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Shrub-based plantings of woody perennial vegetation in temperate Australian agricultural landscapes: What benefits for native biodiversity?

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Summary **In the highly fragmented agricultural landscapes of temperate southern Australia, fodder shrubs are being established as part of commercial grazing enterprises to fill the summer-autumn livestock feed gap. These woody perennial plantings have greater structural complexity than conventional grazing systems and may supplement resources for native fauna. However, to date the resources provided by these systems are poorly defined or documented. In this paper, we identify the potential environmental values of fodder shrub plantings by considering natural and planted shrub-based systems, with a particular focus on planted saltbush in non-saline lands. In marginal agricultural areas, shrub-based perennial fodder crops can not only provide economic benefits through improved livestock productivity, but also contribute to reducing soil erosion and offer potential carbon sequestration opportunities. We contend that these systems may also provide resources for a range of native fauna. More information is needed on the biodiversity value of grazing systems based on perennial shrubs so that their potential to contribute to conservation in multifunctional landscapes can be fully realised and appropriate management recommendations provided.**

Key words: *agricultural landscape, biodiversity, saltbush, woody perennial.*

Broad-Scale Ecological Restoration in southern Australia – Needs and Realities

The temperate landscapes of southern Australia have undergone extensive transformation to agriculture following European settlement. Subsequent intensive land use has resulted in widespread habitat fragmentation and degradation, leading to a loss of biodiversity at local and landscape scales (Hobbs 1993). In an effort to improve natural resource management outcomes, broad-scale revegetation has been underway in agricultural landscapes across southern Australia over recent decades. Significant government and private sector efforts have been targeted at protecting remnant vegetation with fencing and supplementary planting with mixed species native perennial vegetation, mainly through Commonwealth Government programmes such as the *Natural Heritage Trust*.

These plantings play an important role in biodiversity conservation (Kavanagh *et al.* 2005; Loyn *et al.* 2007; Munro *et al.* 2007). However, it is evident that such 'Landcare-style' plantings are falling short of achieving the level of landscape transformation that is required because of constraints associated with short-term profitability and inadequate incentives for farmers to change their land management practices (Morrison *et al.* 2008). This is paralleled by increasing recognition of the importance of different components of these managed production environments for native species and the need to incorporate these components into sustainable landscape management (Craig *et al.* 2000; Hobbs *et al.* 2008).

Protecting and enhancing remnant vegetation or restoring land with mixed stands of indigenous vegetation should remain a priority for biodiversity conservation. However, other elements of managed agricultural landscapes may have the potential to contribute to local and landscape-scale biodiversity conservation, particularly in highly modified environments (Haslem & Bennett 2008; Collard *et al.* 2009). In marginal farming areas of temperate Australia, an increasing number of land managers are using alternative management systems, including perennial fodder shrubs such as saltbush species, to broaden the feed base over summer and autumn in grazing systems (McKenna *et al.* 2009). We contend that such fodder shrubs have the potential to provide shrub layer vegetation and associated resources for biodiversity as well as supplementing existing perennial plantings and stands of native vegetation (which typically lack understorey components) in highly modified landscapes (Table 1). Should these planted systems function as habitat for native biodiversity, they may well represent 'novel' ecosystems (*sensu* Hobbs *et al.* 2008), with potential to 'soften' the agricultural matrix (Manning *et al.* 2006) and thus enhance agro-ecosystem biodiversity.

Across South Australia, 7000 ha of saltbush (mostly Old Man Saltbush, *Atriplex nummularia*) were planted between 1999 and 2006 (Sheppard & Wilson 2007). In the Murray Mallee region of South Australia alone, 6080 ha of woody revegetation were planted during the same period,

Table 1. Potential mechanisms by which planted fodder shrub systems could provide benefits to native fauna at different spatial scales

Spatial scale	Resource	Components	Benefits
Site	Food (direct source)	Flowers, seeds, leaves of planted fodder shrubs	Supplement foraging opportunities – increased survival
	Food (indirect source)	Prey items (e.g. invertebrates and other animals) associated with plantings Volunteer plants and weeds in fodder shrub plantings	Supplement foraging opportunities – increased survival
	Habitat structure	Shrub and groundcover plants	Shelter from elements and predators (i.e. refuge areas), nesting substrate – increased survival
Landscape	Structural heterogeneity	Fodder shrubs planted in blocks and strips	Reduce contrast between adjacent land uses and thereby facilitate movement Reduce the effects of fragmentation Provide for greater landscape resilience by buffering disturbance effects
	Habitat connectivity	Fodder shrubs planted in blocks and strips	Facilitate movement (i.e. dispersal, migration) through the landscape Reduce distance between isolated metapopulations
	Buffers for native vegetation remnants	Plantings adjacent to existing vegetation/revegetation	Reduce harmful incursions from surrounding areas (e.g. weeds, herbicides, grazing) Supplement core habitat for some species

of which 3940 ha (65%) comprised mixed native species and 1600 ha (26%) comprised saltbush plantings (Table 2). The increase in structural complexity that results from such large areas of planted woody vegetation may provide important resources for native biota when considered at a regional level (Fischer *et al.* 2004; Munro *et al.* 2007). However, despite its growing presence in the landscape, few studies have assessed the value of planted saltbush for biodiversity (but see Norman *et al.* 2008; Seddon *et al.* 2009).

Potential Biodiversity Values of Shrub-Based Plantings

The value of understorey vegetation components for native fauna is well established (e.g. Catling & Burt 1995; Arnold 2003; Hobbs *et al.* 2003). However, unlike the growing body of research on broad-scale forestry, agroforestry and native revegetation systems (reviewed by Munro *et al.* 2007), there is little available information on the use of shrub-based plantings by native fauna where trees are absent. While a number of published articles identify the potential benefits of shrub-based systems for biodiversity (e.g. Millsom 2002; Newton & Yunusa 2002; Lefroy *et al.* 2005), few studies demonstrate their actual ecological value.

In their natural state, chenopod shrublands in semi-arid areas are known to provide habitat for a range of native fauna. For example, biological surveys of the North and South Olary Plains in South Australia, found that a number of mammal, bird and reptile groups are associated with different forms of chenopod shrubland (Forward & Robinson 1996; Playfair *et al.* 1997). In the North Olary Plains, Playfair *et al.* (1997) classified fourteen bird species that were characteristic of open chenopod shrublands, including Orange Chat (*Epthianura aurifrons*), Rufous Fieldwren (*Calamanthus campestris*) and White-winged Fairy Wren (*Malurus leucopterus*). These species were associated with low shrublands and are notable as ground-feeding specialists that forage, rest and breed at ground or low shrub level. Forward and Robinson (1996) also recorded the Blue-winged Parrot (*Neophema chrysostoma)* and Stubble Quail (*Coturnix pectoralis*) in treeless chenopod shrublands in the same region of South Australia, both of which are listed as Vulnerable under the SA *National Parks and Wildlife Act 1972*. The apparent dependence of some native species on shrubby vegetation systems suggests that shrub-based plantings in agricultural areas may provide suitable habitat and resources for these and other species.

Evidence of enhanced fauna use of planted saltbush systems exists in the literature. For example, Millsom (2002) reported improvements in habitat value of Old Man Saltbush rotations in New South Wales and Victoria, including casual observations from landholders of increased use

Table 2. Revegetation activities in the South Australian Murray Mallee region [Adapted from Sheppard and Wilson (2007) with permission]. Areas are cumulative totals from data collected annually from 1999 to 2006

Type of revegetation	Total (ha)	%
Indigenous	3940	66
Native	130	2
Farm forestry	200	3
Saltbush	1600	26
Tagasaste	80	1
Product species	20	<1
Softwood forestry	80	1
Total	6080	100

by invertebrates, reptiles and birds. Furthermore, a study by Shields (unpublished data cited in Millsom 2002) showed that a 4-year-old stand of Old Man Saltbush had lower spider populations than remnant vegetation, but higher populations than an open paddock. In northern Africa, Le Houérou (1992) reported higher microbial activity and an elevated concentration of wildlife in areas rehabilitated with saltbush.

Recent research on biodiversity and ecosystem function in saltbush systems has been conducted as part of larger national research programmes such as the *Grain and Graze* and *Sustainable Grazing on Saline Lands* projects. For example, Seddon *et al.* (2009) recorded higher site condition scores in Old Man Saltbush sites, including higher floristic and structural diversity, compared with conventionally managed areas in alley farming systems in Condobolin, New South Wales. Site condition and plant species richness (native grasses and forbs) increased with time since establishment. However, bird diversity and abundance were not significantly higher in saltbush plantings than in conventionally managed farmland (cropping and grazing rotation), even though structural complexity and plant species diversity were higher in the saltbush. Despite this, an increase in site condition over time was linked to an increase in woodland and 'decreaser' bird species. Other more abundant faunal indicators (e.g. invertebrate functional groups) may be able to better reflect the difference in vegetation structure between land uses.

In the salt-affected lands of Western Australia, recent research detected no clear differences in invertebrate abundance, orders, or functional groups between remnant vegetation, unimproved saltland pasture and saltbush treatments (Norman *et al.* 2008). However, other indicators associated with biodiversity and ecosystem function (e.g. groundcover and microbial respiration) were higher in planted saltbush than in conventionally managed control plots (Norman *et al.* 2008). It is likely that the saline nature of such environments may obscure the effect of differences in land management, compared with non-saline systems.

Site-level attributes (e.g. native understorey plants, logs) and wider landscape context are both important determinants of species' occurrence (Lindenmayer & Hobbs 2004). For example, Haslem and Bennett (2008) suggest that 'countryside elements' (i.e. those embedded in the agricultural matrix) can have a positive effect on biodiversity conservation by: (i) providing resources in their own right, (ii) reducing the effects of fragmentation, and (iii) increasing heterogeneity of agricultural environments. Table 1 provides a list of site and landscape-scale mechanisms by which planted fodder shrub systems could provide beneficial resources for native fauna.

Incorporating Shrub-Based Plantings into Agricultural Landscapes

From a faunal perspective, structural complexity is an important factor affecting the occurrence and abundance of different species (Fischer *et al.* 2004). In the highly fragmented and modified forest and woodland agro-ecosystems of temperate southern Australia, different land management practices fall along a gradient of vegetation structural complexity (Munro *et al.* 2007), which generally corresponds to an opposing gradient of land use intensity (Fig. 1). Shrub-based systems (e.g. saltbush) are included as an alternative woody perennial planting type in this framework. Native fauna may be affected in different ways by the type and establishment pathways of revegetation (Fig. 1). Although poorly established for planted woody perennial shrubs, general principles of landscape ecology and metrics developed for native fauna in patches of remnant vegetation in fragmented landscapes (e.g. thresholds of habitat extent, patch size, connectivity) may also be applicable to planted shrub systems. As identified by Munro *et al.* (2007), more information is needed on these landscape factors to guide the placement of planted woody perennial systems in farming landscapes. This could be achieved using approaches such as habitat

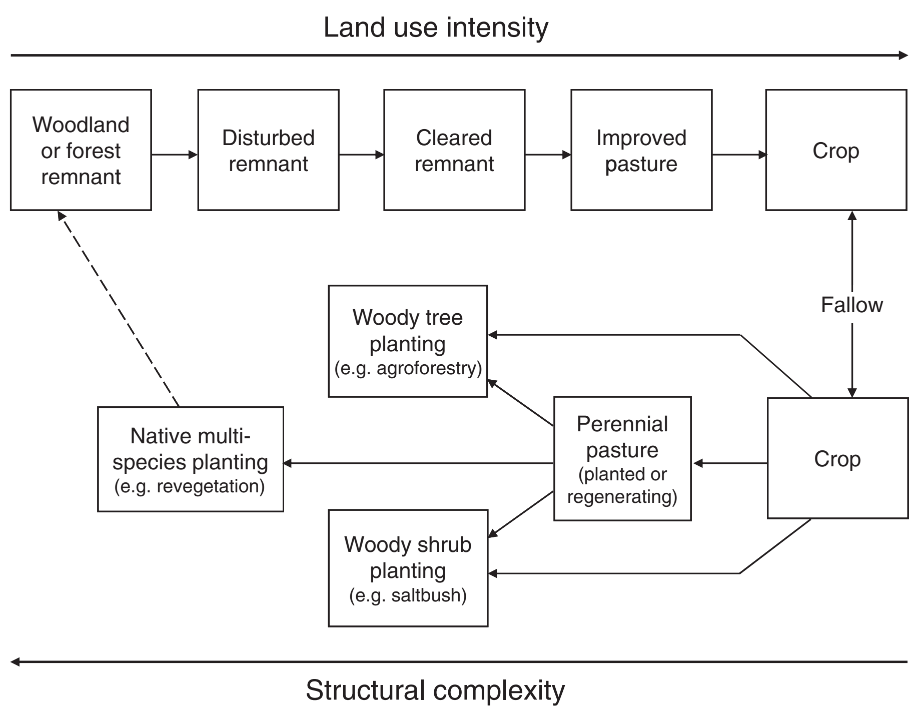

Figure 1. Conceptual framework for considering shrub-based planted woody perennial vegetation in multiple use agricultural landscapes. Local-scale land management practices exist at different points along opposing gradients of land use intensity (top line) and structural complexity (bottom line). Woody shrub plantings are shown in the lowest box.

contour maps proposed by Fischer *et al.* (2004), which consider habitat gradients for individual species.

Multiple Benefits of Planted Shrub-Based Systems

The production aspects of growing shrub-based systems such as saltbush in low to moderate rainfall areas are well documented (Bartel & Knight 2000; McKenna *et al.* 2009). However, such plantations have the potential to play a role in achieving multiple natural resources management objectives for biodiversity and sustainable land management (Lefroy & Smith 2004). Prober and Hobbs (2008) advocate a target of 30% of perennial production systems in degraded woodland landscapes, arguing that they can augment resources for native species and help restore viable farm incomes. Shrub-based forage systems are being explored as the next generation of livestock grazing systems, designed to be resilient in the face of a changing climate (Hobbs *et al.* 2009). Such plantings can improve structural complexity and landscape heterogeneity and it is logical to consider that they may thereby improve resource availability for some native fauna, particularly if they incorporate more than one planted species. Furthermore, native 'volunteer' or planted groundcover components between saltbush rows have the potential to improve carrying capacity, reduce soil erosion and enhance floristic diversity.

Comparatively high productivity on low fertility soils also makes saltbush a potentially useful species for biosequestration in the light of an emerging carbon emissions trading industry (Hobbs 2009). The likely expansion of carbon plantings in coming years, particularly in low-moderate rainfall areas where other agricultural crops may prove marginal or unviable given a changing climate, has potentially significant implications for biodiversity. Considering the limited information on biodiversity and its management in these modified systems, opportunities exist to quantify the biodiversity in existing saltbush plantings and in other planted landscape elements. Evidence-based decisions can then be made about the placement and management of these and future multiple species plantings at property and landscape scales to improve production and biodiversity outcomes.

References

Arnold G. W. (2003) Bird species richness and abundance in wandoo woodland and in tree plantations on farmland at Baker's Hill, Western Australia. *Emu* **103**, 259–269.

Bartel B. and Knight A. (2000) *Oldman Saltbush: Farmer Experiences in Low Rainfall Systems*. Primary Industries and Resources South Australia, Adelaide, SA.

Catling P. C. and Burt R. J. (1995) Studies of the ground-dwelling mammals of eucalypt forests in south-eastern New South Wales: the effect of habitat variables on distribution and abundance. *Wildlife Research* **22**, 271–288.

Collard S., LeBrocque A. and Zammit C. (2009) Bird assemblages in fragmented agricultural landscapes: the role of small brigalow remnants and adjoining land uses. *Biodiversity and Conservation* **18**, 1649–1670.

Craig J. L., Mitchell N. and Saunders D. A. (eds) (2000) *Nature Conservation 5: Conservation in Production Environments: Managing the Matrix*. Surrey Beatty and Sons, Chipping Norton, NSW.

Fischer J., Lindenmayer D. B. and Fazey I. (2004) Appreciating ecological complexity: habitat contours as a conceptual landscape model. *Conservation Biology* **18**, 1245–1253.

Forward L. R. and Robinson A. C. (eds) (1996) *A Biological Survey of the South Olary Plains, South Australia, 1991–1992*. Biological Survey and Research, Natural Resources Group, Department of Environment and Natural Resources, South Australia.

Haslem A. and Bennett A. F. (2008) Countryside elements and the conservation of birds in agricultural environments. *Agriculture, Ecosystems and Environment* **125**, 191–203.

Hobbs R. J. (1993) Effects of landscape fragmentation on ecosystem processes in the western Australian wheatbelt. *Biological Conservation* **64**, 193–201.

Hobbs T. J. (ed) (2009) *Regional industry potential for woody biomass crops in lower rainfall southern Australia. FloraSearch 3c*. Report to the Joint Venture Agroforestry Program and Future Farm Industries CRC. Publication No. 09/045. Rural Industry Research and Development Corporation, Canberra, ACT.

Hobbs R. J., Catling P. C., Wombey J. C., Clayton M., Atkins L. and Reid A. (2003) Faunal use of bluegum (*Eucalyptus globulus*) plantations in southwestern Australia. *Agroforestry Systems* **58**, 195–212.

Hobbs R. J., Arico S., Aronson J. *et al.* (2008) Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* **15**, 1–7.

Hobbs T. J., Bennell M. and Bartle J. (eds) (2009) *Developing species for woody biomass crops in lower rainfall southern Australia. FloraSearch 3a*. Report to the Joint Venture Agroforestry Program and Future Farm Industries CRC. Publication. No. 09/043. Rural Industry Research and Development Corporation, Canberra, ACT.

Kavanagh R., Law B., Lemckert F. *et al.* (2005) *Biodiversity in eucalypt plantings established to reduce salinity*. Rural Industries Research and Development Corporation/Land and Water Australia/Forest and Wood Products Research and Development Corporation/Murray-Darling Basin Commission, Canberra, ACT. Publication No. 05/165 for the Joint Venture Agroforestry Program.

Le Houérou H. N. (1992) The role of saltbushes (*Atriplex* spp.) in arid land rehabilitation in the Mediterranean Basin: a review. *Agroforestry Systems* **18**, 107–148.

Lefroy E. C. and Smith P. F. (2004) The biodiversity value of farming systems and agricultural landscapes. *Pacific Conservation Biology* **10**, 80–87.

Lefroy E. C., Flugge F., Avery A. and Hume I. (2005) Potential of current perennial plant-based farming systems to deliver salinity management outcomes and improve prospects for native biodiversity: a review. *Australian Journal of Experimental Agriculture* **45**, 1357–1367.

Lindenmayer D. B. and Hobbs R. J. (2004) Fauna conservation in Australian plantation forests – a review. *Biological Conservation* **119**, 151–168.

Loyn R. H., McNabb E. G., Macak P. and Noble P. (2007) Eucalypt plantations as habitat for birds on previously cleared farmland in south-eastern Australia. *Biological Conservation* **137**, 533–548.

Manning A. D., Fischer J. and Lindenmayer D. B. (2006) Scattered trees are keystone structures: Implications for conservation. *Biological Conservation* **132**, 311–321.

McKenna D. J., Bennell M. and Mazanec R. (2009) Review of *Atriplex nummularia* (Old Man Saltbush) and its potential for domestication as a fodder plant in Australian dryland farming systems. *In*: *Domestication Potential of High Priority Species (Acacia saligna, Atriplex nummularia and Eucalyptus rudis) for Woody Biomass Crops in Lower Rainfall southern Australia. FloraSearch 3b*. (eds T. J. Hobbs, J. Bartle and M. Bennell) pp. 81–124. RIRDC Publication No. 09/043.Rural Industries Research and Development Corporation, Barton, ACT.

Millsom D. A. (2002) Direct seeding of saltbush: landholder-driven initiatives. *Ecological Management & Restoration* **3**, 156–166.

Morrison M., Durante J., Greig J. and Ward J. (2008) *Encouraging Participation in Market based Instruments and Incentive Programs*. Land and Water Australia, Canberra, ACT.

Munro N. T., Lindenmayer D. B. and Fischer J. (2007) Fauna response to revegetation in agricultural areas of Australia: a review. *Ecological Management and Restoration* **8**, 199–207.

Newton P. J. and Yunusa I. A. (2002) Future roles for native woody species in Australian agricultural landscapes. *In*: *Agriculture for the Australian Environment*. Proceedings of the 2002 Fenner Conference on the Environment, (eds B. P. Wilson and A. Curtis) pp. 326–338, Johnstone Centre, Charles Sturt University, Albury, NSW.

Norman H. C., Masters D. G., Silberstein R. *et al.* (2008) Sustainable grazing on saline lands WA 1 research project – final report. Available from URL: http://www.landwaterwool.gov.au/products/pk071404. Accessed 28 May 2008.

Playfair R. M., De Jong M. C. and Matthew J. S. (1997) North Olary Plains biological survey: birds. *In*: *A Biological Survey of the North Olary Plains South Australia, 1995–1997*. (eds R. M. Playfair and A. C. Robinson) pp. 139–150, Natural Resources Group, Department of Environment and Natural Resources, South Australia.

Prober S. M. and Hobbs R. J. (2008) Temperate eucalypt woodlands. *In*: *Ten Commitments: Reshaping the Lucky Country's Environment*. (eds D. Lindenmayer, S. Dovers, M. Harriss Olson and S. Morton) pp. 19–25, CSIRO Publishing, Collingwood, Vic.

Seddon J., Doyle S., Bourne M., MacCallum R. and Briggs S. (2009) Biodiversity benefits of alley farming with old man saltbush in central western New South Wales. *Animal Production Science* **49**, 860–868.

Sheppard D. and Wilson J. (2007) *Re-Establishment of Vegetation in South Australia 2006*. Department of Water, Land and Biodiversity Conservation, Adelaide; DWLBC Report 2007/26.