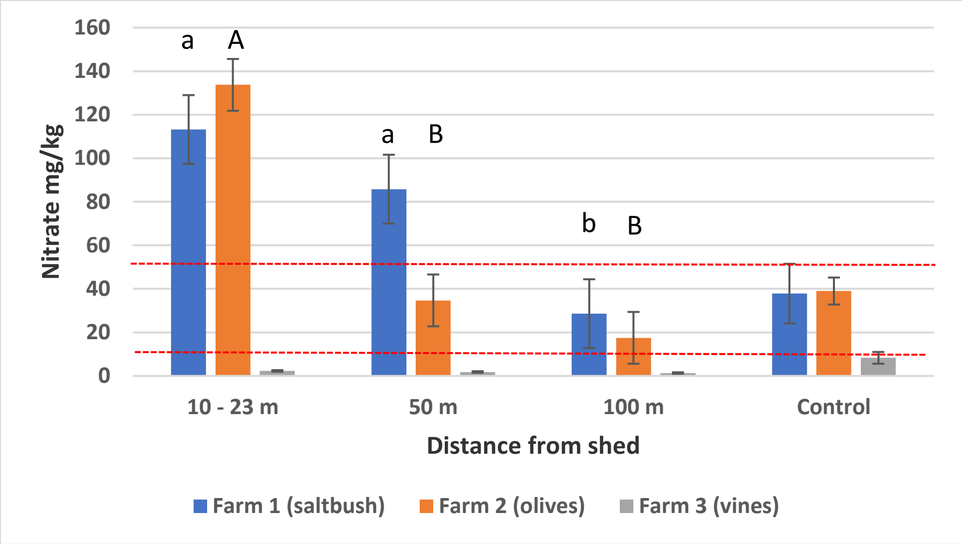

Figure 9 Mean nitrate levels (mg/kg) measured in soil related to distance from the shed on three southern Australian free range layer farms

Between the dashed red lines are the desired levels of nitrate for pastures, olives, and vines. Different lowercase letters are significant (5% level) for Farm 1, and different capital letters are significant for Farm 2. Farm 3 not significant.

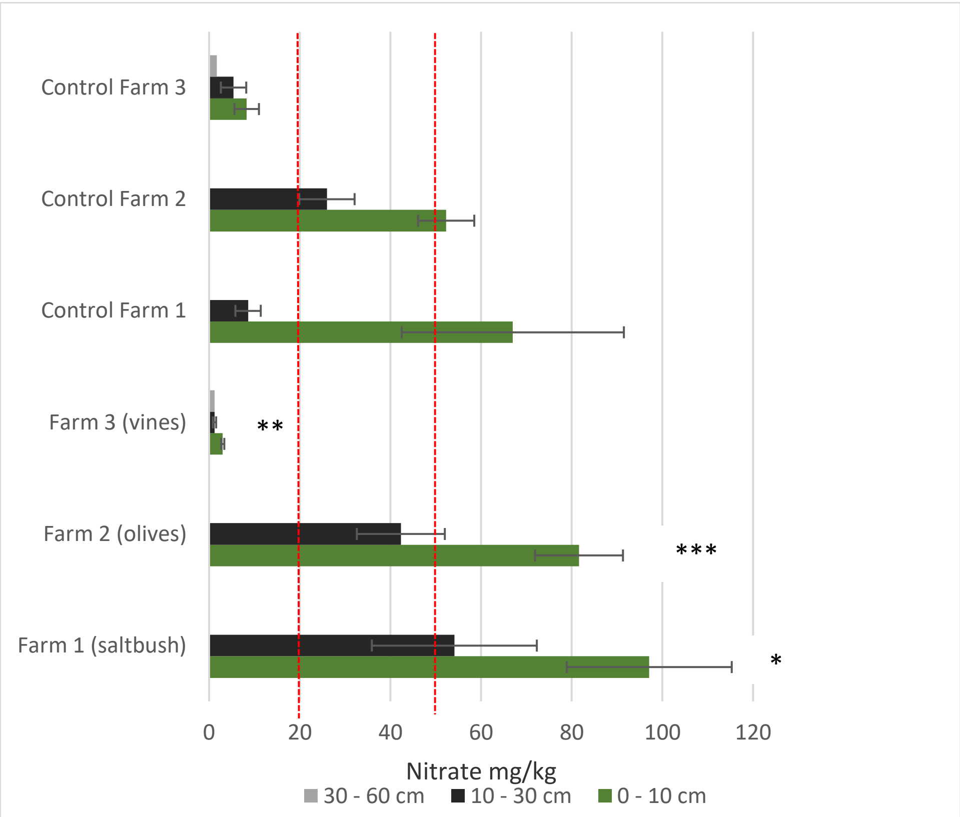

Figure 10 Mean nitrate levels (mg/kg) at three soil depths on three southern Australian free range layer farms

Farms 1 and 2 only measured at two soil depths.
Between the dashed red lines are the desired levels of Nitrate for pastures, olives, and vines.
Depth main effect, * = P < 0.05, ** = P < 0.01 & *** = P < 0.001.

Phosphorus (Colwell) levels were higher in soils under saltbush compared to the adjacent open range areas (148.6 mg/kg vs. 104.3 mg/kg, respectively, $lsd_{5\%}$ = 18.8, P = 0.028). No significant differences were found between permanent vegetation and open range areas on Farms 2 and 3. Levels of phosphorus were highest closest to the shed on Farms 1 and 2 (Figure 11). Farm 3 phosphorus levels were very low. Phosphorus was not leaching into the deeper soil layer (10–30 cm) on Farms 1 and 2 (Figure 12), but levels are high in the top 10 cm.

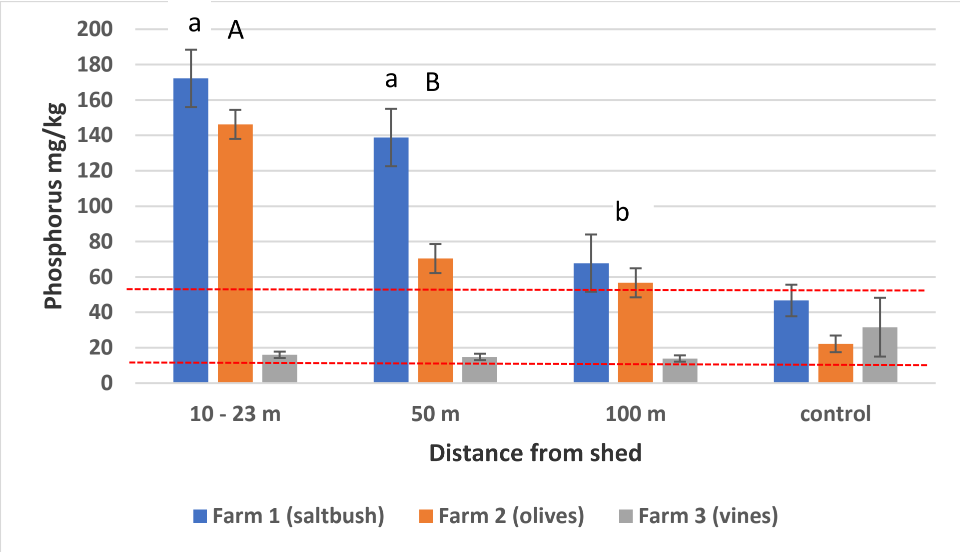

Figure 11 Mean phosphorus levels (mg/kg) found in soil related to distance from the shed on three southern Australian free range layer farms

Between the dashed red lines are the desired levels of phosphorus for pastures, olives, and vines. Different lowercase letters are significant (5% level) for Farm 1, and different capital letters are significant for Farm 2. Farm 3 not significant.

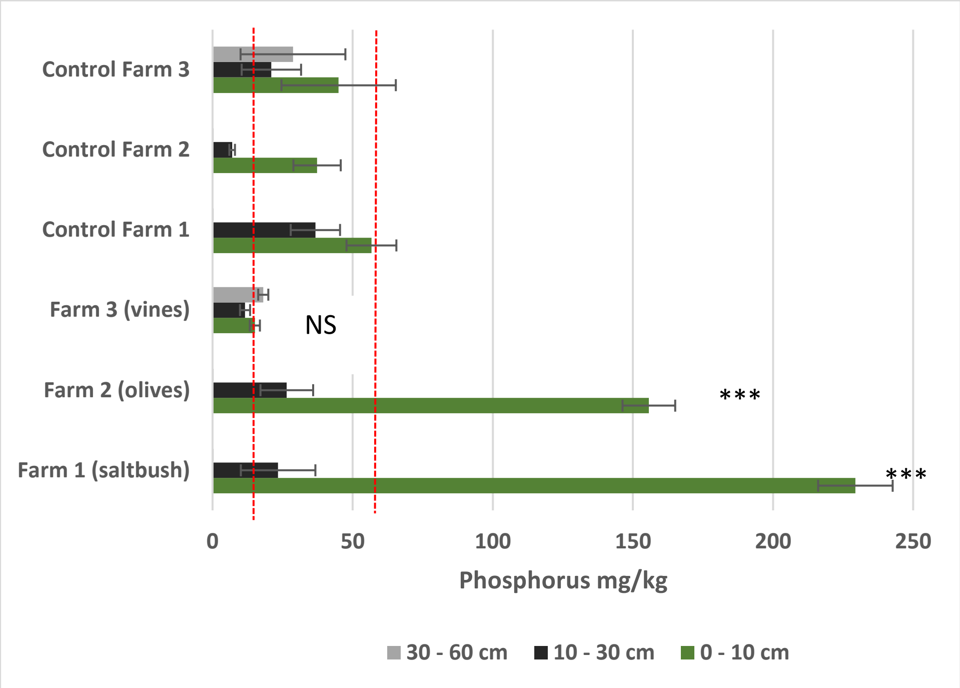

Figure 12 Mean phosphorus (Colwell) levels (mg/kg) at three soil depths on three southern Australian free range layer farms

Farms 1 and 2 only measured at two soil depths (0–10 cm & 10–30 cm).
Between the dashed red lines are the desired levels of phosphorus for pastures, olives, and vines.
Depth main effect, NS = Not significant & *** = P < 0.001.

In saltbush plant tissues, there were no nitrate changes with distance from the shed on Farm 1 (Table 11, overall mean 468 ± 97 mg/kg), this was despite a strong distance from the shed effects for nitrate in the soil on Farm 1. Nitrogen % in the saltbush leaf was also not influenced by distance from the shed (Table 11). However, olive leaf did show higher nitrogen % closest to the shed compared to further away from the shed. At all distances from the shed there was adequate nitrogen in the leaves of olives. Nitrogen % was below the target range for grape vines at the veraison stage on Farm 3, except at 100 m from the shed. Both olives and grapevines had below 30 mg/kg nitrate in their plant tissues, well below that of saltbush. Phosphorus in plant tissues showed no trend across the ranges of Farms 1, 2 and 3, even though there were strong phosphorus gradients across the range soils on Farms 1 and 2. Phosphorus % in plant tissues was within the target range for olives and vines.

On Farm 4 (Table 12), bluebush plant tissue stands out with very high levels of nitrate, while eucalypts had low levels despite being planted closest to the shed.

Table 11 Mean ± SEM plant tissue analysis for nitrate, nitrogen, and phosphorus in the leaves of saltbush on Farm 1, olives on Farm 2 and grape vines on Farm 3 at various distances from the shed

Farm	Nutrient	Target range	Distance from shed		
			10 – 23 m	50 m	100 m
1	Nitrate (mg/kg)	NA	415 ± 83	502 ± 190	350 ± 254
2		NA	< 30	< 30	< 30
3		NA	< 30	< 30	< 30
1	Nitrogen (%)	NA	3.72 ± 0.02	3.94 ± 0.13	3.38 ± 0.17
2		1.5 – 2.0 %	1.78 ± 0.02	1.66 ± 0.05	1.63 ± 0.06
3		2.2 – 4.0 %	2.13 ± 0.02	2.03 ± 0.05	2.29 ± 0.09
1	Phosphorus (%)	NA	0.25 ± 0.02	0.25 ± 0.02	0.21 ± 0.01
2		0.10 – 0.30 %	0.15 ± 0.01	0.17 ± 0.01	0.16 ± 0.01
3		0.15 – 0.30 %	0.25 ± 0.03	0.25 ± 0.01	0.32 ± 0.04

NA – Not available.

Table 12 Mean ± SEM plant tissue analysis for nitrate, nitrogen, and phosphorus in the leaves of eucalypts, small-leaf bluebush and oldman saltbush on Farm 4 at various distances from the shed

Nutrient	Eucalypt (25 m)	Bluebush (50 m)	Saltbush (50 m)	Saltbush (100 m)
Nitrate (mg/kg)	29 ± 0	2700 ± 201	214 ± 77	414 ± 212
Nitrogen (%)	2.45 ± 0.12	5.51 ± 0.13	3.78 ± 0.05	3.79 ± 0.05
Phosphorus (%)	0.16 ± 0.03	0.23 ± 0.01	0.24 ± 0.01	0.22 ± 0.00

Distance from the shed is shown in brackets.

5.4 Nutrient testing conclusions

Hens mostly congregated in large numbers closest to the shed and under nearby trees and shrubs. As a result, nitrate and phosphorus were found at higher levels in soils closest to the shed with a decrease as distance from the shed increased (except for Farm 3). These findings support those of Wiedemann et al. (2018). Even though there were strong nutrient gradients in the soils across the range for nitrate and phosphorus, this was not reflected in plant tissues. There were no toxic levels found in plant tissues and no evidence of luxury uptake. The saltbush and olive trees on these farms were only taking up the amount of nutrient they needed even though nitrate and phosphorus were at higher levels in the soil than they required.

The clay-based soils on Farms 1 and 2 retained nitrate and phosphorus, notably in the top 10 cm of soil and closest to the shed. In contrast, the sand on Farm 3 did not retain nutrients (including nitrate and phosphorus) and was mostly deficient. Nutrients in the sand had most likely been leached further down the sand profile (deeper than 60 cm), and/or the vines and the inter row perennial grasses had intercepted some of the nutrients.

The native tree and shrub species growing on the range of Farm 4 were healthy after 7–8 years of ranging by free range hens. The eucalypts planted closest to the shed at 25 m were not showing any signs of nutrient toxicity. The levels of phosphorus in the tissues of the eucalypts were very similar to those found for the olive trees. Even though nitrate levels were high in bluebush, this was not attributed to hen activity as bluebush naturally accumulates high nitrate levels regardless of the soil nitrate level.

5.5 Key recommendations

- Monitor nutrient levels in range soils, by taking soil samples under trees and shrubs and the adjacent open areas, particularly those trees/shrubs growing closest to the shed.
- Sample soil for nitrate and phosphorus.
- Sample soil at least at two depths (0–10 cm & 10–30 cm), as this will indicate whether nitrate and phosphorus are leaching into deeper soil layers or accumulating in the top layer.
- Moveable constructed shelters are best utilised in the inner range zone (0–25 m) and trees and shrubs planted beyond 25 m.
- Moveable constructed shelters should be re-located often to avoid excessive nutrients being deposited underneath them by hens.
- Select trees and shrubs known to have high nutrient requirements.
- Protect the top layer of soil (0–10cm) closest to the shed from erosion (water and/or wind), with rocks and/or mesh. This is the layer of soil with the highest levels of nitrates and phosphorus, particularly with clay-based soils.

6 References

Abbas, R. Z., Colwell, D. D. and Gilleard, J. (2012) 'Botanicals: An alternative approach for the control of avian coccidiosis', *World's Poultry Science Journal*, 68(2), pp. 203–215. doi: 10.1017/S0043933912000268.

Acamovic, T. and Brooker, J. D. (2005) Biochemistry of plant secondary metabolites and their effects on animals. *Proceedings of the Nutrition Society*, 403 - 412.

Adil, S., Qureshi, S. and Pattoo, R. A. (2015) 'A review on positive effects of of fenugreek as a feed additive in poultry production'. *International Journal of Poultry Science*, 14(12), 664-669.

Akyildiz, S. and Denli, M. (2016) 'Application of plant extracts as feed additives in poultry nutrition', *Animal Science*, LIX(October), pp. 71–74. Available at: https://www.researchgate.net/publication/308919201.

Alloush, G. A., Belesky, D. P. and Clapham, W. M. (2003) 'Forage chicory: a plant resource for nutrient-rich sites', *Journal of Agronomy and Crop Science*, 189(2), pp. 96–104.

Anonymous (2014) Growing bamboos, Department of Primary Industries and Regional Development, Government of Western Australia, https://www.agric.wa.gov.au/growing-bamboos, (accessed 20/01/2021)

Australian Government - Department of Agriculture, Fisheries and Forestry (2022) Australian Animal Welfare Standards and Guidelines for Poultry. 55 pages.

Bassett, A. (2009) Animal Welfare Approved Technical Paper No. 6 - Range Management in Poultry. https://agreenerworld.org/wp-content/uploads/2020/07/TAFS-6-Range-Management-Poultry-v1.pdf (accessed 18/01/2021).

Bestman, M., Verwer, C., van Niekerk, T., Leenstra, F., Reurekamp, B., Amsler-Kepalaite, Z. and Maurer, V. (2019) Factors related to free-range use in commercial laying hens. *Applied Animal Behaviour Science* 214, 57-63.

Boosten, M. and Penninkhof, J. (2018) 'Combining short rotation willow coppice with free range chickens - experiences from experiments on farm level in the Netherlands', *Proceedings of the 4th European Agroforestry Conference - Agroforestry as Sustainable Land Use*, (April 2013), pp. 424–427.

Borland, E A, Hazel S, Glatz P C, Rodda B K Rimmington H, W. S. C. and Miao. Z. H. (2010) 'Attracting laying hens into range areas using shelterbelts', in *Australian Poultry Science Symposium*, p. 134.

Breitsameter, L., Küchenmeister, K., Küchenmeister, F., Wrage-Mönnig, N. and Johannes, I. (2013) 'Canopy cover and herbage accumulation of fourteen grassland species when stocked with chickens', *Agronomy Journal*, 105(3), pp. 727–734. doi: 10.2134/agronj2012.0348.

Breitsameter, L., Gauly, M. and Isselstein, J. (2014) 'Sward botanical composition and sward quality affect the foraging behaviour of free-range laying hens', *Applied Animal Behaviour Science*, 150, pp. 27–36. doi: 10.1016/j.applanim.2013.10.009.

Bright, A., Brass, D., Clachan, J., Drake, K.A. and Joret, A.D. (2011) 'Canopy cover is correlated with reduced injurious feather pecking in commercial flocks of free-range laying hens', *Animal Welfare*, 20(3), pp. 329–338.

Campbell, D. L. M., Lee, C., Hinch, G.N. and Robert, J.R. (2017 a) 'Egg production and egg quality in free-range laying hens housed at different outdoor stocking densities', *Poultry Science*, 96(9), pp. 3128–3137. doi: 10.3382/ps/pex107.

Campbell, D. L. M., Hinch, G. N., Dyall, T.R., Warin, L., Little, B.A. and Lee, C. (2017 b) 'Outdoor stocking density in free-range laying hens: Radio-frequency identification of impacts on range use', *Animal*, 11(1), pp. 121–130. doi: 10.1017/S1751731116001154.

Christaki, E., Eleftherios, B., Giannenas, I. and Florou-Paneri, P. (2012) 'Aromatic plants as a source of bioactive compounds', *Agriculture (Switzerland)*, 2(3), pp. 228–243. doi: 10.3390/agriculture2030228.

Cunningham, S. D. and Berti, W. R. (1993) 'Remediation of contaminated soils with green plants : an overview', (October), pp. 207–212.

Diarra, S. S. (2014) Potential of mango (*Mangifera indica L*.) seed kernel as a feed ingredient for poultry: A review. *World Poultry Science Journal*, 70, 279-288

Diaz-Sanchez, S., D'Souza, D., Biswas, D. and Hanning, I. (2015) 'Botanical alternatives to antibiotics for use in organic poultry production', *Poultry Science*, 94(6), pp. 1419–1430. doi: 10.3382/ps/pev014.

Elkhoraibi, C., Pitesky, M., Dailey, N. and Niemeier, D. (2017) 'Operational challenges and opportunities in pastured poultry operations in the United States', *Poultry science*, 96(6), pp. 1648–1650. doi: 10.3382/ps/pew448.

Elson, H. A. (2015) 'Poultry welfare in intensive and extensive production systems', *World's Poultry Science Journal*, 71(3), pp. 449–459. doi: 10.1017/S0043933915002172.

Ezzat Abd El-Hack, M., Alagawany, M., Ragab, M., Tiwarri, R., Karthik, K., Dhama, K., Zorriehzahra, J. and Adel, M. (2016) Beneficial imapcts of thymol essential oil on health and production of animals, fish and poultry: A review, *Journal of essential oil research*, 365-382.

FREPA (2015) *FREPA free range egg standards*. Free Range Egg and Poultry Australia Ltd (FREPA).

Fürmetz, A., Keppler, C. and Knierim, U. (2005) 'Legehennen in einem mobilen Stallsystem - Auslaufnutzung und Flächenzustand', in Heß, J. and Rahmann, G. (eds) *Ende der Nische. Beitrage zur 8. Wissenschaftstagung bkologischer Landbau, 1-4 March 200S, Kassel.* Kassel: Kassel University Press, pp. 313–314.

Gilani, A. M., Knowles, T. G. and Nicol, C. J. (2014) 'Factors affecting ranging behaviour in young and adult laying hens', *British Poultry Science*, 55(2), pp. 127–135. doi: 10.1080/00071668.2014.889279.

Groot, M., van Asseldonk, T. and Puls-van der Kamp, I. (2011) 'Natural Poultry Health - A guide to keeping your flock healthy with herbs and other natural products'. BioKennis, p. 40.

Hashemi, S. R. and Davoodi, H. (2011) 'Herbal plants and their derivatives as growth and health promoters in animal nutrition', *Veterinary Research Communications*, 35(3), pp. 169–180. doi: 10.1007/s11259-010-9458-2.

Hermansen, J. E., Bestman, M., Westaway, S., Kongsted, A.G., Bondesan, V., Losada, R.M., Luske, B, Novak, S. and Smith, J. (2017) 'Guidelines for improved agroforestry systems for livestock production Work-package 5: Agroforestry for Livestock Systems Milestone Deliverable 5.15 (5.3). Available at: www.agforward.eu.

Knierim, U. (2006) 'Animal welfare aspects of outdoor runs for laying hens: A review', *NJAS - Wageningen Journal of Life Sciences*, 54(2), pp. 133–145. doi: 10.1016/S1573-5214(06)80017-5.

De Koning, C., Kitessa, S.M., Barekatain, R. and Drake, K. (2018) 'Determination of range enrichment for improved hen welfare on commercial fixed-range free-range layer farms', *Animal Production Science*, 59(7), pp. 1336–1348. doi: 10.1071/AN17757.

de Koning, C.T. (2020a) *Resilient plants to entice hens outdoors on free range farms - Final Project Report 1HS801SA*. Australian Eggs.

de Koning, C.T. (2020b) 'Drought impacts on plant ground cover on a free range egg farm', in *Proceedings Aust. Poult. Science Symp.*, pp. 31–33.

Kosmidou, M., Sissidou, I., Fortomaris, P., Yannakopoulos, A. and Tserveni-Gousi, A. (2004) 'A pilot study on free- range laying hens ' preference', pp. 2001–2004.

Madhupriya, V., Shamsudeen, P., Raj Manohar, G., Senthilkumar, S., Soundarapandiyan, V. and Moorthy, M. (2018) 'Phyto feed additives in poultry nutrition – A review', *International Journal of Science, Environment and Technology*, 7(3), pp. 815–822.

Maurer, V. et al. (2013) 'Effects of paddock management on vegetation, nutrient accumulation, and internal parasites in laying hens', *Journal of Applied Poultry Research*, 22(2), pp. 334–343. doi: 10.3382/japr.2012-00586.

Nagle, T. A. D. and Glatz, P. C. (2012) 'Free range hens use the range more when the outdoor environment is enriched', *Asian-Australasian Journal of Animal Sciences*, 25(4), pp. 584–591. doi: 10.5713/ajas.2011.11051.

Philipps, L., Engel, C. and Wolfe, M. (2002) 'Development of an agroforestry system for chicken production', *Proceedings of the COR Conference, 26- 28th March 2002, Aberystwyth*, pp. 257–258.

Pliego, A.B., Tavakoli, M., Khusro, A., Seidavi, A., Elghandour, M.M.M.Y., Salem, A.Z.M., Márquez-Molina, O. and Rivas-Caceres, R.R. (2020) 'Beneficial and adverse effects of medicinal plants as feed supplements in poultry nutrition: a review', *Animal Biotechnology*. doi: https://doi.org/10.1080/10495398.2020.1798973.

Rault, J.-L., Hemsworth, P. and Cronin, G. (2016) 'Free range hen welfare: Characterisation of "outdoor" and "indoor" hens and physical features in the range Final Project Report A report for the Australian Egg Corporation Limited', (1).

Robinson, B., Green, S., Mills, T., Clothier, B., van der Velde, M., Laplane, R., Fung, L., Deurer, M., Hurst, S., Thayalakumaran, T. and van den Dijessel, C. (2003) 'Phytoremediation: Using plants as biopumps to improve degraded environments', *Australian Journal of Soil Research*, 41(3), pp. 599–611. doi: 10.1071/SR02131.

RSPCA (2015) Layer Hens RSPCA Approved Farming Scheme Standards, 33 pages, https://rspcaapproved.org.au/wp-content/uploads/2017/02/RSPCALayerhensStandards.pdf

Russelle, M.P., Lamb, J.F.S., Montgomery, B.R., Elsenheimer, D.W., Miller, B.S. and Vance, C.P. (2011) Alfalfa rapidly remediates excess inorganic nitrogen at a fetiliser spill site. *J. Environ. Qual.*, 30, 30-36.

Smith, J, Westaway, S. and Kling, C. (2017) 'Lessons learnt : Silvoarable agroforestry in the UK', (Part 1), pp. 1–16.

Sossidou, E. N., Dal Bosco, A., Elson, H.A., and Fontes, C.M.G.A. (2008) 'Different soil media for free-range laying hens', *British Poultry Science*, 49(4), pp. 390–395. doi: 10.1080/00071660802159041.

Spencer, T. (2013) 'Pastured Poultry Nutrition and Forages', *National Center for Appropriate Technology*, pp. 10–13. doi: 1-800-346-9140.

Stadig, L. M., Tuyttens, F.A.M., Bas Rodenburg, T., Verdonckt, P., Wauters, E., Borremans, L. and Reubens, B. (2018) 'Opportunities for short rotation coppice production on free-range chicken farms in Flanders: Farmers' perceptions and cost-benefit analysis', *Renewable Agriculture and Food Systems*. doi: 10.1017/S1742170518000546.

Thuy Diep, A., Larsen, H. and Rault, J. L. (2018) 'Behavioural repertoire of free-range laying hens indoors and outdoors, and in relation to distance from the shed', *Australian Veterinary Journal*, 96(4), pp. 127–131. doi: 10.1111/avj.12684.

Trust, Woodland (2014) 'A Woodland Trust guide to Tree planting for free range poultry', (April).

Wallace, R. J., Oleszek, W., Franz, C., Hahn, I., Baser, K.H.C., Mathe, A. and Teichmann, K.(2010) 'Dietary plant bioactives for poultry health and productivity', *British Poultry Science*, 51(4), pp. 461–487. doi: 10.1080/00071668.2010.506908.

Westaway, S., Kling, C. and Smith, J. (2018) 'A comparison of the performance of three sward mixtures sown under trees in a silvopoultry system in the UK', *Agroforestry Systems*, 92(4), pp. 1009–1018. doi: 10.1007/s10457-017-0142-1.

Wiedemann, S. G. and Zadow, E. (2010) *Benchmarking nutrients on egg farms in the Condamine catchment using eElectro-magnetic induction technology - project summary report*. Toowoomba, QLD.

Wiedemann, S., Pratt, C., Bliefield, N., Mayer, D. G., Redding, M. R. and McGahan, E. (2018) 'Establishing soil nutrient distribution zones across free range egg farms to guide practical nutrient management strategies', *Agriculture, Ecosystems and Environment*, 257, pp. 20 - 29.

Yadav, A. S., Kolluri, G., Gopi, M., Karthik, K., Malik, Y.S. and Dhama, K. (2016) 'Exploring alternatives to antibiotics as health promoting agents in poultry- a review', *Journal of Experimental Biology and Agricultural Sciences*, 4(2320), pp. 368–383.

Yitbarek, M.B. (2015) 'Phytogenics As Feed Additives In Poultry Production : A Review', *International Journal of Extensive Research*, 3(1), pp. 49–60.

Zeltner, E. and Hirt, H. (2003) 'Effect of artificial structuring on the use of laying hen runs in a free-range system', *British Poultry Science*, 44(4), pp. 533–537. doi: 10.1080/00071660310001616264.

Zeltner, E. and Hirt, H. (2008) 'Factors involved in the improvement of the use of hen runs', *Applied Animal Behaviour Science*, 114(3–4), pp. 395–408. doi: 10.1016/j.applanim.2008.04.007.

Zeng, Z., Zhang, S., Wang, H. and Piao, X. (2015) 'Essential oil and aromatic plants as feed additives in non-ruminant nutrition: A review', *Journal of Animal Science and Biotechnology*, 6(1). doi: 10.1186/s40104-015-0004-5.

Appendix A – Online survey

Farm demographics

Sixteen respondents answered the question on the type of free range farm system they run. Eight respondents have F, four have FSD set up for rotation, and four have M. The size of the farms ranged from < 10,000 hens through to > 250,000 hens. Average flock sizes were highly variable, with less than 1,000 hens to greater than 20,000 hens. In addition, three respondents indicated that they run many different flock sizes (7,000, 10,000, 17,000, 20,000, 30,000 and 40,000 hens). Outdoor stocking density was also diverse, with seven respondents at < 1,500 hens/ha, three at 1,500–5,000 hens/ha, three at 5,000–10,000 hens/ha, and three respondents have both outdoor stocking densities 1,500 and 10,000 hens/ha. The same stocking density had always been maintained by 11 respondents, one respondent indicated that they increased their stocking density (1 M respondent), while four respondents had stocking densities in both higher and lower classes. Mobile caravan/shed producers tended to have low outdoor stocking densities, < 1,500 hens/ha (3 respondents) and 1,500–5,000 hens/ha (1 respondent). Although, some F producers also had below 1,500 hens/ha (3 respondents from 8).

Identifying real or potential problems

Questions on the soil type, rainfall, erosion risk and depth to groundwater was answered by 16 respondents, while 17 respondents answered questions on watercourses near boundaries and farm topography. Eight respondents indicated that their farms have well structured, well-drained soils. This was followed by five farms with heavy clay through to the surface. One respondent's farm had poorly structured soil. Other soil types were yellow podzolic with a heavy clay and sandstone subsoil, and 150 mm topsoil over clay or gravels.

Over half the farms (9 respondents) are in areas that receive 500–750 mm rainfall annually, four are in areas with 250–500 mm, two farms receive more than 1000 mm, while only one farm receives 750–1000 mm. On the rainfall erosivity map (Figure 13), ten respondents have farms in the yellow zones, five in the green zone, and only one respondent in the pink zone (the second highest erosion risk zone).

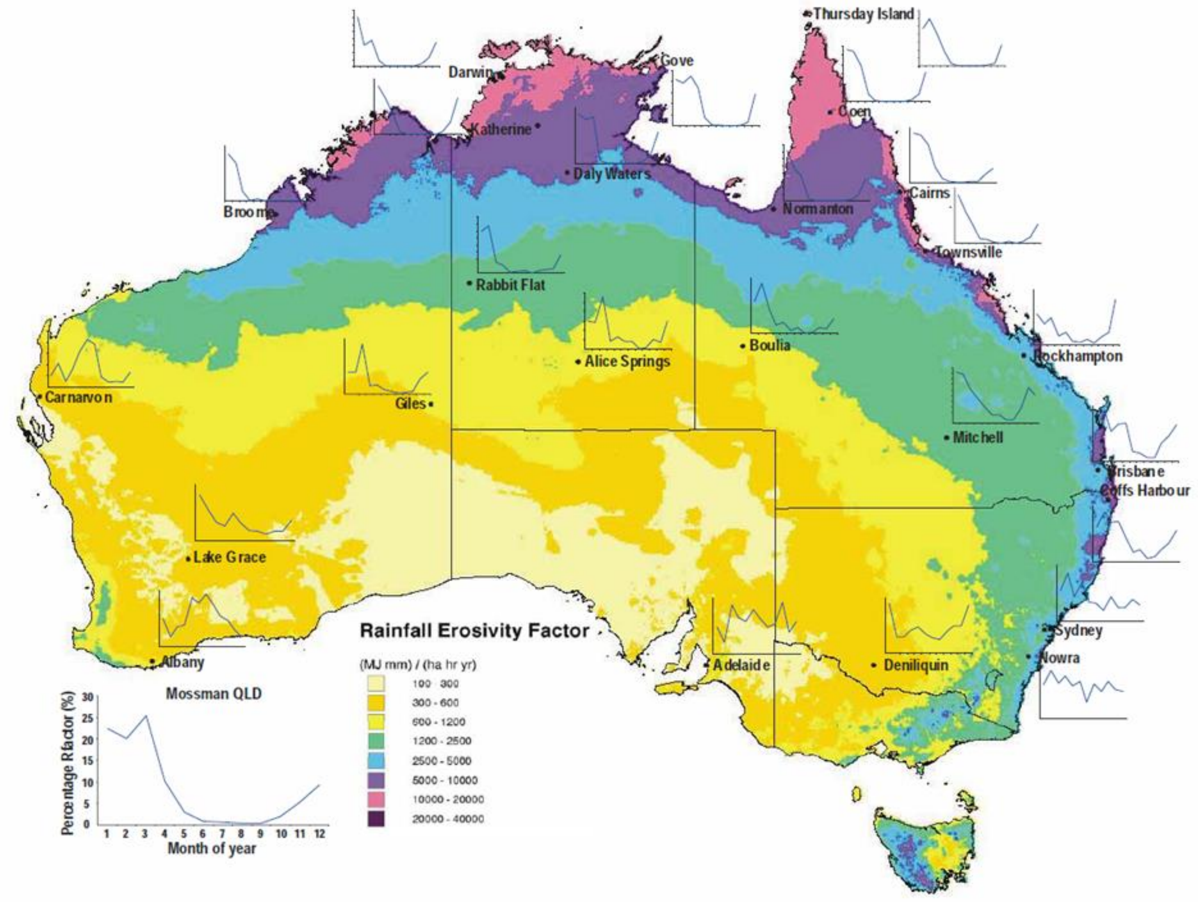

Figure 13 Rainfall erosivity map (erosion risk associated with rainfall)

Almost two thirds (11 respondents) indicated that their range boundary is > 200 m from the nearest waterway, three respondents at 100–200 m, two at 30–100 m, and only one respondent at < 30 m.

Over half (9 respondents) have depth in metres to groundwater > 20 m, two have > 10 m protected with a clay or permeable strata, three at > 10 m, one respondent with > 2 m with a protective clay or permeable strata, and one respondent with < 2 m to groundwater. The main topography on respondents' farms were slightly uneven/minor rills (7 respondents), uniform flat was the next with six respondents, two respondents had swales and contour banks, and two respondents had sloping land. Nobody had highly concentrated gully flow.

Farmer attitudes to free range farming and range regeneration

The final five questions were on producer attitudes to free range farming and answered by 12 respondents.

Most respondents 'Strongly disagreed' or 'Disagreed' with the statement "Free range birds are straightforward to look after when compared to barn & conventional birds", Figure 14. The one respondent who had 'agreed' with the statement is an M producer, although one M 'neither agreed or disagreed' and another 'disagreed'.

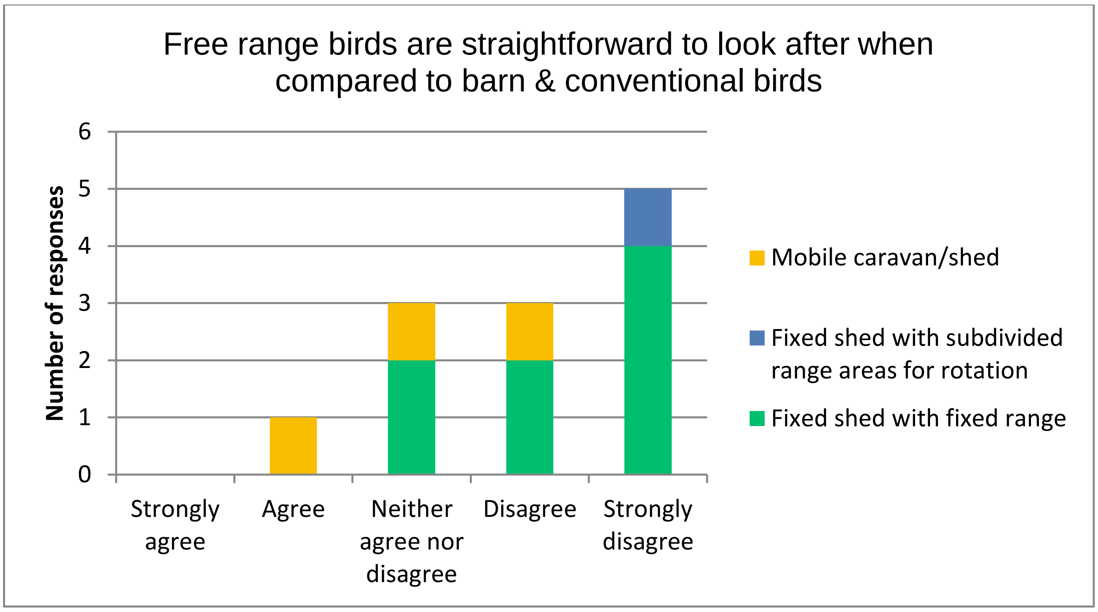

Figure 14 Responses of free range producers to the statement "Free range birds are straightforward to look after when compared to barn & conventional birds"

Response categories are Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree.
Yellow – Mobile caravan/shed producers.
Blue – Fixed shed with subdivided range producers.
Green – Fixed shed with fixed range producers.

Over half the respondents 'Disagreed' or 'Strongly disagreed' with the statement "Minimal bird training is required to manage birds in the range", Figure 15. Although, four respondents did 'Agree' with the statement. Those respondents who 'Disagreed', were from each of the free range farming systems. The 'Strongly disagreed' responses came from two F producers.

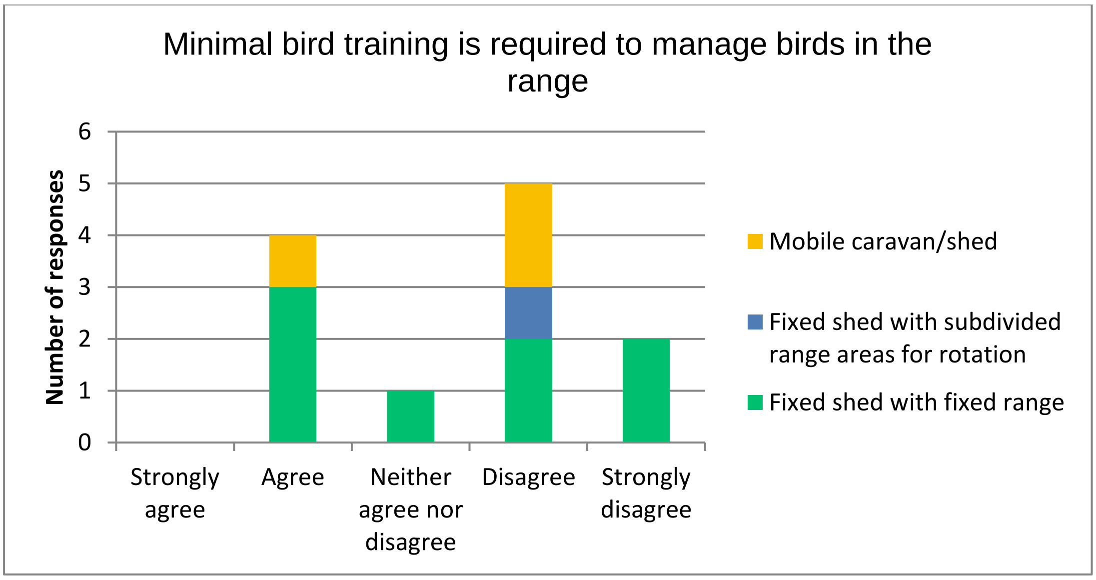

Figure 15 Responses of free range producers to the statement "Minimal bird training is required to manage birds in the range"

Response categories are Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree.
Yellow – Mobile caravan/shed producers.
Blue – Fixed shed with subdivided range producers.
Green – Fixed shed with fixed range producers.

Overwhelmingly, respondents 'Disagreed' or 'Strongly disagreed' with the statement "Little experience is needed from the stockperson to manage birds in the range", Figure 16. Only one respondent 'Strongly agreed' with the statement and another 'Neither agreed nor disagreed'. Both respondents have F. Those respondents who 'Disagreed', were from each of the free range farming systems. All those respondents who 'Strongly disagreed' have F.

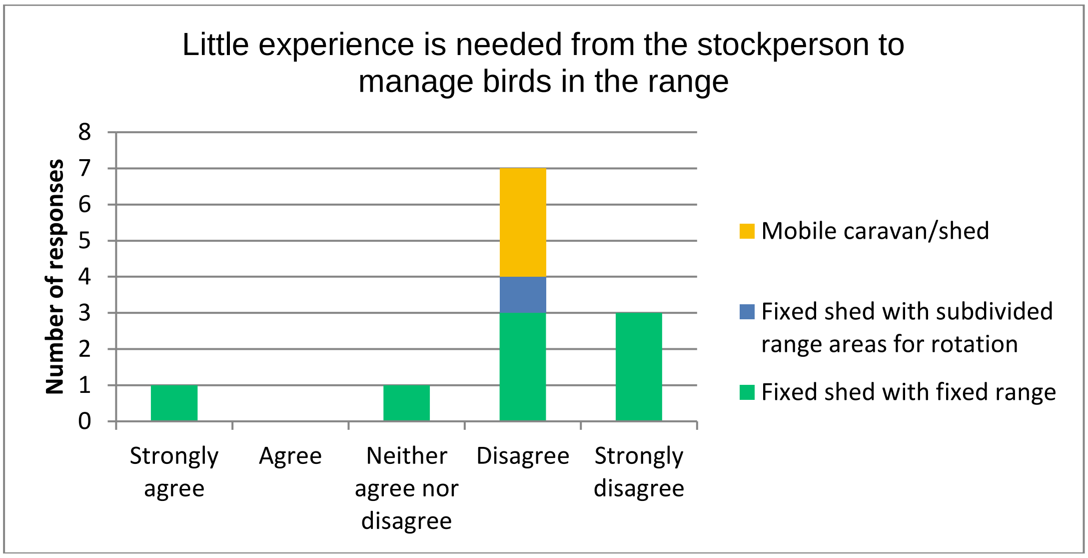

Figure 16 Responses of free range producers to the statement "Little experience is needed from the stockperson to manage birds in the range"

Response categories are Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree.
Yellow – Mobile caravan/shed producers.
Blue – Fixed shed with subdivided range producers.
Green – Fixed shed with fixed range producers.

There was 'Strong agreement' or 'Agreement' with the statement "Maintaining groundcover and shrubs in the range improves bird welfare", Figure 17. The responses came from F and M producers. No producers with F responded with 'Disagree' or 'Strongly disagree', whereas one M producer responded 'Disagree', and one producer with FSD responded with 'Strongly disagree'.

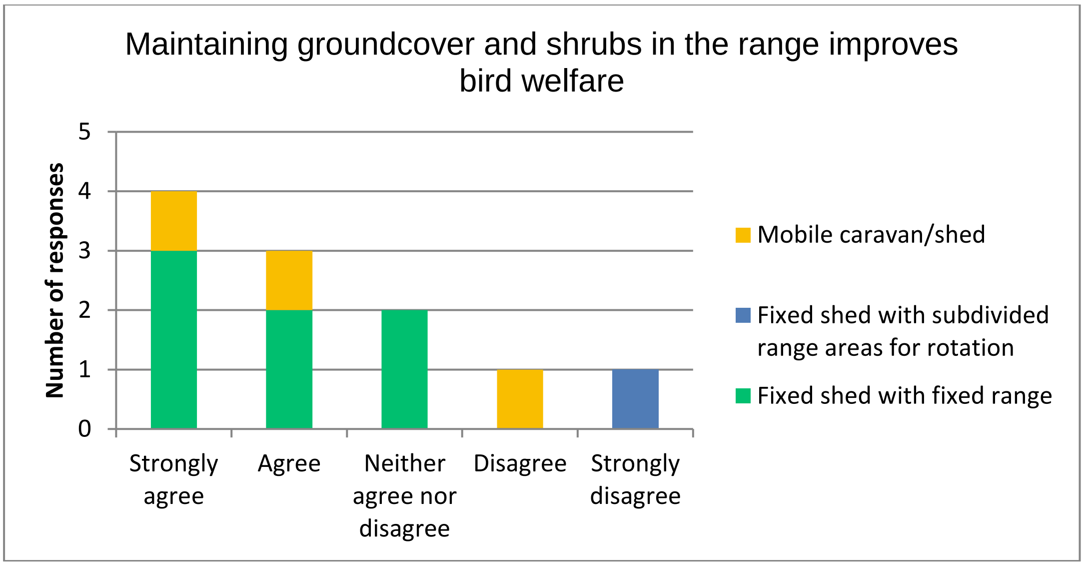

Figure 17 Responses of free range producers to the statement "Maintaining groundcover and shrubs in the range improves bird welfare"

Response categories are Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree.
Yellow – Mobile caravan/shed producers.
Blue – Fixed shed with subdivided range producers.
Green – Fixed shed with fixed range producers.

Responses are more divided to the statement "I have a marketing advantage by having a good groundcover vegetation regeneration system on my farm", Figure 18. Four respondents 'Strongly agree' or 'Agree', four respondents 'Neither agree nor disagree', and four respondents 'Disagree' or 'Strongly disagree'.

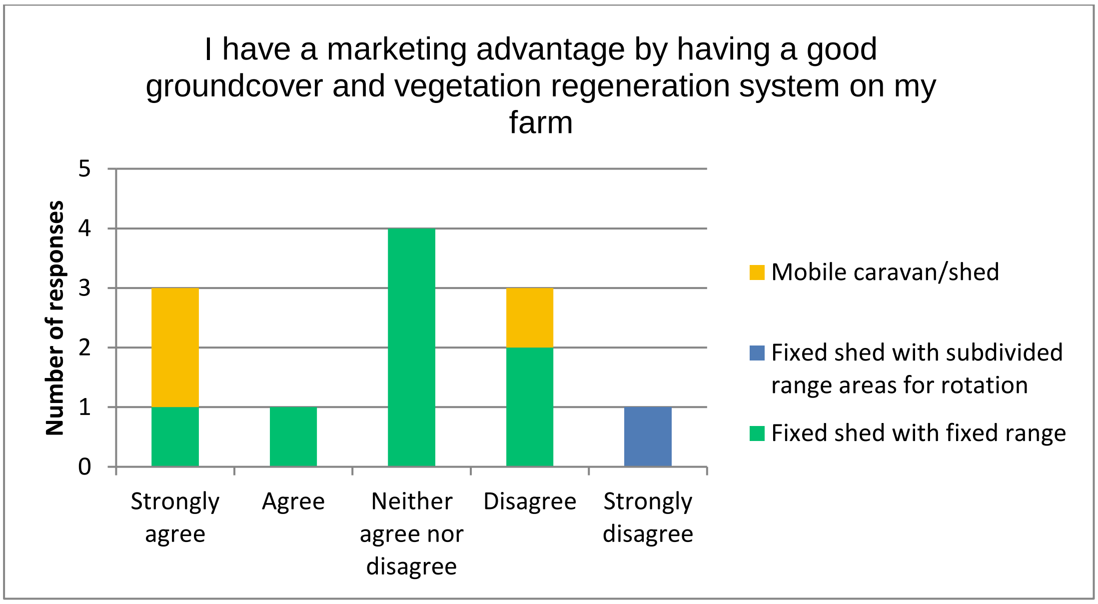

Figure 18 Responses of free range producers to the statement "I have a marketing advantage by having a good groundcover and vegetation regeneration system on my farm"

Response categories are Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree.
Yellow – Mobile caravan/shed producers.
Blue – Fixed shed with subdivided range producers.
Green – Fixed shed with fixed range producers.

Respondents had the opportunity to add comments on their range regeneration experiences. One comment was received from an M producer: "The range has little effect on bird's production, our experience is that too much vegetation leads to loss in production, a good feed is more important than vegetation they have access to."

Appendix B – Plant tissue results

Table 13 Mean ± SEM plant tissue results for Farm 1 saltbush, Farm 2 olive trees and Farm 3 grapevines at different distances from the shed

	Farm 1*			
	10 m	**50 m**	**100 m**	**Target range**
K (%)	2.30 ± 0.37	2.49 ± 0.16	2.20 ± 0.11	-
S (%)	0.54 ± 0.01	0.66 ± 0.06	0.82 ± 0.02	-
Ca (%)	0.70 ± 0.03	0.79 ± 0.12	0.89 ± 0.05	-
Mg (%)	0.56 ± 0.04	0.61 ± 0.04	0.69 ± 0.04	-
Na (%)	7.57 ± 0.18	7.67 ± 0.09	7.77 ± 0.03	-
B (mg/kg)	70.0 ± 6.0	67.0 ± 5.7	85.3 ± 8.7	-
Fe (mg/kg)	72.3 ± 4.2	65.3 ± 5.4	57.0 ± 2.1	-
Mn (mg/kg)	42.0 ± 2.1	45.3 ± 7.8	79.3 ± 12.2	-
Cu (mg/kg)	4.4 ± 0.1	4.1 ± 0.5	7.9 ± 0.7	-
Zn (mg/kg)	21.7 ± 0.3	21.0 ± 1.0	25.0 ± 0.6	-
Cl (%)	8.8 ± 1.2	9.7 ± 0.1	10.1 ± 0.5	-
Al (mg/kg)	36.0 ± 5.5	25.0 ± 4.7	23.3 ± 3.2	-
Mo (mg/kg)	0.56 ± 0.08	0.53 ± 0.08	0.60 ± 0.08	-
	Farm 2			
	15 m	**50 m**	**100 m**	**Target range**
K (%)	1.31 ± 0.01	1.38 ± 0.02	1.45 ± 0.02	All above 1.2%
S (%)	0.16 ± 0.01	0.13 ± 0.01	0.17 ± 0.01	0.10 – 0.25
Ca (%)	0.58 ± 0.01	0.55 ± 0.03	0.50 ± 0.01	1% <
Mg (%)	0.11 ± 0.00	0.11 ± 0.01	0.10 ± 0.00	0.1 – 0.5
Na (%)	0.06 ± 0.01	0.03 ± 0.00	0.04 ± 0.00	0.08 – 0.14
B (mg/kg)	24.7 ± 0.7	19.3 ± 1.9	24.3 ± 0.3	19 - 100
Fe (mg/kg)	87.0 ± 8.1	50.3 ± 4.4	40.0 ± 0.0	30 -130
Mn (mg/kg)	19.3 ± 0.9	15.3 ± 0.3	15.3 ± 0.3	20 - 40
Cu (mg/kg)	5.8 ± 0.5	4.9 ± 0.6	7.1 ± 0.1	4 - 10
Zn (mg/kg)	17.0 ± 0.6	13.0 ± 1.0	17.7 ± 0.3	10 - 30
Cl (%)	0.25 ± 0.02	0.17 ± 0.01	0.20 ± 0.00	0.2 – 0.39
Al (mg/kg)	100.7 ± 11.0	49.7 ± 9.0	31.3 ± 0.3	No target available
Mo (mg/kg)	0.10 ± 0.01	0.11 ± 0.03	0.15 ± 0.02	0.8 – 1.8
	Farm 3			
	23 m	**50 m**	**100 m**	**Target range**
K (%)	1.25 ± 0.02	1.27 ± 0.04	1.68 ± 0.49	0.80 – 1.60
S (%)	0.22 ± 0.02	0.24 ± 0.00	0.30 ± 0.07	0.21 – 0.40
Ca (%)	1.8 ± 0.1	2.0 ± 0.1	2.5 ± 0.5	1.8 – 3.2
Mg (%)	0.28 ± 0.02	0.24 ± 0.01	0.41 ± 0.09	0.3 – 0.6
Na (%)	0.03 ± 0.01	0.03 ± 0.00	0.06 ± 0.01	0.05 – 0.2
B (mg/kg)	21.7 ± 1.2	24.7 ± 1.8	33.0 ± 8.5	30 - 100
Fe (mg/kg)	108 ± 22	113 ± 7	170 ± 60	30 - 130
Mn (mg/kg)	65.3 ± 13.1	98.7 ± 5.7	116.7 ± 14.5	30 - 150
Cu (mg/kg)	1.60 ± 0.00	1.60 ± 0.00	1.63 ± 0.03	10 - 100
Zn (mg/kg)	41 ± 6	59 ± 5	65 ± 9	30 - 60
Cl (%)	0.24 ± 0.04	0.28 ± 0.03	0.26 ± 0.03	0.1 – 1.3
Al (mg/kg)	147 ± 9	120 ± 12	159 ± 56	No target available
Mo (mg/kg)	0.42 ± 0.05	0.96 ± 0.13	0.73 ± 0.11	0.09 – 0.45

The target range for good growth is given for olives (flowering/early fruit set) and wine grapevines at veraison.
* There is no suitable target range available for saltbush.

Plain English Summary

Project Title:	Cost effective and practical ways to regenerate layer hen ranges
Australian Eggs Limited Project No	31RS101SA
Researchers Involved	C.T. de Koning, S. Clarke, E. McGahan, F. Copley and S. Wiedemann
Organisations Involved	SARDI, PPPI building, Roseworthy Campus, Roseworthy SA 5371 Integrity Ag and Environment, 10 Neil Street, Toowoomba, QLD 4350
Phone	08 8313 7781
Fax	Not Applicable
Email	Carolyn.dekoning@sa.gov.au
Objectives	Provide farmers with tools and examples of how to increase vegetation cover on free range farms.
Background	Free range layer hens can be damaging while they are foraging on the outdoor range. Their scratching and pecking behaviour causes physical damage to tree roots and groundcover plants. In addition, nutrients (e.g. nitrates and phosphorus) from hen excreta build up in soils where hens congregate close to the shed and under shelters and trees. As a result, the functionality of the range can be diminished, with the increase of weed plant species, soil compaction in heavily utilised areas, and parasite build up in soils. Cost-effective and practical strategies and design features are needed to mitigate the impacts caused by hen activities on the range.
Research	This project had four components to enable the collection of information on successful range regeneration strategies from different sources that considered the diverse climate and soils of Australia. The four components of the project were: 1. Literature review 2. Online survey 3. Targeted case study interviews 4. The impact of high soil nutrient levels on trees and shrubs growing on the range. All four components contributed to the development of the Guideline Package.
Outcomes	Guideline Package for Australian free range egg producers outlining practical and cost-effective strategies to regenerate the range.
Implications	Increase the number of free range producers actively regenerating their ranges and/or using practices that minimise the need for range regeneration.
Key Words	Free range, regenerate, fixed shed, mobile caravan, enrichments.
Publications	The main publication was the Guideline Package.