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FEATURE

Working with nature to improve the environment and profitability of irrigated cotton production at 'Kilmarnock', Namoi Valley, New South Wales

By Rhiannon Smith and Andrew Watson

Several environmentally positive farming innovations at 'Kilmarnock' near Boggabri, New South Wales, have been monitored over time and have revealed a positive impact upon this irrigated cotton farming enterprise's financial sustainability and environmental footprint. This study demonstrates economic benefits from environmental approaches to farm management.

Key words: *birds, natural pest control, nitrogen, revegetation, water-use efficiency.*

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Figure 1. Environmental and agroforestry plantings alongside cotton crops at Kilmarnock provide habitat for natural pest control agents, including insectivorous birds, microbats and predatory and parasitoid invertebrates (photograph by R. Smith).

Introduction

Sustainable agricultural production relies on a variety of ecosystem services provided by biodiverse landscapes. Services such as nutrient and water cycling, pollination, pest and disease regulation, and carbon assimilation are vital to support agricultural production (Daily 1997; MA 2005). However, some agricultural practices may decrease ecosystem service provision. For example, homogenisation of landscapes and a reliance on chemical insecticides to control pests may reduce natural predator numbers, decreasing the capacity of natural control agents to regulate pests (Naylor & Ehrlich 1997; Wilson & Tisdell 2001; Wilby & Thomas 2002; Bianchi *et al.* 2006;

Chaplin-Kramer *et al.* 2011; Gagic *et al.* 2017). Farmers who understand the ecosystem they operate in, minimise off-target impacts of their management and restore habitat to improve their farm's environmental service provision, can capitalise on ecosystem processes to support sustainable agricultural production.

Much research has illustrated the benefits of organic production in terms of minimising impacts on natural pest control agents, thereby increasing natural pest control services (Crowder *et al.* 2010). However, the effect of reduced insecticide use in conventional cropping systems is less well understood (although see Lichtenberg *et al.* 2017). Adoption of innovations by landholders depends on a range of personal, social, cultural, economic and environmental factors (Pannell *et al.* 2006). Innovations are more likely to be adopted when they have a high 'relative advantage' (i.e. perceived superiority compared with the prevailing idea or practice) and are readily transferable (i.e. easy to test and learn about before adoption). Without detailed, credible information about the benefits of practice change, growers are hesitant to move away from conventional practices, particularly when a significant lag-time before any return on investment is likely.

This study details the management strategies, yield and profitability of an irrigated cotton farm business near Boggabri, New South Wales, on the banks of the Namoi River, incorporating a range of practices to improve profitability and reduce the farm's environmental footprint. The scientific literature contains many studies of specific farming innovations, but rarely are examples of sustainable practices and their economic implications documented at a whole-farm scale, as in this study. A key innovation has been to embrace natural processes to take advantage of a range of ecosystem services. Approximately 80% of the farm's income currently comes from cotton production, and this component of the operation is the focus of this study. Specifically, we address: (i) the natural pest control benefit associated with revegetation and reduced pesticide spray use; (ii) increased water-use efficiency; (iii) alternative fertiliser strategies; and (iv) the resulting economic benefits of these management strategies.

'Kilmarnock' – background

Kilmarnock is a mixed cropping and cattle grazing operation on the Namoi River on the north-west plains of New South Wales, Australia. When John and Robyn Watson first arrived at Kilmarnock over 50 years ago, the scene was typical of many farms at the time. Much of the property was overgrazed, and livestock were allowed access to the river for water, creating bare ground and significant soil and river bank erosion (Watson 2009). The Watsons undertook an ambitious programme of revegetating and stabilising the riverbank, after removing invasive Willows (*Salix* spp.). The initial focus of their riparian projects was on reinforcing their farm boundaries to contain cattle and stabilise the river bank as floods in the 1970s had excavated large volumes of soil. This left the water turbid, the river banks prone to further erosion and slumping, and infrastructure at risk of further damage. However, the restored riparian vegetation has become important as a breeding site for waterbirds such as Little Pied Cormorant (*Phalacrocorax melanoleucos*) and Darter (*Anhinga melanogaster*) (Norton & Reid 2013), fish such as the Murray Cod (*Maccullochella peelii*) and the Koala (*Phascolarctos cinereus*).

To complement their riparian works, the Watsons established vegetated corridors to both act as spray drift barriers to restrict agricultural chemical movement to and from adjacent farms and to connect the riparian vegetation with remnant floodplain vegetation (Fig. 1). As the trees grew, their role in connecting the riparian corridor with significant floodplain remnants and in facilitating fauna movement was realised, and the Watsons' understanding of and interest in ecosystem services grew. Where previously they had viewed the natural and agricultural parts of their property separately, the Watsons began to approach their management in an integrated way.

The current owners of Kilmarnock, Andrew and Heike Watson (Fig. 2), are fifth-generation farmers and took over from John and Robyn (Andrew's parents) in 2007. Andrew and Heike are highly motivated by their vision to create a sustainable and profitable operation producing food and fibre, while minimising their environmental impact. Three main aspects of conventional cotton production that the Watsons have sought to address in their approach to crop management are the use of: (i) insecticide sprays, (ii) water and (iii) nitrogen. All three have significant associated economic costs and environmental impacts. The Australian cotton industry has reduced the environmental footprint of crop production through the introduction of genetically modified cotton varieties that have reduced insecticide use to control lepidopteran pests, and new varieties that have increased water-use efficiency (Cotton Australia & CRDC 2014). The Watsons have taken advantage of these technologies and used them as a starting point to improve production at Kilmarnock. However, given the location of the farm (adjacent to the town of Boggabri), there was greater pressure to minimise chemical use (to control non-lepidopteran pests) in order to maintain the family's social licence to farm.

The Watsons' farm operations based at Kilmarnock currently occupy 7000 ha, of which irrigated and dry land cropping (and associated

Figure 2. Andrew, Heike, Xanthia and Doug Watson on-farm at Kilmarnock. The mixed *Eucalyptus* species planting in the background was planted by John and Robyn Watson in the early 1990s. (photograph by A. Watson).

infrastructure) occupies 5055 ha; grazing land (beef cattle on native pastures) occupies 1000 ha; 500 ha is dedicated to tree plantings, a conservation area and ungrazed riparian lands, and the remaining land consists of houses, gardens, sheds, machinery yards and other infrastructure (445 ha). The breakdown of different land uses on Kilmarnock is comparable to industry averages (Roth Rural 2013). The focus at Kilmarnock for the past 50 years has been growing cotton and wheat, with a number of other crops including canola, sorghum and barley used as rotation crops to make use of the land between cotton seasons and to control the build-up of pests and pathogens.

The Watsons have established 20,000 trees at Kilmarnock from tubestock, as well as planting many hundreds of grass plants, including a native vetiver species that grows naturally on the property, along the Namoi River banks (Watson 2009). They have installed 17 nest boxes and retain hollow-bearing trees where possible to provide habitat for insectivorous microbats. The floodplain occupied by Kilmarnock is valuable real estate due to high productivity, and setting aside land for conservation is not common practice in this landscape. However, the Watsons justified the cost of these restoration works from a commercial viewpoint by potential benefits they hoped to receive from provision of habitat for natural pest control agents (i.e. a reduction in pesticide and fuel costs) and strengthening their social licence to farm, thus investing in their business and their future.

Natural pest control at Kilmarnock

Between the 1970s and mid-1990s, cotton industries around the world were heavily reliant on insecticides and in some years, the amount of chemical required to control insect pests (and the yield loss to insects) was so high that cotton growing was arguably unviable on economic, environmental and social grounds (Bottrell & Adkisson 1977; Fitt 1994). Flora and fauna were known to be adversely affected in some areas, and long-term human health effects including fatalities were connected to insecticide exposure (Wilson & Tisdell 2001). The introduction of the first genetically modified (GM) cotton varieties in the 1990s made cotton plants toxic to lepidopteran pests, including

Cotton Bollworm (*Helicoverpa armigera*), the major insect pest of cotton (Fitt 2003). In addition, the Australian cotton industry also invested heavily in research, development and extension (RDE) to minimise the environmental impacts of production. A key focus of cotton RDE has been on pesticide use: what to spray and when, integrated pest management, resistance management and minimising environmental harm (Fitt *et al.* 2004).

While Cotton Bollworm is no longer a major problem in cotton production, most growers employ insecticides to manage secondary pests, including aphids (Aphidoidea), mirids (*Creontiades* spp.), Silverleaf Whitefly (*Bemisia tabaci*), thrips (*Frankliniella* spp. and *Thrips* spp.), spider mites (Tetranychus spp.), Green Vegetable Bug (*Nezara viridula*) and Rutherglen Bug (*Nysius vinitor*), with the number of sprays and chemicals determined by seasonal conditions and the insect in question. Beneficial (predatory and parasitoid) invertebrates are impacted by some pesticides, and this exacerbates pest invertebrate issues because pest populations increase rapidly in the absence of predators (Ripper 1956; Bottrell & Adkisson 1977). Common predators of cotton pests include (Williams *et al.* 2011): ants (Formicidae), lacewings (*Micromus tasmaniae, Mallada signatus*), ladybeetles (Coccinellinae), spiders (Araneae), predatory bugs (*Deraeocoris signatus, Cermatulus nasalis, Geocoris lubra, Oechalia schellenbergii, Orius* spp.), predatory beetles (*Dicranolaius bellulus, Calosoma, schayei, Chauliognathus pulchellus*), various parasitoid wasps (*Aphidius colemani, Heteropelma scaposum, Lysiphlebus testaceipes, Lyssopimpla excelsa, Microplitis demolitor, Netelia producta*) and flies (tachinid spp.).

Increasing on-farm biodiversity in response to reduced insecticide use (following the introduction of GM cotton varieties) and improved natural habitat (tree plantings and riparian restoration) encouraged the Watsons to think about the potential for natural pest control agents to regulate secondary pest populations in their crops. They began recording weekly measurements of pest and beneficial invertebrate abundance throughout the growing season (12 weeks) using the beat-sheet method in their cotton crops, where a metre of crop row is beaten with a wooden stick to knock invertebrates onto a 1.5 × 1.5-m yellow plastic sheet for counting (Deutscher *et al.* 2003). Three beat-sheet measurements were taken in each cotton field at varying locations to allow calculation of mean invertebrate numbers for each field.

On various occasions when pest numbers got to potentially damaging levels that would have previously led them to spray insecticides, Andrew deliberately took a hands-off approach to see what would happen. Interestingly, the invertebrate counts and plant growth data showed that as pest numbers increased, the number of beneficial predatory and parasitoid invertebrates also increased. Pest numbers then dropped while 'beneficials' continued to increase, so Andrew avoided the cost of spraying (Fig. 3). Note that the threshold recommended trigger for insecticide application for mirid nymphs is three individuals per beat sheet (Williams 2017). In the example in Figure 3, the number of mirid nymphs recorded in weeks 10 and 11 was above this threshold. Cotton produces more fruit than it can carry by the end of the season, so some insect damage has negligible impact on final yields. In fact, damage at early stages in the season may encourage more fruit development (Wilson *et al.* 2013).

To assure himself and others that his approach to natural pest control works, Andrew conducted a trial in 2010 to investigate the impact of 'spraying' against 'not spraying' at a time when mirid numbers increased to the threshold that would normally trigger a spray. The chemical 'Shield' (Sumitomo Chemical Australia, containing 200 g/L clothianidin as the active ingredient) was applied at 150 mL/ha on 11 February 2010 over three fields (totalling 90 ha) and compared with three unsprayed fields. Invertebrate numbers were measured using three beat sheets in each field (nine beat sheets in three fields in the sprayed treatment and 24 beat sheets across eight fields in the unsprayed treatment). The trial showed that beneficial invertebrates were regulating pest numbers, with

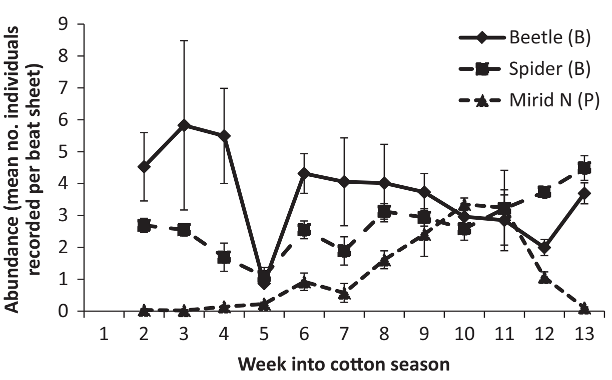

Figure 3. Relationship between the most abundant beneficial ('B', spiders and predatory beetles) and pest ('P', mirid nymphs) invertebrates at Kilmarnock during the 2010/2011 cotton season (n = 33 beat sheets sampled across 11 fields each week during the 2010/2011 season). Note: as mirid numbers increased in weeks 8, 9 and 10, the number of beneficials increased in response, with a subsequent reduction in pest numbers, presumably as the beneficials performed their natural pest control service. This pattern has been seen on numerous occasions. Error bars are ± 1 s.e.m.

the unsprayed plot showing a similar decrease in pest numbers as the sprayed plot (Fig. 4), except that it took a week longer for mirid numbers to decline in the unsprayed plot. Andrew also compared yield data in the sprayed and unsprayed plots and found no difference. This trial reassured Andrew that the beneficial invertebrates were providing natural pest control services in his crops.

Andrew acknowledges that there were sleepless nights in the early days as pest numbers rose to levels that would normally trigger the application of insecticides. Early results confirmed his hunch, however, and for the past 11 years, insecticide spraying in cotton at Kilmarnock has been reduced to zero applications, and grain crops have only been sprayed once in the last 11 years. This is in contrast to an average of 2–6 sprays each season in cotton and 1–2 sprays in grain crops each year on conventionally managed properties in the district. Andrew and his agronomist have observed natural pest control in action in cotton fields on Kilmarnock (e.g. Fig. 5) and are satisfied that predatory and parasitoid invertebrates have the capacity to control pest numbers or respond to pest outbreaks when they occur.

Much of the research conducted in cotton industries around the world has focused on beneficial invertebrates (predatory or parasitoid invertebrates) as natural pest control agents in an integrated pest management framework (Fitt 2003; Deguine *et al.* 2008). However, a 2003 review of biodiversity research in the Australian cotton industry noted that insectivorous birds and microbats could play an important role in controlling invertebrate pests in cotton and recommended further research to clarify the role of vertebrates in natural pest control on cotton farms (Reid *et al.* 2003). Consequently, research projects were funded by the Cotton Catchment Communities Cooperative Research Centre and Cotton Research and Development Corporation to investigate bird (Smith 2005, 2010, 2015; Cleland 2008; Jacobs 2012) and microbat (Dillon *et al.* 2004; MacKinnon 2007) species richness and abundance on cotton farms.

Insectivorous birds and microbats are recognised by the Watsons as important natural pest control agents, and research projects are currently being conducted at Kilmarnock to investigate the impact of birds and microbats on crop pests, as well as bird and microbat abundance in different habitats. Several species of conservation concern have been recorded during bird and microbat surveys at Kilmarnock (Smith 2005, 2010, 2015; Jacobs 2012; Ms Heidi Kolkert, unpub. data, 2017), including the Yellow-bellied Sheath-tailed Bat (*Saccolaimus flaviventris*), Painted Honeyeater (*Grantiella picta*), Red-capped Robin (*Petroica goodenovii*),

Figure 5. Predatory Shield Bug (*Oechailia schellenbergii*) feeding on a *Helicoverpa* caterpillar at Kilmarnock (photo by A. Watson).

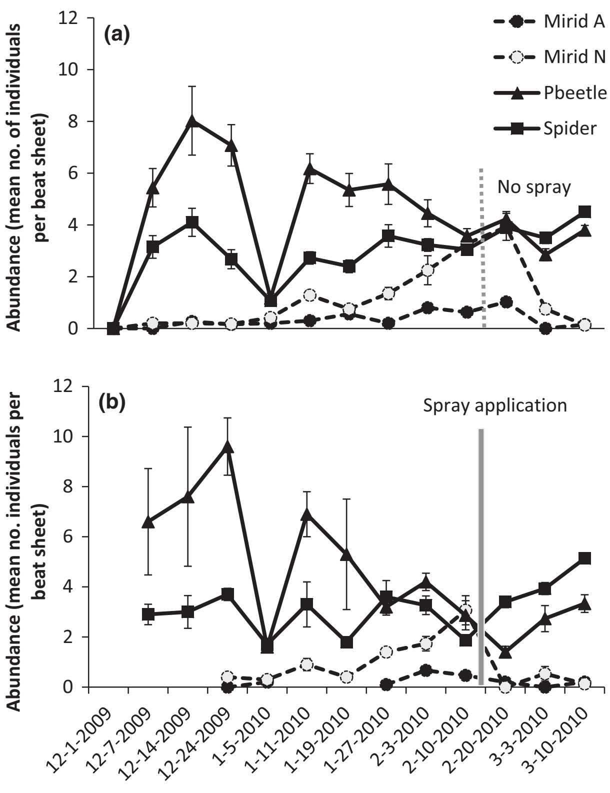

Figure 4. Invertebrate numbers at Kilmarnock in paired plots (sprayed vs unsprayed) during the 2009/10 season, illustrating an increase in the number of mirid nymphs (N). (a) The natural reduction in mirid adults (A) and nymphs as a result of natural pest control (n = 24 beat sheets sampled across eight unsprayed fields each week) and (b) the reduction in mirid numbers as a result of a trial spray application (n = 9 beat sheets sampled across three fields each week). Note: the industry threshold that would normally trigger an application of insecticide to control mirid nymphs is three individuals per beat sheet. 'Pbeetle' = predatory beetle. Error bars are ±1 s.e.m.

Black Falcon (*Falco subniger*), Barking Owl (*Ninox connivens*), Grey-crowned Babbler (*Pomatostomus temporalis*) and Little Eagle (*Hieraaetus morphnoides*) (Fig. 6). Much of the research conducted to date on cotton farms has concentrated on recording the species present and the potential for natural pest control, without quantifying the natural pest control service itself. Current research into birds, bats and beneficial invertebrates on cotton farms such as Kilmarnock, including dietary analysis, will more clearly identify benefits to biodiversity while helping growers design farm layouts that promote natural pest control.

Water-use efficiency at Kilmarnock

Water is a highly variable and major expense associated with cotton production, averaging approximately A$300/ha over the past 10 years (Boyce Chartered Accountants 2016) with a significant environmental footprint (Kingsford 2000). Water-use efficiency has been a key consideration in cotton production and management at Kilmarnock. Water demands are dictated by soil type and organic matter content (moisture-holding capacity), seasonal weather conditions (rainfall distribution and evaporative demand) and plant physiology (breeding). Water-use efficiency has improved at Kilmarnock through the installation of overhead irrigation systems, the use of capacitance probes to better predict crop water needs and overall farm management to reduce evaporation and seepage from dams and channels. Water-use efficiency (measured as the number of bales produced per megalitre of irrigation water) has almost doubled at Kilmarnock over the past 14 years, while cotton average yields have improved from 8.5 bales/ha to 12 bales/ha in line with district averages (Fig. 7). Increased yields per hectare of land and efficient use of water when it is available result in a more sustainable operation on economic, environmental and social grounds.

Figure 6. Bird species of conservation concern recorded during surveys at Kilmarnock: (a) Grey-crowned Babbler (photo by Tom Tarrant), (b) Barking Owl (photograph by Georgie Sharp), (c) Painted Honeyeater (photo by Tony Morris) and (d) Red-capped Robin (photograph by birdsaspoetry).

Nitrogen use and soil improvement at Kilmarnock

Another significant input in cotton production, at an average cost of $460/ha over the past 10 years, is fertiliser (Boyce Chartered Accountants 2016). The average rate of nitrogen application to irrigated cotton in Australia in 2016 was 275 kg/ha (Roth Rural 2016). The Watsons use only 60% of this, after a small experiment with different sources and application rates to reduce input costs and N losses to the environment and atmosphere. In addition to the normal farm fertiliser programme, Andrew trialled three different manures (chicken, cattle and seagull) compared with mineral fertilisers, mono-ammonium phosphate (MAP) and sulphate of potash and Twin N (Mapleton Agri Biotech Pty Ltd), a freeze-dried microbe which encourages plant uptake of nitrogen. The cost of

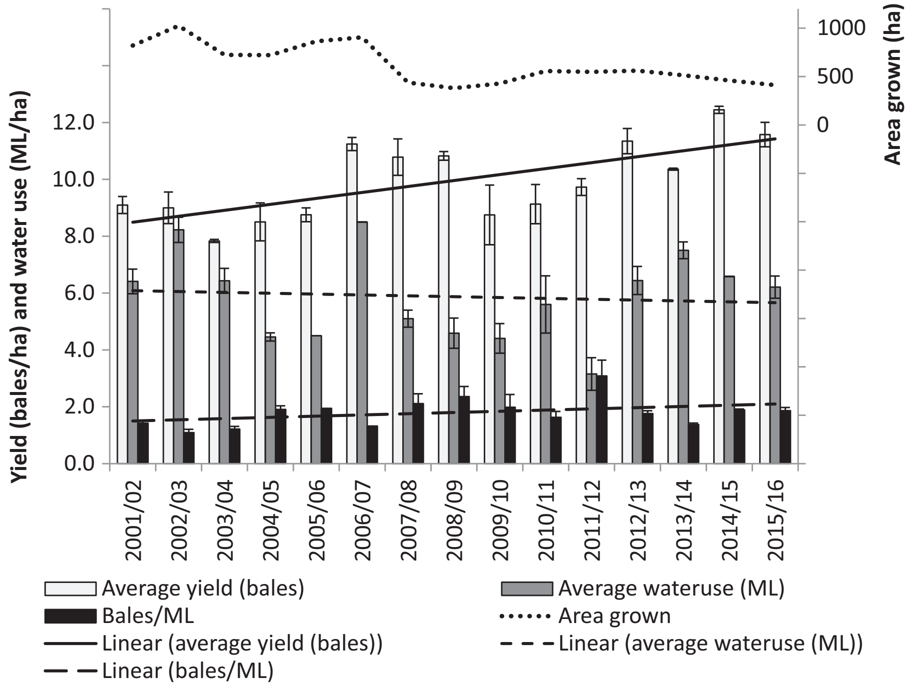

Figure 7. Mean cotton yield data (bales/ha: y = 0.22x + 8.259, r^2 = 0.481), water use (ML/ha: y = –0.02x + 6.02, r^2 = 0.003) and yield per megalitre of water applied (bales/ML: y = 0.04x + 1.47, r^2 = 0.149) for the seven farms making up Kilmarnock Pty Ltd's operations during the period 2001/2002 to 2015/2016 ($n \geq 3$ farms with area grown each season varying from 412 ha to 1024 ha, depending on water availability). Note variability in yield per ha is largely driven by weather (number of cloudy days, hail, flooding, etc.). Error bars are ±1 s.e.m.

purchase and application of the various fertilisers was compared over a 4-year period, along with yield in a replicated trial. In the first year, application of an extra 100 kg of MAP resulted in a positive $77.13/ha impact on the gross margin (Table 1). The application of Twin N also resulted in a positive impact on gross margin of $28.63/ha. All other applications, including the three manures, cost more to apply than they returned in the first year, even if they showed a yield increase over the control. In the second year of the trial, the decision was made to treat the entire trial with the extra 100 kg of MAP and add the remaining various fertilisers on top of that. There was no further positive response to MAP. However, despite the high costs of purchasing and applying chicken manure, it produced a significant economic advantage in the second year ($51.61/ha). This is a common observation amongst those who use manure amendments: there is initially a lag between application and impacts on yields. The field was rotated out of production in 2015, and no amendment was applied in 2016, but a positive economic advantage was observed in 2016 for the plot treated with cattle manure, again indicating the delay between application and effect on yields. Andrew's study convinced him that yearly chicken manure application is the most cost-effective amendment for Kilmarnock and is a more sustainable product than synthetically produced fertilisers. Reducing N use at Kilmarnock lowers greenhouse gas emissions to the atmosphere.

Table 1. Value proposition for a range of manure and fertiliser applications at Kilmarnock. Figures in bold represent a positive impact on profit

Fertiliser/ manure	Application rate (rate/ha)	Value proposition ($/ha)			
		Fertiliser applied		Fertiliser not applied	Final proposition
		2013	2014	2016	
Chicken manure	6 m^3	−51.4	51.6	−13.1	−12.9
Sulphate of potash	100 kg	−181.3	−20.4	−23.5	−225.3
Guano	10 m^3	−182.9	−184.0	−29.8	−396.6
MAP	100 kg	**77.1**	−89.0	−87.1	−99.0
Cattle manure	10 m^3	−998.4	−223.2	**32.7**	−1188.9
Twin N	Recomm. rate	**28.6**	−20.8	−50.7	−42.9

MAP, Mono-ammonium phosphate; 'Recomm. Rate', manufacturer's recommended rate, which varies by product.

Cotton yields and economics

In order to be confident that the management techniques and investment at Kilmarnock are beneficial, the Watsons benchmark their cotton yields and economic data each season against local, similar-sized farming operations in the region (Fig. 8). In the past two seasons (2014/2015 and 2015/2016), there has been little difference in yields between members of the benchmarking group, indicating that the alternative management strategies used for cotton production at Kilmarnock have not resulted in yield losses.

While cotton yields (income) are one side of the profit story, costs are the other. Decreases in the amount of chemical used to produce cotton crops and investment in their own spray equipment at Kilmarnock have resulted in a decrease in contractors' fees (Fig. 9). However, part of these savings has been counteracted by an increase in on-farm wages to apply chemicals such as herbicides.

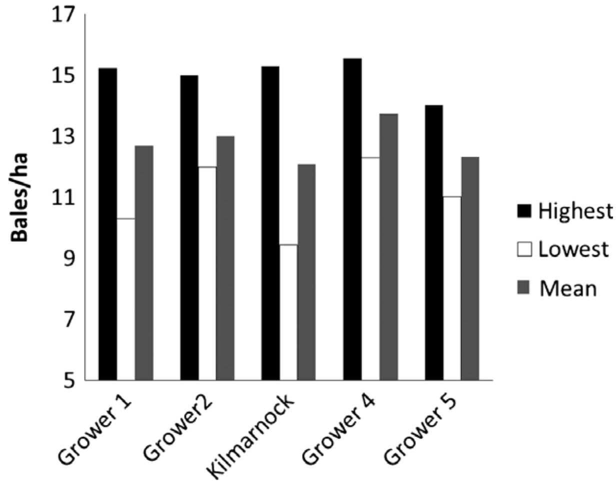

Figure 8. Yield data for five farms in the Boggabri benchmarking region for the 2015/2016 growing season illustrating minimal difference in cotton yields between farms. Despite differences in management, the several farms managed by Andrew contributing to the Kilmarnock result did not differ substantially in yield to other farms in the region.

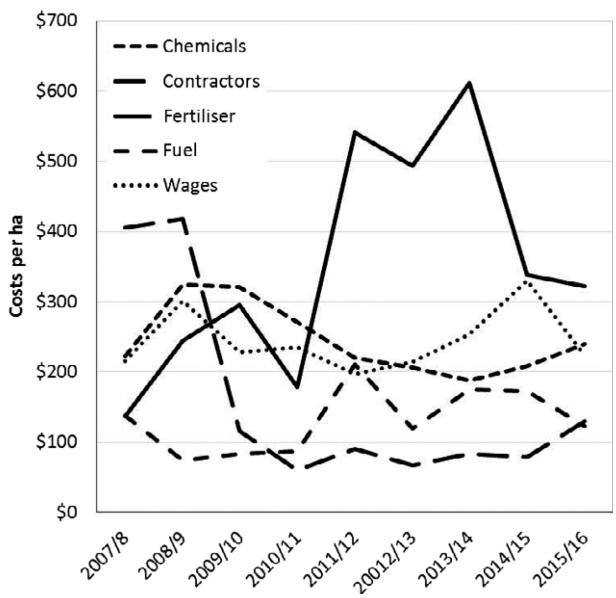

Figure 9. Selected variable costs associated with cotton production at Kilmarnock for the period 2007–2016. Fertiliser refers to the raw product only and does not include application. 'Chemicals' also refers to raw product only and consist of the range of different herbicides used in weed control in cotton.

A significant cost saving relating to fuel through improved herbicide application efficiency has been offset by increasing fuel prices. Fertiliser prices have fluctuated considerably through time due to changes in global and domestic factors affecting supply, demand and the cost of production (Incitect Pivot Ltd 2009; Cotton Australia 2017).

The 5-year average operating cost for cotton production in Australia in 2016 was $4038/ha (Boyce Chartered Accountants 2016). For the top 20% of producers, the 5-year average operating cost for cotton production was $3729/ha. In 2015/2016, the average operating cost across the industry was $4500/ha and for the top 20% of producers, $3923/ha. At Kilmarnock, the average operating cost of cotton production in 2015/2016 was approximately $3600/ha. The Watsons attribute their low operating cost to economies of scale and near-zero costs for insecticides and their application.

Environmental accolades for Kilmarnock

Members of the Watson family have been awarded several production and environmental awards over the years, including the 2001 National Gold Landcare Award (Robyn), 2002 Australian Large Cotton Grower of the Year, 2004 NSW Farmers Young Farmer of the Year (Andrew), a 2006 Nuffield Farming scholarship (Andrew), 2008 Australian Cotton Grower of the Year, 2014 Brownhill Cup Conservation Award and 2016 NSW State Winner and Australian Finalist in the Landcare Sustainable Farming Award. At the core of the Watsons' success has been a proactive approach to seeking out, trialling and adopting new technologies that support their farming and environmental philosophies. Their properties have been the focus of numerous research projects over the years, including many student projects, government and non-government-supported trials, as well as their own research carried out on different aspects of the operation. Adaptive management in response to research findings and a culture of innovation at Kilmarnock have resulted in changes in the Watsons' farming practices and approaches to natural resource management over the years. Central to the journey has been their vision for improved sustainability and profitability, and their willingness to trial and adopt more sustainable technologies and practices, acquire more farmland and absorb occasional losses.

Future plans at Kilmarnock

The Watsons recently purchased a farm to the east of their current operations and have begun works there to restore and protect the riverbank as they have done at Kilmarnock. They hope to use what they have learned at Kilmarnock to improve the environment of the new farm and implement similar management practices there. The new farm has approximately 10 km of river and creek frontage and a noxious weed control, and tree planting programme is underway to stabilise banks and create habitat for birds, microbats and beneficial invertebrates. The Watsons' neighbours at the new property are keeping a keen eye on the works being undertaken and have already sought advice from the Watsons on how they may initiate similar projects on their own properties.

A concern for the Watsons moving forward is the increase in mining in the district, potential degradation of ground and surface water sources and the impacts of these on-farm operations and water-dependent flora and fauna in the region. The use of native vegetation by feral animals, particularly feral Pigs (*Sus scrofa*), is also a concern, and the Watsons are investigating control methods to minimise damage to crops and native vegetation.

Conclusions

By providing habitat for natural pest control agents and eliminating insecticide use, increasing water-use efficiency and minimising fertiliser inputs by switching to more natural alternatives, the Watsons have been able to minimise their environmental footprint and the economic costs associated with cotton production. Their efforts to restore habitat for natural pest control agents have paid off in the form of environmental benefits due to the presence of a number of threatened species, economic benefits through reduced chemical costs and social benefits by minimising human and environmental impacts due to insecticide use. Increased water- and nitrogen-use efficiency is improving the sustainability of the operation by allowing the Watsons to 'grow more crop for every drop' and minimise greenhouse gas emissions to the atmosphere. They hope that their success and communication of their story will inspire others to appreciate the interrelationship between agricultural production and the health of the surrounding environment in which it is situated. Greater awareness and restoration of natural ecosystems are integral to the long-term sustainability of agricultural production by supporting ecosystem service provision.

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