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TECHNICAL ARTICLE

Softening the agricultural matrix: a novel agri-environment scheme that balances habitat restoration and livestock grazing

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The loss and degradation of woody vegetation in the agricultural matrix represents a key threat to biodiversity. Strategies for habitat restoration in these landscapes should maximize the biodiversity benefit for each dollar spent in order to achieve the greatest conservation outcomes with scarce funding. To be effective at scale, such strategies also need to account for the opportunity cost of restoration to the farmer. Here, we critique the Whole-of-Paddock Rehabilitation program, a novel agri-environment scheme which seeks to provide a cost-effective strategy for balancing habitat restoration and livestock grazing. The scheme involves the revegetation of large (minimum 10 ha) fields, designed to maximize biodiversity benefits and minimize costs while allowing for continued agricultural production. The objectives and design of the scheme are outlined, biodiversity and production benefits are discussed, and we contrast its cost-effectiveness with alternative habitat restoration strategies. Our analysis indicates that this scheme achieves greater restoration outcomes at approximately half the cost of windbreak-style plantings, the prevailing planting configuration in southeastern Australia, largely due to a focus on larger fields, and the avoidance of fencing costs through the use of existing farm configuration and infrastructure. This emphasis on cost-effectiveness, the offsetting of opportunity costs through incentive payments, and the use of a planting design that seeks to maximize biodiversity benefits while achieving production benefits to the farmer, has the potential to achieve conservation in productive parts of the agricultural landscape that have traditionally been "off limits" to conservation.

Key words: agricultural landscapes, cost-effective conservation, ecological restoration, farmland biodiversity

Implications for Practice

- The use of existing farm infrastructure and configuration, efficient restoration technologies, and a focus on large fields can achieve woody vegetation restoration within the agricultural matrix at lower cost than prevailing approaches.
- An emphasis on co-benefits of restoration to the farmer and offsetting of opportunity costs through incentive payments, coupled with minimal disruption to farming systems, creates a restoration approach with the potential to achieve large-scale adoption in grazing-dominated landscapes.
- Careful consideration of economic costs, including private opportunity costs, in restoration scheme design and implementation can greatly increase the conservation outcomes per dollar spent.

Introduction

Conserving biodiversity in agricultural landscapes in the face of growing agricultural production represents a key challenge at a global scale (Green et al. 2005). Conservation efforts typically focus on the protection and restoration of remnant habitats, which provide important refuges in an environment that is otherwise largely uninhabitable for many species (Fischer & Lindenmayer 2002*a*). Recent research, however, has highlighted the importance of the agricultural matrix itself in the ecology and conservation of species in fragmented landscapes (e.g. Driscoll et al. 2013).

Within the agricultural matrix, woody vegetation represents important habitat, with much of the remaining cover restricted to narrow, linear features such as fence boundaries, riparian strips, roadside remnants, and scattered trees (Manning et al. 2006; Welsch et al. 2014). These habitat features serve to "soften" the agricultural matrix (Franklin 1993) and facilitate important ecological functions at a variety of scales (Fischer & Lindenmayer 2002*a*).

However, continued clearing of remnant woody vegetation (Hansen et al. 2013) and the loss of scattered trees (Gibbons et al. 2008) will lead to an increasingly homogeneous and impermeable agricultural matrix suitable for a much narrower spectrum of species (Duncan & Dorrough 2009), prompting

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increasing calls for restoration of habitat in the agricultural matrix as part of a comprehensive landscape-scale response to biodiversity conservation (Vandermeer & Perfecto 2007; Fischer et al. 2010).

Restoring Habitat in the Matrix

Conservation efforts in the agricultural matrix need to account for opportunity cost; that is the loss of revenue from agricultural production that results from an alternative use of that land (i.e. conservation; House et al. 2008). Agri-environment schemes (AES), which broadly involve the payment of incentives to farmers in return for the provision of ecological goods (Burrell 2012), provide such a mechanism. Billions of dollars are spent annually on AES around the world (European Commission 2014; USDA 2014). These schemes typically focus on the maintenance of traditional farming practices (e.g. organic farming) and grassland-focused restoration (e.g. sown wildflower strips). There have been relatively few attempts to restore native woody vegetation at scale in the agricultural matrix (e.g. Benayas et al. 2008; Zahawi et al. 2013). These approaches typically establish small or linear habitat patches, focus on expansion of existing woodlands, or target abandoned agricultural land. There is a clear need for large-scale, cost-effective strategies to restore woody vegetation in the agricultural matrix using measures that integrate production and biodiversity conservation.

The Whole-of-Paddock Rehabilitation Scheme

Up to 95% of some woodland communities have been cleared across Australia's southeast, with remaining patches of vegetation typically small and isolated or restricted to reserves (Yates & Hobbs 1997). Opportunities for biodiversity conservation on private land are therefore limited. Whole-of-Paddock Rehabilitation (WOPR) is a voluntary, self-nominating AES developed as a strategy for achieving large-scale, cost-effective landscape restoration in agricultural landscapes through the integration of production and biodiversity benefits.

WOPR was established in 2008 by Greening Australia (GA), a national environmental nonprofit organization, with the primary objective of integrating biodiversity conservation and agricultural production through the generation of multiple environmental and production benefits (Greening Australia 2014). The scheme targets livestock grazing or mixed enterprise farms and involves active restoration, using direct seeding, to restore native woody plants across large (>10 ha) fields through a 10-year management agreement that provides farmers with a fixed, area-based incentive payment to offset production losses (Streatfield et al. 2010) (see Box 1 for overview). Existing fields in active production areas are targeted, focusing on sites with the greatest potential for environmental benefits and issues that impact on farm productivity (e.g. exposed, eroding, saline, or weed-infested fields).

Enrolment in WOPR has increased from 10 agreements (covering a total of 198 ha) in 2008 to 80 agreements in 2014 which now cover a total of 2,012 ha (Table 1). The average size of enrolled fields has doubled from 19.8 to 38.6 ha (Table 1). Two fields greater than 90 ha have been enrolled, and the scheme now has farms enrolled across approximately 24,000 km^2. The enrolled fields are within southeastern New South Wales where the dominant agricultural land use is sheep and cattle grazing on modified pastures, with increasing dryland crop production to the west.

Here, we profile and critique this novel AES. We aim to explore the strengths and weaknesses of the design and implementation of the scheme with a view to identifying factors that may contribute to the development of similar programs elsewhere.

Box 1: Typical WOPR Establishment Process and Timeline

1. Contract developed between farmer and GA outlining project design, management obligations, and payment schedule.
2. Field prepared by farmer, including herbicide application, supplementary fencing, and pest control.
3. Field sown by GA with 10–20 native tree and shrub species in 15 m wide bands consisting of four lines of direct seeding 5 m apart, with each band 40 m apart.
4. Farmer excludes livestock for 5 years in return for $50/ha year stewardship payment (50% in year 1 and 50% in year 5).
5. Livestock reintroduced under rotational grazing for the remaining 5 years.

Methods

We focused our critique on the potential biodiversity benefits of WOPR as well as other environmental and production benefits. The relative infancy of the program and limited number of established fields prevents a detailed evaluation of on-ground outcomes. Therefore, we draw here on the restoration literature to consider potential outcomes, focusing where possible on studies of revegetation in similar landscapes across the region.

We also evaluated the scheme's cost-effectiveness by comparing the costs of establishing a typical WOPR field with two

Table 1. Enrolment statistics for the WOPR scheme for the period 2008–2014.

Year of Establishment	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*Overall*
No. of fields enrolled	10	5	3	10	23	17	12	80
Total area enrolled (ha)	198	154	58	299	382	454	467	2,012
Cumulative total area (ha)	198	352	410	709	1,091	1,545	2,012	2,012
Average field size (ha)	19.8	30.8	19.3	29.9	16.6	26.7	38.9	25.2

Table 2. Comparison of the characteristics, cost, and cost-effectiveness of three alternative scenarios for the restoration of woody vegetation in a hypothetical 20 ha field (see Methods). Costs provided in AUD.

	WOPR	*Block Planting*	*Windbreak Planting*
Field characteristics			
Vegetation cover (%)	27	100	13
Vegetation cover (ha)	5.4	20	2.6
No. of stems/ha[a]	7,200	20,000	3,600
Private opportunity cost			
Loss of agricultural revenue[b]	$13,654	$24,578	$3,195
Public costs			
Site design ($50/ha), overheads ($200/ha), and contingency ($100/ha)	$7,000	$7,000	$7,000
Direct-seeding ($200/km)	$2,880	$8,000	$1,440
Fencing ($3,000/km)[c]	$0	$0	$5,040
Stewardship payment ($50/ha/year)	$4,051	$0	$0
Total public cost	$13,931	$15,000	$13,480
Total public cost per hectare of vegetation	$2,580	$750	$5,185
Total public cost per hectare of land	$696	$750	$674
Total public cost per stem	$1.93	$0.75	$3.74

[a]Based on 0.5 stems/m. [b]After Stewardship payment. [c]Assumes existing perimeter fencing used for WOPR and block scenarios; 50% of existing perimeter fencing used for windbreak scenario.

alternative scenarios selected to represent the spectrum of active restoration approaches in agricultural landscapes, including (1) a "windbreak" planting involving revegetation of a field perimeter with 15 m wide bands, arguably the most prevalent planting configuration and (2) a "block planting" involving revegetation and livestock exclusion of an entire field, a much less common planting design but beneficial for biodiversity, given minimization of edge effects (Helzer & Jelinski 1999).

We calculated the total public cost of each scenario in a restoring field of 20 ha (0.4 × 0.5 km). Costs were calculated over a 10-year time frame with a 10% discount rate, using 2015 prices ($AUD) provided by GA. We also estimated private opportunity costs for each scenario based on typical gross margins ($200/ha/year) for a sheep grazing enterprise on native pasture in the study region (NSW Department of Primary Industries 2014). We assumed a reduction in gross margin equal to the area of land under revegetation (i.e. approximate vegetation cover; Table 2). In other words, for the windbreak and block planting scenarios, the reduction in gross margin was 13 and 100%, respectively, whereas for the WOPR scenario, the reduction was 100% for 1–5 years (reflecting the livestock exclusion period) and 27% for the remaining 5 years.

Ideally, such an evaluation would use realized biodiversity benefits as the measure of effectiveness. In the absence of these data, we used two measures of native vegetation structure as a measure of the scheme effectiveness: native vegetation cover (% cover/ha) and number of stems per hectare. As the establishment of habitat for biodiversity is a key objective for WOPR, this provides an adequate measure of benefit for comparative purposes. Lastly, we consider the transferability of the scheme to other agricultural landscapes and explore the potential for its long-term viability.

Results

Biodiversity Benefits

WOPR aims to maximize biodiversity value by integrating a number of design aspects known to influence biodiversity response to restoration. Firstly, by establishing a minimum patch size of 10 ha, the scheme aims to avoid the proliferation of small plantings (e.g. 1–5 ha), which can support fewer species and abundances (Munro et al. 2011) and often dominate restoration on farms (Smith 2008). The design aligns with minimum patch size recommendations for woodland bird conservation in southeastern Australia (Freudenberger 1999), and the amount of vegetation cover across the WOPR field (approximately 30%) is consistent with recommended landscape-scale cover for sustainable land management in Australian temperate woodlands (McIntyre et al. 2000).

Secondly, the design seeks to avoid edge effects associated with narrow linear habitat patches (Helzer & Jelinski 1999), with the gaps between direct-seeded vegetation (40 m) sufficient to allow future agricultural production but less than movement thresholds identified for some woodland fauna (Robertson & Radford 2009; Doerr et al. 2011). Lastly, the sowing of several tree and shrub species in WOPR fields increases habitat complexity and provides habitat structures that are often missing from grazed woodland remnants in farmland but are important for many species (Kavanagh et al. 2007; Munro et al. 2011). In addition to planting design, of similar importance is the location in the landscape, such as proximity to remnant vegetation or other restoration sites (Lindenmayer et al. 2010). Currently, there are no criteria in the WOPR program relating to landscape context that guide site selection. As the scheme expands, consideration of landscape context will be an important factor in prioritizing sites.

Although WOPR fields provide habitat features often missing from agricultural landscapes within a much shorter time frame than natural regeneration often permits (Dorrough & Moxham 2005), the long-term biodiversity benefits are difficult to forecast. Direct-seeded habitat patches in the same region became more simplified over time as stem density and species richness decreased (Schneemann & McElhinny 2012). Similarly, the impact of resumed grazing in WOPR fields on biodiversity values is unknown at this stage. Rotational grazing, required under the WOPR agreement, can improve natural tree regeneration (Fischer et al. 2009) and the habitat value of direct-seeded vegetation in the long term compared to traditional grazing regimes (Sherren et al. 2011). Management choices beyond the WOPR agreement, however, rest with the farmer and will be influenced by factors beyond that of environmental gains. Maximizing biodiversity value in the long term is likely to be dependent on the continued use of rotational grazing, potentially coupled with activities aimed at maintaining vegetation structural complexity and diversity (e.g. use of native pasture species, soil disturbance, and prescribed-burning) (Schneemann & McElhinny 2012).

Agricultural Production and Other Benefits

The spatial configuration of vegetation planted within a WOPR field allows for the use of the space between vegetation bands for continued livestock grazing. This focus on co-benefits is the key to facilitating ecological restoration measures in productive parts of the agricultural landscape that have traditionally been "off limits" to conservation.

Anticipated production benefits to the farmer of enrolment in WOPR include the provision of shelter, shade, and additional forage, with potential improvements in the health, survival, and productivity of livestock and pasture (Lynch & Donnelly 1980; Monjardino et al. 2010; Greening Australia 2014). The approximate vegetation cover in an established WOPR field is consistent with identified vegetation cover thresholds for maximal pasture output (Walpole 1999). Additional benefits provided by the use of deep-rooted perennial plants include improved soil stability and erosion control as well as salinity mitigation (Bird et al. 1992; Schofield 1992; Lovell & Sullivan 2006). WOPR fields could also provide economic and environmental benefits through enrolment in carbon accreditation schemes (Department of Agriculture 2013).

Cost-Effectiveness

Comparison of the costs of restoration reveals the greater cost-effectiveness of WOPR relative to the prevailing windbreak planting configuration, with WOPR yielding more than twice the amount of vegetation for the same cost (Table 2). A key factor in this is WOPR's use of existing fields within the farm layout, thus avoiding additional fencing costs, a major cost component of restoration on farm land (Freudenberger et al. 2004; Table 2).

This comparison also shows the superior cost-effectiveness of the block planting scenario, which achieves restoration at costs approximately 71 and 85% less per vegetation hectare than WOPR and the windbreak planting, respectively. This is partly due to the absence of a stewardship payment under this hypothetical scenario. Our estimation of private opportunity costs (Table 2) demonstrates the substantial increase in cost to the farmer associated with this design, which would in turn necessitate an increase in public cost in the form of stewardship payments to offset the private costs. The efficiency of this configuration would be further reduced by the addition of fencing costs, which are assumed to be nonexistent in this scenario but which, unlike WOPR, would likely be required in reality. These factors coupled with the incompatibility of such an approach with future agricultural production make it non-viable for large-scale application. In contrast, the low opportunity costs of the windbreak configuration explain its prevalence in farming landscapes. However, this configuration is the least cost-effective in terms of public expenditure and likely to have lower biodiversity benefit as outlined above. This underscores the critical influence of private opportunity cost on the total public cost and potential benefits of restoration, and the necessity of offsetting these costs through incentive-based schemes and/or the incorporation of private benefits into scheme design.

Opportunities exist to further improve the cost-effectiveness of the scheme. Preliminary monitoring reveals an average eucalypt density (667 stems/ha; Greening Australia unpublished data), which greatly exceeds that found in natural Yellow box *Eucalyptus melliodora* woodlands (212–343 stems/ha; Gibbons et al. 2010). Although the higher density provides insurance against unpredictable losses due to grazing or adverse environmental conditions, the cost of *Eucalyptus* seed represents approximately 40% of the cost of direct seeding and could potentially be reduced without compromising biodiversity benefits.

Scheme Transferability and Longevity

To date, WOPR has largely targeted livestock grazing and mixed enterprise systems. Although such systems currently remain dominant in Australia, the extent of cropland is increasing (Mewett et al. 2013) and represents the most common agricultural land use type at a global scale (Wood et al. 2000). Though there are predicted production benefits of WOPR in grazing-dominated systems, the potential benefits to crop production have not been established. Revegetation using deep-rooted perennial species can provide benefits for crop production through salinity mitigation (Knight et al. 2002) and encourage important crop pollinating insects (Arthur et al. 2010). However, farmer concerns over potential competition between crops and planted vegetation for water presents a possible barrier (Woodall & Ward 2002). Landholders who focus on cropping are less likely to restore tree cover than those based on grazing (Schirmer et al. 2012). Cropping systems typically maximize the use of available land, and thus opportunities for biodiversity restoration are limited to marginal and highly fragmented areas of the landscape such as field edges, corners, and gullies (G. Fifield 2014, personal observation). Although more complex agri-environment delivery mechanisms (e.g. auctions and results-based payments) could be used to increase uptake in other agricultural systems, their inherent complexity increases transaction costs (Klimek et al. 2008) and places greater demands on already scarce funding. Current efforts to establish a modified WOPR design in a cropping landscape in Western Australia will provide a valuable test of the scheme's transferability.

Long-term funding stability is a priority issue in biodiversity conservation in agricultural landscapes (Lindenmayer et al. 2013). AES by their nature are not financially self-sustaining, requiring long-term funding to achieve restoration across large scales. The low rates of agricultural subsidy in Australia mean that additional funds must be found for conservation (Hajkowicz 2009). The WOPR scheme has been funded primarily through government, however, funding is secure for at most 3–5 years as a result of government expenditure cycles. Diversifying the program's funding sources to spread risk will be equally as important as looking to secure funds from existing government sources in the future.

Discussion

The WOPR scheme provides an example of a simple, innovative, and cost-effective solution to large-scale habitat restoration integrated with agricultural production. It uses an incentive-based mechanism to target biodiversity outcomes and production benefits and fills an important gap in the conservation of biodiversity within productive areas of agricultural landscapes. The scheme has been designed to balance factors known to be important in determining biodiversity benefits, such as size, shape, and habitat complexity of restoration sites, while seeking to minimize costs by using existing farm infrastructure, focusing on large fields, using efficient revegetation technologies, and permitting a rapid return to agricultural production.

Innovative approaches to ecological restoration in agricultural landscapes such as WOPR should be seen as complementary, providing additional tools in the restoration practitioner's toolbox, rather than replacing traditional measures (Benayas et al. 2008). The conservation of remnant habitat patches remains a key biodiversity conservation priority in farming landscapes (Cunningham et al. 2008). Likewise, windbreak plantings can provide important ecological functions such as improved connectivity and to some farmers may provide the only acceptable planting configuration and therefore will continue to be important habitat restoration strategies.

Despite the success of the WOPR scheme to date, there are several issues that present barriers to continued growth. These include continuity of funding, limited transferability to other agricultural systems, and uncertainty regarding the long-term biodiversity benefits. Continued ecological, economic, and social research will be required to further demonstrate the potential of the scheme to achieve biodiversity and production benefits.

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LITERATURE CITED

Arthur AD, Li J, Henry S, Cunningham SA (2010) Influence of woody vegetation on pollinator densities in oilseed Brassica fields in an Australian temperate landscape. Basic and Applied Ecology 11:406–414

Benayas JMR, Bullock JM, Newton AC (2008) Creating woodland islets to reconcile ecological restoration, conservation, and agricultural land use. Frontiers in Ecology and the Environment 6:329–336

Bird PR, Bicknell D, Bulman PA, Burke SJA, Leys JF, Parker JN, Van Der Sommen FJ, Voller P (1992) The role of shelter in Australia for protecting soils, plants and livestock. Agroforestry Systems 20:59–86

Burrell A (2012) Evaluating policies for delivering agri-environmental public goods. Pages 49–68. In: OECD (ed) Evaluation of agri-environmental policies: selected methodological issues and case studies. OECD Publishing, Paris, France

Cunningham RB, Lindenmayer DB, Crane M, Michael D, MacGregor C, Montague-Drake R, Fischer J (2008) The combined effects of remnant vegetation and tree planting on farmland birds. Conservation Biology 22:742–752

Department of Agriculture (2013) Carbon Farming Initiative case study—environmental plantings of native tree species: 13.12 Whole of Paddock Rehabilitation (WOPR) plantings. Department of Agriculture, Canberra, Australia

Doerr VJ, Doerr ED, Davies MJ (2011) Dispersal behaviour of brown treecreepers predicts functional connectivity for several other woodland birds. EMU 111:71–83

Dorrough J, Moxham C (2005) Eucalypt establishment in agricultural landscapes and implications for landscape-scale restoration. Biological Conservation 123:55–56

Driscoll D, Banks S, Barton P, Lindenmayer D, Smith A (2013) Conceptual domain of the matrix in fragmented landscapes. Trends in Ecology & Evolution 28:605–613

Duncan D, Dorrough J (2009) Historical and current land use shape landscape restoration options in the Australian wheat and sheep farming zone. Landscape and Urban Planning 91:124–132

European Commission (2014) Agri-environment measures—agriculture and rural development. http://www.ec.europa.eu/agriculture/envir/measures/index_en.htm (accessed 8 Sep 2014)

Fischer J, Lindenmayer DB (2002a) The conservation value of paddock trees for birds in a variegated landscape in southern New South Wales. 2. Paddock trees as stepping stones. Biodiversity and Conservation 11:833–849

Fischer J, Stott J, Zerger A, Warren G, Sherren K, Forrester RI (2009) Reversing a tree regeneration crisis in an endangered ecoregion. Proceedings of the National Academy of Sciences 106:10386–10391

Fischer J, Zerger A, Gibbons P, Stott J, Law BS (2010) Tree decline and the future of Australian farmland biodiversity. Proceedings of the National Academy of Sciences 107:19597–19602

Franklin JF (1993) Preserving biodiversity: species, ecosystems, or landscapes? Ecological Applications 3:202–205

Freudenberger D (1999) Guidelines for enhancing grassy woodlands for the vegetation investment project. Ecology CSIRO Wildlife and Ecology, Canberra, Australia

Freudenberger D, Harvey J, Drew A (2004) Predicting the biodiversity benefits of the Saltshaker Project, Boorowa, NSW. Ecological Management and Restoration 5:5–14

Gibbons P, Briggs SV, Murphy DY, Lindenmayer DB, McElhinny C, Brookhouse M (2010) Benchmark stem densities for forests and woodlands in south-eastern Australia under conditions of relatively little modification by humans since European settlement. Forest Ecology and Management 260:2125–2133

Gibbons P, Lindenmayer D, Fischer J, Manning A, Weinberg A, Seddon J, Ryan P, Barrett G (2008) The future of scattered trees in agricultural landscapes. Conservation Biology 22:1309–1319

Green RE, Cornell SJ, Scharlemann JPW, Balmford A (2005) Farming and the fate of wild nature. Science 307:550–555

Greening Australia (2014) Introducing—Whole of Paddock Rehabilitation. Greening Australia, Canberra, Australia. http://www.greeningaustralia.org.au/uploads/knowledgeportal/ACT_WOPR_brochure_2014.pdf (accessed 14 January 2015)

Hajkowicz S (2009) The evolution of Australia's natural resource management programs: towards improved targeting and evaluation of investments. Land Use Policy 26:471–478

Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, et al. (2013) High-resolution global maps of 21st-century forest cover change. Science 342:850–853

Helzer CJ, Jelinski DE (1999) The relative importance of patch area and perimeter-area ratio to grassland breeding birds. Ecological Applications 9:1448–1458

House APN, MacLeod ND, Cullen B, Whitbread AM, Brown SD, McLvor JG (2008) Integrating production and natural resource management on mixed farms in eastern Australia: the cost of conservation in agricultural landscapes. Agriculture, Ecosystems & Environment 127:153–165

Kavanagh RP, Stanton MA, Herring MW (2007) Eucalypt plantings on farms benefit woodland birds in south-eastern Australia. Austral Ecology 32:635–650

Klimek S, Richtergenkemmermann A, Steinmann H, Freese J, Isselstein J (2008) Rewarding farmers for delivering vascular plant diversity in managed grasslands: a transdisciplinary case-study approach. Biological Conservation 141:2888–2897

Knight A, Blott K, Portelli M, Hignett C (2002) Use of tree and shrub belts to control leakage in three dryland cropping environments. Crop and Pasture Science 53:571–586

Lindenmayer DB, Knight EJ, Crane MJ, Montague-Drake R, Michael DR, MacGregor CI (2010) What makes an effective restoration planting for woodland birds? Biological Conservation 143:289–301

Lindenmayer D, Willinck E, Crane M, Michael D, Okada S, Cumming C, Durant K, Frankenberg J (2013) Murray catchment habitat restoration: lessons from landscape-level research and monitoring. Ecological Management & Restoration 14:80–92

Lovell ST, Sullivan WC (2006) Environmental benefits of conservation buffers in the United States: evidence, promise, and open questions. Agriculture, Ecosystems & Environment 112:249–260

Lynch J, Donnelly J (1980) Changes in pasture and animal production resulting from the use of windbreaks. Australian Journal of Agricultural Research 31:967

Manning AD, Fischer J, Lindenmayer D (2006) Scattered trees are keystone structures—implications for conservation. Biological Conservation 132:311–321

McIntyre S, McIvor JG, MacLeod ND (2000) Principles for sustainable grazing in eucalypt woodlands: landscape-scale indicators and the search for thresholds. Pages 92–100. In: Hale P, Petrie A, Moloney D, Sattler P (eds) Management for sustainable ecosystems. University of Queensland, Brisbane, Australia

Monjardino M, Revell D, Pannell DJ (2010) The potential contribution of forage shrubs to economic returns and environmental management in Australian dryland agricultural systems. Agricultural Systems 103:187–197

Mewett J, Paplinska J, Kelley G, Lesslie R, Pritchard P, Atyeo C (2013) Towards national reporting on agricultural land use change in Australia. ABARES Technical Report, ABARES, Canberra, Australia

Munro N, Fischer J, Barrett G (2011) Bird's response to revegetation of different structure and floristics—are "restoration plantings" restoring bird communities? Restoration Ecology 19:223–235

NSW Department of Primary Industries (2014) Livestock gross margin budgets. http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets/livestock (accessed 6 May 2015)

Robertson OJ, Radford JQ (2009) Gap-crossing decisions of forest birds in a fragmented landscape. Austral Ecology 34:435–446

Schirmer J, Clayton H, Sherren K (2012) Reversing scattered tree decline on farms: implications of landholder perceptions and practice in the Lachlan catchment, New South Wales. Australasian Journal of Environmental Management 19:91–107

Schneemann B, McElhinny C (2012) Shrubby today but not tomorrow? Structure, composition and regeneration dynamics of direct seeded revegetation. Ecological Management & Restoration 13:282–289

Schofield NJ (1992) Tree planting for dryland salinity control in Australia. Agroforestry Systems 20:1–23

Sherren K, Fischer J, Clayton H, Hauldren A, Dovers S (2011) Lessons from visualising the landscape and habitat implications of tree decline—and its remediation through tree planting—in Australia's grazing landscapes. Landscape and Urban Planning 103:248–258

Smith F (2008) Who's planting what, where and why–and who's paying? An analysis of farmland revegetation in the central wheatbelt of Western Australia. Landscape and Urban Planning 86:66–78

Streatfield S, Fifield G, Pickup M (2010) Whole of Paddock Rehabilitation (WOPR): a practical approach to restoring grassy box woodlands. Pages 23–31. In: Lindenmayer D, Bennett A, Hobbs RJ (eds) Temperate woodland conservation and management. CSIRO Publishing, Melbourne, Australia

USDA (United States Department of Agriculture) (2014) Conservation programs. http://www.ers.usda.gov/topics/natural-resources-environment/conservation-programs/background.aspx (accessed 28 Jan 2015)

Vandermeer J, Perfecto I (2007) The agricultural matrix and a future paradigm for conservation. Conservation Biology 21:274–277

Walpole SC (1999) Assessment of the economic and ecological impacts of remnant vegetation on pasture productivity. Pacific Conservation Biology 5:28–35

Welsch J, Case BS, Bigsby H (2014) Trees on farms: investigating and mapping woody re-vegetation potential in an intensely-farmed agricultural landscape. Agriculture, Ecosystems and Environment 183:93–102

Wood S, Sebastian K, Scherr S (2000) Pilot analysis of global ecosystems: agroecosystems, a joint study by International Food Policy Research Institute and World Resources Institute. International Food Policy Research Institute and World Resources Institute, Washington D.C.

Woodall GS, Ward BH (2002) Soil water relations, crop production and root pruning of a belt of trees. Agricultural Water Management 53:153–169

Yates CJ, Hobbs RJ (1997) Temperate eucalypt woodlands: a review of their status, processes threatening their persistence and techniques for restoration. Australian Journal of Botany 45:949

Zahawi R, Holl KD, Cole RJ, Reid JL (2013) Testing applied nucleation as a strategy to facilitate tropical forest recovery. Journal of Applied Ecology 50:88–96

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