Cotton Catchment Communities CRC

FINAL REPORT

Part 1 - Summary Details

Cotton CRC Project Number: **2.04.09**

Project Title: Healthy Cotton Catchments

Project Commencement Date: 1 July 2006 **Project Completion Date:** 30 Sep 2009

Cotton CRC Program: **The Catchment**

Part 2 – Contact Details

Administrator: Justin Harsdorf
Organisation: CSIRO Sustainable Ecosystems
Postal Address: Bellenden St, Crace, ACT
Ph: 02 62421546 **Fax:** **E-mail:** **justin.harsdorf@csiro.au**

Principal Researcher: Dr Alan House
Organisation: CSIRO Sustainable Ecosystems
Postal Address: 306 Carmody Road, St Lucia, Qld 4067
Ph: 07 32142365 **Fax:** 07 32142308 **E-mail:** alan.house@csiro.au

Supervisor: Dr Phil Polglase
Organisation: CSIRO Sustainable Ecosystems
Postal Address: Bellenden St, Crace, ACT
Ph: 02 62421623 **Fax:** 02 62421565 **E-mail:** philip.polglase@csiro.au

Signature of Research Provider Representative:

Part 3 – Final Report Guide (due within 3 months on completion of project)

(The points below are to be used as a guideline when completing your final report.)

Background

Outline the background to the project.

One of the challenges for sustainable cotton enterprises is to optimise the production of goods and services from all parts of the landscape. Most cotton farms support a wide range of habitats suitable for native wildlife through the retention of patches of native vegetation (woodlands and grasslands) and other farming systems (cropping and grazing) that may benefit the environment and sustainability of cotton production. The perceptions that wildlife is only found in nature reserves, and is only valuable there, is incorrect, and the contribution of small patches and marginal habitats to both production (e.g. natural pest control) and biodiversity and conservation is often overlooked. Yet we know that there are ecosystem services associated with cotton farms. For example, predators and parasitoids of cotton pests visit different vegetation types (native, weeds and crops) before colonising cotton fields, and native birds and bats prey on cotton pests and may disrupt egg laying. There is a growing understanding that the maintenance of habitat heterogeneity (e.g. mix of cropping, grazing, native vegetation) and the intensity of management in the farmed component of agricultural landscapes are critical for sustaining biodiversity. There are also links between levels of biodiversity and ecosystem function, which in turn can affect farm performance and ecological outcomes at a broader scale. However the means to manage for biodiversity and ecosystem services on cotton properties and across catchments is poorly understood.

Objectives

List the project objectives and the extent to which these have been achieved.

The project objectives were to:

1. Determine how the condition and spatial arrangement of patches of vegetation (native, other crops and pastures) provide habitat opportunities for wildlife conservation and increased biodiversity in cotton catchments;

This objective formed the major part of the project and has been achieved.

2. Provide scientific knowledge to inform regional resource management plans for the Catchment Management Authorities, e.g. Condamine Alliance and QMDC;

This report and the papers that will come from it will achieve this objective. Once this final report is approved by the CRC we will brief both groups on the major findings and implications for land management in their catchments.

and (together with projects 2.04.11 and 2.04.13)

3. Support refinement of industry best management practices for cotton insect and native vegetation management (cf Land & Water Management module of BMP Manual).

This is a longer-term objective for developers of the BMP modules to build research findings into advice and practice. The research team cannot claim to have achieved this yet, apart from the shared outcomes with project 2.04.11.

Methods

Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

Site selection

Three landscapes, representing contrasting amounts of retained native vegetation and containing intensive agriculture including cotton, were identified on the Condamine and Macintyre River floodplains (Fig. 1). Using existing map layers (regional ecosystem mapping and QLUMP land use data) we imposed circles of 10 km diameter and calculated proportions of land uses within these. Of principle interest was the amount of land mapped as native vegetation. Landscapes chosen for field sampling comprised 6% (Jandowae), 12% (Broadwater) and 35% (Callandoon) native vegetation.

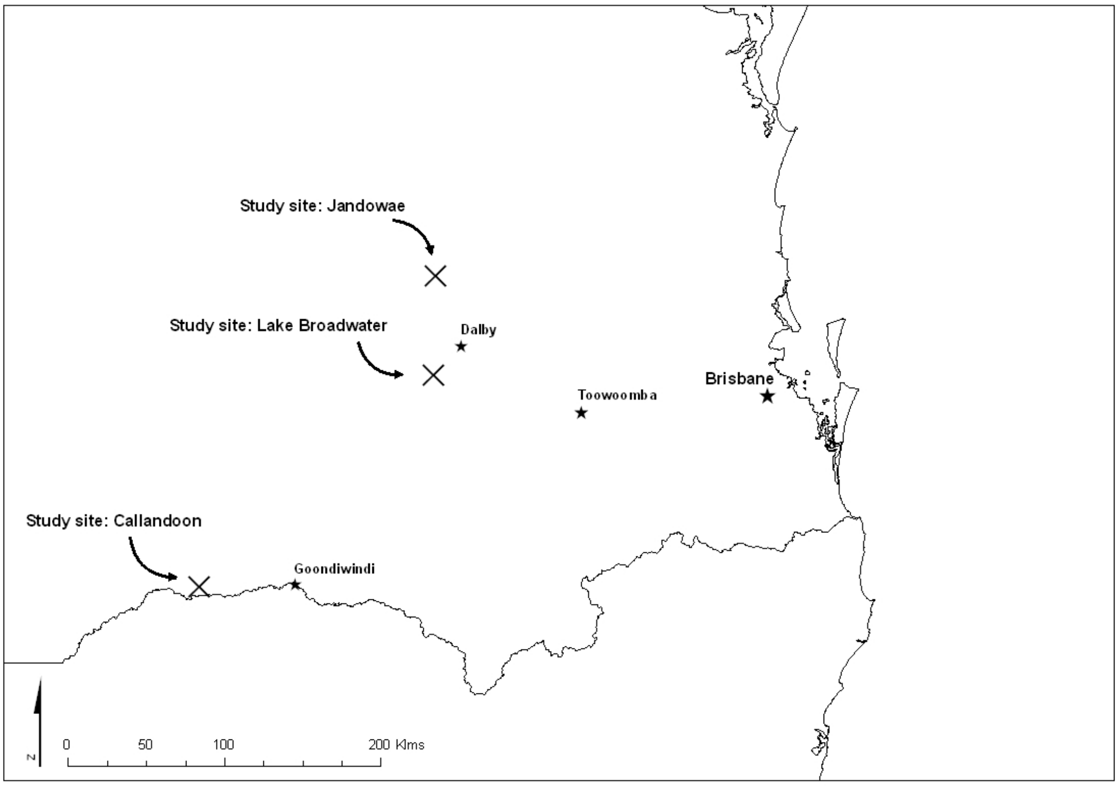
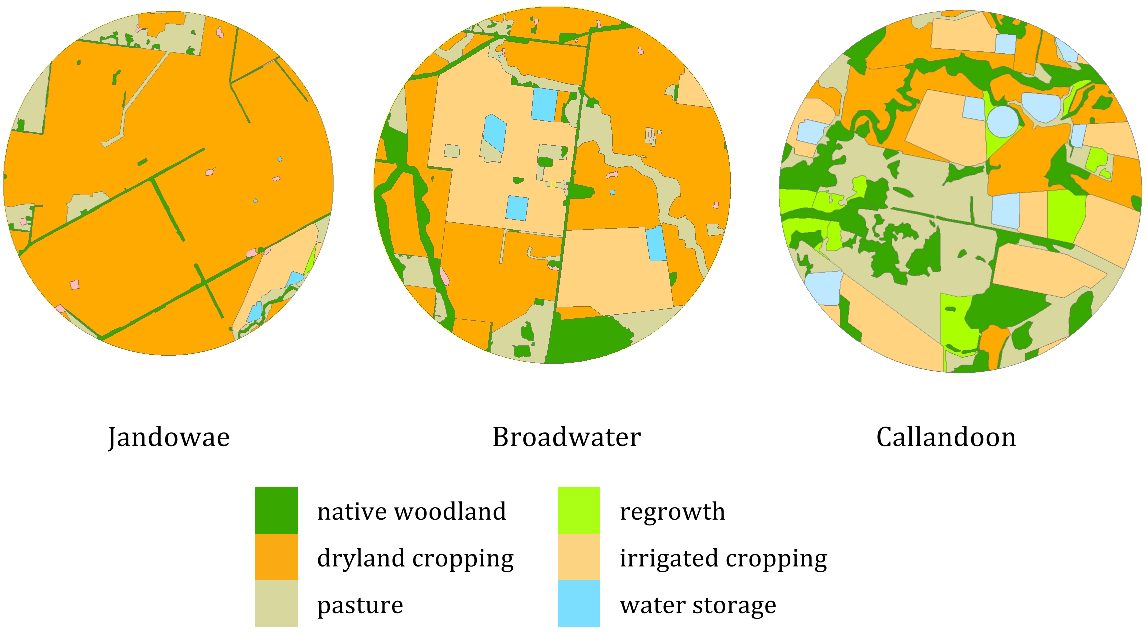


Fig. 1.Location of 3 study landscapes in southern Queensland

Within these landscapes, sites were chosen for (a) vegetation condition assessments and (b) ground active arthropod sampling. Sites were selected to represent a range of native vegetation elements, including roadside strips, discrete patches, and including both native woodlands and open grassy woodlands. Twenty sites were selected at both Jandowae and Broadwater, and 40 at Callandoon (where we had to select some sites outside of the original 10 km landscape because of access difficulties).

Landscape composition was calculated for each site at 3 scales (100 m, 500 m and 1000 m radius) using detailed mapping of key landscape elements from recent satellite imagery (i.e. not relying on the coarser 1:100,000 scale mapping done for regional ecosystems). Landscape elements defined and mapped were native woodland (NWD), native pastures and open woodland (POW), regrowth vegetation (RGTH), irrigated cropping (IRRC[1]), dryland cropping (DRYC), water storages (WAT), and other (roads, farm buildings etc) (OTH) (Fig. 2).


Jandowae

Broadwater

Callandoon

Fig. 2. Examples of the 3 study landscapes. Circles are 10 km in diameter. Note: OTH land use class not shown at this scale.

Vegetation condition

At each site, vegetation was scored on a range of structural, compositional and functional attributes following protocols used by CSE in other projects in similar landscapes. For patches, a ten-minute walk through at least 1 hectare was used to record habitat attributes; for linear roadside strips a length of 100 m was used to delineate a "site". The full range of attributes used is given in Appendix A. Individual attribute scores were adjusted for each vegetation type (i.e. open eucalypt woodland, brigalow-belah woodland, open pasture etc.) and an aggregate site score determined. This was then compared to a notional benchmark score that the particular vegetation type might attain in the absence of disturbance and modification.

Arthropod sampling

We sampled both epigeal (ground active) arthropods and those in ground vegetation (grasses, forbs, low shrubs) using pitfall trapping and suction sampling respectively.

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[1] For both irrigated and dryland cropping, the mapping does not distinguish between farming practices, i.e. it includes traditional till and no-till systems

At each site, two lines of 3 pitfall traps were established at 10 m spacing, with 20 m between lines. Traps consisted of 11 cm diameter plastic food containers containing 60% ethylene glycol and a few drops of detergent to break surface tension). Pitfalls were opened for 4 days. Suction sampling was done using a modified petrol-driven leaf blower with a fine mesh bag attached to the air intake; suction was applied for 5 bursts of 10 seconds each to grassy and shrubby vegetation over a 500 m^2 area, using an open-ended compost bin (53 cm diameter) to confine sampling to a fixed area for each burst. Trap and bag contents were then sorted to species level (ants) and for higher taxonomic groups (HTG: see Appendix B) for all others; within these higher groups morphospecies were recognised, but no attempt was made to match these across samples. Ants were further classified into functional groups based on habitat preferences, thermal behaviour and feeding biology. Ants were chosen as a key group to focus on as they have been shown to respond in predictable ways to environmental conditions, they are easy to sample, they are ubiquitous and common, and can be identified to species level reasonably quickly.

At each trap location, local habitat conditions were recorded in a 1 m^2 quadrat (proportion of bare ground, leaf litter, ground vegetation, logs, rocks, and vegetation cover at 1-5 m and >5 m above the trap). Values were averaged for each site.

Data analyses

Vegetation condition scores were analysed with simple means tests (t-tests) based on a binary classification of sites into linear strips (roadsides, shelterbelts) and patches (where width ≥ length x2).

Three arthropod datasets were analysed: pitfall trapped ants at species level, pitfall trapped other arthropods at HTG level (see Appendix B), and suction-sampled arthropods (including ants) at HTG level. Initially, all datasets were combined at HTG level (i.e. all ants included as Hymenoptera-Formicidae) to determine overall patterns of arthropod assemblage composition in relation to landscape and landscape elements.

Abundance data was square-root transformed prior to analysis, and means were used to account for some loss of data through traps being destroyed. Summary statistics were derived for total arthropod abundance, and species (ants) and morphospecies (all others) richness. Non-metric multi-dimensional scaling (NMDS) based on a Bray-Curtis similarity matrix was used to explore patterns of assemblage composition. Cluster analysis using group averaging identified groupings of sites based on ant assemblage composition and the SIMPER (similarity percentages) routine in PRIMER (Plymouth Routines in Multivariate Ecological Research) extracted species primarily responsible for these groupings. Multivariate analysis of similarities (ANOSIM) was used to test for differences in assemblage composition between landscapes and between landscape elements within landscapes. The BIOENV routine (using normalised environmental variables) was used to determine environmental correlates of assemblage composition, and linkage trees (non-metric multivariate regression trees) to identify environmental variables principally responsible for splits in the classification of arthropod assemblages. Prior to the BIOENV analyses an inter-correlation matrix was used to identify and eliminate variables that were correlated at $r \geq 0.80$ (variable chosen randomly from each pair).

Results

Detail and discuss the results for each objective including the statistical analysis of results.

Landscape configuration

The proportions of mapped land use types in each study landscape are shown in Fig. 3. For the major land use sampled for arthropods (native woodland) there were significant differences between landscapes in mean proportion at 100, 500 and 1000 m radius except between Jandowae and Broadwater at 100 m. Jandowae is mainly a dryland cropping area, whereas Callandoon is predominantly irrigated. The proportion of linear strips to patches varies between the 3 landscapes, with an increasing proportion of patches at higher overall levels of native vegetation cover. This reflects the development history, and land potential, of the 3 areas (Table 1).

Table 1. Percentage linear strips and patches sampled in the 3 landscapes.

landscape	linear	patch
Jandowae	40	60
Broadwater	35	65
Callandoon	22.5	77.5

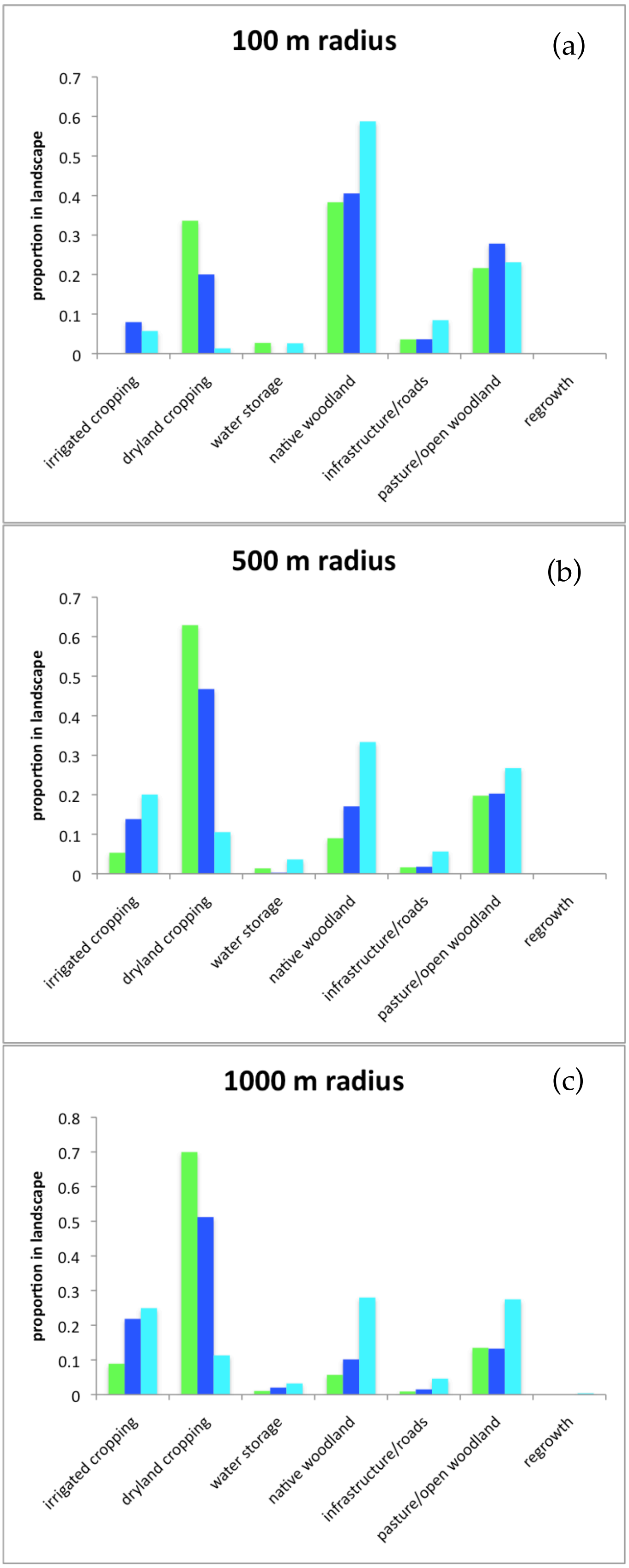


Fig. 3. Proportions of mapped land use types in each study landscape at (a) 100 m radius, (b) 500 m, (c) 1000 m. 🟩 = Jandowae, 🟦 = Broadwater, ■ = Callandoon.

Vegetation condition

Vegetation condition scores ranged from 45.2-76.5% At Jandowae, 41.2-73.4% at Broadwater, and 34.2-73% at Callandoon. Mean scores (± standard deviation) across all sites were not significantly different at landscape level (Jandowae 61.91 ± 9.45, Broadwater 63.17 ± 8.55, Callandoon 59.16 ± 8.75), but there were significant differences in scores between landscape element types (i.e. patches or linear strips) at both Broadwater (linear strips in better condition) and Callandoon (patches in better condition) (Fig. 4).

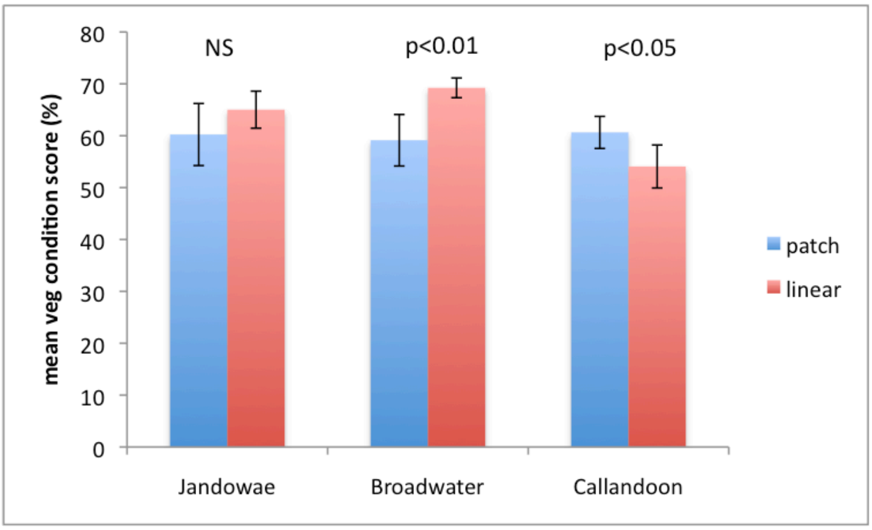


Fig. 4. Mean vegetation condition scores for patch and linear landscape elements in each study landscape.

Contrasting patterns are found if the condition scores are disaggregated into individual attributes. For instance, there was significantly less sapling stage regeneration of trees in both Jandowae and Broadwater compared with Callandoon, and in turn, significantly more regeneration in linear strips at Broadwater and Callandoon than in patches (Fig. 5).

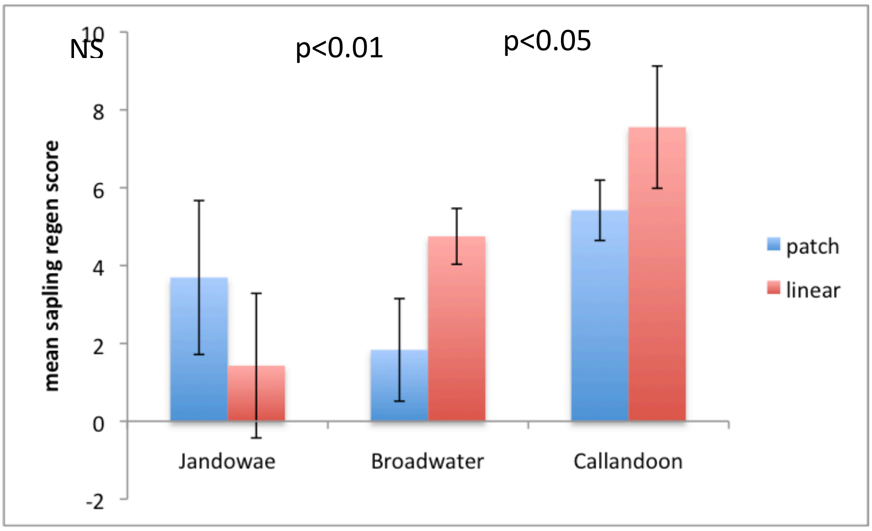


Fig. 5. Mean sapling regeneration scores for patch and linear landscape elements at each study landscape.

Arthropod diversity – all taxa

There were no significant differences in overall arthropod compositions between landscape elements (Fig. 6 (a); Global R = -0.064, p = 0.91) or landscapes (Fig. 6 (b), Table 2).

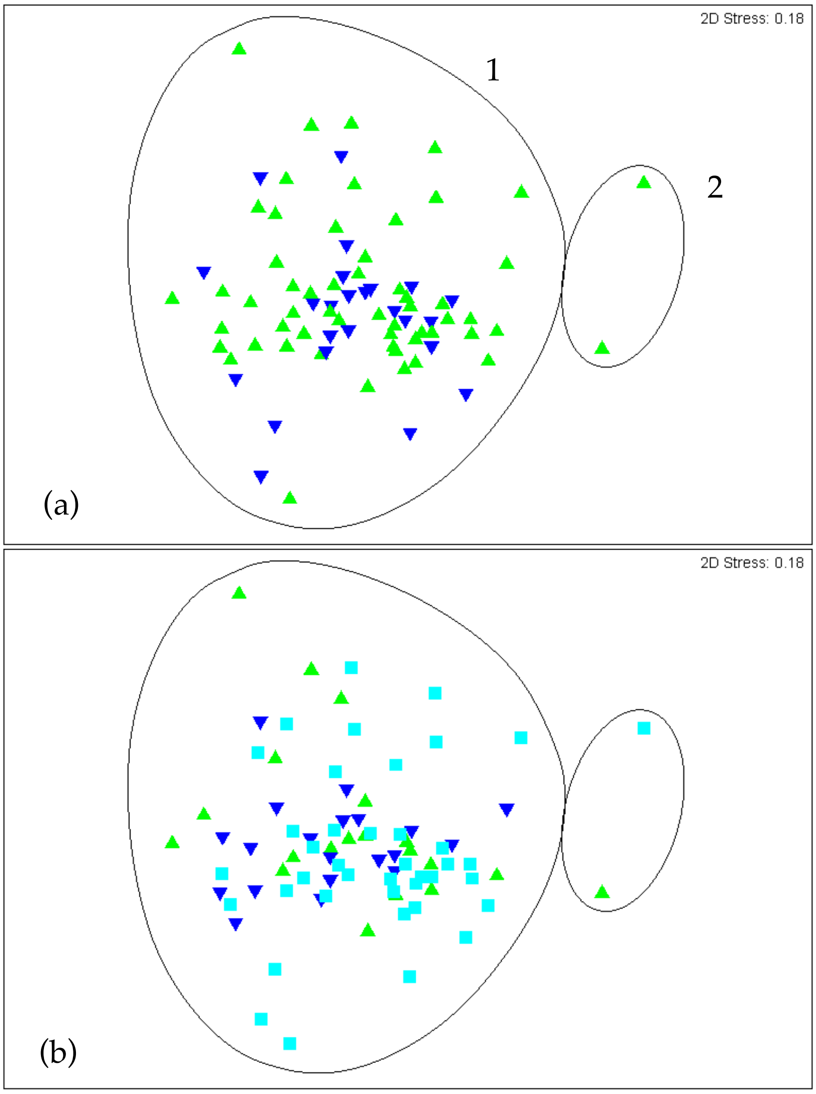


Fig. 6. NMDS on combined arthropod data. (a) Landscape elements: ▲ = patch; ▼ = linear. (b) Landscapes: ▲ = Jandowae; ▼ = Broadwater; ■ = Callandoon. Groupings significant at p = 0.05 are shown.

Table 2. ANOSIM results for between landscape pair-wise comparisons.

Global R = 0.045, p =0.128		
comparison	R	p
Jandowae vs Broadwater	0.012	0.275
Broadwater vs Callandoon	0.082	0.085
Jandowae vs Callandoon	0.031	0.254

Significant groupings in the data (Fig. 6 (a) and (b)) were based primarily on a higher abundance of ants in group 2.

Arthropod diversity – ants

Totals of 9183 individuals from 85 species of ants were trapped at Jandowae, 22,864 individuals from 95 species (Broadwater), and 47,549 individuals from 96 species from Callandoon (note: 40 sites at Callandoon). These levels of species richness compare with other mixed farm sites in the region of between 69 and 80 species (from smaller sample sizes than this study).

Ant species richness was significantly greater at Broadwater than at Jandowae ($p < 0.05$) and Callandoon ($p < 0.01$), but Jandowae and Callandoon were not different. There were no significant differences between landscape elements within any landscape (Fig. 7).

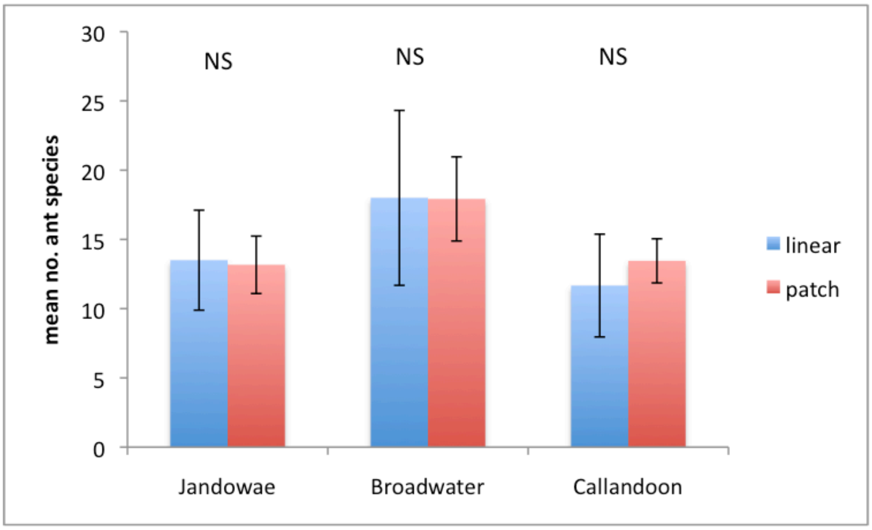


Fig. 7. Ant species richness in patch and linear landscape elements for each study landscape.

At assemblage level, landscapes differed significantly (Fig. 8, Table 3), and there were significant groupings of sites (irrespective of landscape or landscape element) based on different indicator species.

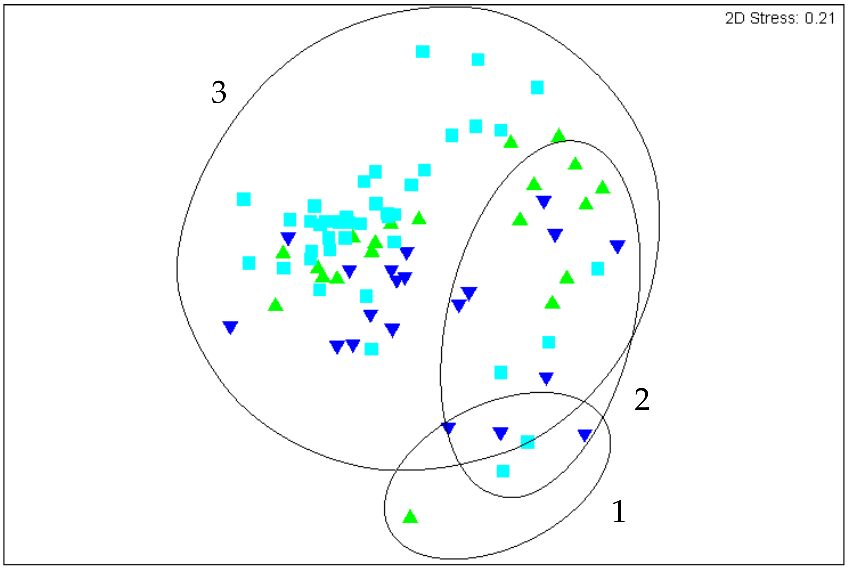


Fig.8. NMDS on ant assemblages, all landscapes. ▲ = Jandowae; ▼ = Broadwater; ■ = Callandoon. Groupings significant at p = 0.05 are shown. Species contributing >10% to group similarity (i.e. species characteristic of that group): Group 1 *Monomorium sordidum* sp. K (45.7%), *M. carinatum* sp. L (20.3%); Group 2 *Rhytidoponera metallica* sp. C (30.7%), *Iridomyrmex rufoniger* sp. O (26.4%), *I. purpureus* (14.1%); Group 3 *I. rufoniger* sp. A (48.1%), *R. metallica* sp. C (19.1%).

Table 3. ANOSIM results for ant assemblage composition between landscapes.

Global R = 0.179, p < 0.01		
comparison	R	p
Jandowae vs Broadwater	0.150	**<0.01**
Broadwater vs Callandoon	0.181	**<0.01**
Jandowae vs Callandoon	0.185	**<0.01**

At individual landscape level, although there were significant groupings of sites based on ant assemblages, these did correspond to the major landscape elements (Fig. 9), a result supported by ANOSIM analyses (Table 4).

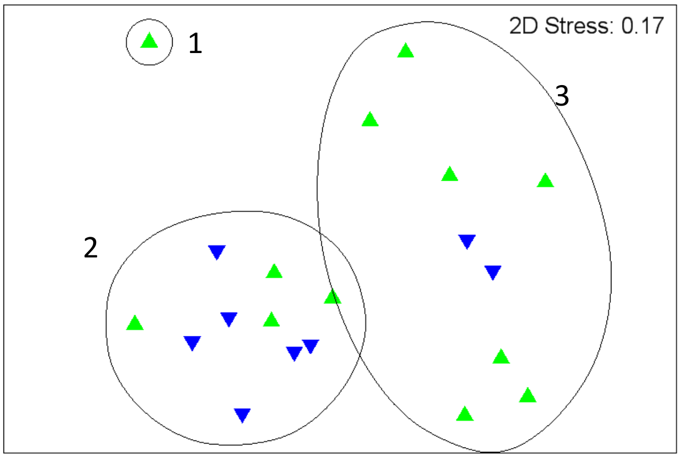
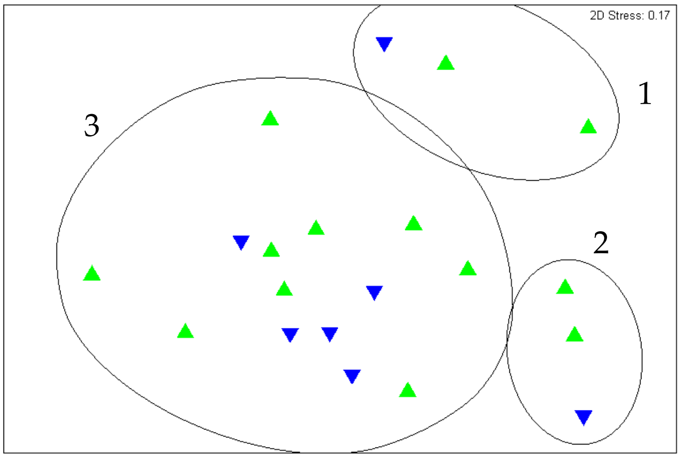
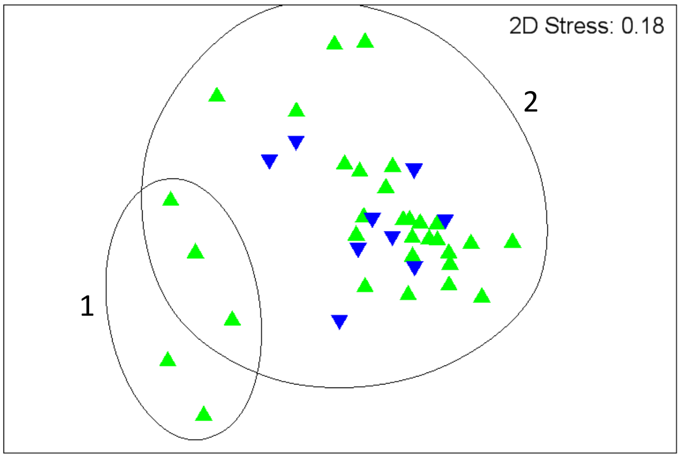


Fig. 9. NMDS ordinations of ant assemblages, individual landscapes. ▲ = patch; ▼ = linear. Groupings significant at p = 0.05 are shown, with species contributing >10% to group similarity (i.e. species characteristic of that group) listed.

(a) Jandowae. Group 2 *Iridomyrmex rufoniger* sp. A (72.7%); Group 3 *Rhytidoponera metallica* sp. C (44%), *Rhytidoponera* sp. G (14.4%).



(b) Broadwater. Group 1: *Iridomyrmex rufoniger* sp. O (39.3%), *Rhytidoponera metallica* sp. C (19.4%, *Monomorium* sp. K (14%); Group 2 *R. metallica* sp. C (51.2%), *Camponotus consobrinus* sp. A (17.3%), *I. rufoniger* sp. O (12.9%); Group 3: *I. rufoniger* sp. A (42.4%), *R. metallica* sp. C (11.9%).



(c) Callandoon. Group 1 *Iridomyrmex purpureus* (62.6%), *Rhytidoponera metallica* sp. C (14.8%), *I. rufoniger* sp. O (12.2%); Group 2 *I. rufoniger* sp. A (52.2%), *R. metallica* sp. C (14%).

Table 4. ANOSIM results for between landscape elements comparisons – ant species.

	Global R	p
Jandowae	-0.018	0.524
Broadwater	-0.056	0.689
Callandoon	-0.071	0.704

There were no strong relationships between ant species richness and vegetation condition (Fig. 10), although there was a trend for decreasing species richness with increasing vegetation condition at Broadwater. In contrast Jandowae and Callandoon showed slight positive trends.

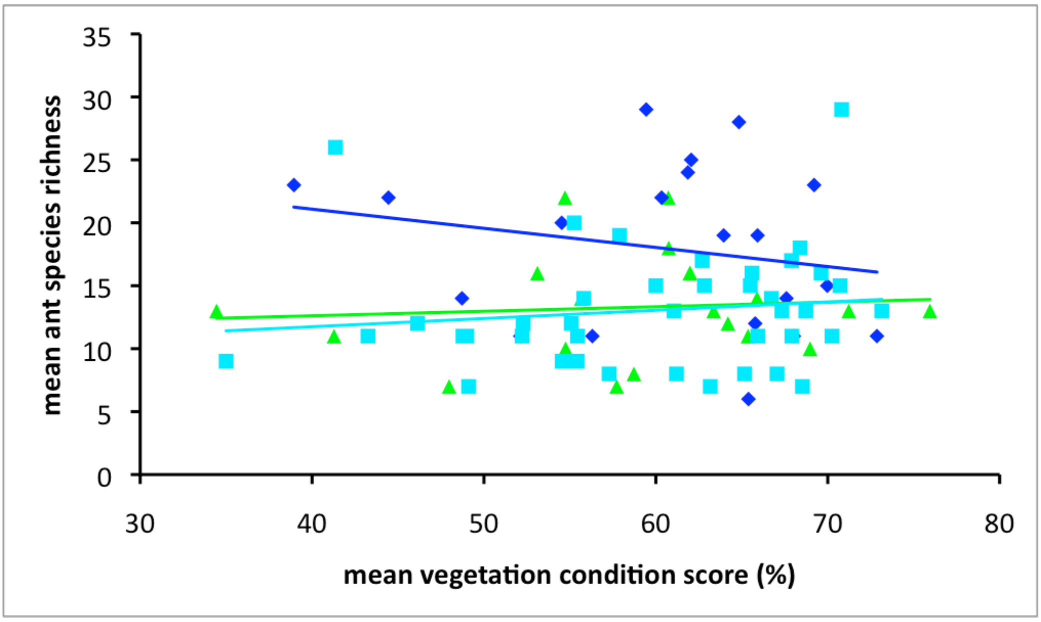


Fig. 10. Relationship between ant species richness and vegetation condition in each study landscape. ▲ = Jandowae; ◆ = Broadwater; ■ = Callandoon.

Assemblage-environment relationships

At Jandowae and Broadwater, local habitat variables were more important than landscape variables in determining ant assemblages. At Callandoon, the influence of landscape structure appears to be greater, comprising 4 of the 5 variables contributing to the best solution. However, there was no statistically significant effect of environment on ant assemblages in any landscape (Table 5).

Table 5. BIOENV results for ant assemblages.

landscape	ρ	p	variables contributing to solution
Jandowae	0.257	0.80	litter
Broadwater	0.419	0.11	POW100, NWD500, bare ground, sapling regen, native plant richness
Callandoon	0.394	0.13	IRRC1000, WAT100, POW100, RGTH1000, % tree cover

The linkage tree analyses confirm these patterns. At Jandowae sites are classified firstly on the amount of litter (> or < 45% cover; $\pi = 1.71$, $p < 0.01$), and then on the mean number of native plant species in the understorey (> or < 5.5; $\pi = 2.39$, p =

0.01). Broadwater sites are classified firstly on a combination of the amount of native woodland at 500 m (< 9% or > 12%) and open woodland/pasture at 100 m (>86% or < 73%; π = 1.71, p = 0.01), and then on the amount of bare ground at site level (> or < 32%; π = 1.69, p = 0.02). Both landscape and local attributes are significant at Callandoon, where the proportion of irrigated cropping at 100 m (> or < 50%) and % tree cover (0 or >0%; π = 2.59, p = < 0.01) determine the first split in the classification, followed by the proportion of water storages within 100 m (< 27% or > 69%; π = 2.3, p < 0.01) and % tree cover (< 35% or > 50%; π = 2.29, p < 0.01).

Ant functional groups

Dominant Dolichoderinae (mainly *Iridomyrmex* spp. – meat ants) dominated all ant assemblages in all landscapes (Fig. 11). There was a significant difference in functional group composition between the Broadwater and Callandoon landscapes, based on the higher ratio of dominant Dolichoderinae to opportunists at Callandoon, but other pair-wise comparisons were not significant (Table 6). There were no significant differences in functional group composition between linear strips and patches in any of the 3 landscapes (Table 7).

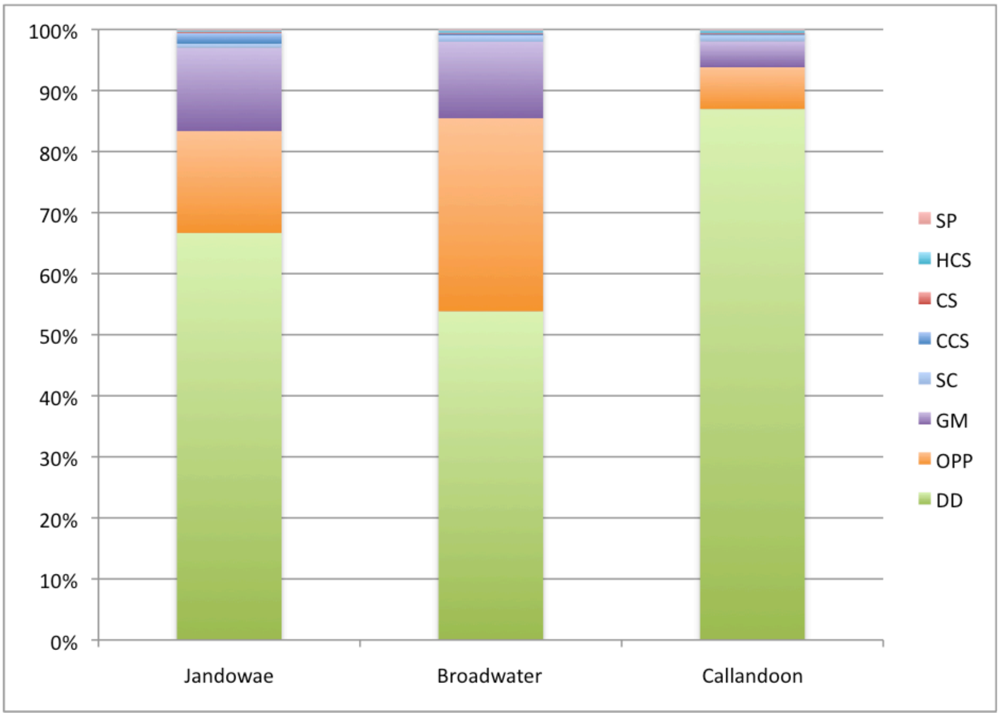


Fig. 11. Relative abundance of ant functional groups at each landscape. SP = specialist predators; HCS = hot climate specialists; CS = cryptic species; CCS = cold climate specialists; SC = subordinate Camponotini; GM = generalised Myrmicinae; OPP = opportunists; DD = dominant Dolichoderinae.

Table 6. ANOSIM results for between-landscape pair-wise comparisons – ant functional groups.

	Global R	p
Jandowae vs Broadwater	0.016	0.25

Jandowae vs Callandoon	0.080	0.08
Broadwater vs Callandoon	0.093	**0.05**

Table 7. ANOSIM results for between landscape elements (linear vs patch) pair-wise comparisons – ant functional groups.

	Global R	p
Jandowae	-0.107	0.87
Broadwater	-0.056	0.69
Callandoon	-0.026	0.59

Higher Taxonomic Group analyses

There was a statistically significant difference between assemblages at Jandowae and Broadwater, but not in other pair-wise comparisons (Fig. 12, Table 8)

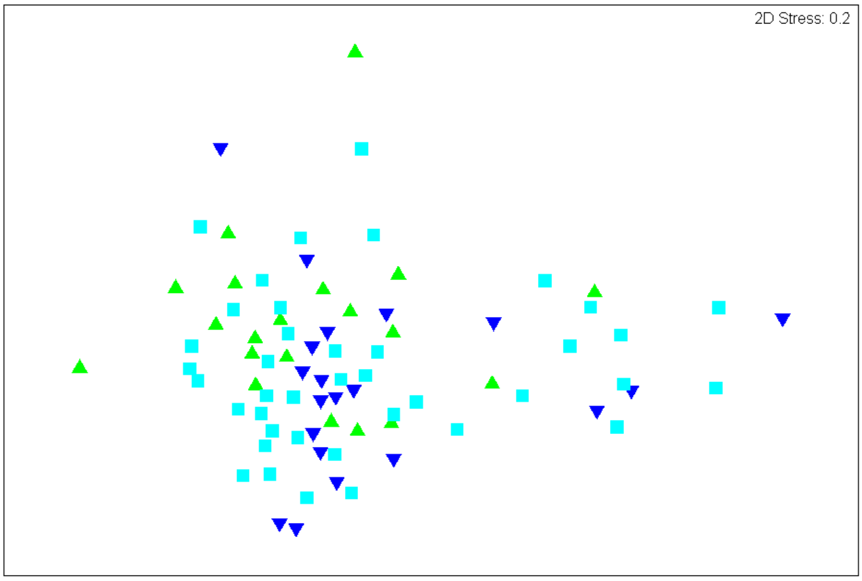


Fig. 12. NMDS on HTG, all landscapes. ▲ = Jandowae; ▼ = Broadwater; ■ = Callandoon. There were no significant groupings of sites.

Table 8. ANOSIM results for between-landscape pair-wise comparisons, HTG-level abundance data.

Global R = 0.034, p = 0.17		
comparison	R	p
Jandowae vs Broadwater	0.058	**0.03**
Broadwater vs Callandoon	0.036	0.21
Jandowae vs Callandoon	0.028	0.22

Similarly, there were no significant differences between landscape elements at any landscape (Fig. 13, Table 9).

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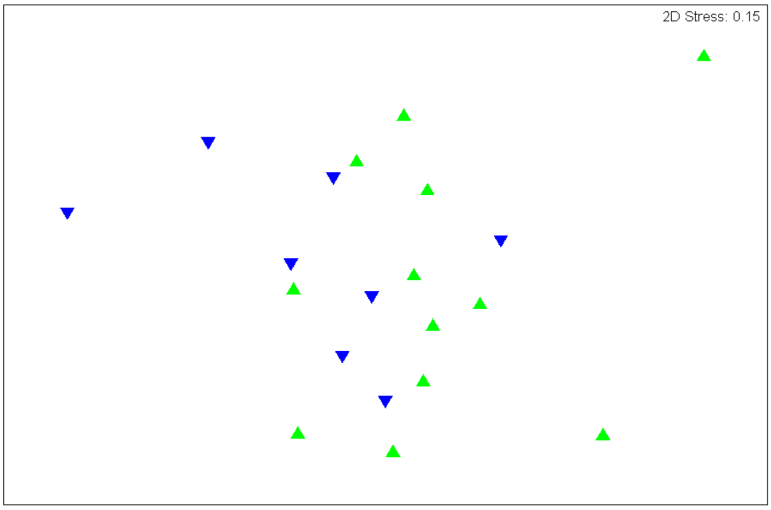
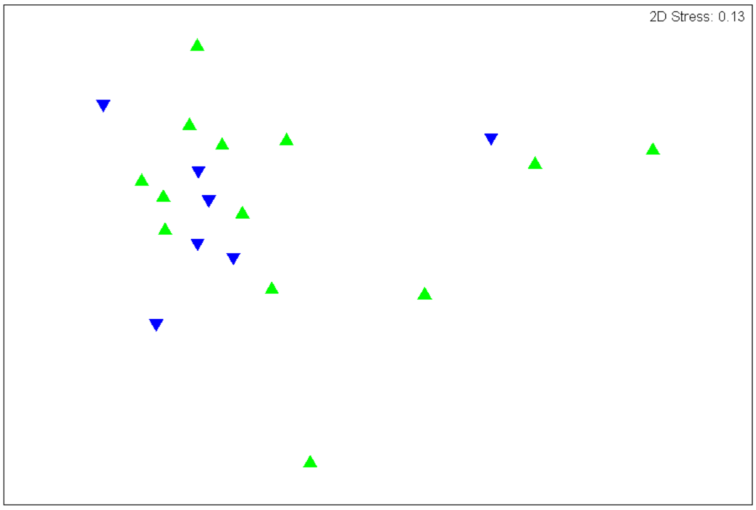
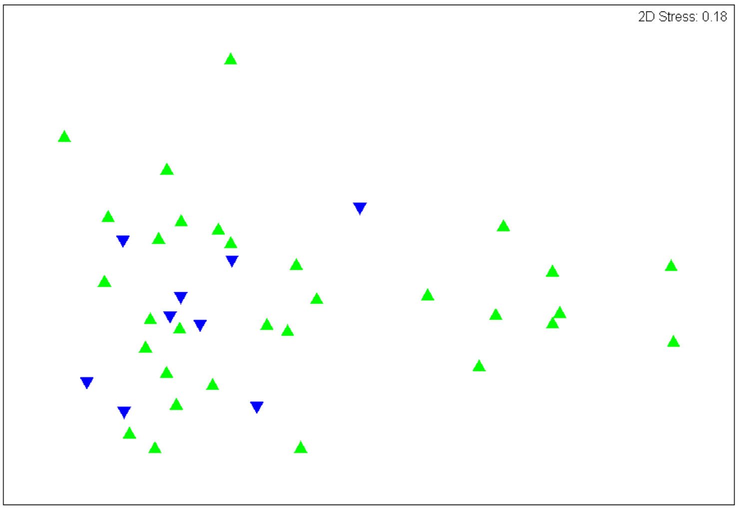


(a) Jandowae



(b) Broadwater



(c) Callandoon

Fig. 13. NMDS ordinations of HTG-level assemblages. ▲ = patch; ▼ = linear. There were no significant groupings of sites at any landscape.

Table 9. ANOSIM results for between landscape elements comparisons – HTG-level abundance data.

	Global R	p
Jandowae	-0.011	0.513
Broadwater	-0.090	0.843
Callandoon	-0.076	0.808

As with ants, assemblages based HTG were not correlated with vegetation condition. Neither habitat or landscape features explained assemblage variation at either Jandowae or Callandoon, but assemblages were significantly associated with the proportion of dryland cropping (at 500 m radius) and the amount of sapling regeneration at Broadwater (Table 10).

Table 10. BIOENV results for HTG-level assemblages.

landscape	ρ	p	variables contributing to solution
Jandowae	0.31	0.76	NWD500, disturbance, shrub cover, native plant richness
Broadwater	0.56	**0.02**	DRYC500, sapling regen
Callandoon	0.367	0.32	WAT100, NWD500, WAT1000, litter, dead trees

Suction sampled arthropods

Three groupings of sites were found in suction sampled arthropods (Fig. 14). Leaf-hoppers were characteristic of all 3 groups, with wasps, flies and grasshoppers contributing to group differences. Pair-wise comparisons between landscapes shows that they are all significantly from each other (Table 11).

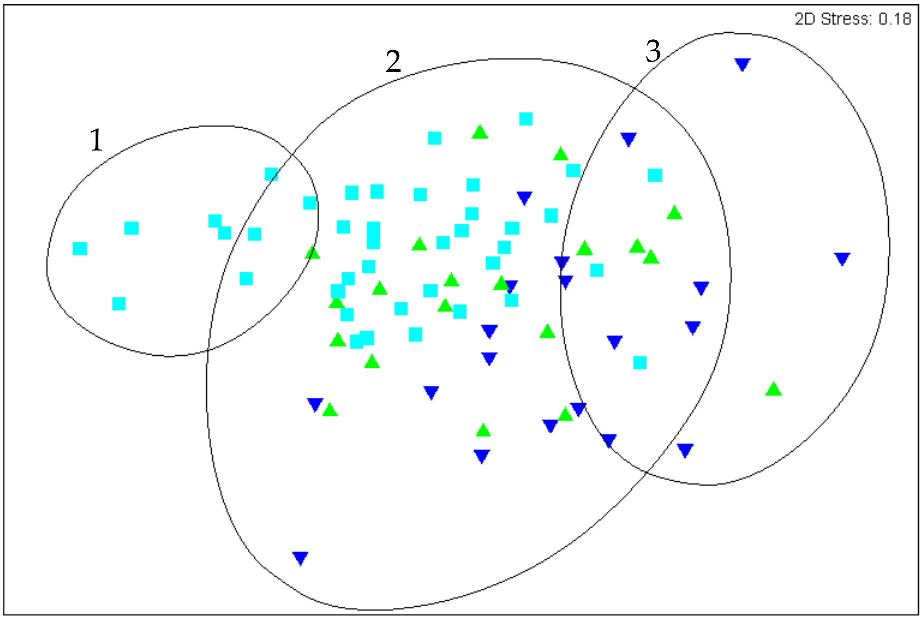


Fig. 14. NMDS on suction-sampled assemblages, all landscapes. ▲ = Jandowae; ▼ = Broadwater; ■ = Callandoon. Groupings significant at p = 0.05 are shown. HTGs contributing >10% of group similarity (i.e. characteristic of the group): Group 1 Homoptera (32.1%), Hymenoptera – wasps (22.3%), Diptera (13.0%), Thysanoptera (12.8%); Group 2 Homoptera (33.8%), Diptera (21.3%), Araneae (13.3%), Hymenoptera – wasps (13.1%); Group 3 Homoptera (33.8%), Diptera (26.6%), Orthoptera (13.1%).

Table 11. ANOSIM results for between landscape pair-wise comparisons, suction-sampled arthropods.

Global R = 0.218, p = 0.001		
comparison	R	p
Jandowae vs Broadwater	0.101	**0.004**
Broadwater vs Callandoon	0.368	**0.03**
Jandowae vs Callandoon	0.112	**0.001**

At individual landscape level, grouping was evident at Jandowae and Callandoon but not at Broadwater (Fig. 15). These groups corresponded significantly with landscape elements only at Callandoon (Table 12).

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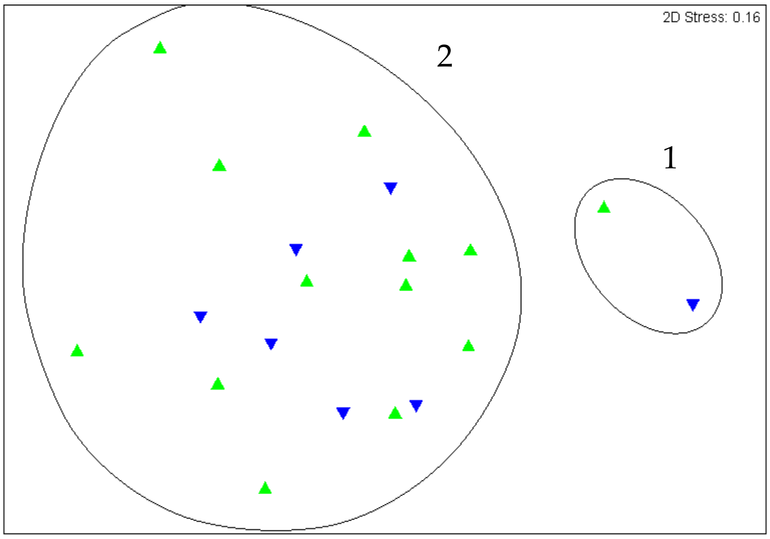
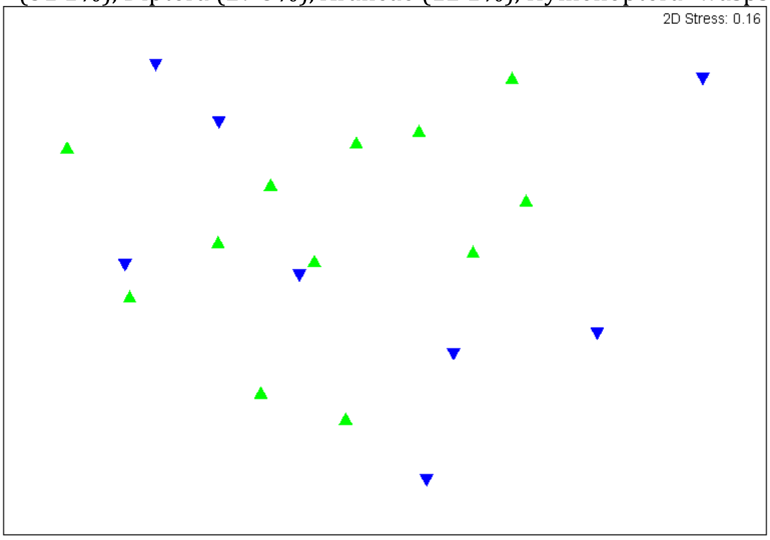
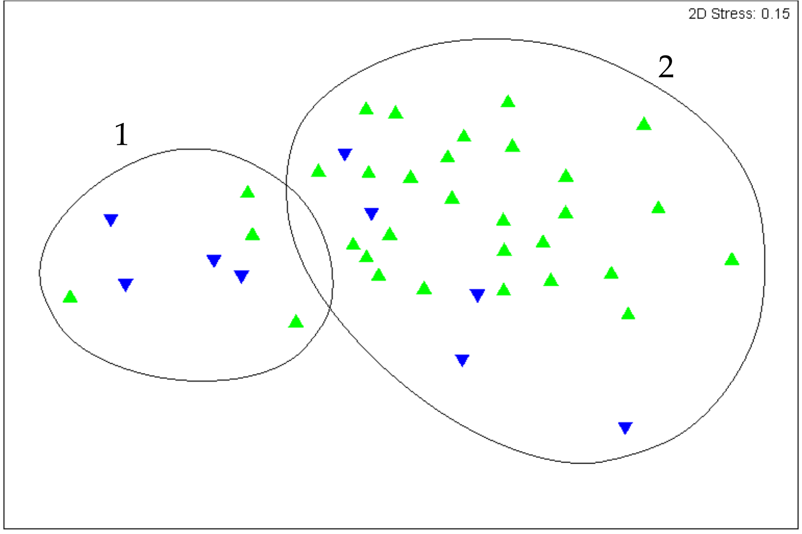


Fig. 15. NMDS ordinations of suction-sampled assemblages. ▲ = patch; ▼ = linear. Groupings significant at p = 0.05 are shown, with species contributing >10% to group similarity (i.e. species characteristic of that group) listed.

(a) Jandowae. Group 1 Diptera (44%), Hemiptera (24.5%); Group 2 Homoptera (31.1%), Diptera (29.5%), Araneae (12.1%), Hymenoptera- wasps (10.8%).



(b) Broadwater. No significant grouping of sites



(c) Callandoon. Group 1 Homoptera (32.4%), Hymenoptera – wasps (22.8%), Diptera (13.6%, Thysanoptera (11.8%); Group 2 Homoptera (35.0%), Diptera

(17.4%), Hymenoptera – wasps (16.1%), Araneae (10.3%).

Table 12. ANOSIM results for between-landscape elements (linear vs patch) pair-wise comparisons – suction-sampled assemblages.

	Global R	**p**
Jandowae	-0.150	0.96
Broadwater	0.074	0.20
Callandoon	0.202	**0.03**

At all landscapes, local habitat variables contribute most to pattern in suction-sampled arthropods. Only at Callandoon do environmental variables significantly explain these patterns (Table 13).

Table 13. BIOENV results for suction-sampled arthropods.

landscape	**ρ**	**p**	**variables contributing to solution**
Jandowae	0.47	0.17	OTH500, tree cover, sapling regen, disturbance, native plant richness
Broadwater	0.43	0.10	OTH500, OTH1000, seedling regen, disturbance, native richness
Callandoon	0.40	**0.01**	OTH500, WAT1000, bare ground, dead trees, disturbance

The linkage tree analyses confirm these patterns. At Jandowae sites are classified firstly on the proportion of infrastructure at 500 m (>16 or <2%; $\pi = 1.64$, $p = 0.04$) and then on sapling regeneration (< 2 or > 3; $\pi = 1.49$, $p = 0.04$). Callandoon sites are split firstly on the proportion of infrastructure at 500 m (> or < 13%; $\pi = 1.86$, $p = 0.001$) and then on the abundance of dead trees (< 2 or > 3; $\pi = 1.21$, $p = 0.003$). Further splits are based on the amount of bare ground and levels of disturbance.

Conclusions

There are complex impacts of landscape scale patterns of vegetation, agricultural land use, vegetation condition and local habitat attributes on arthropod assemblages in these landscapes. Different components of the arthropod fauna respond in different ways to either landscape or local environmental features, but there was no significant relationship between the total arthropod fauna (as sampled by the methods used) and environment. Vegetation condition was not a good predictor of arthropod assemblages, but did vary in a predictable way, with no difference between patches and strips at Jandowae, where grazing is rare; higher condition in strips than patches at Broadwater, where stock are still present but grazing resources are limited; and higher in patches than strips at Callandoon, where grazing is still practised but is spread over much larger areas.

Pitfall trapped arthropods described at higher taxonomic level did not differ between patches and linear strips of native vegetation, but there was a difference in composition between Jandowae (the lowest % native vegetation) and Broadwater. The same faunal group sampled from the ground vegetation showed differences between patches and linear strips at Callandoon, these differences being correlated with both landscape features (amount of irrigation infrastructure) and habitat (bare ground, dead trees and disturbance); there were also significant differences between all landscapes.

For the ants, there were significant differences between all landscapes in assemblage composition, but not between patches and linear strips within landscapes. Similarly, ant functional groups showed no difference between patches and linear strips at any landscape, but the Broadwater and Callandoon landscapes were significantly different from each other. Ant assemblages were not significantly determined by the environmental attributes measured, but there was a trend for landscape features (i.e. proportion of land use types) to be more important, and for habitat attributes to be less important, in explaining variation in assemblages as the proportion of native vegetation increases.

Seasonal succession of ants in summer crops

See attached Honours thesis by Belinda Walters. The salient outcomes were:

1. Considerable densities of ants were found in both cotton and sorghum crops at early stages of growth, with significant differences in ant numbers between remnant and crop habitats
2. Species richness of ants declined over time in cotton (although this was not significant), but increased significantly in sorghum.
3. There were significantly fewer ant species in crop habitats than in remnant for both crops. Within-crop richness was not different at any distance for cotton; similar pattern was found in sorghum but there was a less sharp decline in species numbers at the crop edge.
4. There were clear trajectories of ant assemblages with distance in cotton and sorghum – these were matched by trajectories in functional groups in sorghum, although in cotton this was less clear.
5. The number of ant functional groups declined with distance into crop for both crops.
6. Environmental variables responsible for patterns in ant assemblages explained a significant proportion of the variation in both cotton and sorghum. Canopy height and soil moisture were significant for cotton; canopy height, shading, soil moisture and leaf litter were all important in sorghum.

From these results it is clear that there are predictable changes in the ant fauna over time in some crops that follow a successional sequence, and that are governed partly by the development of cover, structure and habitat diversity in the crops. However, ants are present in good numbers early in the growing season, allowing for rapid provision of pest control services as soon as cotton seedlings emerge. We do not know the impact of extended fallows on ants in these systems, but a single winter fallow allows for some tax to persist in-paddock. Remnant native vegetation adjacent to paddocks presumably supplies habitat resources for a range of taxa that then migrate into the crop during the season, but we have not shown this definitively in this project.

Outcomes

Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

This project will provide more of a scientific basis for consideration of native vegetation as a conservation resource in natural resource planning in highly modified landscapes. For farmers and natural resource managers, the knowledge that remnant (in the broadest sense) strips and patches of native vegetation contribute significantly to regional biodiversity pools, and that there are some landscape level relationships in species richness and assemblage composition, will help encourage retention of these key assets.

Please describe any:-

a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);
b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
c) required changes to the Intellectual Property register.

None applicable

Conclusion

Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

Impact

The impact of this work will depend upon uptake of principles with respect to vegetation management retention and management. If native vegetation is managed sensitively and appropriately, then even small patches and narrow strips can continue to provide habitat for species that may contribute to regional ecosystem processes, and local ecosystem services. In highly modified landscapes, protection of small patches may not be enough to ensure their viability in the long term, and consideration could be given to expanding them (either through passive regeneration or tree planting) and re-connecting them to the wider network of linear strips along roads and paddock boundaries.

Take home messages

- Native vegetation supplies ecosystem services (including natural pest control) but is also good for conservation irrespective of the amount of clearing.
- Appropriate management of native vegetation is important to retain biodiversity value in the long term – keep weeds out, allow some dead wood

to accumulate, apply fire (where possible and appropriate) to encourage tree regeneration. This is relevant for local councils and main roads departments as well as for farmers. Strategic, cooperative and targeted vegetation management across intensively farmed landscape can ensure the continued delivery of private (pest control) and community (biodiversity conservation) ecosystem services.

- Roadside strips are of increasing importance to biodiversity as the total amount of native vegetation in the landscape declines.
- Farm infrastructure appears to have an impact on arthropod assemblages, presumably through the removal of alternative habitat resources (e.g. cropped areas, uncultivated strips and corners) in landscapes already modified by clearing.
- Crops themselves provide habitat for beneficial species, some of which appear to persist between crops. The retention of stubble and zero-till practices enhances this persistence and provides early in-crop pest control services. Native vegetation adjacent to cropping paddocks is important as a source for predatory arthropods such as ants.
- The direct benefits of native vegetation for pest control have been demonstrated in the sister project to this (2.04.11).

Extension Opportunities

Detail a plan for the activities or other steps that may be taken:

(a) to further develop or to exploit the project technology.

There is no new technology from this project.

(b) for the future presentation and dissemination of the project outcomes.

Journal papers are in preparation to present (1) the key results from the landscape study and (2) the in-crop seasonal ant study. In addition, a third journal paper is planned to synthesise a number of projects and datasets from landscape-scale studies of arthropod biodiversity in southern Queensland agricultural landscapes (including this one).

(c) for future research.

Future research in relation to arthropod biodiversity in cotton-growing landscapes could include:

1. Further research to determine consistency of results across other landscapes representing different levels of native vegetation.
2. Assessment of the impacts of irrigation and irrigation infrastructure on arthropod movements – do drainage channels and earthworks hinder movement?
3. Crop rotations and the persistence of ants in cropping paddocks – what works best of we want to retain useful predatory species within the paddock?

4. Increasing climate variability and arthropod dynamics in agricultural landscapes – how will key taxa like ants respond, and how resilient are assemblages to rapid environmental change?
5. Evolution of novel ecosystems in agricultural landscapes - what are the long-term consequences of highly intensive agriculture such as cotton on biodiversity resources in these landscapes, and what are the relationships between biodiversity and ecosystem function?

Publications

9. A. List the publications arising from the research project and/or a publication plan.

   (NB: Where possible, please provide a copy of any publication/s)

   House, A.P.N., Schellhorn, N.A., Brown, S.D. & Bianchi, F.J.J.A. 2007. Landscape configuration, vegetation condition and ecosystem services in cotton agro-ecosystems in southern Queensland, Australia. Pp. 86-87 in: R.G.H. Bunce, R.H.G. Jongman, L. Hojas & S. Weel (eds) '25 years of Landscape Ecology: Scientific Principles in Practice'. Proceedings of 7th International Association of Landscape Ecology World Congress, Wageningen, The Netherlands, 8-12 July 2007. [abstract attached]

   Walters, B. 2009. Ant colonisation of dryland annual crops: cotton and sorghum. Honours thesis, Griffith University. [attached]

   House, A.P.N., Brown, S.D. & Walters, B. (in prep.) Arthropod diversity in intensively farmed landscapes: vegetation cover, distribution and condition in eastern Australia. *Landscape Ecology*.

   Walters, B., House, A.P.N., Burwell, C.J. &Nakamura, A. (in prep.) Seasonal changes in ant assemblages in cotton and sorghum crops in southern Queensland. *Agriculture, Ecosystems and Environment*.

   B. Have you developed any online resources and what is the website address?

   No.

Acknowledgements

This work was carried out by Alan House (project leader, project design, analysis and reporting, fieldwork), Stuart Brown (GIS and fieldwork) and Belinda Walters (invertebrate taxonomy and fieldwork), all CSIRO Sustainable Ecosystems, Brisbane. We would like to thank the following landowners and managers for graciously allowing us to conduct this work on their properties: Russell Bach, Cecelia Jeitz, Stuart Higgins, John Alexander, Noel Griffiths, Glen & Shaun Fresser, Roy Siddans, Ross Skerman, Peter Schultz, Liz & John Wood, Ben Taylor, Hamish Johnson, John Norman. Thanks also to Renee Stephenson, Kate Charleston, Geoff McIntyre, Penny Hamilton, Trish Goudie for contacts and advice, and John Lawrence for assistance in the field. This work was funded by the Cotton Catchment Communities CRC, CSIRO Sustainable Ecosystems, Condamine Alliance and Queensland Murray-Darling Committee.

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

The maintenance of biodiversity in intensively farmed landscapes in Australia relies mainly on small patches and linear strips of native vegetation – what's been left behind to delineate paddock and property boundaries, alongside roads and stock routes, where soils were unsuitable for farming, or wherever landholders wanted to retain trees. The agricultural matrix itself provides some habitat opportunities but these are limited, especially in areas where irrigation is used.

This project set out to answer the simple question: what is more important for the conservation of insect and spider biodiversity in these landscapes – is it the amount of native vegetation, where that vegetation is, or the condition it is in?

As with all ecological studies, the question is simple but the answers are complex.

Taking three "typical" cotton landscapes that included either or both irrigated and dryland cropping systems, we sampled arthropods and analysed the species richness and functional diversity of the ants, and the morphospecies (identifiable as distinct species but not named) diversity of all other arthropod groups. We used 2 sampling techniques: pitfall trapping and suction sampling of arthropods from ground vegetation. We also recorded vegetation condition and local habitat variables, and calculated landscape metrics based on the proportions of major land use types within circular zones of 100, 500 and 1000 m radius of sampling sites.

On average there were no differences between landscapes in vegetation condition. However, condition was significantly higher in linear strips than in patches in the medium native vegetation landscape, with this trend being reversed at higher levels of native vegetation. This is almost certainly due to the impact of livestock grazing, which is more diffuse at higher levels of native vegetation, and more or less absent at lower levels.

Different components of the arthropod fauna appear to respond in different ways to what happens in the landscape, so there is no "one size fits all" answer to the question posed above. Ant assemblages were different in each landscape, but did not respond to the type of habitat they were found in, e.g. discrete patches or linear strips of vegetation. Similarly, other ground active arthropod groups showed no habitat specificity, and differences were found only between the very low (Jandowae) and low (Broadwater) native vegetation landscapes. Arthropods in the ground vegetation did respond to the amount of native vegetation in the landscape, although these relationships were not statistically significant. They also responded to habitat type, but only at the high native vegetation landscape, Callandoon, where irrigation infrastructure (dams, channels etc.) is thought to be responsible through removal of marginal habitats.

There was a clear pattern of change in the ants within crops during the growing season. Some species persist in the paddock during fallow seasons, and this might be assisted by stubble retention and no-till practices.

Strategic management of retained native vegetation in intensively farmed landscapes such as these, including narrow roadside strips, can provide essential habitat resources for a range of biota, including arthropods that deliver ecosystem services of benefit to both production and conservation.

For more details on this project, please contact: Dr Alan House, CSIRO Sustainable Ecosystems (ph: 07 32142365; email:alan.house@csiro.au).

Appendix A – attributes recorded for vegetation condition assessments

Structural
% total tree cover
% native tree cover
relative abundance of large trees (0-3)
relative abundance of dead standing trees (0-3)
relative abundance of sapling regeneration (0-3)
relative abundance of seedling regeneration (0-3)
% trees with large mistletoes
% total shrub cover
% native shrub cover
relative abundance of shrub regeneration (0-3)

Compositional
major tree canopy dominants (list)
major shrub layer dominants (list)
ground vegetation species composition (list)

Functional
relative disturbance rating (0-3)
evidence of soil erosion (0 or 1)
evidence of salinity (0 or 1)
relative abundance of fallen timber (0-3)
tree health (% in each of 5 classes: excellent, good, moderate, poor, dead – based on Wylie *et al.* 1992).

Appendix B – higher taxonomic groups recognised and sorted to morphospecies.

Araneae	spiders
Opiliones	harvestmen
Hymenoptera-others	wasps
Phasmotodea	stick insects
Orthoptera	grasshoppers, crickets
Pseudoscorpionidae	pseudoscorpions
Scorpionidae	scorpions
Coleoptera	beetles
Isoptera	termites
Blattodea	cockroaches
Hemiptera	true bugs
Homoptera	leaf hoppers, aphids
Dermaptera	earwigs
Mantodea	mantids
Archeognatha	bristletails
Thysanura	silverfish
Collembola	collembola
Diplura	diplurans
Protura	proturans
Thysanoptera	thrips
Psocoptera	booklice
Diplopoda	millipedes
Chilopoda	centipedes
Isopoda	woodlice
Gastropoda	snails, slugs
Diptera	flies
Lepidoptera	butterflies, moths
Trichoptera	caddis flies
Plecoptera	stoneflies
Embioptera	web spinners
Strepsiptera	stylops
Neuroptera	lacewings
Ephemeroptera	mayflies

Landscape configuration, vegetation condition and ecosystem services in cotton agro-ecosystems in southern Queensland, Australia

A.P.N. House[1], N.A. Schellhorn[2], S.D. Brown[1] & F.J.J.A. Bianchi[2]

[1] CSIRO Sustainable Ecosystems, 306 Carmody Road, St Lucia, Qld 4067, AUSTRALIA. email: alan.house@csiro.au
[2] CSIRO Entomology, 120 Meiers Road, Indooroopilly, Qld 4068, AUSTRALIA

Introduction

Cotton (both dryland and irrigated) is one of Australia's most intensive agricultural crops. One of the challenges for sustainable cotton enterprises is to optimise the production of goods and services from all parts of the landscape. Most cotton farms support a wide range of habitats suitable for native wildlife through the retention of patches of native vegetation (woodlands and grasslands) and other farming systems (cropping and grazing) that may benefit the environment and sustainability of cotton production. The maintenance of habitat heterogeneity (e.g. mix of cropping, grazing, native vegetation) in agricultural landscapes is the key to sustaining biodiversity (Benton *et al.* 2003), and there are links between levels of biodiversity and ecosystem function (Díaz and Cabido 2001). However the means to manage for biodiversity and ecosystem services on cotton properties and across catchments is poorly understood.

Project components

Vegetation condition and ecosystem services

The ecological condition of vegetation may be as important to landscape function as spatial arrangement (Debuse *et al.* 2006). Our project will assesses vegetation condition by looking at surrogates of function – evidence of stand replacement, levels of ground cover, structural complexity, diversity and abundance of key arthropod groups (ants, beetles, spiders) – and analyse these in respect of landscape context (i.e. patch size, isolation, shape, connectance). These spatial analyses will inform subsequent analyses of predator-prey/parasitoids-host complexes and vertebrate habitat use.

Spatial configuration and bio-control

Colonisation of cotton and grain crops by predator-prey/parasitoid-host complexes is influenced by the surrounding landscapes (Tscharntke and Brandl 2004). Crops and non-crop habitat (i.e. native vegetation and weeds) can be both sources and sinks for pests and natural enemies (Tscharntke *et al.* 2005; Rand *et al.* 2006). However, little is known of how the degree of synchrony between sources and sinks, and spatial characteristics of these habitats influences (i) the timing and numerical response of colonization by pests and natural enemies, (ii), species accumulation over time and (iii) trophic interactions. This project will address these issues using empirical and modelling approaches. Experiments will quantify insect colonisation in crops and non-crop habitats, identify habitats that function as sources and sinks of pests and natural enemies, and monitor the population dynamics of pests and natural enemies in crop and non-crop habitats. Modelling will focus on how the spatial arrangement and synchrony of sinks and sources of pests and natural enemies impacts insect dispersal, trophic interactions, and population dynamics.

Birds in cotton landscapes

Birds can play important roles in pest control in agricultural landscapes (Jones *et al.* 2005). We know that birds have been impacted by agricultural development through loss of habitat, habitat fragmentation and habitat simplification (Radford *et al.* 2005). Our interest is in the residual habitat value for birds of native and non-native vegetation elements in cotton-dominated landscapes, and the potential pest control services that birds provide.

Contrasting landscapes

We will test the influence of landscape configuration on ecological and pest control services in two contrasting landscapes. Cotton is a component of both and occupies similar proportions of the landscape, but there are major differences in the proportions of irrigated cropping, non-irrigated cropping and native vegetation, and in the sptial arrangement of native vegetation patches (Table 1).

Table 1. Proportions of land use types and key landscape metrics in 2 contrasting cotton landscapes in southern Queensland, Australia. Measures based on 5 km radii; landscape metrics calculated using FRAGSTATS (McGarigal *et al.* 2002).

	landscape 1	landscape 2
irrigated cropping	26.1	30.4
non-irrigated cropping	55.5	27.4
native vegetation	15.4	39.3
for native vegetation:		
largest patch index	7.8	39.1
no. patches	16	4
splitting index	148.2	6.6

By examining the relationships between spatial pattern, ecological condition of vegetation, and the provision of ecosystem services to both production and conservation, we will provide scientific knowledge to inform regional resource management plans and support the refinement of best management practice in cotton systems.

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