



ARGOS Research Report: Number 07/12

ISSN 1177-7796 (Print)  
ISSN 1177-8512 (Online)

## **Environmental indicators from alternative farm management systems: Signposts for different pathways to sustainable primary production in New Zealand?**

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July 2007



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## **EXECUTIVE SUMMARY**

The Environment Objective of the ARGOS research programme has been determining the impacts of different production systems on biodiversity and ecological processes on farms which until now have received little attention. Environmental monitoring of the ARGOS farms began with baseline ecological surveys to understand what was present on each farm and how land-use varied. These occurred in 2004 for kiwifruit, 2005 for sheep/beef and 2005/06 for dairy farms. An important output of these surveys has been the production of a GIS database containing spatial and biological data for each farm. This database will be enriched and updated in successive surveys to allow longitudinal tracking of ecological changes. The GIS work has enabled farm maps to be produced and distributed and these have been a well received tangible output for farmers who have used them to assist with farm management.

Following the completion of the baseline surveys of landforms and habitats, the environment team focused on supplementing this information with surveys of soil ecosystems, birds, bats, lizards, frogs, fish, insects, and plants across the different farming sectors. These surveys have been used to test monitoring methods to allow appropriate selection of a small group of 'focal species' to be used as indicators in repeated surveys for efficient long-term monitoring. Because the ARGOS project researches a wide diversity of habitats, landscapes and ecological processes operating on a wide range of spatial and temporal scales, the appropriate selection of the focal species was crucial.

Subsequently, the main investment by the environment team has been in the areas of terrestrial biodiversity (birds and invertebrates), stream health, landcover (especially weeds) and soil quality. The main findings of ARGOS' environmental monitoring are given below.

### **Main Findings**

#### **Kiwifruit**

The three main production systems have been compared. These are:

- Hayward variety grown under the IPM system ("Green")
- Certified Organic Hayward ("Organic")
- Hort16A variety grown under IPM ("Gold")

A number of soil quality indicators have been shown to differ significantly between production systems. While Organic has been the most different with higher values for many of the indicators, generally the levels have been acceptable for all three systems.

Some invertebrate populations have differed significantly between systems. Gold in particular has on average been found to contain consistently less cicadas' shells and spider webs.

Bird communities have generally not differed between systems, the exception being more species found on Organic orchards in the first year of monitoring (2005).

In one-off surveys of orchard habitats, there was some evidence of greater diversity in the sward and shelterbelts of Organic orchards.

No bats or lizards were found on orchards.

Water quality was not measured due to very few orchards having sources of freshwater.

## **Sheep/beef**

The three main production systems have been compared. These are:

- Conventional
- Integrated
- Organic

Soil quality differences were fewer compared to kiwifruit with Organic being the most different in terms of soil chemistry and microbial populations.

Stream health, measured once in 2005/06, was highly variable between farms, clusters (location) and systems. Consequently, very few significant differences were detected in measured parameters between systems.

No bats or lizards were found on farms.

Bird communities did not differ between systems.

No significant difference was detected in the abundance of weeds between systems. This is contrary to anecdotal evidence of a higher level of weed infestation on organic farms. Evidence collected in this study suggests that difference in weed abundance is impacted more by geographical location, as opposed to management style.

## **Dairy**

Two production systems have been compared. These are:

- Conventional
- Organic Conversions

In common with the sheep/beef survey results, soil quality differences were fewer compared to kiwifruit, although some differences were found.

In general, bird communities have not differed much between systems with the exception of more skylarks on conventional farms in the first survey.

Bats and lizards have not yet been surveyed.

In common with the sheep/beef survey results, water quality results were highly variable. Consequently, very few significant differences were detected in water quality between systems.

Our 2005/06 stream health results were consistent with other research demonstrating that water chemistry, community structure and ecosystem functioning are vastly different in agricultural waterways compared to those in unmodified habitats. We found evidence of different levels of pollution between farming sectors, with higher levels of nutrients (nitrate and nitrite, ammonium, dissolved reactive phosphorus, and total phosphorus) in waterways on dairy farms than on sheep/beef properties, while average concentrations of total organic carbon and organic and total sediment, and turbidity levels were higher on sheep/beef properties. We did not consistently find larger relative increases in nutrients or other pollutants between upstream and downstream sites on individual dairy farms than on sheep/beef farms.

## **High country**

The high country section of ARGOS is focused on the merino sector and involves the monitoring and analysis of eight eastern South Island high country properties from Marlborough to Otago. A land-cover, aquatic and soil monitoring protocol for high country properties was developed and implemented during the 2005/06 and 2006/07 summers.

Preliminary surveys of ARGOS high country properties identified eight exotic woody weeds that are considered as threats to farm production and/or biodiversity values. The most commonly recorded species was sweet briar, which is present on all properties. Wilding conifers were present on all but one of the properties, and gorse and broom were also widely present across the properties. These results are consistent with the findings of other studies on key woody weeds of South Island agricultural and pastoral properties.

On one property there has been a marked increase in sweet briar abundance since the 1990s, coincident with a decrease in grazing pressure from rabbits due to intensive rabbit control. Cattle may also hasten the spread of sweet briar on some properties, which creates conflicting management decisions. All high country farmers involved in the ARGOS study undertake some degree of weed control. Wilding conifers, broom and gorse are actively controlled on most properties, while sweet briar is controlled to a lesser degree.

Initial results of the High Country land-cover, aquatic and soil monitoring were presented in 2007 and it is proposed to repeat the monitoring across all eight properties in 2008/09.

Five adjunct MSc and PhD studies are currently underway on ARGOS high country properties including an assessment of the role of native shrubland and tussock for shelter during lambing, the effects of intensification on ecosystem resilience and soluble soil carbon, interaction between hawkweed invasion and spatial patterning of plants in tussock grassland, and the ecology and restoration of remnant woodland ecosystems.

## **Between Farming Systems**

As summarised above, a number of significant differences have been identified between farming systems, especially in soil indicators where most of the research investment has been focused. Other differences may exist but the sample sizes may not have been large enough to detect them and we are currently running analyses to find out if this is the case. Nevertheless, the quasi-experimental design of the ARGOS study has successfully provided enough power to detect average differences between farming systems for some important indicators.

## **Future priorities**

Now that differences have been observed between farming systems, the ARGOS environmental team must adjust its focus to investigate the cause of these differences. This is necessary to disentangle cause from simple correlation of indicators resulting from prior inherent qualities of the farmers or their land. In other words, are the observed differences due to management practices or the farms being inherently different to start with? Enlisting the help of the social and economic objective teams in ARGOS will be crucial in this quest, because they can help test causation by examining why farmers have chosen to manage their farms the way that they do, and how farmers' views about their farm environment have changed through being associated with particular management systems and practices.

The ARGOS environment team has identified the following priorities as being important for enhancing the sustainability of agriculture in NZ:

- Habitats on farms. Our broad recommendation is to increase the amount and connectivity of woody vegetation on New Zealand's pastoral landscape, and to do this in ways that capture multiple benefits for biodiversity, soil and water retention, maximising profit, securing animal welfare and easing the day to day burdens of farmers.
- Focal species to brand eco-verification and incentivise sustainability. While this would have potentially valuable marketing and on farm benefits, we do not wish to recommend a key focal species until (i) we can bring a more transdisciplinary lens to our choice, (ii) we are sure that it is a reliable indicator of ecological wellbeing, and (iii) that its numbers can be managed effectively.
- Biological processes in soils. This is promulgated as the key to successful primary production especially in the organic and 'biological farming' sectors. Future work will look to concentrate on measuring a wider range of soil biological indices to see what differences exist between management systems for each sector and whether these reflect the intensity of operation and impact on biological activity and diversity.
- Stream care. ARGOS research will aim to help farmers best maximize the health of their waterways and the resilience of their farming operations, particularly sheep/beef farmers where less information is available and the potential impacts of new accreditation schemes may be relatively greater.
- Increased links across sectors. There is an excellent opportunity to cross-reference the environmental monitoring across the different sectors in the ARGOS project.

In order to address these priorities with the resources available, ARGOS's environmental monitoring will be readjusted by:

- Sampling less frequently where indicators are stable.
- Focusing sampling on key variables.
- Restriction of attention to focal species as industry flagships (e.g. fantails), ecological indicators (e.g. cicadas, spiders, soil microbes, birds) and ecological keystones (e.g. earthworms).
- Digging deeper in areas of particular interest or importance for resilience, or where early results have demonstrated likely production system effects.
- Shifting emphasis to discovery of why ecological indicators differ. To date, we have only been able to concentrate on what differs.
- Testing causation of change from the organic and IM market accreditation schemes.
- Expanding inquiry into different spatial scales. Thus far most indicators have been assessed at whole farm scales. The next emphasis will be to question the variation in indicators in different parts of each farm, and in the wider landscapes within which each farm is situated.
- Grounding components of our research in more direct and tactical outcomes such as the weed research.
- Moving more from an 'external assessor' (passive observer) role to a more active 'involved assessor' role where we will give more direct environmental advice to farmers and study why that advice was or was not useful (a Participatory Action Research framework).

- Providing more structured help and education outreach tools for the agriculture/industry sectors' facilitators.
- Consideration of transdisciplinary needs and emphasis to better assist the overall project.

## Meta-hypotheses

Fundamentally, the priorities above are being guided by the following hypotheses:

ARGOS's farming systems null hypothesis :

*H<sub>0</sub>: environmental outcomes from Organic, Integrated Management and conventional farming are the same.*

Intensification as a driver of different environmental outcomes between farming systems:

*H<sub>1</sub>: Agriculture intensification is a background driver of increasing risk and opportunity for the social-ecological resilience of New Zealand agriculture.*

*H<sub>2</sub>: organic agriculture causes changes in environmental outcomes primarily by being less intensive.*

*H<sub>3</sub>: The more intensive the agricultural sector, the greater the difference there will be in sustainability outcomes between organic, IM and conventional systems.*

Clarifying the relative positions of conventional, IM and organic farmers -

*H<sub>4</sub>: IM farming is intermediate in approach and outcomes between organics and conventional farming.*





# 1 INTRODUCTION: THE NEED FOR THIS REPORT

Biodiversity and ecological processes on New Zealand production landscapes have received little study [Norton 2001]; most environmental research and conservation advocacy has focused on threatened species and Protected Natural Areas [Norton 1998, Norton & Miller 2000, Moller et al. 2001, Perley et al. 2001, Moller et al. 2005]. There is an opportunity in New Zealand to extend conservation management to the two-thirds of its land area outside reserves, especially the production landscapes. Lowland landscapes are highly fragmented, but they are fertile and warm places where indigenous biota could flourish in greater variety and abundance than in upland national parks, provided they are appropriately managed in an integrated way with agriculture [Moller et al. 2005, McLeod et al. in press].

Since the beginning of the ARGOS project in 2003, the environmental objective has been working on assessing the sustainability and socio-ecological resilience of farms and orchards across different farm management systems. The systems approach that has been adopted is necessary to understand and help manage farmscapes. Holistic in nature and application, a systems approach allows for transdisciplinarity, multiple scales, incorporates uncertainty, includes the farmer's local knowledge and sees people as embedded within nature. This approach is guided by 'resilience theory' which emphasizes the discovery of what makes socio-ecological systems strong enough to withstand perturbations by new threats [Berkes & Folke 1998; Gunderson 2000; Gunderson & Holling 2002]. Using this theory, we aim to create robust farming systems that can go with change or be taken in new directions by future generations of New Zealanders.

Answering specific research questions that focus on understanding smaller parts of the puzzle will help build the bigger picture of what's happening in the farming systems. Focusing on specific aspects of the farmscape will also assist in establishing a monitoring programme to track social, economic and environmental changes over the next 20-30 years as part of an 'independent assessor' role. Resilience indicators for the monitoring programme need to be tested and perfected before gradual escalation of research into understanding of how the indicators change or do not change. Identifying the reasons for the observed changes or lack of them is the key to advising participating farmers towards improved resilience of their farmscape as part of an 'involved assistor' role.

Change for improved resilience is potentially slow and costly for farming families and their servicing industries. On the other hand, failure to act soon enough to meet consumer and society demands for more resilient farming systems could damage families, rural societies and national income from agriculture. Our dilemma is that adequate study of complex adaptive social-ecological systems like agriculture could take decades to find reliable general recommendations that are practical and achievable. Nearly a century of empowered agricultural research has greatly increased production and economic rewards for New Zealand, but the type of ecosystems-level knowledge of the way New Zealand's production landscapes function and change is in its infancy. While we expect the Agriculture Research Group On Sustainability (ARGOS) to contribute successively more powerful recommendations for social-ecological resilience as longer term databases accumulate, there is an interim need to take stock of the overall project design and table preliminary inferences. This will invite peer review from farmers, industry facilitators, research investors and fellow scientists in the coming year. Our aims are to collate feedback, have our peer's check our methods and rationale, to enable a more efficient and robust analysis in two years time, and to help prioritise our efforts in the remaining part of the first six years of the ARGOS project. We expect that most of this prioritisation will involve optimum choice of where to explore links between environmental indicators and the economic, social and farm management

indicators assembled by other objectives in ARGOS. Accordingly this report, and the ensuing synthesis from similar reports of other ARGOS objective teams contributes to the Foundation's reporting objectives for contracted **Milestone 8** (Selection of environmental indicators) and **Milestone 13** (Preliminary evaluations of environmental dimensions of conventional, integrated and organic production systems).

**Milestone 8: Farm and industry level targets for desired long-term environmental changes have been established:** *ARGOS's overall assessment of industry and farm-level environmental indicators will be compared with international and New Zealand audit standards and best professional practice to suggest preliminary targets for improved environmental sustainability and resilience of kiwifruit, sheep/beef, High Country and Ngai Tahu farms.*

and

**Milestone 13: Synthesis:** *Preliminary evaluations will be completed in 2007 and 2009, of environmental dimensions of conventional, integrated and organic production systems to develop long term targets for improved farm management and ongoing research to a) improve resilience of agriculture and b) improve market access and security.*

Most of the information summarized in this report concerns testing the ARGOS 'Farming systems null hypothesis' which states that environmental outcomes from Organic, Integrated Management and conventional farming are the same. For each indicator species or system, we first outline the reasons for selection and then present the preliminary investigation of the environmental differences between alternative management systems. We present sector-based summaries of any differences, but structure our discussions around the indicators (rather than sector by sector), as we believe this approach is a more integrative, holistic and insightful way to investigate the environmental state and functioning of the study farms.

## **2 RESULTS**

### **Measuring baselines: landuse surveys and mapping**

#### **Baseline surveys**

The first step to creating a monitoring programme with robust resilience indicators is to conduct baseline ecological surveys on each of the ARGOS farms. Between June and August 2004, baseline surveys of 37 Kiwifruit orchards were undertaken, while between April and July 2005, similar baseline surveys of the 36 ARGOS sheep/beef farms were performed. Baseline surveys of 19 ARGOS dairy farms were undertaken during October and November 2005 with five others surveyed in February 2006.

The proximate aim of the baseline surveys was to gather sufficient spatial and ecological data such that a basic landuse-map of each farm could be created. The aim of the project is to enrich and update these maps with spatial and ecological data that will be collected during a series of surveys. This approach will allow longitudinal tracking of ecological changes at a range of spatial scales. All collected data were integrated into an ArcGIS geodatabase. This process was undertaken by ground-truthing orthophotos (orthorectified aerial photos), incorporating farmers' comments and existing maps and collecting GPS data where appropriate.

Surveys took 1-3 people between 1 and 3 days per farm, with the mean time spent on each farm being approximately 15 hours for sheep/beef and 11 hours for dairy farms. Kiwifruit orchards were much quicker to survey due to their smaller size i.e. a few cf a few hundred hectares. The focus was set on the "management units" (i.e. paddocks, blocks, utility areas) and therefore over 60% of the total survey time on each farm was used to map fencelines. In addition to paddock boundaries, the roads, tracks, and buildings on each farm were also mapped. In the time remaining, data were collected on the extent of woody vegetation within the farm boundaries. For 30 of the 36 sheep/beef farms and all of the dairy farms visited, quantitative data were recorded for all shelter belts and patches of woody vegetation about their height, porosity and species composition. Although notes were made on ecological observations, a thorough ecological survey was not possible within the time available.

The raw outputs of the baseline surveys were:

- Survey overview sheet
- A ground – truthed aerial photo with field notes
- GPS data (locations of fencelines)
- Completed quantitative data sheets (on woody vegetation and shelterbelts)

#### **Geographical Information Systems (GIS)**

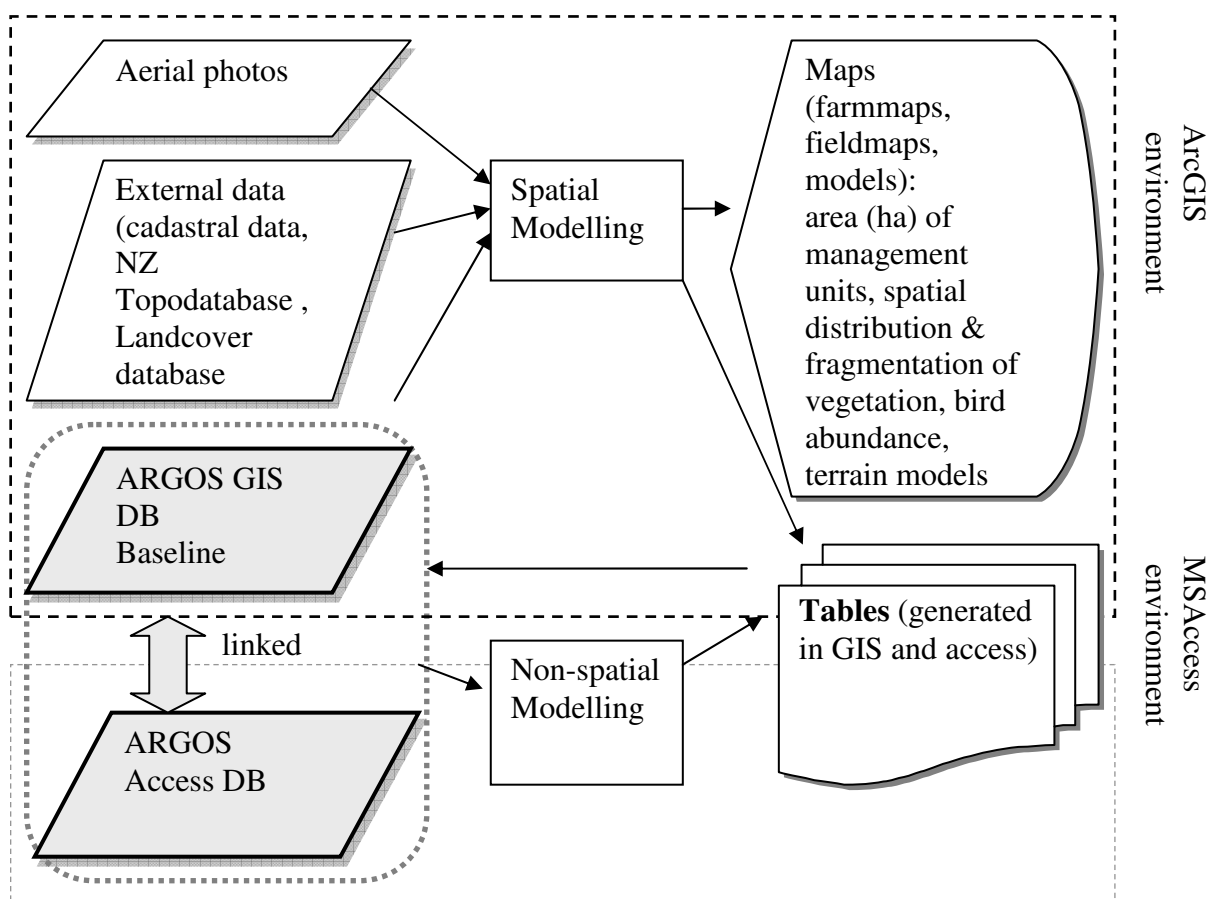
GIS software and environmental spatial datasets play increasingly bigger roles in the management of natural resources and prove to be valuable spatial decision support tools as a part of agricultural management [MacMillan et al. 2004]. GIS has a big potential to achieve an integrated view on required adjustments and innovation in agricultural systems where complex, uncertain and value-laden issues occur and is therefore a logical choice for multi-disciplinary work. Furthermore, spatial variation in landscapes is recognised as an integral

element of human-environment interaction [Blaschke 2006]. GIS within ARGOS can and should be used as a major tool to support the synthesis and transdisciplinary milestones. It is also a hypothesis generating tool for future work and can test the ARGOS farming systems null hypothesis.

All of the geographically referenced data are stored in an ArcGIS geodatabase, which is used for data management, visualisation of farm maps and spatial analyses. The geodatabase has been created to be compatible with the ARGOS Access database that contains all of the economic, social, management and detailed ecological survey data available for each farm (Figure 1) [Emanuelsson & Maegli 2006 and Maegli et al. 2007]. Orthorectified aerial photos, 'cadastral' data and NZ Topodata provided an information base. As listed above, a baseline field survey was carried out to enrich/complete the data on fencelines, vegetation, streams etc. to gather more detailed information on a within-farm scale (Table 1). These survey data have been added into the geodatabase and then crosschecked again by talking with and writing to the farmers and growers. The databases are updated and enriched constantly to track changes and provide a time series of detailed land use changes. The databases store spatial and non-spatial multidisciplinary information and hence provide a valuable information base for transdisciplinary research.

**Table 1:** Data in the ARGOS GIS database for the sheep/beef & dairy sectors. The kiwifruit database is slightly different.

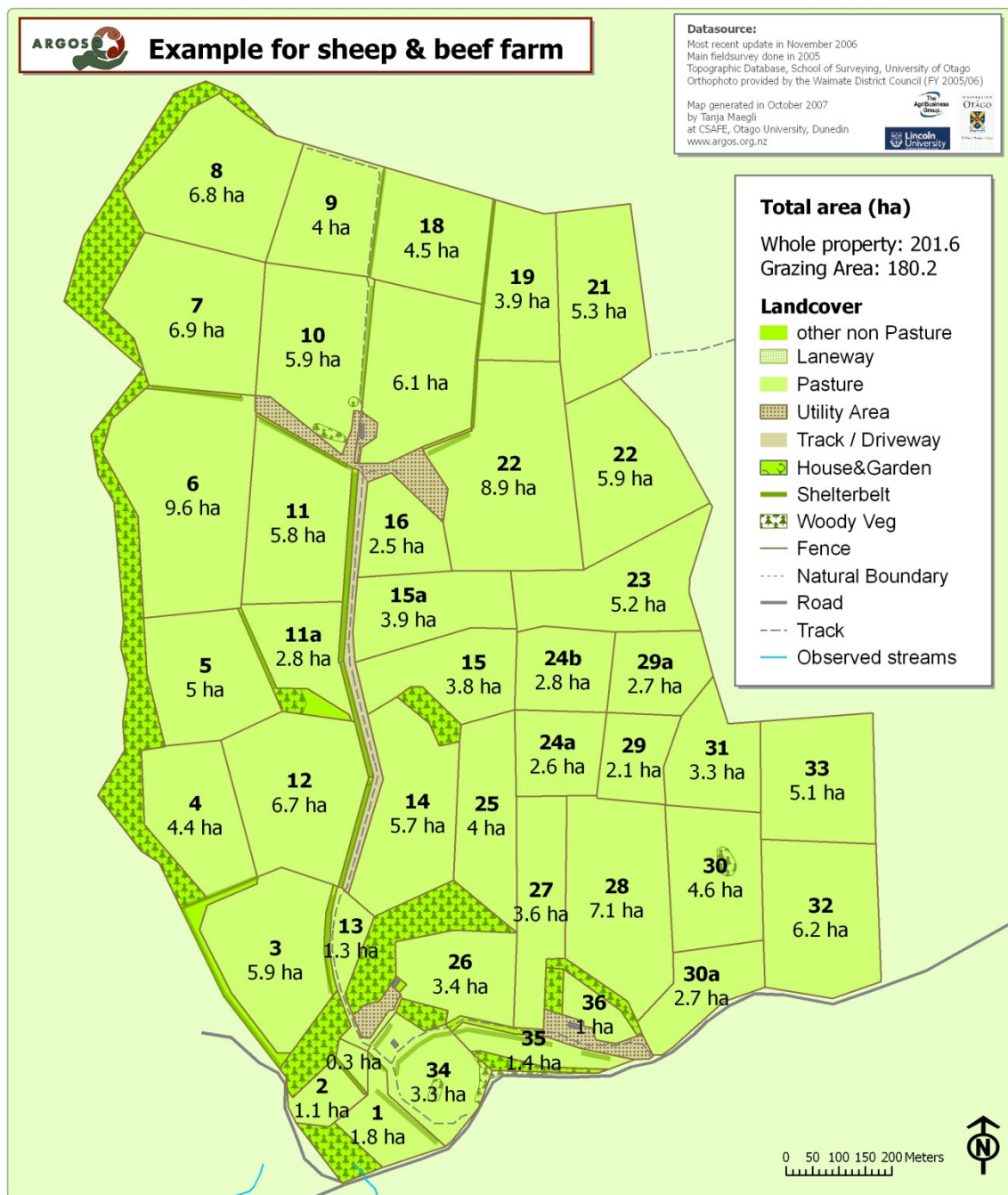
Feature class	Types / Classes	Additional attributes
Parcels		PropertyID, Farmers name, area (ha)
Landuse	Paddocks, utility area, house & garden area, laneways, fenced off woody vegetation and shelterbelts etc	PropertyID, paddock name, area (ha), status (current, removed, planned), Date In/Out
Landcover	Pasture, woody vegetation, wetland area, water	PropertyID, area (ha), vegetation class, vegetation-element ID, status (current, removed, planned), Date In/Out
Boundaries	Fences, natural boundaries along vegetation or streams...	PropertyID, status (current, removed, planned), Date In/Out
Waterways	Streams, drains	PropertyID, focal streams (Y/N)
Transport	Roads, tracks	Name
Monitoring sites	Soil monitoring sites, stream survey points etc	PropertyID, status (current, removed, planned)
Monitoring transects	Bird survey transects, pasture survey transects	PropertyID, status (current, removed, planned)
Buildings	House, shed, milking shed, woolshed	PropertyID, status (current, removed, planned)
Survey points	Data points from baseline surveys	PropertyID, Date, ID, accuracy



**Figure 1:** ARGOS framework for GIS modeling

Farm and orchard maps have been generated as a first output (Milestone 6), displaying the environment and spatial structure of each participating farm/orchard. Farmers have received two maps each, a large map with an aerial photo as a background (either A3 or A2 depending on the size of the farm) and one map (A3 / A4) with all the surveyed features (an example is given in Figure 2). These maps are important reporting tools and get updated on an annual basis. Example maps for each sector have been selected and added to the ARGOS website.

Additional maps have been produced to support field teams, to provide a basis for interviews with the farmers and for presentation [e.g. Lucock 2006, Lucock 2007, Mondot et al. 2007]. The field maps show where the monitoring areas and survey transect lines are and act as a guide during the fieldwork. The interview maps show the basic spatial structure of the farms and serve as a communication tool during farm management surveys. They have proven invaluable for an effective dialogue between farmers and researchers, but also leave a practical tool for the farmers to guide other consultants and contractors servicing their farm, and to calculate specific paddock-level inputs. We were surprised to learn that many farmers had little quantitative information about areas of different management units and tended to make investment decisions based mainly on an overall farm planar area estimate of the entire farm.



**Figure 2:** Example map of ARGOS farm

The GIS database provides information for several studies (such as area sizes, length of survey transects, location of the farms) and is a very useful visualization tool (for showing farmers research results, depicting future landuse scenarios etc.). One of the very important ecological habitat parameters for the farm is how much land is excluded from grazing or fruit production. Depending on vegetation cover, habitat diversity and structure, and ecological connectivity, such areas are ‘refuges’ from ‘ecological disturbance’ wrought by farming practice [Steven and Bengé 2007]. The GIS farm maps will allow the researchers to focus on future management of these potentially important promoters of biodiversity and ecological resilience at finer spatial scales, as well as at landscape connectivity scales, than previously possible from course landcover databases that were not designed to offer within farm level guidance. There is a big GIS component in an actual bird distribution study [Mondot et al.

2007] where the location of the bird sightings has been correlated with the landcover. For the “Herbaceous Plant Walk Survey”, the survey transects have been mapped using a GPS and the transect length and paddock area has been calculated within the GIS [Lucock 2006].

In the annual ARGOS S&B sector report 2005/06 [Lucock 2007] basic descriptors of the sheep/beef farms have been presented (average number and size of paddocks, area and patchiness of woody vegetation etc per farm). The area and type of trees and shrubs was determined from the GIS database for a study that investigates the extent of carbon sequestration in the woody biomass on farms compared to their greenhouse gas emission [Barber & Pellow, unpublished report].

The GIS database also provides crucial information for a case study approach within the main study, where the topography and landform elements of the farms is incorporated into the study. Topography is the key driver of many environmental processes [e.g. Blaschke & Dragut 2003 and Dorner et al. 2002] and therefore should be considered when analysing spatial patterns on farms. A trial Digital Terrain Model (DTM) of one ARGOS farm was created using a stereopair of aerial photos and the models. Three-dimensional depiction of landscapes will help build accuracy into upcoming metrics of farming efficiency and intensification (e.g. inputs and outputs per unit area of land surface) and this will facilitate comparisons between the rolling hill country study farms and the flat ones on the Canterbury plain. However, its main advantage is enabling quantification of the diversity of micro-habitats existing within folded topography within each farm’s boundary. We expect the main win:wins for sustainable production and maximum biodiversity care to emerge from judicious adjustment of farming input and offtake within different parts of farms, rather than treating and accounting for the farm enterprise and a whole farm boundary level. The first step in this efficient ‘downscaling’ inquiry is to identify which parts of the farms are too shaded, steep or poorly drained to allow cost-effective farm production. The three-dimensional GIS map is the only practical tool available to researchers to process the volume of data required to integrate seasonal changes required – but in the longer run we expect such tools to be accessible to the farmers themselves, or to act as scenario-building tools that allow the farmers to ‘see’ land use choices in ways that any number of tables and graphs could not.

The mapping and three dimensional modeling trial allowed estimation of time and expense to create a full set of DTMs for all the farms. It was sufficiently encouraging that three dimensional maps are now part way through construction for four of the ARGOS sheep-beef ‘clusters’ (12 farms in all). This will allow a sufficiently replicated trial of the value and practicability of the tool for guiding land use choice by June 2011, from when further investment can be considered if the ARGOS project is refunded from mid 2009.

## **Evaluation and refinement of environmental indicators**

Biodiversity conservation in New Zealand has so far mainly focused on the one-third of the land that lies within public reserves such as national parks. This reflects a preservation rather than conservation attitude that targets mainly indigenous or native species in natural habitats and has no place for extractive use of natural resources. Only 6% of public conservation land lies in the productive and warmer lowland areas (below 500m) where biodiversity naturally flourishes. Conservation management has recently begun to focus on the other two-thirds of New Zealand’s land outside public reserves, especially the lowland production landscapes. These lowland areas are highly valued for agricultural production but could also become areas where introduced and native biodiversity could flourish if managed appropriately. Many farmers seek a role as environmental stewards and are searching for ways to sustain a



profitable and productive off-take of food and fibre while still maintaining or enhancing biodiversity and ecological processes on their land. Both introduced and native species play important ecological and social roles in production landscapes. Economic benefits stem from species such as nitrogen fixing plants, insect pollinators, earthworms and other soil invertebrates that increase soil structure and fertility, and insects, spiders and birds that control pasture and crop pests. Many farmers also are very pleased to see tui, wood pigeons, and fantails in farmland, or whitebait and eels in farm streams. Overseas food market chains and their customers are increasingly wishing to be assured that the food and fibre they buy from New Zealand farms has been produced in an ecologically sustainable way that supports other plants and animals in the farm landscape as well as the ‘agricultural biodiversity’ that directly assists production [Moller et al. 2001, Perley et al. 2001].

### **Biodiversity surveys and selection of focal species**

Following completion of the baseline surveys of landforms and habitats, we focused our efforts on supplementing this information with biodiversity surveys of soil ecosystems, birds, bats, lizards, frogs, fish, insects, and plants in the different farming sectors. These surveys were used to test monitoring methods to allow appropriate selection of a small group of ‘focal species’ to be used as indicators in repeated surveys for efficient long-term monitoring and trend analysis. Consequently, it is important to ensure that actions and sampling protocols are standardized and that any sampling error is minimized to have the best chance of reliably detecting changes in farming environments. It is also essential that the sampling methods used are clearly and logically defined, scientifically defensible, and repeatable. Because the ARGOS project researches a wide diversity of habitats, landscapes and ecological processes operating on a wide range of spatial and temporal scales, the appropriate selection of the focal species is crucial. Focal species are selected based on their importance to farming and ecological processes in farmscapes. Selected species might provide ecosystem services like pollination, soil formation, predator biocontrol, seed dispersal, and they might be considered important ‘pest’ species or conversely they might be valued as ‘flagship’ or ‘taonga’ species. Focal species must be practical to measure, reasonably common and widespread and particularly sensitive to ecological differences [Moller et al. 2005].

In the following sections we outline the biological surveys conducted by the ARGOS Environment Objective, along with any preliminary tests of the farming system null hypothesis that there are no differences in environmental state or performance between farms following alternative farm management systems. A summary of the significant differences between farming systems within Kiwifruit orchards, sheep/beef farms and dairy farms is given in Tables 2, 3 and 4 respectively.

**Table 2:** Differences between kiwifruit management systems (IM ‘Hayward’ (i.e. ‘Green’), Organic ‘Hayward’ (i.e. ‘Organic’) and IM ‘Hort16A’ (i.e. ‘Gold’). Unless stated otherwise, any of the differences described here are significant.

Element	Sub-element	Indicator	Significantly different	Comment	Ref
Soil	Chemistry	Olsen P, Resin P and Sulphate-S	✓	Organic lower than Gold but not Green	[1]
		P retention and exchangeable K	X	No difference	[1]
		Total carbon and nitrogen	✓	Green lowest	[1]

		pH, exchangeable Ca, and potentially mineralisable N	✓	Organic highest	[1]
		Organic S	✓	Gold highest	[1]
		CEC and exchangeable Mg	✓	Organic higher than Green but not Gold	[1]
	Biology	Microbial N	✓	Highest for Organic	[1]
		Microbial C	✓ <sup>†</sup>	Organic higher than Green but not Gold per unit of soil; no difference per unit of soil C	[1]
		Nematodes – total <sup>†</sup>	X	No difference	[2]
		Nematodes – groups	✓	More omnivorous species for Organic	[2]
		Earthworm abundance	✓	Highest for Organic	[1]
	Structure	Bulk density	✓	Organic lower than Green but not Gold	[1]
		Aggregation and porosity (visual soil assessments)	✓	Highest for Organic	[1]

Terrestrial invertebrates	Pests	Cicada density & diversity	✓	More in Green and less in Gold with Organic intermediate. Sig. yet to be determined.	[3]
				More <i>Amphipsalta cingulata</i> and less <i>A. zelandica</i> found in Green. Green and Gold similar. Sig. yet to be determined.	[4]
	Beneficials	Insect abundance	✓	More insects in Organic	[5]
		Mite abundance	✓	Predator mites sig. lower in 'Green'  Tydeid mites (detrital feeders) lower for Organic (almost absent)  <i>Czenspinksia</i> mites (another detrital feeder) higher for Organic	[5]
		Spider web density	✓	No difference between Green and Organic but lower in Gold.	[5]
Terrestrial vertebrates	Bird communities	Total abundance	✓	More species on Organic than either Green or Gold	[6]
		Species richness	X	No difference	[6]

		Native species proportion	X	No difference	[6]
	Lizards	Lizard abundance	X	None found	[7]
	Bats	Bat abundance	X	No confirmed sightings	[7]
Habitats	Orchard sward	Sward height	✓	Highest for Organic	[8]
	Shelterbelts	Species diversity	✓	More incidental woody species in Organic shelterbelts	[9]
		Structure (height, porosity, length)	X	No difference	[9]

† Acceptance of the null hypothesis ('X' in the table) is not necessarily evidence of no difference – in many cases our sampling may not have had sufficient power to detect real differences between our farm systems. References: 1. Carey & Bengt 2007; 2. Richards et al. (2006); 3. Bengt 2007; 4. Bengt et al 2006; 5. Steven & Bengt 2007. 6. Rate et al. 2007. 7. Bengt 2007; 8. Bengt 2006; 9. Moller et al. 2007.

**Table 3:** Significant differences between sheep/beef management systems (conventional, integrated and organic).

Element	Sub-element	Indicator	Significantly different	Comment	Ref
		pH, exchangeable cations, total and calcium base saturation; potentially mineralisable N	✓	Sig. higher for Organic	1
	Biology	Microbial C & N	✓	Sig. higher for Organic	1

		Basal respiration	✓	Significantly higher for Organic	1
		Nematodes	X <sup>†</sup>	No difference between systems	1
		Soil invertebrates	X	No difference between systems	1
		Earthworm abundance	X	Not significantly different between systems.	1
	Structure	Porosity, aggregation and mottles	X	No differences between systems	1
		Bulk density	X	No differences between systems	1
Pasture weeds	Total herbaceous species	Prevalence	✓	Significantly greater on Organic	2
		Pasture composition	X		2
	Weeds of Mgt concern	Abundance	✓	Nodding thistle sig. more abundant on Organic	2
		Size	X		2
Terrestrial invertebrates	Pests	Porina	?	Data not yet analysed	
		Grass grub	?	Data not yet analysed	
Terrestrial vertebrates	Bird communities	Total abundance	X	No differences between systems	3
		Species richness	X	No differences between systems	3
		Native species proportion	X	No differences between systems	3
	Lizards	Lizard abundance	X	None found	4
	Bats	Bat abundance	X	No confirmed sightings	4
Aquatic ecosystems	Stream management	Fencing to exclude stock	X	No differences between systems	5
	Physical properties – average values	Width, depth, temperature, pH, velocity, conductivity	X	No differences between systems	5

		Turbidity	✓	Sig. higher on conventional	5
	Physical properties - % change across farm	Width, depth, temperature, pH, velocity, conductivity, sediment	X	No differences between systems	5
	Nutrients - averages	Ammonium, nitrate + nitrite, dissolved reactive phosphorous, total P, N	X	No differences between systems	5
		Total organic carbon (TOC)	✓	Sig. higher on Organic	5
	Nutrients - % change	Nitrate + nitrite, dissolved reactive phosphorous, total P, N	X	No differences between systems	5
		Ammonium	✓	Sig. greater on Conventional	5
	Periphyton	Overall community structure	X	No differences between systems	5
		Individual species differences	✓	Sig. more thin black algae on Conventional	5
	Invertebrates	Total individuals	✓	Sig. lower on IM	5
		Species richness, proportion of insects, abundance of mayflies, stoneflies and caddis flies	X	No differences between systems	5
	Streamside vegetation	Overall composition	X	No differences between systems	5
		Cover of trees, scrub, pasture	X	No differences between systems	5

<sup>†</sup> Acceptance of the null hypothesis ('X' in the table) is not necessarily evidence of no difference – in many cases our sampling may not have had sufficient power to detect real differences between our farm panels. References: 1. Carey et al 2007; 2. Blackwell et al 2007; 3. Blackwell et al 2005a; 4. Blackwell et al 2005b; 5. Blackwell et al 2006a.

**Table 4:** Significant differences between dairy management systems (Conventional and Organic converting).

Element	Sub-element	Indicator	Significantly different	Comment	Ref
Soil	Chemistry	Olsen P and Sulphate-S	✓	Sig. lower for Organic	1
		pH, exchangeable cations, total and calcium base saturation;	✓	Sig. higher for Organic (Soil-C & N also higher	1

		potentially mineralisable N, C/N ratio		but not significant)	
	Biology	Microbial C & N	✓	Microbial-C sig. higher for Organic	1
		Basal respiration	X <sup>†</sup>	Higher for Organic but ns	1
		Nematodes	X	No differences between systems	1
		Soil invertebrates	X	No differences between systems	1
		Earthworm abundance	✓	More found under (converting to) Organic	1
		Vegetation cover %	✓	Significantly higher for Organic	1
	Structure	Porosity, aggregation and mottles	X	No differences between systems	1
		Bulk density	X	No differences between systems	1
Soil invertebrates	Pests	Porina	?	Data not yet analysed	
		Grass grub	?	Data not yet analysed	
		Clover root weevil	?	Data not yet analysed	
Terrestrial vertebrates	Bird communities	Total abundance – all species	X	No differences between systems	2
		Species richness	X	No differences between systems	2
		Skylark abundance	✓	Sig. higher on Conventional	2
		Use of pasture by skylarks	✓	Sig, greater on conventional	2
	Lizards	Lizard abundance	NA	No surveys conducted	
	Bats	Bat abundance	NA	No surveys conducted	
Aquatic ecosystems	Stream management	Fencing to exclude stock	X	No differences between systems	3
	Physical properties – average values	Width, depth, temperature, pH, velocity, conductivity	X	No differences between systems	3

		Organic sediment	✓	Sig. higher on Organic	3
	Physical properties - % change across farm	Width, depth, temperature, pH, velocity, conductivity	X	No differences between systems	3
		Organic and total sediment	✓	Higher on Conventional (P = 0.07)	3
	Nutrients - averages	Ammonium, nitrate + nitrite, dissolved reactive phosphorous, total P, N, TOC	X	No differences between systems	3
	Nutrients - % change	Ammonium, nitrate + nitrite, dissolved reactive phosphorous, total P, N, TOC	X	No differences between systems	3
	Bacteria - averages	<i>E. coli</i> and fecal coliforms	X	No differences between systems	3
	Bacteria - % change	<i>E. coli</i> and fecal coliforms	X	No differences between systems	3
	Periphyton	Overall community structure	X	No differences between systems	3
		Individual species differences	X	No differences between systems	3
	Invertebrates	Total, individuals, species richness, proportion of insects, abundance of mayflies, stoneflies and caddis flies	X	No differences between systems	3
	Streamside vegetation	Overall composition	✓	Sig. more trees and tussock on Organic conversion	3
Landcover		Cover of trees, scrub, pasture	X	No differences between systems	3
	Within-farm metrics	Nearest patch distance, patch shape index, fractal dimension	X	No differences between systems	2
	Landscape scale	Area of woody vegetation, number of patches, % woody vegetation cover, mean patch size	X	No differences between systems	2

† Acceptance of the null hypothesis ('X' in the table) is not necessarily evidence of no difference – in many cases our sampling may not have had sufficient power to detect real differences between our farm systems. References: 1. Carey et al. 2007; 2. Mondot et al. 2007; 3. Blackwell et al. 2006a.



## **Soil quality: physico-chemical profiles**

Soil quality is the highest priority in the ARGOS monitoring programme. The quality of the soil is fundamental to sustaining production, livelihoods and diverse and abundant ecological communities on farms. Soils and associated microbes and animals are equally important across all farming sectors and farming systems, thus providing a common ground to compare across all the ARGOS farms. Two complete soil sampling rounds were completed in the 2004-7 period for the Sheep/Beef and Kiwifruit sectors, and one each for the Dairy and High Country sectors [Carey et al. 2007, Pearson et al. 2005a and Pearson et al. 2005b].

Soil quality was found to be high for the pastoral sectors overall for the indices tested. Statistically significant differences between S&B management systems were generally few and soil quality was similar between management systems although some evidence of lower P, S and K levels in organic systems may be of future concern if they indicate trends of decline. Dairy showed greater divergence between conventional and organic systems for a number of soil chemical, physical and biological properties despite our study farms being in an early stage of conversion.

Soil P levels were excessive for a considerable majority of both conventional and converting (to organic) dairy farms and there was evidence of greater Carbon sequestration in converting farms. Soil quality was generally lower for the Kiwifruit sector overall compared with pastoral systems because of the higher carbon inputs associated with grazing systems.

Both the number of differences in soil properties between kiwifruit systems and their significance were greater than for the pastoral systems. Generally organic kiwifruit soils had more soil organic matter (C, N & S) mineralisable-N, higher cation contents and exchange capacities, lower P levels (but not detrimentally) and lower bulk density indicating higher soil quality than IM orchards (Table 2). That said, the indicator levels for IM orchards were generally within the normal ranges for kiwifruit.

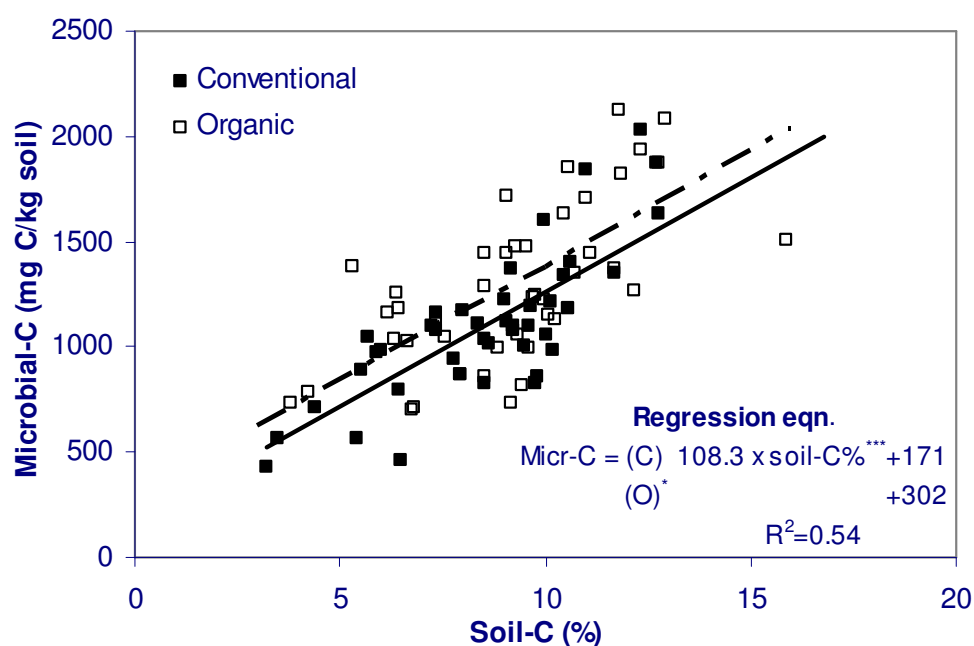
## **Soil quality: biological indicators**

### **Biological activity measures**

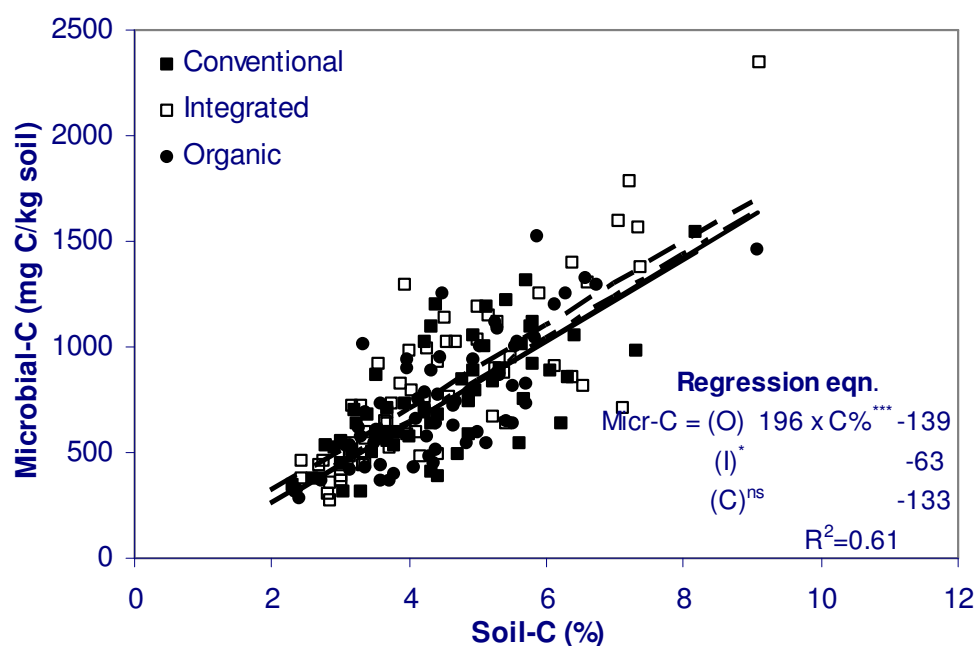
To date only a few basic measures of biological properties have been made, notably microbial biomass, basal respiration and macrofauna present such as earthworms.

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The majority of soil biological measures including microbial carbon and respiration did not differ significantly between kiwifruit systems. Nevertheless, there was evidence that the soil from Kiwifruit organic orchards was biologically more favourable as indicated by significantly more earthworms and higher microbial carbon and nitrogen. There were generally fewer differences in microbial biomass and basal respiration in Dairy and Sheep & Beef systems. However, significantly greater earthworm numbers and microbial-C (per unit soil-C) were found in organic (converting) dairy systems compared with conventional. Sheep & Beef differed, with significant increases in microbial-C only but this time for integrated farms over conventional and organic farms (Figure 3 & Figure 4). Increased earthworm numbers under Dairy converting suggests that although conventional farms are more intensive and tend to have greater excreta inputs, that in turn promote higher earthworm numbers, soil physical conditions were apparently harsher, reducing their survival rates. This supports the notion that biological systems can be affected positively by the subtraction and addition of nutrients at the intensive and extensive ends of the farming spectrum, respectively.



**Figure 3:** Microbial biomass (as measured by microbial carbon) scaled against total soil carbon in conventional and organic Dairy farms.

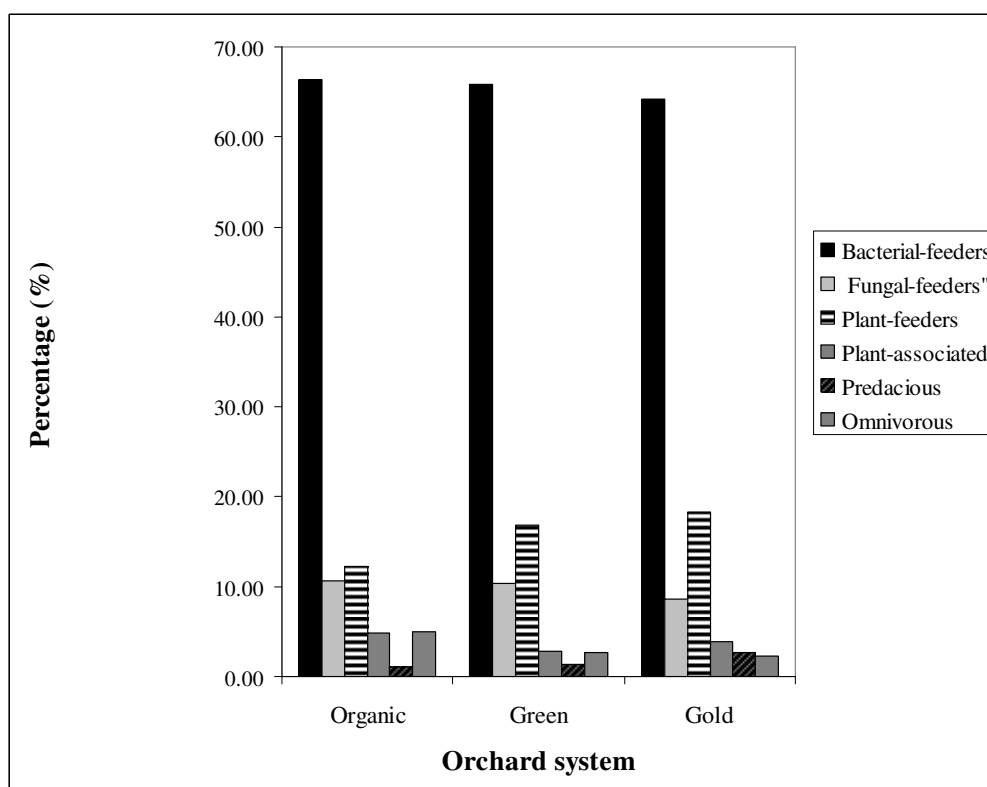


**Figure 4:** Microbial biomass (as measured by microbial carbon) scaled against total soil carbon in conventional, IM and organic sheep/beef farms.

## Nematodes

The potential for using soil nematode assemblages as indicators in the monitoring programme was explored in the kiwifruit sector [Richards et al. 2006, Richards 2007 and Richards et al. 2007]. At each orchard, soil cores were taken from within the vine line (under the leaders) at three randomly established sites in each of three blocks. The composition of nematode feeding groups was similar across the three orchard systems, but there were more omnivorous nematodes in organic soils (Figure 5).

Our pilot study confirmed nematode abundance and diversity as a potentially subtle indicator of community food web differences. However the importance of the nematodes as indicators of soil quality is still contested in the international literature. Until the importance or otherwise of nematodes as food web health indicators is proven, investment in long-term monitoring can not be justified. Other indicators of soil quality may be preferable, specifically the more easily identified and more widely known earthworms. Also we experienced extreme difficulties in identifying nematodes and it was a time intensive and therefore expensive procedure [Richards 2007]. We have therefore abandoned taking regular monitoring of nematodes any further.



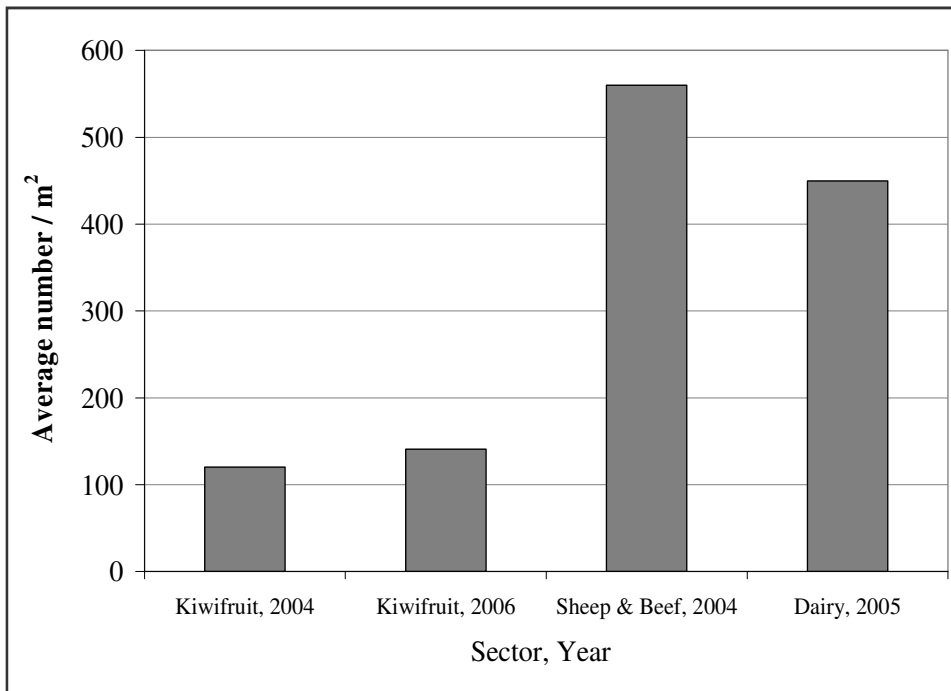
**Figure 5:** Feeding group composition of nematode assemblages in ARGOS kiwifruit orchards in the Bay of Plenty.

## Earthworms

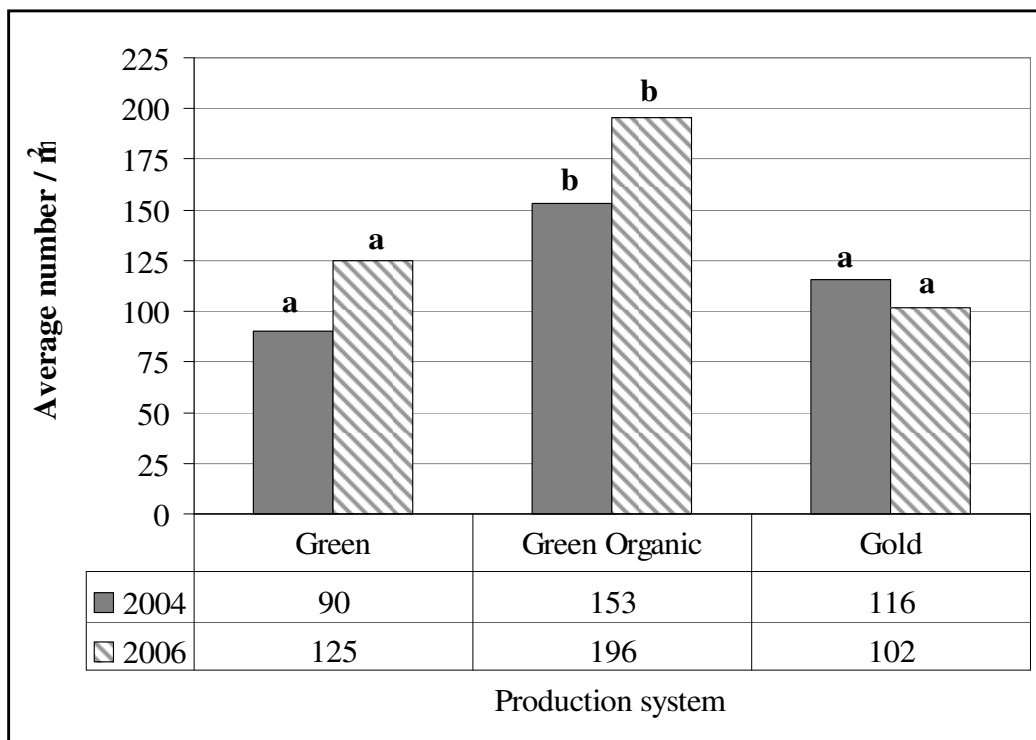
Earthworm abundance and diversity is potentially a much more practical soil quality indicator and one that is used extensively overseas [Edwards 2004]. They provide an indication of the biological, chemical and physical fertility of a soil and are important for incorporating and

breaking down organic matter, making the nutrients available to plants. In addition, burrowing earthworms mix soil and improve soil aeration and drainage.

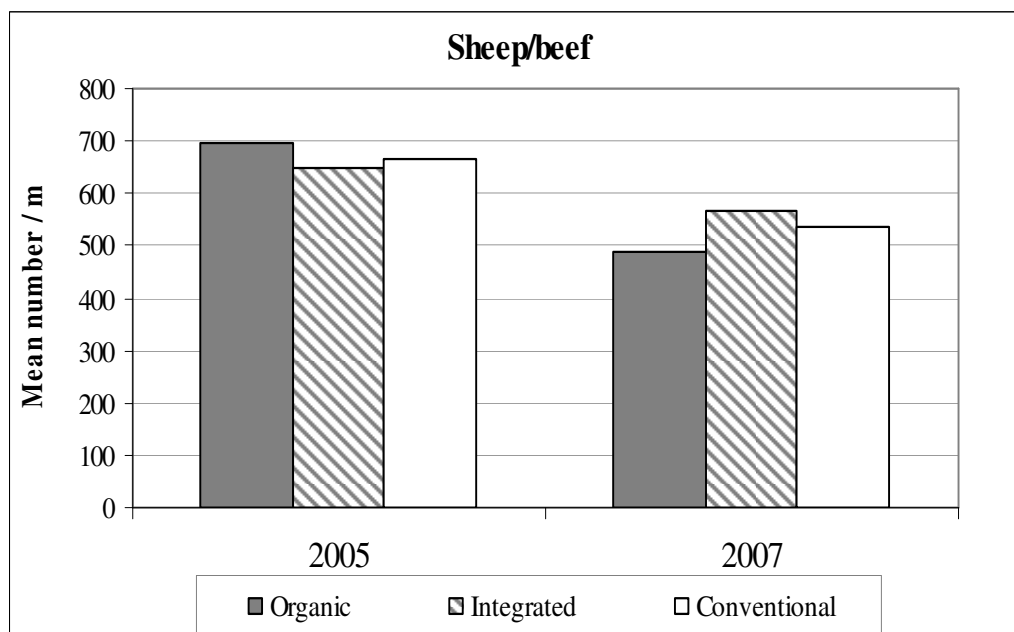
Earthworms were much more abundant in the pastoral sectors than in kiwifruit (Figure 6). Within kiwifruit orchards, organic soils had almost twice as many earthworms as in IM soils and there was no evidence of a difference in abundance between IM Hayward and IM Hort16A (Figure 7). Also, there was no evidence that earthworm abundance differed between organic, IM or conventional sheep/beef farms (Figure 8). Earthworms were considerably more abundant within the alleyways between the vinelines than within the vinelines themselves (Figure 7 & Figure 9).



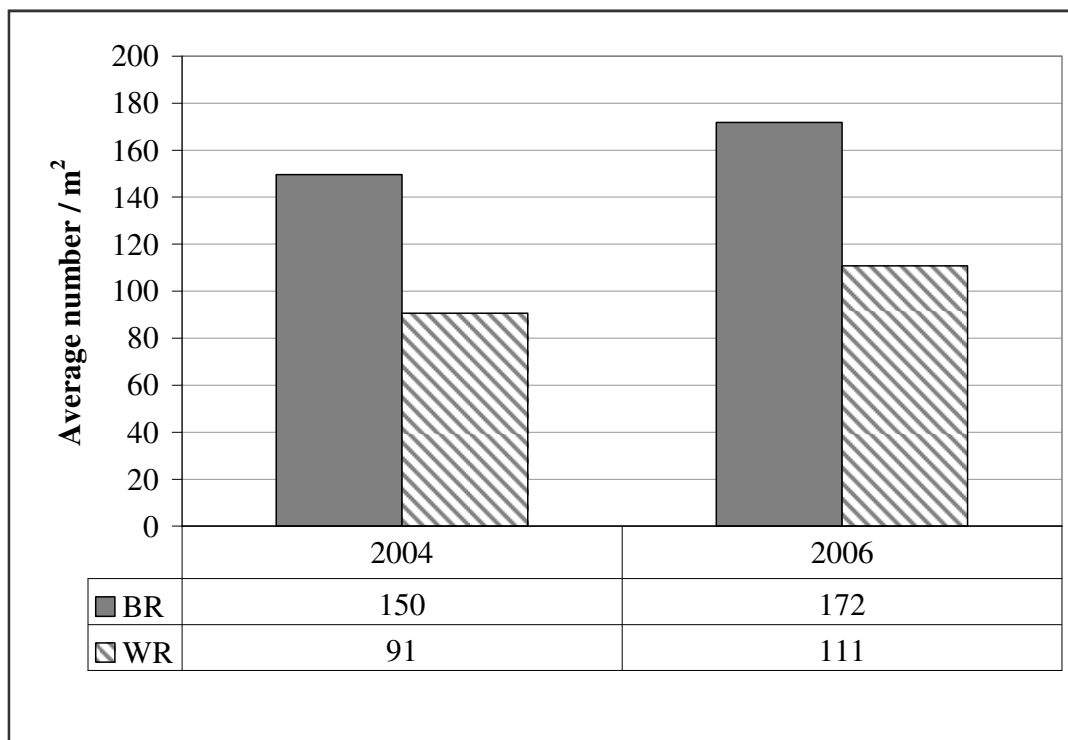
**Figure 6:** Average density of earthworms found in each of the farming sectors in the ARGOS programme.



**Figure 7:** Average density of earthworms found in ARGOS kiwifruit orchards. Within each year, bars with letters in common are not significantly different at the 5% level.



**Figure 8:** Mean number of earthworms found in ARGOS sheep and beef farms.



**Figure 9:** Average density of earthworms in ARGOS kiwifruit orchards in soils down the vinelines (WR = within-row i.e. under the leaders) and between the vinelines (BR = between rows, middle of bay). Within each year, the differences shown are significant at the 5% level.

#### Laminar bait probes for soil activity monitoring

Soil biological activity was monitored using laminar bait probes (Figure 10) on the kiwifruit orchards in the summer of 2004/05 [Hewson 2005, Hewson et al. 2006, Richards et al. 2006, Richards et al. 2007]. The rate at which artificial bait is removed from holes within plastic strips inserted into the soil gives a generalised measure of biological breakdown rates in soils, probably driven by soil invertebrate abundance and microbial levels.

No evidence was found that organic or IM orchards had different overall average rates of bait removal except at the lower depths of the probe (ca 80 mm) there was faster breakdown of the bait material on organic orchards. Further trials are now needed to see whether greater differences in soil activity appear deeper in the soil and if so, to trace why these differences occur. Removal of the bait proved to be extraordinarily rapid compared to rates discovered in Marlborough vineyards and Canterbury pastoral farms. This rapid removal of bait-lamina (and covering of the holes in the probes with soil) reduced the power in our data to detect differences. Future experiments would need to be repeated over much shorter time periods and at deeper levels in the soil before optimum long term soil health monitoring protocols can be designed. Redesign and repetition of the study is very likely to detect more differences in soil activity even in the upper layers of soil from different farming systems.

Despite uncertainties, the lamina bait test is inexpensive, rapid and repeatable and high statistical power can be achieved from the extensive replication possible. It shows excellent promise as a bio-assay of soil biological activity to monitor and compare the sustainability and ecological resilience of soil managed under different farming systems. Strong differences in soil activity were found under and near shelterbelts compared to under vines, so it is a robust relative index of some of the 'landscape ecology' features within

kiwifruit orchards. Its primary disadvantage is it can not inform researchers on what is removing the baits and alteration in bait uptake rates is caused by soil moisture and rainfall just before and after the trials.



**Figure 10:** Bait lamina probes used for assessing biological activity in the soil of kiwifruit orchards.

### **Terrestrial invertebrates**

Research and monitoring of invertebrates beyond soil systems must be included if ARGOS is to adequately understand functioning of agro-ecosystems and the influences of farming on them. Invertebrates play key roles in nutrient cycling and provide ecosystem services such as pollination and biological control of pests and have a rising profile as conservation targets (New Zealand has an enormous diversity of endemic species and Lepidoptera (especially moths) and Coleoptera (beetles) are likely inhabitants of ecological refuges in farming landscapes [Perley et al. 2001]). Others are considered pests by most farmers due to their impact on farm production.

The arthropod fauna will be mainly cryptic but nevertheless the most numerous and most diverse component of the animal life present on farms. This extreme diversity makes it impractical to monitor the entire arthropod fauna and focusing of effort is needed. We have singled out some pest invertebrates for targeted monitoring, and spiders as keystone predators in invertebrate communities. Aquatic insect abundance in the pastoral sectors is also measured by our stream sampling protocols.

### **Pest species**

The invertebrates and micro-organisms include the primary pests of crops and livestock. This means that these groups can be used both to help define the farm management system being followed (conventional versus integrated management, low input or organic), and also to provide ways to measure the impacts of the systems, both direct and indirect. In both kiwifruit and sheep/beef the main focus of the pest control measures are arthropods. The use of pesticides that are directly active against arthropods reinforces the potential of this broad group to provide useful focal species that could illustrate differences in the impact of the management systems being investigated. Their small size means that they are able to form localised populations which can be sustained within the limited confines of a kiwifruit

orchard, or an even smaller area. These localised populations are most likely to be modified by localised impacts such as different management practices.

The approach we followed was to initially focus on those parts of vines and pasture renovation that are most directly targeted by pest control measures, and look there for differences caused by the management systems. Those insects targeted by the management practices, the pests, and associated groups known to be adversely impacted, especially parasitoids and predators, will be the prime focus of later studies.

#### Invertebrate pests in kiwifruit orchards

Cicadas were chosen as a potential focal species and counted in our ARGOS orchards partly because they are classified as a minor pest (adults can cause fruit marking and the eggs are laid in the vines potentially weakening them) and partly as a potential indicator species (they are highly visible, well known and easy to sample). Each of the ARGOS orchards was sampled annually from 2004 to 2007. The average number of cicada skins found attached to vines was consistently greatest in integrated management (IM) 'Hayward', least in IM 'Hort16A' and intermediate in the organic 'Hayward' orchards [Moller et al. 2006a]. The reasons for these differences are not entirely clear, but may relate to differences in inputs or soil conditions in orchards. We also identified differences in the species composition between management systems [Benge et al. 2006]. ARGOS will continue to monitor cicadas on kiwifruit orchards in order to identify the relative impacts of alternative management systems on species composition and abundance.

The small insects and mites present on leaves from each ARGOS orchard in 11 of the 12 clusters (the Motueka cluster was not sampled) were surveyed in late summer 2005 [Steven & Benge 2007]. Most leaves examined had insects or mites present, with mites the more common. More leaves were infested by insects in Organic orchards than in either IM system (67% versus 39% and 47% for Green and Gold respectively,  $p < 0.02$ ), but mite infestations overall did not differ among management systems. Psocids, or booklice, were the most common insect found, while armoured scales were the commonest pest. Significantly more scales occurred in Organic orchards (15.2 per 50 leaves) than in either IM system (3.5 and 4.2 per 50 leaves for Green and Gold respectively,  $p = 0.001$ ). A range of mites were present, some abundantly. There were fewer predator mites on IM 'Hayward' leaves than in either other cohort ( $p < 0.02$ ). Tydeid mites, detrital feeders, were equally abundant on either type of IM orchard but were almost entirely absent from Organic orchards ( $p < 0.001$ ). The reverse applied for Czenspinksia mites, another detrital feeder, which were more abundant in Organic orchards than either IM system ( $p = 0.001$ ). Production practices clearly influenced the arthropod fauna present. The low incidence of tydeid mites in Organic orchards probably reflects the use of oil for scale control in this system [Steven & Benge 2007].

#### Spiders on kiwifruit orchards

Spiders are a conspicuous component of the orchard fauna, but the number of species involved and the ecology of each have not been studied. All spiders are predators, however the type of prey chosen varies considerably. Important pests, such as leafroller moths and passion-vine hoppers, are eaten by web-forming spiders. 'Wolf spiders' have also been observed feeding on passion-vine hoppers in kiwifruit. Spiders are also food for birds and valuable invertebrates in their own right, so they are worth investigating on orchards. In



addition, they are widespread, generally easily indexed (counts of webs can give an index of abundance), and likely to be affected by orchard management practices, and so have been chosen as an indicator group for the ARGOS project.

Spider webs were surveyed on the ARGOS orchards from 2004 to 2007 [Moller et al. 2006a]. Numbers of spider webs have on average been consistently higher for organic 'Hayward', lowest for IM 'Hort16A' and intermediate for IM 'Hayward'. It is not yet clear why these differences have manifested. ARGOS will continue to monitor spiders in kiwifruit orchards, and will expand our studies of spiders to other sectors as time and funding permit.

### Microflora in kiwifruit

The microflora, especially the fungi and bacteria present in the canopy, the phylloplane flora, is probably also diverse but is very poorly known and understood. It offers potential for original, ground-breaking research, but cannot be properly investigated with current funding and expertise. Initial discussions with potential collaborators have been undertaken, and studies may be initiated if time and funding permit.

### Flying predatory insects

A pilot run of measuring predation rates of 'prey facsimiles' (blowfly maggots arranged on small platforms) was trialled at 3 kiwifruit orchards in the summer of 2004/05 [Hewson & Moller 2005]. Prey removal rates were disrupted by patchy distributions of ants that swarmed some prey facsimile platforms but not others. A new system using moats to exclude ants will be trialled in the coming year if resources allow. The method has promise in measuring the abundance of flying predatory insects in organic compared to Integrated Management orchards. These insects are potentially important biological control agents that could indirectly promote ecological resilience.

### Pasture pests in the sheep/beef and dairy sectors

Grass grub and porina remain the most widespread and serious pests of pastoral farming, although pasture pests are now much less of a problem than in the 1970s and 1980s. In retrospect, this subsidence is seen as relating to banning of DDT in the late 1960s [Moller et al. 2005]. This led to a huge "flareback", probably because the natural enemies (especially bacterial diseases) of the pests had been wiped out by DDT, leading to irruptions until natural soil balances were restored. In general, pasture pest levels are thought to be sufficiently low at the moment to not make it cost-effective to apply chemicals in low intensity pastoral farming like sheep/beef. However a lingering problem that is still treated on sheep/beef farms is pestilence in the pasture establishment phase. It has been shown that >2 year pastures become less damaged, so provided a grower can get the pasture established or renovated, grass grub is usually no longer acute enough to trigger insecticide application.

Surveys for grass grub and porina on ARGOS sheep/beef farms, and porina, grass grub and clover root weevil on dairy farms have now all been carried out in conjunction with the soil surveying programme. The data have all been collated and summarized, but to date, have not been fully statistically analysed, nor formally reported (this is on the work programme for the coming year). This delay was decided when visual inspection of the results confirmed the above expectations of low pest numbers (abundance was below the levels normally

considered to impose sufficient economic injury to justify direct control [Barratt 1990]) and a survey showed that very few ARGOS farmers applied chemicals for pasture pest control in 2005/06. Only very low intensity monitoring of pasture pests associated with regular and standard soil monitoring will follow unless unexpected irruptions in pest numbers occur.

It is possible that, even though pasture pests are below economic damage thresholds, a hidden effect of grass grub and Argentine Stem Weevil (ASW) will be to shorten the life of the pastures i.e. “they run out sooner” because of the pests. If so, we might expect pasture quality and age of pasture to be lower or frequency of “pasture renovation” to be higher where there are more pests. We are therefore investigating the distribution of ages of paddocks on IM, organic and conventional farms to measure how long does pasture quality last in the different farming systems. We have begun by quizzing the farmers on the time since renovation of pasture on each of their paddocks (winter 2007 survey). Many other factors will influence this (such as stocking rate, landform, climate, and seed stock) which in turn might vary between organic and IM and conventional farms. Therefore we do not expect to necessarily find a clear signal for this indirect pasture pest damage.

It is possible that pasture pests are much more of an economic problem on North Island dairy farms [S. Goldson, pers. comm.]. His conclusion is partly based on a perception that dairying is closer to the production limit of the system. This widespread and often repeated perception will be quantified by ARGOS because it has several implications for social and economic as well as ecological resilience. An additional pest of increasing concern for New Zealand dairy farmers is the spread of the clover root weevil (CRW), which is currently known to be increasing in prevalence on dairy farms in both the North and South Islands, and at high infestation levels, can completely destroy the clover crop in infected pastures. We would like to escalate the CRW measures when sustainable financial resources are secured for more in-depth monitoring, and in the meantime have to be content with measuring their numbers in the standard soil monitoring methods (these occur in sub optimal times for CRW monitoring and statistical power will be limited).

## **Lizards and frogs**

There are at least 18 threatened or declining New Zealand lizards living on farmland, 13 of which are in the South Island. The more common lizards may be valuable bio-indicators for long-term monitoring and currently unthreatened species may become locally threatened if farming is intensified [Benge & Moller 2005]. Frogs have also been declining in New Zealand and throughout the world and are considered potentially sensitive as environmental indicator species. Native frogs are believed not to occur on farmland in New Zealand, although three introduced Australian *Litoria* species are widespread.

Lizards can be found using a variety of techniques, including direct searching techniques, by pitfall trapping, and the placement of ‘Artificial Cover Objects’ (ACOs) for indexing lizard abundance. We decided that ACOs were the only potentially practical standardised method. As they had never been applied in production landscapes, we considered it prudent to test their efficacy in a limited trial ground-based ACOs targeting skinks over 3 clusters of kiwifruit orchards only in the 2004/05 summer. Despite deployment for 3 months, not a single occupant was detected [Benge & Moller 2005]. In the 2006/07 summer we tried ACOs again, this time targeting gecko species by deploying watertight ‘nest boxes’ at different heights on trees (especially shelter belts but also some of the vines). These devices have recently met with great success in native forest to detect a whole cryptic population of geckos that live almost entirely high in the canopy [C. O’Donnell, pers. comm.]. Again despite deployment of ACOs for 3 months, no geckos were found [Benge & Moller 2007]. The rarity of lizards on

orchards is further supported by a number of orchardists commenting that they had never seen lizards in their orchards. As lizards do not appear to be present at any detectable levels on kiwifruit orchards they are not a practical indicator of management impacts for this sector and further work on them has been abandoned.

Standardised international sampling protocols exist for frogs that may apply to farm ponds and streams encountered on ARGOS farms. Introduced frog distribution in New Zealand is strongly influenced by human dispersal (frogs are commonly kept as pets and then released), so absence cannot be used to infer missing habitat requirements. However, monitoring trends in abundance where they do already occur in the wild could indicate environmental health. Initial surveys in 2004/05 of frogs on ARGOS kiwifruit and sheep/beef farms recorded very few ponds or frogs on any of the properties [Blackwell et al. 2005b]. We conclude that their distribution and numbers were too sparse to use frogs as long-term environmental indicators in the ARGOS project.

A further check for rare lizards and frogs is advisable, but forthcoming long-term biodiversity monitoring on ARGOS farms will concentrate on indicators of environmental impact and restoration of more common species and agricultural biodiversity without diversion of resources to a few threatened species.

### **Bats**

Bats are being used in the United Kingdom as bioindicators of agricultural impacts, with significantly more bat activity and higher bat species richness occurring on organic compared to conventional farms in southern England and Wales [Wickramasinghe et al. 2003]. The latter probably relates to higher overall invertebrate abundance on the organic farms, and therefore bats have the potential to be important indicators in the ARGOS project.

Bats have a special importance in New Zealand conservation because they are our only native terrestrial mammals. Both the long-tailed and short-tailed bat are considered threatened and now occupy a much smaller area than earlier. Surveys of bat distribution in New Zealand farmland landscapes are incomplete so we are unsure how many ARGOS farms may be used by bats. Long-tailed and short-tailed bats are known to persist in farmed landscapes or forage out over farmland even if the roost and breed mainly in adjacent unmodified forest. The bats are cryptic unless specialised 'bat detectors' are used to convert their ultrasonic echo-location calls to a signal audible to humans, and most surveys using bat detectors have centered on large reserves or National Parks.

Surveys were conducted for long-tailed and short-tailed bats in 2004/05 on all sheep/beef and kiwifruit orchards in the project. These two sectors were chosen as they were considered most likely to support bat populations (several sheep/beef clusters are in regions with large extents of remnant native forest, and 10 of the 12 kiwifruit clusters are near the Kaimai Ranges which are known to support bat populations). Surveys were conducted on dusk using two ultrasonic bat detectors, set to the frequencies used by long- and short-tailed bats. No bats were found on any of the sheep/beef farms, and one unconfirmed call was heard on one kiwifruit orchards [Blackwell et al. 2005b]. Consequently, bats have not been chosen as environmental indicators.

### **Birds**

#### **Overview: the value of birds as focal species**

Birds are potential focal species for the monitoring programme because (a) they are good indicators of wider ecosystem health and functioning; (b) they are generally well recognized

and familiar to farmers, politicians and the public; and (c) some species have potential as indicators of good farming system practices for increased farm produce market access.

#### First aim: choosing optimum methods

We first trialled bird surveys were conducted in the kiwifruit and sheep/beef sectors in the summer of 2004/05 [Blackwell et al. 2005b] We used two techniques to estimate bird abundance on the study farms: (a) 'Five-minute bird counts', a relative index where all birds seen or heard in a five minute period are recorded; and (b) distance sampling (a technique that takes differences in detectability of individual birds into account in order to arrive at more accurate 'absolute' density estimates ie. birds per hectare). The former method has been commonly applied in New Zealand forest habitats, but never in farmland, so we included some five-minute counts to benchmark our study results. The latter technique has rarely been applied anywhere in New Zealand and potentially gets around several of the conspicuousness variation problems that might have confound our comparisons of bird abundance on organic, IM and conventional farms and between farming sectors. Our first aim was therefore to evaluate the cost-effectiveness and reliability of different methods to choose the most reliable and cost-effective method of monitoring birds on farmland for the next 20 years.

We found tentative evidence that the conspicuousness of birds varied (i) between orchards and farms, and (ii) between organic, conventional and integrated sheep/beef farms. Observer inexperience in identifying different bird species, particularly when the birds were far away or did not sing their full distinctive song created difficulties. Nevertheless this pilot run still provided sufficient baseline measurements from which changes in bird abundance can be assessed and showed without doubt that further ARGOS bird surveys must use the more sophisticated but expensive distance sampling methods for reliable long term monitoring of bird abundance.

In the meantime the bird count indices of relative abundance and diversity described in this study must be interpreted cautiously because they only give a broad-brush picture of variation in bird communities. Bird monitoring proved workable, cost effective and obviously of interest to participating farmers. Our results have also piqued interest amongst European co-funders (a UK supermarket chain) of the ARGOS project and there is clear evidence of rising consumer awareness of farming impacts on birds and consequent need to demonstrate bird-friendly production of New Zealand produce. Bird monitoring and population management has become a prime part of ARGOS's research and biodiversity monitoring.

#### Second aim: benchmarking current farmland bird abundance against other habitats and countries

The second aim of the bird survey was to compare the number and type of birds we counted on ARGOS kiwifruit and sheep/beef farms with the number counted by other researchers in native forest, scrub and pine forests elsewhere on mainland New Zealand [Blackwell et al. 2005a]. We wanted to benchmark in this way as part of active advocacy of improved management and research of birds living within production landscapes, and the research team has made several conference presentations and published two formal peer reviewed papers as part of this effort [Moller et al., in press and MacLeod et al in press]. Our analysis showed that ARGOS sheep/beef and kiwifruit orchards had remarkably high bird counts if all species are combined. Our counts on orchards and farms were significantly higher and there were more species present than in native bush, pine plantations and scrub on public land. The

majority of the farm and orchard species were introduced finches and song birds (passerines). A number of native species were seen or heard regularly on the farms and orchards, but in most cases at relatively low abundance. They included pied oystercatcher, southern black-backed gull, harrier hawk on sheep/beef farms, and pūkeko and kingfisher on kiwifruit orchards. Sheep/beef farms mainly supported introduced and native open-habitat species such as skylark, spur-wing plover, redpoll, starling, pied oystercatcher and southern black-backed gull. Kiwifruit orchards supported native and introduced woodland birds, such as blackbird, song thrush, myna, kingfisher and pūkeko. The type of bird community we saw on farms and orchards was most similar to that seen in exotic pine plantations and scrub.

Overall then, our study has showed that (i) the majority of farms do not at present sustain a high diversity of native bird species, but (ii) they generally support a wide range of introduced species and (iii) the abundance of birds in production landscapes is relatively high compared to in native habitats on public reserves. Our results demonstrate the magnitude of the challenge to restore native bird species in New Zealand's production landscapes but also that trace populations are present in most remaining fragments from which restoration could be rapid. The results also underscore the natural productivity of the systems and the potential for vibrant and resilient bird communities to be established. The final stage of these benchmarking comparisons is a formal comparison of the absolute abundance of the European birds in New Zealand compared to in Europe itself – our ballpark preliminary analyses suggest that we have many more of the birds currently considered at risk in Europe where most of our consumers choose our products. This analysis is mid preparation and will be submitted for publication by the end of the first six years of the ARGOS project's FRST contract.

#### Third aim: comparing birds between farming systems, locations and landscapes

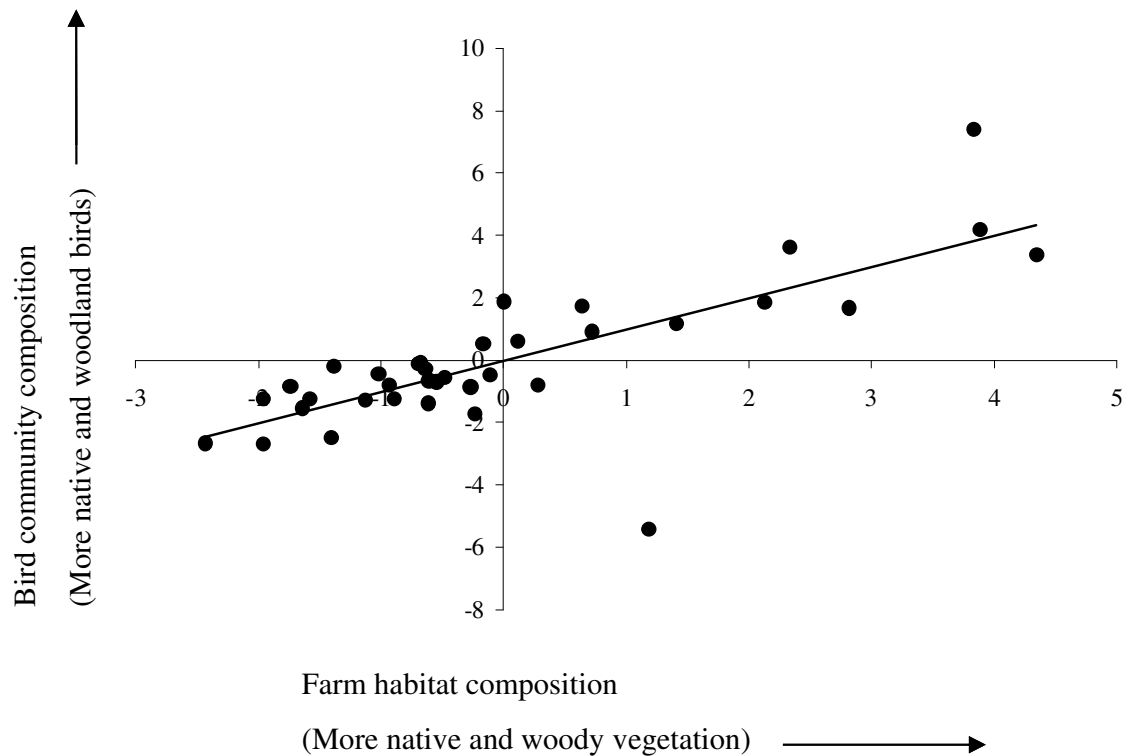
The third aim of our bird studies was to compare bird abundance and diversity between the three different farming systems within each of the agricultural sectors. On average we saw and heard more individual birds and more species in five-minute counts on organic 'Hayward' kiwifruit than on both types of IM orchards. However, there was no evidence that the number of individual birds counted, or the proportion of them that were native, differed between kiwifruit systems. In contrast to kiwifruit, there was no evidence of differences in bird counts or species richness on organic, IM or conventional sheep/beef farms. However the seen/heard ratio of birds was significantly lower in organic than IM sheep/beef farms, so variation in the conspicuousness of birds may have obscured real differences between systems – model selection using DISTANCE approaches are currently underway to cross-check this potential disruption.

#### Fourth aim: determining drivers of variation in bird abundance and diversity

The bird communities differed markedly amongst different clusters (locations). This emphasizes the importance of ARGOS's overall matched (clustered) study design and the increased statistical power that emerges from it. The broad spread of the clusters allows the ARGOS team to infer outcomes for a large part of New Zealand and to include regional variation, but the close proximity of the farms within the clusters filters out local and ecological landscape features that would otherwise have obscured the effects of farming system on environmental variables.

Farms and landscapes with more habitat diversity and more native vegetation have more diverse bird communities and have more native species in particular. For example, ARGOS farms near Owaka (the Catlins region, eastern Southland) and Banks Peninsula had more native species irrespective of their farming system (see Figure 11). This indicates the need for better quantification of habitat diversity, extent and structural complexity on ARGOS farms and their surrounding landscape. This theme is of particular interest to the environment team, and is a specific area of focus for several current and planned research projects.

Figure 11 also illustrates some of the sampling challenges inherent in bird community monitoring. The outlier represents a farm where two large flocks of sparrows (ca 120 and 200 birds in each flock respectively) were encountered. Our results are so far based on only 1 day of bird sampling in each of two years, so chance sampling variation can obscure pattern. Environmental stochasticity (eg. year to year variations in populations) can further complicate the picture and make long term trend detection problematic. The real power and value of the bird data set will emerge after 10 – 15 years, so the type of broad pattern building possible so far represents a small beginning. In the meantime we have concentrated on applying the techniques in a standard and precisely described manner so as to lock in methodological certainty and consistency, and to apply stratified random methods that maximise representativeness of the sampling [Blackwell et al. 2005b]. Since the initial surveys in 2004/05, we have repeated the bird community survey in the kiwifruit sector. We will repeat the full bird survey on the sheep/beef and dairy farms in summer 2007/08, as well as conducting the survey on the He Whenua Whakatipu case studies. Unfortunately, the scale of the high country properties and project budget constraints will preclude conducting the bird surveys in the high country sector.



**Figure 11:** Comparison of habitat diversity and bird community composition on 36 AGROS South Island sheep/beef farms.

*The horizontal axis shows the First Principal Component score from a PCA of the habitat present on the farms (correlation matrix, standardized variance) i.e. each dot represents a separate ARGOS sheep/beef farm. Key variables lining up positively with this horizontal axis are the area of native vegetation, native scrub, number of isolated trees and extent of riparian vegetation; while variables negatively associated with the horizontal axis include extent of open paddocks (in pasture or crop), shelterbelts and exotic hedges. The vertical axis gives the First Principal Component scores from a PCA of the bird communities present on the same farms. Farms negatively associated with the vertical axis are dominated by introduced species and open country birds (eg skylarks, dunnock, mallard ducks, goldfinch and house sparrow paradise ducks); while species positively associated with the vertical axis include native and introduced woodland birds (e.g. bellbird, blackbird, song thrush, silvereye, tomtit and grey warbler).*

### Magpie effects on bird biodiversity and monitoring reliability

Several sheep/beef farmers reported sporadic attempts to control magpies on their farms, mainly to reduce harassment of native bird species. Analysis of our bird data was unable to detect a correlation between magpie distribution and relative abundance and the counts of other species, but habitat use (especially predominance of use of open pasture) was different where there was relatively high magpie abundance. In particular, skylark, song thrush and starling appeared to avoid open paddocks on high magpie density farms (a habitat preferred by magpies) and were found more frequently in ploughed and planted paddocks. In addition, there were fewer records of bellbirds in open paddocks and more in shelterbelts and exotic vegetation where magpies were more abundant. This may reflect attempts by bellbirds to escape interference from magpies as they crossed open paddocks to reach isolated bush fragments. This raises the prospect that magpies indirectly affect bird counts by altering the conspicuousness of the other species, and calls into question the interpretation of an earlier experimental evaluation of magpie impacts in the Waikato region.

Our study was not designed specifically to evaluate magpie impacts on other bird abundance, or the advisability of controlling them. But tentative evidence of shifts in conspicuousness points to a need to consider abundance as a covariate in any long-term trend investigations of bird numbers, if only for factoring out a potential nuisance variable that could mask real changes in bird communities.

### Bird relative abundance and habitat use on ARGOS dairy farms

We surveyed birds on the recently added dairy sector ARGOS farms in summer (2006/07). Pasture composition, biomass and quality are likely to be the first vegetation features to change on farms undergoing organic conversion. Changes in the degree and nature of woody vegetation should be slower to occur, as should changes in bird densities in these habitats. The ARGOS dairy farms provide an excellent opportunity to look at the effects of changing management systems on bird communities. The organic conversion farms are currently two years into the three-year conversion process, so our hypothesis is that there are no differences in the landscape composition and degree of wood vegetation present on organic conversion or conventional dairy farms. However, we also predict that changes in pasture composition or quality may already be occurring, so we expect to see differences in the proportional use of pasture habitats by key bird species and a corresponding increase in their abundance in pasture.

We used data from the ARGOS GIS database and from the 2006/07 summer bird survey on the ARGOS dairy farms to first compare the landscape composition of organic conversion and conventional farms, before comparing the bird abundance and diversity on the farm [Mondot et al. 2007]. We then focused specifically on the use of open pasture by selected key species that may show rapid behavioural response to changes in pasture composition and quality.

As for sheep/beef farms, the landscape composition measures were highly variable between the geographic clusters of dairy farms. Once this variation was controlled for there were no detectable differences between organic conversion and conventional farms for any of the habitat measures. Skylarks were the only species to show any differences in habitat use between the two management systems, and were recorded significantly more often in open habitats on conventional than on organic conversion farms (predicted proportion of sightings in open habitats  $\pm$  standard error: conventional =  $0.94 \pm 0.01$ , organic conversion =  $0.84 \pm$



0.03,  $F_{1,118} = 15.83$ ,  $P < 0.001$ ). There were non-significant trends for increased use of pasture on organic conversion farms by blackbirds (predicted proportion of sightings in open habitats  $\pm$  standard error: conventional =  $0.23 \pm 0.06$ , organic conversion =  $0.39 \pm 0.05$ ,  $F_{1,59} = 3.26$ ,  $P = 0.07$ ) and song thrush (conventional =  $0.50 \pm 0.08$ , organic conversion =  $0.71 \pm 0.07$ ,  $F_{1,23} = 2.92$ ,  $P = 0.09$ ). The reasons for these differences are unclear, but may be related to differing plant diversity and associated food resources in pasture for different species offered by conventional and organic conversion dairy farms. Habitat use and abundance of birds in woody vegetation were very similar on organic conversion and conventional farms, perhaps mainly because of similar habitat extent and composition on the study farms. There were significantly more skylarks recorded on conventionally managed farms than on organic conversion farms (predicted mean  $\pm$  standard error: conventional =  $2.29 \pm 0.67$ , organic conversion =  $1.19 \pm 0.22$ ,  $F_{1,173} = 44.09$ ,  $P < 0.001$ ), although the reason for this is not currently known.

Overall then, there were few differences in bird abundance or diversity between the two management systems within the dairy sector. The fact that almost no significant differences were found at this stage highlights the strength of the BACI (Before-After-Control-Impact) approach and provides a robust basis for the ARGOS project's ongoing investigation of management related temporal changes in the social, environmental and economic dimensions of New Zealand dairy farms. The BACI design achieved in the dairy farms allows a much more direct and powerful check of conversion of management system actually causing changes in environmental indicators, whereas finding differences across systems within kiwifruit and sheep/beef sectors does not necessarily indicate causation [Fairweather & Moller 2004; Moller 2004]

#### Narrowing down to fewer focal bird species

In addition to broadly identifying birds as a key indicator group, we have also identified subsets of species that are of particular interest as indicators of environmental conditions or processes on New Zealand farms. An ongoing more detailed study of the seasonal fluctuations in the number, activity and habitat use of four bird species started on a subset of 12 sheep/beef farms in December 2005. The focal species chosen were:

- Skylark
- Blackbird
- Song Thrush
- Magpie

We settled on these species as they are present on the vast majority of sheep/beef farms, and thus provide comparability across farms of different location, management style and habitat composition. The chosen species also have proven to be easy to monitor accurately due to their conspicuous habits and easily recognized song.

Partly we wish to control inter-annual variation in bird abundance – a necessary component to estimate the power of longer term trend detection. But we also sought to understand the behaviour and habitat use of a representative range of species so that we can identify their ecological requirements. This eventually will lead on to recommendations of how to

reconfigure land use on farms so as to capture multiple gains for biodiversity, carbon sequestration, soil conservation, animal welfare etc.

### Future bird research

Studies on European farms have identified widespread declines in birds and consequent triggered rising concern about the impact of agricultural intensification on biodiversity. ARGOS will now monitor trends in birds, hopefully for the next 20 years, to see if similar problems are occurring here and, if so, what can be done about them. If the abundance and diversity of New Zealand farmland birds is stable or increasing, the growing environmental awareness of overseas consumers could create an incentive to buy New Zealand's products.

This specific study raises several questions that will be addressed in the coming years of the project, including:

1. What is the role of structural complexity, diversity and extent of habitat in determining bird species presence and abundance?
2. How do different farming systems and particular farmer actions affect bird communities?
3. What are the beneficial or negative effects of different introduced and native birds in production landscapes?
4. What regulates the populations of key focal species?
5. What actions are required to increase and sustain native birds on farmland and what might they cost and provide for farmers, and what are the costs and benefits of these actions for farmers and wider society?

A more comprehensive assessment of the effects of farm management on birds communities on ARGOS farms using the distance sampling techniques should be completed by mid 2008. These analyses will include the data from the most recent surveys in the kiwifruit and dairy sectors as well as updated spatial and farm management information.

PhD student Sarah Meadows has just commenced a study using bird diversity as a proxy for wider system biodiversity of South Island sheep/beef farms and birds as model species with which to assess social attitudes toward biodiversity on production lands. Farmland bird surveys will be conducted to examine differences in diversity and habitat associations of birds across conventional, Integrated Management, and organic farms, and individual species and habitat characters that are indicative of high bird diversity will be identified. Pairing social survey data with scientific measures of bird diversity across management schemes will direct the identification of practical indicator species and establish management strategies that complement farmer and public attitudes. While New Zealand's production lands rely on agricultural biodiversity for essential agro-ecosystem services, many endemic species are associated with high intrinsic value by both farmers and the New Zealand public. Despite the increasing body of international research linking agricultural intensification to declines in biodiversity and the national desire to conserve endemic biota, the relationships between agricultural intensification, biodiversity, and the social contexts in which they are rooted remain unstudied [Moller et al. in press]. Sarah's project will identify enablers and constraints for building conservation care of birds in production landscapes, a valuable step toward conserving agricultural and native biodiversity while ensuring New Zealand agricultural products remain internationally competitive.

Fantails have emerged as a potentially powerful ‘flagship’ species upon which to promote ecological sustainability of New Zealand farming. They are reasonably widespread and therefore can indicate ecological change or stasis on most farms and orchards. They are recognised as a ‘supertramp’ species [Begon et al. 2006], being often found in new and disturbed ground. Agriculture is fundamentally a form of ecological disturbance [Moller et al. in press] and its impact is therefore predetermined by altering disturbance regimes away from their natural or optimal state – the Intermediate Disturbance Hypothesis [Moller et al. 2005]. Accordingly fantails are likely to be relatively abundant and secure in agricultural landscapes and therefore a safe choice for branding ecologically responsible farming. They are easily observed, charming and loved companions of farmers at work. Indeed, one of the repeatedly mentioned observations of Kiwifruit growers is that the imposition of chemical application restrictions through the Integrated Management (‘KiwiGreen’) programme triggered a return of fantails to the orchards [Rate et al. 2007]. This suggests that the fantails will be an effective indirect indicator of insect abundance, and quantification of feeding success is relatively straightforward than measuring foraging of other bird species. Finally, this small insectivorous species is reminiscent of flycatchers well known in Europe, so it may have immediate appeal as a ‘green-tick’ label. We now propose some fundamental ecological studies of fantails in a variety of New Zealand farmland settings to determine what regulates their populations and how their numbers might be boosted and secured. We do not wish to recommend a key focal species for branding ecological sustainability of New Zealand farming until we can be sure that it is a reliable indicator of ecological wellbeing and that its numbers can be managed effectively. The first of the detailed fantail studies is proposed to commence in the 2007/08 breeding season.

### **Introduced mammals as predators of valued wildlife**

We had hoped to monitor small introduced mammalian predators (cats, ferrets, stoats, weasels, rats, mice, hedgehogs) before introducing predator control on farms with high and low habitat diversity and structure to monitor the response from native animals. This would have allowed us to determine if native animals will respond more to future management of suitable habitat, than to removal of predators, or to a combination of both [Moller et al. 2005]. Large-scale field experiments often suffer from low power as a result of low numbers of replicates and short experimental press durations [Moller & Raffaelli 1998; Raffaelli & Moller 2000]. We therefore set out to simulate likely responses of bird populations to predator control using literature descriptions of predation rates and efficacy of predator control and our observed variation in bird counts as a measure of sampling error [Weller et al. 2006]. The target power was set at being 70% certain to detect differences in population size between treatments after three years.

Computer simulations emphasized the need to maintain 3-4 replicates of any such predator removal experiments for 3 years before we could obtain sufficient statistical power to detect shifts in abundance of most birds – other species are present in such low numbers or are so variable that their responses to predator control can not be reliably assessed even with 4 replicates of each treatment.

We have been able to get ready for this experiment by the seasonal study of bird counts on our focal farms while studying detailed habitat use, but the cost of imposing predator control on 3-4 of them is prohibitive (around \$250,000 per annum). Unfortunately, this requires more funding than currently available from most additional grant sources, so the proposed experiment has been postponed in the meantime.

## **Aquatic ecosystem health**

### **Overview**

Perhaps one of the most important environmental, political and economic issues surrounding agriculture is the impact and interdependence of intensive agricultural production on water resources. There is a growing body of evidence that links agricultural production with reduced water quality and degraded ecological communities in farms streams and that ongoing intensification will degrade aquatic ecosystem health all the more [PCE 2004, Moller et al. in press]. In New Zealand the majority of agricultural pollution comes from diffuse, non-point sources, and most commonly takes the form of inputs of excess nutrients, sediments and micro-organisms. Habitat change due to clearing, channel modification, and drainage also contribute to diminished water quality in most NZ agricultural landscapes.

Agricultural impacts on aquatic ecosystems occur at a range of scales from individual sites on waterways to whole-catchment effects of land management practices. Theoretical and practical knowledge on how to reduce impacts on water quality and aquatic ecosystem functioning focuses on reducing flow of pollutants into waterways. Fencing of waterways to exclude stock access, retention of grassy buffer strips, planting of riparian vegetation to increase shading and reduce sediment and nutrient entry, and the careful management of livestock wastes can all reduce agricultural impacts on waterways. Several national and local government, NGO and industry level reports and actions are dedicated to improving stream health in production landscapes.

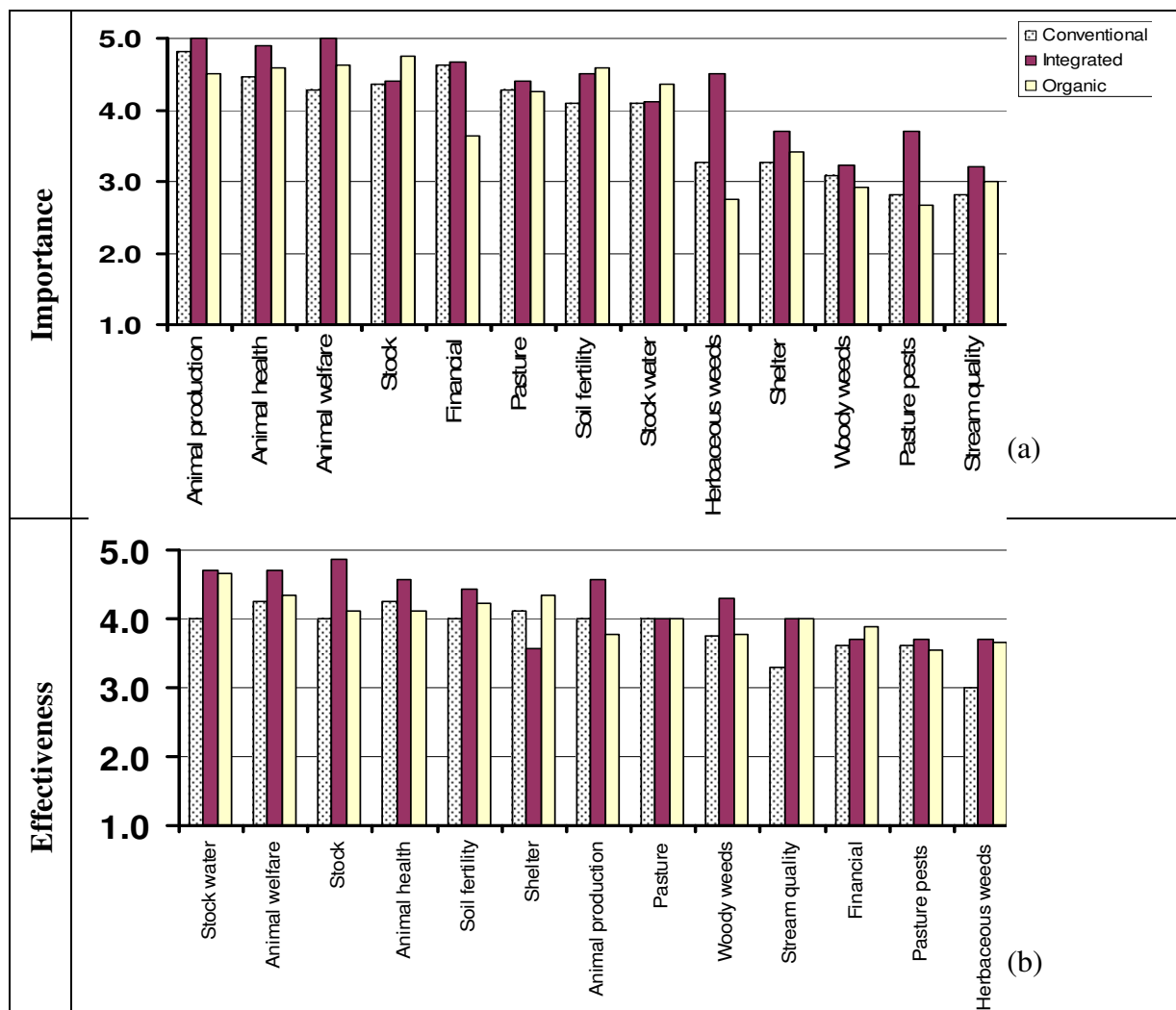
Demonstration of scientifically defensible and ongoing monitoring of stream health<sup>1</sup> could add safety to New Zealand's agricultural market access and allow product price premiums. Accreditation systems for Integrated Management and organic farming may require improved stream health, and increasingly stringent agricultural product import stipulations are likely to require stream health impact assessments. In light of this, ARGOS is conducting stream surveys as the first step in a long-term effort to support New Zealand farmers to instigate practical farm management strategies that improve sustainability and ecological resilience.

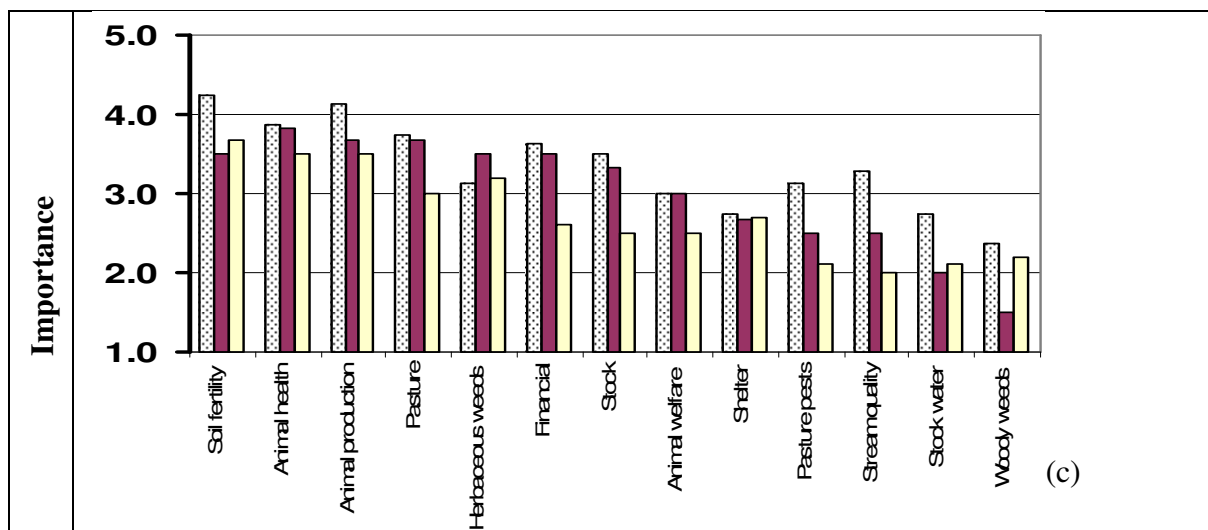
A preliminary assessment of how ARGOS sheep/beef farmers rank the importance of stream management (and weed management) was conducted in 2006 to provide the farm management priority context of our subsequent studies. Stream management was considered of low priority especially when compared with farm management challenges that directly affect animal production and financial viability of the farm enterprise (Figure 12a). Most farmers considered that they were effectively managing stream health already (Figure 12b) and accordingly there was relatively little enthusiasm for receiving more information about strategies for improving stream health (Figure 12c). The perception that stream health is relatively unimportant compared to pressing production and financial priorities is not evidence that farmers do not care about stream health itself, nor that they will be unwilling to invest in improved stream care should wider societal and market pressures continue to escalate a need for them to respond. However, sheep/beef farmers belief that they are already

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<sup>1</sup> We define stream health as: the ability to sustainably supply the goods and services of both human and non-human residents (stakeholders).

managing stream care very well is in marked contrast with our preliminary ecological surveys of stream health on their properties. The first surveys, discussed further on, showed that about 30% of the streams were below at least one of the standards set by Australian and New Zealand Environment and Conservation Council. However, a single survey on a summers' day is insufficient information to reliably gauge stream health. It is essential that ARGOS repeats the stream surveys under different seasonal and weather conditions before concluding that there is, or is not, a widespread and persistent problem of inadequate sheep/beef stream health. If problems are confirmed, the perception amongst the farmers that they are managing stream care effectively would be a significant barrier to trigger changed land use and farming practice. A key factor in the degree of implementation and success of riparian management by farmers and land managers is the extent to which tangible benefits are achieved at the farm scale.





**Figure 12:** South Island sheep/beef farmer's relative ranking of (a) the importance of various farm management challenges, (b) their perceived effectiveness in managing those challenges, and (c) the value of receiving more information on how to manage those challenges better in future.

In the initial biodiversity survey in the summer of 2004/05, a moderate diversity of fish species was found on the sheep/beef farms although most kiwifruit orchards did not have running water on them [Blackwell et al. 2005]. The preliminary surveys of streams demonstrated that a reasonably balanced, extensive and cost effective stream health monitoring programme can be instigated on ARGOS sheep/beef farms but not on kiwifruit orchards. Consequently, deepening and extending the stream work on sheep/beef, dairy and high country runs was identified as the next priority for the environmental research. Discovery of some native fish in farm drains suggests the potential value of farm landscapes as refuges for native fish conservation. Farm ponds obviously provide distinct and potentially valuable habitats for biodiversity on farms, but they were too infrequent to allow intensive study for testing the potential differential environmental impact of organic, IM and conventional farming.

### Stream survey results

In the summer of 2005/06 a Sustainable Farming Fund grant provided funding for stream surveys to be conducted in sheep/beef and dairy sectors in the summer [Blackwell et al. 2006a, Moller et al. 2006c]. FRST funds were used to survey again in the summer of 2006/07 to gain better information on inter-annual variation and to strengthen the research findings. However, these data have not been analysed at the time of writing and will not be reported here.

We examined whether different farm and waterway management actions on sheep/beef and dairy farms resulted in detectable changes in water quality and ecosystem functioning at the farm scale. More farmers may invest time or money into stream care if they can detect real improvements in stream health within the reach of streams on their own property. Immediate and local responses in stream health to improved farm management will also allow farmers to experiment with alternative land management options to learn what is most cost effective.

This field research had three specific aims:

1. Provide baseline data on waterway quality and ecosystem function on sheep/beef and dairy farms, from which future trends in stream health can be determined;

2. Identify the relative impacts of organic, integrated management, and conventional farming systems on water quality and aquatic ecosystem function on both sheep/beef and dairy farms; and
3. Develop customized stream care management strategies for each participating farmer for incorporation into long-term whole-farm management plans.

We measured physical parameters, nutrient and sediment levels, and periphyton and aquatic macro-invertebrate communities at upstream and downstream sites in streams. We also used the Stream Health Monitoring and Assessment Kit (SHMAK), an assessment tool developed for use by farmers and landholders and additional measures to record relative changes in water quality and stream functioning at the farm scale.

Our 2005/06 findings were consistent with other studies and research demonstrating that water chemistry, community structure and ecosystem functioning are vastly different in agricultural waterways compared to those in unmodified habitats. We found evidence of different levels of pollution between farming sectors, with higher levels of nutrients (nitrate and nitrite, ammonium, dissolved reactive phosphorus, and total phosphorus) in waterways on dairy farms than on sheep/beef properties, while average concentrations of total organic carbon and organic and total sediment, and turbidity levels were higher on sheep/beef properties. We did not consistently find larger relative increases in nutrients or other pollutants between upstream and downstream sites on individual dairy farms than on sheep/beef farms in this study.

The data on stream health and impacts of farm management from both the sheep/beef and dairy sectors were highly variable between farms, clusters, management systems and farming sectors. Consequently, there were very few significant differences in the measured parameters between organic, Integrated Management or conventional farms in either sector. Of the differences that we did find, there were significantly greater increases in ammonium ions ( $\text{NH}_4^+$ ) in streams flowing through conventional sheep/beef farms compared to IM or organic farms, while the difference in sediment increase and ammonium ions across conventional and converting dairy farms approached significance, with greater increases in ammonium on converting farms in the study, and greater increases in sediment in the conventional farms.

Integrated management sheep/beef farms had greater total numbers of stream invertebrates than Organic or Conventional farms, although the numbers of species and overall community composition was very similar across management types. Numbers and diversity of stream invertebrates in streams on Converting Organic and Conventional dairy farms were very similar, with no significant differences. Similarly there were no significant differences in either stream algae (periphyton) or riparian vegetation composition or extent between farm management systems in either the sheep/beef or dairy sectors.

Water quality and in-stream conditions often changed and sometimes improved at the farm scale. In some cases conditions were significantly affected by specific farm management actions (such as effective stock exclusion) and the nature and extent of riparian vegetation. Our findings support the belief that landholders can implement management actions that will result in protected or improved water quality within their own property boundaries, whatever their management system. Of course their investment in stream care also provides downstream benefits to other stakeholders, but the immediate and local improvements on their own property should create incentives for individual farming families to act and provide them with first hand experience and an opportunity to learn what works best to protect their waterways.

The SHMAK assessment kit did not detect overall changes in stream health and functioning across individual farms. We did record some changes in nutrient levels, sediment levels and other physical and biotic parameters across the study farms using the additional sampling techniques. We do not know at this stage if the SHMAK assessment is too insensitive to detect these subtle changes. Conversely, it may be that the additional measurements may be picking up trivial differences of no biological importance, and the SHMAK assessment may in fact be giving an accurate picture of overall stream health. It has become clear that SHMAK has been used little by farmers or environmental agencies and researchers. We will persist in using it in the meantime until we have better evidence of its robustness and sensitivity (or otherwise), and have evaluated why farmers do not apparently apply the tool.

The conclusions from this study are only tentative, as they are based on only one survey per farm, and lack information on several potentially important variables. Analysis of results from the additional sampling in summer 2006/2007 will allow us to better control for inter-annual variation in water quality measurements and to include additional variables in future analyses. Information on stock rotations and subsurface drainage systems are potentially important additional variables.

The results of the first survey have been relayed to each farmer in a report detailing: the state of waterways on their own farm; comparison data from other farms in the sector; and information on what factors or actions are affecting these results. The general findings have also been summarized in an ARGOS Research Note and posted on the project website [Blackwell et al. 2006b].

A survey of farmer attitudes and actions relating to waterway management was conducted on all the sheep/beef and dairy farms in summer 2006/07. With the addition of data from the ecological stream surveys in summer 2006/07, we will work with individual farmers to ensure that they have cost-effective and practical ways to manage waterways on their farms that provide environmental benefits. Suggested management actions may include stock exclusion for all or part of the year, riparian vegetation planting or management of existing vegetation, and modification of fertilizer application or stock management in areas adjacent to the waterway. However, it is crucial that any proposed actions do not threaten the long-term economic, social and environmental sustainability of the farming operation.

From this research we recommended the following future work:

- Repeat stream monitoring in subsequent years to explore the causes of variability in stream health between individual farms, and to reveal underlying differences between farming systems.
- Link stream health data to economic, social and farm management data generated by the ARGOS project so as to strengthen the explanatory power of the surveys.
- Provide feedback directly to farmers and assist with the development of management plans. The results of this survey have identified important impacts to water quality at the farm scale and linked several key indicators to farm management practices. The ARGOS research design includes industry representatives who have working relationships with each of our participating farm families and can provide direct and meaningful feedback and advice based on the findings of stream health monitoring. This process must begin immediately and continue for the duration of the research programme.
- Continue to apply SHMAK protocols alongside ARGOS stream monitoring protocols in order to assess the power of SHMAK as a tool and make recommendations on improvements to the SHMAK design.



## Weeds

There is no doubt that both woody weeds and herbaceous (pasture) weeds limit the output from New Zealand's pastoral lands by removing land from production, reducing the quality of forage, and by adversely affecting the health of grazing animals. The presence of weeds, and the techniques used to combat them can also adversely affect the environment in pastoral landscapes. Managing weeds to minimise economic and environmental damage is critical to achieving sustainable agriculture because weeds can not only dictate land-use choices, limit productivity, and limit profitability, but management techniques can be energy intensive, labour intensive, and/or increase the pesticide load in the environment. There is a widespread belief that weed management is a significant barrier to achieving profitable organic pastoral farming, yet we were unable to locate any literature or even semi-quantitative surveys to support these assertions. ARGOS's emphasis on uptake of alternative pathways is crucially interested in evaluating barriers and enablers to alternative pathways to sustainable production, so the environment team has paid particular attention to weed management options in sheep/beef.

The situation with weed management is further confounded by the potential costs and benefits of different weed species, as well as different perceptions of the value or otherwise of weed species. One farmer's weed may be another farmer's biodiversity. There is evidence that a greater diversity of herbaceous plants within the agricultural landscape can lead to higher animal biodiversity, and a number of European agri-environment schemes promote the retention of herbaceous species in hedgerows or field margins as ways to increase overall on-farm biodiversity. No such schemes exist in New Zealand. In addition some herbaceous species may provide significant nutritional benefits for stock, and may be favoured under some farm management systems. These considerations need to be balanced against the costs of herbaceous weeds in pastoral systems. The range of farm inputs, management styles, available control techniques and personal attitudes of farmers mean there is significant potential for weed prevalence and pressure on sustainable production to differ between farms with different management systems.

### Sheep/beef herbaceous plant survey

In this study we compared the diversity, abundance, size and community composition of herbaceous weeds<sup>1</sup> on 32 South Island sheep/beef farms [Blackwell et al. 2006c]. Between three and six paddocks per farm were surveyed using walking transects in November 2005, and the presence and abundance of all weeds encountered was recorded.

Herbaceous weeds were recorded on all the farms in the study, although individual species occurrence, species richness and weed abundance were highly variable between individual farms and the different geographic clusters. Our findings demonstrate the over-riding importance of climatic and physiochemical variables in determining weed extent and impacts.

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<sup>1</sup> Here we define weeds as herbaceous plant species present in the sward that are not grasses or species specifically planted as animal feed or as part of farm management actions e.g. clover species. It includes species such as the thistles and the 'flat weeds' (dandelion, daisy, plantain). We place no specific positive or negative value on weeds in this study, although acknowledge that the majority of these species are sources of concern and the focus of active management by farmers.

Farms in areas with higher rainfall, greater topographic relief and greater variation in soil types and quality, such as those in the Catlins and Gore, frequently had significantly greater weed abundance and diversity than farms with less rainfall and greater homogeneity of topography and soil types, such as the farms on the Canterbury Plains.

We found very few significant differences in the distribution, diversity and abundance of herbaceous weeds present between farms employing organic, IM or conventional management techniques, although weeds were found at a significantly greater percentage of the sampling points on organic farms (found at 66 % of sample points on organic farms, compared with 40 % of points on IM farms and 39 % of points on conventional farms,  $\chi^2 = 7.05$ , d.f. = 2,  $P < 0.05$ ). Herbaceous species constituted 8 % of the sward in the composition sampling points on organically managed farms, compared to 2 % of the sward on IM farms and 5 % on Conventional farms. The proportion of grass was highest on IM farms and clover was most prevalent on conventionally managed farms, although none of these panel differences were significant. Management system had a significant effect on abundance only for nodding thistle, with the number of weeds/m highest on IM farms, intermediate on conventional farms and lowest on organic farms (average predicted abundance  $\pm$  standard error: organic =  $0.05 \pm 0.02$ , IM =  $0.69 \pm 0.30$ , conventional =  $0.33 \pm 0.17$ ;  $F_{2,13} = 4.57$ ,  $P = 0.03$ ). Nodding thistle can rapidly form large infestations, shows increasing herbicide resistance and the long-term effectiveness of biological control agents is not known. Therefore specific information on management options, attitudes to control and actual weed prevalence and population dynamics on farms would be valuable.

The average size of buttercup, dandelion, dock, plantain and scotch thistle was greater on organic farms, but no differences were statistically significant. Poor power may have weakened comparisons, especially given the patchy nature of weed infestations, but it may well be that no real differences in average size exist. Buttercup, dock and scotch thistle are widely acknowledged problem plants. In comparison, dandelion and plantain are often encouraged in organic farming as a source of minerals and vitamins for livestock, and so larger size may reflect active management to increase the prevalence and size of these species on organic farms.

Counter to expectations of the wider farming community, overall we found very little evidence to suggest that herbaceous weed diversity and abundance are significantly greater on organic sheep/beef farms in New Zealand. This was supported by results from a concurrent ARGOS survey (details further on), which indicated most organic farmers did not consider weeds as a barrier to successful organic production. However, further research is needed before we would conclude unequivocally that weeds are indeed not a barrier to the actual economic, social and environmental performance of organic farming.

Areas of future research should try to gather information on:

- Trends in weed prevalence, particularly on organic and IM farms where pasture weed communities may still be responding to changes in management following conversion to either of these production systems.
- The degree and effectiveness of biological control methods on organic, IM and conventional farms.
- Species seen both as a nuisance or beneficial by farmers, and which are the targets of management actions so as to identify the effectiveness, challenges and benefits that accrue from weed management.

- Information on weed prevalence should now be combined with estimates of forage quantity and quality, to investigate relative stock growth and health on farms with different weed prevalence and management.
- A full economic analysis of the direct and indirect costs of herbaceous species on organic, IM and conventional sheep/beef farms should be conducted. This should include the direct costs associated with lost production due to key weeds of management concern (buttercup, dock, thistles), as well as indirect costs or savings from the presence of other herbaceous species.

### Weed management perceptions amongst sheep/beef farmers

A survey of farmers' beliefs and actions to control weeds was completed in 2006 [Hill et al., not yet submitted]. This preliminary survey revealed consistent differences in perceptions of weeds by organic, IM and conventional farmers and their remarkably detailed knowledge and awareness of weed threats, pathways to infestation and the need for a co-ordinated strategy to manage those threats.

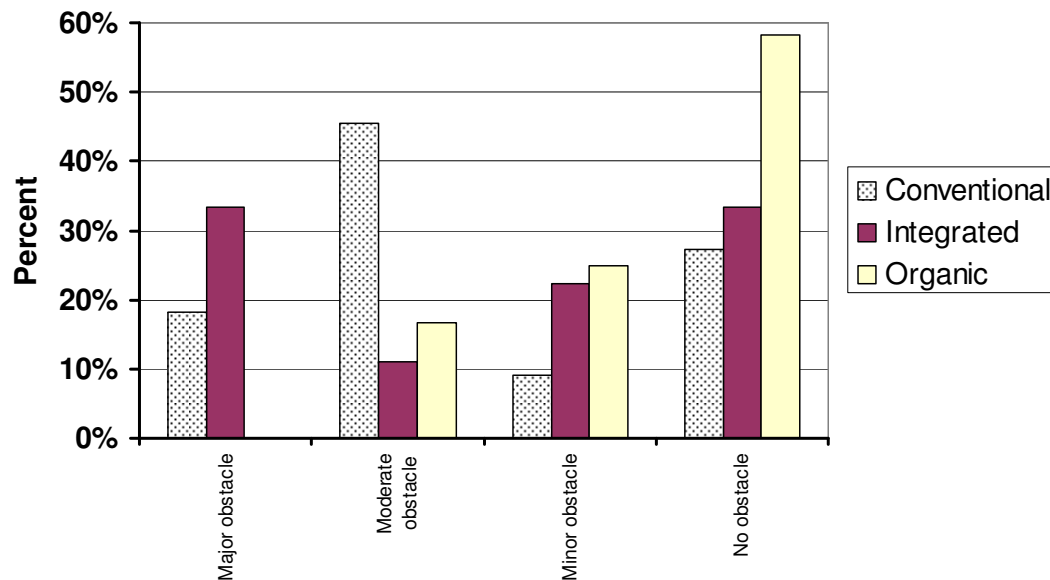
In general herbaceous weeds are considered to be more of a problem than woody weeds by most farmers, but as for stream care, weed management ranks below farm management challenges that directly affect farm production and financial success (Figure 13). Organic growers did not see weeds as a significant barrier to sustainable agriculture, but conventional and IM growers considered the prospect of managing weeds with only organic methods was a significant barrier to sustainability (Figure 14).

Overall 30% of control expenditure was for woody weeds and 70% for herbaceous weeds; and 40% of all expenditure on weed control used chemical and 60% non-chemical methods. By far the greatest expenditure on weed control and most frequent control operations are for Californian thistle, followed by gorse, nodding thistle, broom and other thistles. A few farms are engaged in extensive matagouri and gorse or broom control which is comparatively very expensive. IM and conventional farmers commonly used spot applications of chemicals, whereas organic growers relied almost entirely on mechanical methods, especially grubbing and pulling weeds. All types of growers relied heavily on topping for herbaceous weed control. Helicopters were used regularly by many farmers and fire much less frequently than in past decades. Chemicals are mainly being applied in late spring until mid summer to pasture and crops, but occasionally to shelterbelts, riparian zones, farm utility areas, fencelines and in scrub and 'waste lands'. Overall farmers relied almost exclusively on direct killing of plants for weed management, but organic growers indicated an increased use of other indirect methods (such as adjustment of stock grazing, soil fertility management, changing of fencing and stock access, and withdrawing control from low productivity areas of the farm).

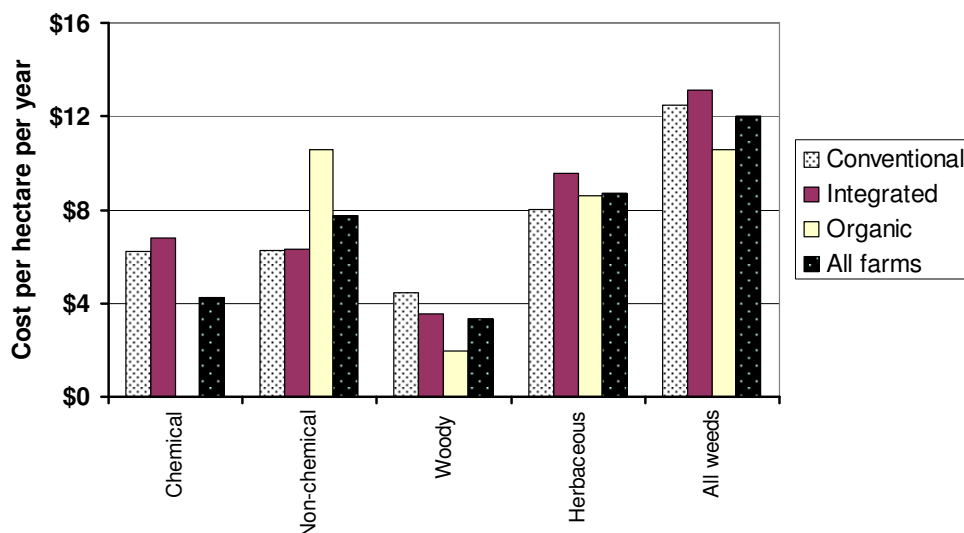
Organic growers spent much less on direct expenditure for weed control than their counterparts, but they did expend more time manually controlling weeds. Comparison of costs of weed control between systems is therefore critically dependent how much one costs an hour of the farmers time. Assuming this as \$25 per hour (following the Sustainable Farming Fund's guidelines for quantifying help-in-kind of research projects), there is no evidence that weed management costs are different between organic, IM and conventional sheep/beef farming (Figure 14).

Our discovery of (a) little difference in weed prevalence between systems (see section 2.2.9.1); (b) little difference in cost of current weed control (Figure 14); and yet (c) strong

differences in the perception of the weed threat to conversion amongst farmers (Figure 13) all combine to suggest that barriers to organic conversion may be more socially than ecologically driven. ARGOS can make a strong contribution for triggering change by public dissemination of science results that clarify the real risks and so present farming families with extra and safe choices.



**Figure 13:** Barriers to sustainable organic production posed by restricted chemical use for woody weed management, as perceived by 11 conventional, 9 Integrated Management and 12 organic sheep/beef farmers from South Island, New Zealand.



**Figure 14:** Average annual cost per hectare of chemical compared to non-chemical methods, woody compared to herbaceous weed control, and control of all weeds on 11 organic, 10 Integrated Management and 11 conventional sheep/beef farms in 2005/06. The total area of

the farm was used, not just the production area, because some weed control happens in riparian and 'scrub/waste' areas.

### Recommendations to improve weed management on South Island low altitude sheep/beef farms

The following recommendations relate entirely to South Island low altitude sheep/beef farms. It is important to remember that weed patterns may be very different in more northerly latitudes and at higher altitude.

- Nationally and within the ARGOS project, main investment should be targeted at improved herbaceous weed management and provision of information to help.
- Nationally and within the ARGOS project, support for weed management should be targeted at the minority of farmers experiencing severe problems.
- Research should investigate regional, altitudinal, climatic and management predictors of where weeds are a particular problem to allow better targeting of information distribution.
- A fully quantified costing of woody and herbaceous weeds be researched separately for organic, IM and conventional sheep/beef farming that incorporates effects of lost pasture production, and opportunity cost from avoiding cropping on certain areas.
- A preliminary costing of weed impacts should ignore benefits of shelter from woody weeds, and nutriceutical values of all weeds, but interpretation of results must acknowledge resulting values as simplified and pessimistic calculations of loss to farm income.
- Most research and development of Integrated Weed Management tools for South Island sheep/beef farming should target Californian thistle because this is clearly the most widespread and expensive weed control currently operating; however nodding thistle and Scotch thistle are also important secondary targets amongst herbaceous species in pasture.
- Most research and development of Integrated Weed Management tools for woody weeds should target gorse as the primary target, followed by broom.
- Priorities for targeting of different weed species for research and the development of Integrated Weed Management tools should be the same for organic, Integrated Management and conventional farming systems; however the methods used will have to be very different to meet accreditation protocols.
- The potential effectiveness of weed-wiping should be communicated more widely and vigorously to conventional and IM farmers.
- A wide variety of organically acceptable weed management techniques should be promulgated nationally and vigorously.
- A detailed market and non-market evaluation of the way organic, IM and conventional farming families value their time and make their choices about work on their own farms should be undertaken.
- Whole farm and transdisciplinary predictors of differential investment in weed management should be researched to allow better targeting of help to improve effectiveness and efficiency of weed management.
- Research on farmers' awareness and evaluation of indirect weed management techniques should be done to determine whether they offer effective longer term strategies for reduction in herbicide and petrochemical fuel use.

- Ecological and economic modelling to assess the relative cost effectiveness of eradication compared to management for low density is needed to evaluate divergent philosophies of weed management currently undertaken by South Island sheep/beef farmers.
- Investigation and debate of the value of tidiness in good farming practice should be fostered nationally, and within the ARGOS project.
- Further investigation of farmers' and consumers' attitudes to chemical use on farms should be completed to better understand the fundamental divergence in accreditation between organic and IM schemes.
- Formal economic assessment of the added market value of IM and organic products to consumers should be completed using willingness to pay approaches.
- Long-term monitoring of gorse, broom, Californian and nodding thistle population processes should be established using a set of stratified random sites throughout New Zealand.
- A detailed study of weed management like that done here should be repeated in dairy, High Country and in North Island hill country farms.
- A streamlined and much reduced subset of the most important questions from our weed survey should be included in the next AERU national survey of around 2000 farmers from a variety of sectors to gain confidence of their generality, and especially to test the absence of difference apparent so far in our small survey.
- A full costing of relative impacts of weeds and pasture pests on farming should be completed to advise an optimum ratio of investment in research and decision-support to manage pasture animal pests compared to weeds.
- A careful formal review and analysis of comparative herbicide and pesticide applications to European, South American and North American and New Zealand pastoral farms should be completed.
- Further and more detailed transdisciplinary research should be mounted to test our preliminary findings that weed management is more a perceived than real barrier to sustainable organic sheep/beef farming.
- A detailed study of the costs and benefits of the withdrawal of public-good funded advisory services should be completed to recommend on how to best provide such advice to New Zealand farmers.
- An Integrated Weed Management decision-support package should be prepared and trialled for two years amongst sheep-beef farmers, with a view to modifying it (a) for improved usefulness for sheep/beef farmers, and if successful, (b) for customising the package for dairy farmers thereafter.
- A plan should be drawn up by representatives from all stakeholders to create a national strategy for Integrated Weed Management in New Zealand agriculture. This will include co-ordinating research, monitoring, tool development and information dissemination .

Our recommendations are critically dependent on available resources and have not yet been ranked on the basis of urgency and importance. The formal economic analysis of the cost of weeds and opportunities from improved management (Recommendation 4) will be the best place to start. If it demonstrates that the return from Integrated Weed Management is much greater than the costs of added research, we suggest that a nationally co-ordinated Integrated Weed Management research and management support plan is formulated by the Ministry for

Research Science & Technology, the Ministry of Agriculture & Forestry, Regional Councils, Landcare organisations and farmer representatives.

We have chosen to highlight weed management recommendations here as an example of the tactical level outputs that will subsequently flow from the ARGOS project. This report has mainly concerned synthesis and big picture evaluations as requested by the FRST PGSF 'Request for Proposals' and the subsequent ARGOS bid. We expect similar detailed recommendations to emerge from several aspects of the research once linked to other environmental data and research by the other ARGOS objectives.

### High country woody weed prevalence

Woody weeds can be a significant limitation to farm activities, with gorse, broom and sweet briar regarded as the most problematic woody weeds in South Island agricultural and pastoral land including high country farms. Woody weeds can also impact significantly on biodiversity conservation values, with several species present in the high country (hawthorn, crack willow, wilding pines and blackberry) regarded as serious conservation weeds.

While the importance of woody weeds in limiting both economic production and biodiversity conservation values in the high country is widely recognised, there is less information on the ecology of these species and especially their distribution in the high country. As a consequence, we have started to develop a database on the woody weeds present on the eight ARGOS high country properties as a basis for better understanding the ecology of woody weeds in the South Island high country. Resource limitations prevented a full quantitative study of the weeds present on each property; rather, notes were made on the main woody weeds present on each property based on discussions with the farmer and field observations during the initial environmental assessment of the property.

Eight exotic woody weeds were identified during the preliminary surveys of ARGOS high country properties [Norton & Stevenson 2007]. The most commonly recorded woody weed species was sweet briar, which is present on all properties. Wilding conifers were present on six of seven properties, and gorse and broom were also widely present across the properties. These results are consistent with the findings of other studies on key woody weeds of South Island agricultural and pastoral properties.

On at least one property there has been a marked increase in sweet briar distribution since the 1990's, coincident with decreases in grazing pressure from stock and rabbits. Cattle may also hasten the spread of sweet briar on some properties, which creates conflicting management decisions.

All high country farmers involved in the ARGOS study undertake some degree of weed control. Broom and gorse are actively controlled on most properties, while wilding conifers are also regularly removed by farmers as they undertake day-to-day farming operations. On one property, a few days each year are spent exclusively on wilding conifer control. Sweet briar is controlled to some degree, mainly by spraying. While broom, gorse and wilding conifers are actively controlled as part of farm management, sweet briar is less actively controlled, even though it appears to potentially present a greater problem.

The results presented here are only preliminary and as further survey of the eight ARGOS high country study properties occurs, a more comprehensive assessment of woody weeds and their distribution will be developed.



### Weeds and other plant biodiversity on Kiwifruit orchards

A survey of vegetation under kiwifruit shelterbelts and vines encountered several recognised weeds, but not in sufficient quantities to threaten kiwifruit production [Wearing et al. 2005 and Bengé & Moller 2006]. They were categorized as insipient threats if control was not maintained, but the reality is that orchards actively mow and manage the vegetation on their properties. There is markedly more bare ground on IM orchards than organic ones, and the latter have a lush, longer sward made up by a more diverse range of herbaceous species [Benge & Moller 2006]. Amongst our ARGOS systems, 67% and 75% of Green and Gold growers maintain a 'herbicide strip' along the vine lines, partly to reduce weed and pasture competition, partly to maintain a tidy looking orchard, and partly to reduce risk of insect pests living in the soil or orchard floor sward from accessing the canopy [Benge & Moller 2006]. Naturally none of the organic orchardists have a herbicide strip, and they also seem to mow the grass less frequently than their IM counterparts.

## **Shelterbelt management**

In general ecologists expect that restoration of biodiversity in New Zealand's farmed landscapes will require provision of a greater variety of habitat and habitats with increased complexity compared to pastoral monocultures. This led Meurk and Swaffield [Meurk & Swaffield 2000] to suggest a target of returning 20% of the landscape back into woody vegetation. While we think that this target is somewhat arbitrary and that there are several other considerations (connectivity, habitat mosaics, critical choices of woody species), we do accept that the goal of increased woody vegetation would be desirable for environmental sustainability. It brings species variety, foods for whole ecological communities and increased structural complexity of vegetation that provided microhabitats, shelter and food for other species.

Aside from native forest reservation or farm forestry, the main other way of reintroducing woody vegetation to farmland landscapes is through planting trees for shelter and/or erosion control and thereby indirectly gaining biodiversity. Shelterbelts are conspicuous elements of production landscapes and a major component of successful agricultural systems. For instance, a study of spiders in farm shelterbelts in Canterbury identified 28 species, 25 of which were found in shelterbelts and 13 in pasture [McLachlan & Wratten 2003]. Thirteen endemic, one native and one introduced spider species were found only in shelterbelts. Spiders are important foods of many introduced birds, at least in forest [Moeed & Fitzgerald 1982]. On the other hand, shelterbelts may be conduits and nursery areas for introduced mammalian predators and browsers in New Zealand farmland.

ARGOS proposed a detailed cost benefit analysis of different types of shelter to identify barriers and opportunities for increased planting of optimal species in ideal micro-sites on farms and orchards. A multifunctional analysis is required because shelter provides services (eg. biodiversity retention, soil and water conservation, C sequestration, shelter for stock, nutraceutical options) and aesthetic values. Most of this research has taken place in sheep/beef farms and kiwifruit orchards. Diane Sage is just starting a PhD study (University of Canterbury) of the role of scrub and vegetation patches for shelter in ARGOS High Country farms, but results will not be available until 2010.

## **Survey of shelterbelts in kiwifruit orchards**

Within kiwifruit orchards, shelterbelts protect the fruit and vines from wind damage which would otherwise reduce crop yield and fruit quality but they also intercept light and take up space that could be used for fruit production. Shelterbelts can harbour incipient weed threats, but also provide potentially important refuges for maintaining valued biodiversity on orchards. Some orchardists have recently removed shelterbelts or replaced them with shade-cloth screens, partly to increase fruit dry matter.

ARGOS conducted an ecological survey of shelterbelts on the 36 ARGOS kiwifruit orchards in 2004 [Moller et al. 2007, Moller et al. 2006b]. Species composition and stature of shelter on orchards from the three systems (organic 'Hayward', IM 'Hayward', and IM 'Hort16A') were compared. There were 437 shelterbelts across all 36 orchards, of which 13 (3.0%) were "artificial" i.e. made of wind cloth stretched between high poles. Most (77%) of the artificial shelterbelts were "internal" (dividing blocks within the orchard) rather than "external" or "boundary" (ranged around the outside of the orchard), whereas 53% of the living shelterbelts (formed by vegetation) were internal. The proportion of shelterbelts that were artificial rather than living was not significantly different between orchard types.

Altogether 26 different woody species were found in the shelterbelts. Three species groups (Japanese cedar, *Cryptomeria japonica*, she-oak, *Casuarina* spp., and willow, *Salix* spp.) predominated in all orchards. Organic orchards had a comparatively large number of different introduced species, and more species overall. Overall, only 5-8% of the woody species were native to New Zealand. There was no evidence that shelter differed in stature (height and width) or porosity between systems. External shelter was wider and less porous near the ground than was internal shelter.

There were more incidental woody species in shelterbelts on Organic orchards (1.94 per shelterbelt) than in IM 'Hayward' (1.17) or IM 'Hort16A' (1.13) orchards, but there was no evidence of a difference between orchard types in the number of species forming the main shelter (or in the number of herbaceous species under the shelterbelts).

Thick litter beds were much less common under shelterbelts in Organic (1.2%) than IM 'Hayward' (18.6%) or IM 'Hort16A' (18.0%) orchards. Rank growth was found more frequently under shelterbelts in Organic orchards (9.7%) than in IM 'Hayward' (3.4%) or IM 'Hort16A' (1.5%) orchards, but this result was not formally significant ( $p = 0.19$ ).

Overall then, our preliminary survey of kiwifruit orchards suggests that shelterbelt composition and stature is broadly similar between orchard systems, so it is unlikely to be driving differences in mean fruit production, quality and animal diversity and abundance between orchard systems.

Shelterbelts are sites of reduced ecological disturbance in an orchard environment having areas that receive a comparative lack of mowing, compaction by vehicles, spraying of herbicides and insecticides, and weeding. Plants that can survive cutting by mechanical trimmers can find ecological refuge in the shelterbelts provided that they can compete successfully for light, nutrients, water and space with the shelter species themselves. Native species found in the shelterbelts such as mahoe (*Melicytus lanceolatus*), Hall's totara (*Podocarpus hallii*), mapou, (*Pittosporum eugenoides*), lemonwood (*Pittosporum eugenoides*) and kohuhu (*Pittosporum tenuifolium*), are known to withstand browsing and therefore hedge trimming, but rewarewa (*Knightia excelsia*) was a surprise find. The introduced vines (moth plant/kapok, *Araujia sericifera*, and banana passion-fruit, *Passiflora mollissima*) benefit from their ability to climb the light-rich exterior of the shelterbelts. The rare native mistletoe (*Lleostylus micranthus*) was a notable species in willow shelterbelts in the Motueka cluster.

The overall frequency of native plants present in the shelterbelts was low, and often they were concentrated in less than 1% of the shelterbelt or in small clumps. Shelterbelts are notable perching and feeding sites for native birds in kiwifruit orchards. ARGOS will compile a list of native species that can withstand hedge trimmers and assess their potential suitability for shelter and as food sources for native animals as part of a long-term strategy to enhance environmental conservation in New Zealand's production landscapes. Follow-up research by ARGOS must consider the impacts of shelter on 'agricultural biodiversity' – those plants and animals that directly enhance maintain or decrease fruit production. But we are also concerned about the other species and processes that connect kiwifruit orchards to the wider ecological landscape and that connect orchardists and their families to their local and wider New Zealand society and economy and their international consumers.

Detailed bird habitat use studies are just beginning to pinpoint the value of hedgerows in promoting bird abundance, which when combined with the novel plant research by Dr Johnson (see next section), will allow an integrated assessment of plant choice for maximum gains of biodiversity, farm production and removal of parasite management barriers to sustainable organic pastoral farming. Similarly, an experimental and observational study of

insect and bird use of shelter and inserted native/introduced plants is about to be started on ARGOS dairy farms by Dr Yuki Fukuda, a postdoctoral researcher in the ARGOS project funded by the Japan Society for the Promotion of Science (September 2007 – August 2010). Her studies mark the beginning of evaluation of habitat connectivity issues for biodiversity enhancement, a potentially important issue for redesign of woody vegetation pattern for more resilient ecological landscapes in future. Dr Fukuda will (i) describe species composition of shelterbelts (including native vs exotic), porosity, density, biomass, age and disturbance to, as well as distance from the nearest alternative refuge of existing shelterbelts; (ii) compare the use made of shelterbelts by birds, and abundance and species richness of bird and invertebrates within shelterbelts and pasture; (iii) determine whether a pattern of invertebrate colonisation on native ground vegetation away from a refuge differs with regard to distance from a refuge; (iv) investigate whether invertebrate colonisation rates differ between organic and conventional dairy farms; and (v) determine farmers' attitudes towards shelterbelt management and adding native vegetation for biodiversity promotion on their properties.

### 3 DISCUSSION

#### Environmental findings and research priorities

Some of the important findings of the ARGOS environment research will be emphasised here in the discussion before turning to more generic synthesis questions that might invite more interest for our economic, social, Māori and farm management colleagues.

##### **The first priority: Enhance habitats on farms**

While physical landscape composition will have an underlying influence on both the economic performance of the farming operation, and the social landscape within which the farm and farming household reside, the interactions between the physical landscape and biodiversity are primarily ecological. We are therefore interested in how topography and habitat elements combine to affect biodiversity both within and beyond the farm (see Figure 11), as well as how the physical landscape interacts with management options and actions.

Information from all ARGOS farms are now entered into a spatial database, including the presence and locations of physical landscape features such as shelterbelts, native vegetation and waterways. At the same time we are developing techniques to build 3-dimensional models of each farm (initially as a pilot study to be expanded if additional funds are secured). In the coming years we will begin to understand how these habitat and landscape patterns and spatial arrangements influence observed on-farm biodiversity and how these relationships interact with farm management actions and priorities. Transdisciplinary analysis to identify economic, social and environmental trade-offs and synergies (win:wins) will be the next priority.

Our emphasis on habitat creation (stemming from analyses like those shown in Figure 11) does not preclude the possibility that adding predator control to farm management goals will not also add ecological resilience and hasten biodiversity restoration. Quantification of the added value from predator control on production landscapes must await more substantive research funding. In the meantime we simply assert that restoration of habitats should be the main priority - though not necessarily a sufficient response - to rebuild ecological resilience of the farming systems and we leave open the possibility that effective predator control may also be needed.

##### **Opportunities for interplanting native trees into shelterbelts and riparian zones of sheep/beef farms**

Recently, the practice of interplanting native trees in shelterbelts has been suggested to improve indigenous biodiversity within agricultural landscapes. Indeed, our survey of kiwifruit orchards did find occurrences of a range of native tree species. In agricultural landscapes—whether using traditional management practices or more ecologically-sustainable ones—there is a need to investigate whether interplanting native trees in shelterbelts and riparian zones would increase indigenous biodiversity, but not abundance of pest insects. The multifunctionality of riparian zones and shelter plantings is an emerging theme within the ARGOS environmental research and will next be coupled with whole farm plans and scenario building with the farmers using GIS and mapping to evaluate choices. In the meantime a much more general inquiry into the nutraceutical qualities of various native plants has been progressed by Dr Marion Johnson, a FRST Postdoctoral Fellow mentored within the ARGOS team. Laboratory bioassays of bioactivity of 98 native plant extracts against deer lungworm

identified 40 with promise. Of those 40 plants, five were tested in a closely controlled animal trial with promising results. As plants may act indirectly boosting immunity through improved health a start has been made upon evaluating the nutrient and trace element status of native species, so far 43 plants have been analysed. Results from this initial research would suggest that there may be compelling reasons to increase use of native species upon farms, boosting animal health, building biodiversity and resilience into farming systems. The next phase is to explore the practical methods of successfully introducing native plants into farm systems, melding the various plant functionalities, growth and management requirements and contributions to habitat creation.

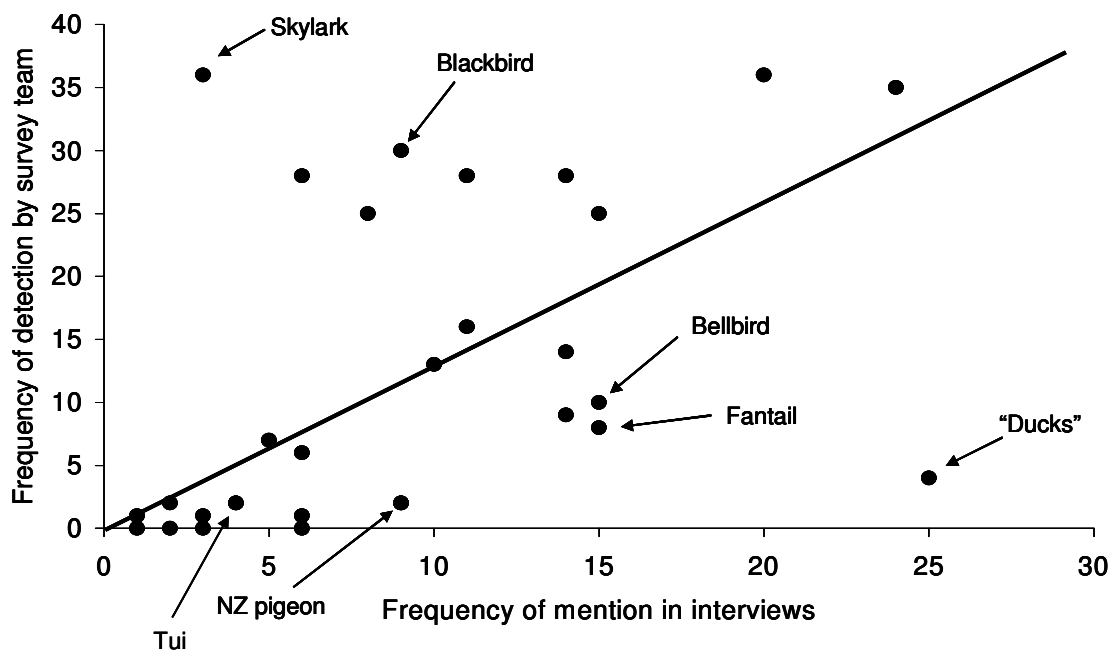
### **The second priority: choosing the focal species for eco-verification branding and incentivise sustainability**

Birds on ARGOS farms have been given a very high research priority, due to their use as indicators of sustainable environmental practice and ecological conditions and their familiarity and value to farmers, politicians and the public. Two further factors make birds an important research focus for the ARGOS programme. Firstly, many of the European farmland birds common in New Zealand have been declining in their home range for the last 20-30 years, with changes in agricultural practices and intensity often implicated as or proven to be the causes of these declines [Moller et al. 2005, MacLeod et al. in press]. We have few data on population trends for these same species in New Zealand, but preliminary investigations suggest densities are much higher here than in Europe. There is therefore potential for New Zealand to brand agricultural products as produced in ways that are environmentally beneficial (or benign) for birds of conservation concern in the markets we sell into. A second, related point is that many of our markets are implementing accreditation schemes that specifically focus on farm management actions that support farmland birds. For example the LEAF Marque (Linking Environment and Farming) is an accreditation scheme supported by UK retailers such as Sainsbury's and Waitrose. LEAF requires farmers supplying to the scheme to have bird management plans and undertake specific actions to enhance bird populations (such as timing of management to avoid disturbing nesting birds, and leaving all hedgerows and trees in place to provide habitat). EUREPGAP/GLOBALGAP is also currently introducing standards for livestock farming that include measures to protect farmland birds. These actions will ultimately affect New Zealand producers, as they will be required to meet similar standards in order to maintain market access.

This situation raises some important issues and opportunities for ARGOS and New Zealand agriculture. Specifically, what species should we select as indicators of sustainable practice? Suitable indicators will need to be widespread on the New Zealand farms signing up to the accreditation scheme, they will need to be easy to accurately and reliably measure on the farms, known to be affected by management actions and have secure populations in the face of those actions, and resonate with both producers and consumers. We have good baseline information on the distribution, abundance and ease of surveying the bird species on our ARGOS sheep/beef, dairy and kiwifruit properties. However, we don't have information on the population ecology to know how they respond to management, climate, landscape composition, predators, competitors and disease. The worst thing we could do is select a particular species as an indicator of sustainable management only to find in a few years that it has disappeared from farmlands and the only place left that it is common is as an image on our product packaging!

In addition to the ecological considerations above, the most appropriate species to choose as indicators will also depend on the attitudes and perceptions of both (a) New Zealand

producers, industry and consumers, and (b) those of suppliers and consumers in our target markets. Should we select native species, and develop a “tui tick” or “fantail friendly” product label? Comparison of ecological survey data and the information about birds supplied by the farmers themselves shows that they often do not correlate well (Figure 15). Some species are noted much more frequently by the farmers than would be expected from what is commonly encountered on their farm, presumably because those species are of particular interest to the growers – correspondingly, some species like skylarks are ubiquitous and common, but hardly rate a mention by the growers.



**Figure 15:** The presence of bird species on ARGOS farms as revealed by ecological surveys by the research team compared with the frequency of that species being mentioned by farmers in social interviews.

The data collected allow for a comparison of the number of South Island sheep and beef farmers that mentioned a particular species during social interviews (X axis) and the number of those farms on which that species was recorded during scientific field surveys (Y axis). There was a significant relationship between the two variables that explained 31% of the variation. Some highly visible native species were recorded in similar proportions by both techniques (e.g. Australasian harrier), while some iconic but rare native species (e.g. N.Z. pigeon) or valued introduced species (e.g. ducks) were commented on by farmers in much greater proportions than they were recorded in the field surveys. Conversely, species of potential ecological or economic importance (e.g. skylark, blackbird) were recognized or commented upon by farmers in much lower proportions than they were recorded in the scientific surveys. Tui are mentioned much more frequently than they are observed in surveys than might at first seem apparent (it is a relatively rare bird on farms and so the data point is not shifted far to the right of the line – had the results been expressed in relative terms it would be more evident that it is mentioned many times more than its actual occurrence). The ARGOS environment team is particularly interested in making the fantail a focal species for eco-verification.



Fantails have emerged as a potentially powerful ‘flagship’ species upon which to promote ecological sustainability of New Zealand farming if we only consider ecological issues. They are widespread in kiwifruit and dairy landscapes, and moderately so in sheep/beef farming areas. Therefore they can indicate ecological change or stasis on most farms and orchards. They are recognised as a ‘supertramp’ species [Begon et al. 2006], being often found in new and disturbed ground. Fantails are likely to be relatively abundant and secure in agricultural landscapes and therefore a safe choice for branding ecologically responsible farming. As insect feeders their abundance is likely to be primarily driven by insect abundance. Insects are more widespread on farms than frugivorous and nectivorous species like the kererū and native honey eaters (tui and bellbird) which will be correspondingly more dependent on small bush reserves, riparian strips and house gardens. Persistence of fantails in unmanaged farming landscapes suggests that they are resilient to predation by introduced mammals (their numbers may be greatly enhanced by predator control too, but in the meantime they seem safe without it), and are valued by many farmers. This suggests that the fantails will be an effective indirect indicator of insect abundance, and quantification of feeding success is relatively straightforward than measuring foraging of other bird species. New Zealanders’ greatly favour conservation of native species over introduced ones, so fantails will have local appeal. Finally, this small insectivorous species is reminiscent of flycatchers well known in Europe, so it may have immediate appeal as a ‘green-tick’ label. We now propose some fundamental ecological studies of fantails in a variety of New Zealand farmland settings to determine what regulates their populations and how their numbers might be boosted and secured. The first of the detailed fantail studies is proposed to commence in the 2007/08 breeding season but in the meantime we invite transdisciplinary debate on their choice as our flagship species.

### **The third priority: management of biological processes in soils**

Soil biological activity is critical to soil health and quality because the microbial life-forms present perform an important range of functions within soils, mediating many important chemical and physical processes. Management of soil biology is promulgated as the key to successful primary production especially in the organic and ‘biological farming’ sector [Savory & Butterfield 1999, Andersen 2000, Coleby 2000, Kopke et al. 2005]. Consequently, biological activity measures can indicate what functions are predominantly occurring, how active or primed the microbial population is to various inputs, and the size and distribution of the active microbial population. Whilst it is difficult to interpret differences in soil biology as being “good” or “bad”, the importance of soil biology may lie in its multifaceted ability to enhance the soil’s chemical and physical qualities and interactions with plants. Ensuring that microbial populations are as diverse and healthy as possible may mean that the soil is better able to cope with external stresses.

ARGOS funds have been exhausted by establishing standard physico-chemical indicators of soil health as the top priority for long-term monitoring and matching overseas indicator protocols. Assessment of the variance of these standard indicators now shows that some are unlikely to change quickly and that there is sufficient power in our sampling framework to detect important differences. This gives us confidence to shift emphasis by slowing up on the frequency and extent of standard physico-chemical soil descriptors and to allow greater investment in measuring biological indicators of soil activity and health. This trend will be accelerated in the next phase of the ARGOS Environment Objective’s programme. Future work will look to concentrate on measuring a wider range of soil biological indices to see what differences exist between management systems for each sector and whether these reflect the intensity of operation and impact on biological activity and diversity.

#### **Priority four: stream care**

While the public and regulatory spotlight is trained mainly on dairy farming impacts on waterways, it will be prudent for the sheep/beef farmers to build resilience by thorough evaluation of the size of the potential problem and targeting assistance to farmers and landscapes where threats to market access and eco-accreditation are greatest. Although levels of sediment and nutrients were lower (sometimes by several orders of magnitude) on ARGOS sheep/beef farms compared to the dairy farms in the project, levels of active stream care (such as riparian planting and fencing to exclude stock) were also much lower on the sheep/beef farms. In some cases, this resulted in much larger percentage increases in nutrients or sediment across the sheep/beef farms than on the dairy farms, highlighting that sheep/beef farms can indeed have negative impacts on freshwater ecosystems.

It is likely that more attention will be focussed on the impacts of sheep/beef farms on water quality, for several reasons. Accreditation schemes such as LEAF and EUREPGAP/GLOBALGAP specifically require demonstrated management actions to minimize impacts on waterways, such as exclusion fencing, riparian planting and stock rotation management. Widespread adoption of eco-accreditation schemes therefore has the potential to increase management requirements and compliance costs for New Zealand sheep/beef farmers, and the ways that farmers respond to these challenges should be the focus of transdisciplinary research within ARGOS. Specific areas of research focus include the investigation of the ecological, social and economic costs and benefits of audit imposed compliance actions. For example, do the gains in animal health (and associated reductions in costs) and production that come from fencing off waterways outweigh the economic costs of installing the fencing itself? Similarly, there are questions around which user pays in the market-based New Zealand setting. Dairy farmers can access financial assistance for waterway care through regional and district council schemes, usually to help offset the specific targeting of intensive dairying for monitoring and regulation. If sheep/beef farms are required to meet increased compliance costs to access export markets, should individual farmers, industry or the wider tax- and rate-paying New Zealand society foot the bill? ARGOS research should aim to help farmers best maximize the health of their waterways and the resilience of their farming operations, particularly sheep/beef farmers when less information is available and the potential impacts of new accreditation schemes may be relatively greater.

#### **Priority five: increased links across ARGOS sectors**

##### **a) Increasing the linkage between pastoral sector farms and Māori-owned farms included in He Whenua Whakatipu research.**

So far there has been little cross-referencing of environmental monitoring and research on pastoral sector farms and Māori-owned farms included in He Whenua Whakatipu, ARGOS's objective to support Ngāi Tahu whānui searching for more sustainable lifeways [Reid 2005]. This is partly because He Whenua Whakatipu's focus has been on a whānau-led sustainable livelihoods approach and enterprise planning; partly because that objective is well-served by Tim Jenkins, an ecologist; and partly because of the enormous variability in land use within He Whenua Whakatipu's panel.

Soil monitoring was completed in a similar way to pastoral farms, and preliminary land use maps have been drawn. We also mounted a more general investigation of how Māori farmers approach soil management. Soil is both a bio-physical property as well as social and cultural construct. Therefore soil quality can be approached, analysed and understood from multiple

directions. A study by Monica Peters investigated soil quality (SQ), how it is described, which key indicators are used, monitoring methods and ways in which soil knowledge is gained through the experiences of 8 Māori pastoral farmers located in the southern South Island of New Zealand. Many of these study informants were ARGOS participants in He Whenua Whakatipu.

As the maintenance of soil quality / health is integral to maintaining both farm socio-economic viability as well as cultural and spiritual health for Māori, broader engagement with Māori farmers is needed in order to facilitate a more inclusive understanding of how the soil resource is understood in terms of both its productive and intrinsic values. This study explored the tension that exists between local knowledge and scientific knowledge. The basis of this tension lies in the fact that farmers and scientists describe and measure soil health using different languages. Their methods differ, just as their tools do. Key findings are outlined below.

### **Soil Quality (SQ) indicators**

Understanding the key SQ indicators used by farmers in their daily and seasonal routines served as a useful starting point for developing a dialog based on the shared understandings between farmers and researchers both in terms of the terminology used and the priorities of each. Key SQ indicators to emerge from interviews included intrinsic properties i.e the physical, biological and chemical make-up of the soil, though SQ was also seen as dynamic, a property which could be improved, maintained or degraded. SQ is therefore strongly linked to management, and gauged through the performance of pasture species (e.g. rye and clover), forage crops and stock in particular:

*“...to make the land productive, you’ve gotta make it healthy... nice looking sheep and nice looking cows!... well that’s the product that comes from that land...”*

*“...we look at the cow... because we understand cows more than soil”*

### **Monitoring**

Examining the range of formal and informal monitoring methods used by farmers to assess the quality of their on-farm resources provides an insight into both conscious and tacit forms of decision-making underpinning daily and seasonal farm management. Overall, these combined methods used by interviewees were diverse, reflecting the extensive range of factors linked to the farm as a socio-cultural and economic system situated in a modified natural environment. The choice of formal and/or informal monitoring methods was therefore inextricably linked to a wide range of current and historic factors. Farmers’ informal monitoring methods were based primarily on factors both observed and directly experienced. Monitoring was therefore integrated into daily and seasonal activities and occurred as a matter of course.

Commercial soil testing was the most common formal method used by interviewees who either wanted to improve pasture / crop productivity or were already engaged in intensive farming. Industry bias – as soil tests are carried out by fertiliser suppliers, however remained an unanswered problem for interviewees unable to afford independent advice.

## Information exchange

Understanding the information sources most trusted by farmers as well as the ways in which new knowledge evolves on farm provided stepping-stones for future collaborative initiatives which seek to integrate knowledges. Although there are two key ingredients for sustainable development – information generation and social participation, the latter is still lacking particularly for Māori farmers. Māori farmers are often underrepresented at field days and demonstrations (Andrew *et al.* 1997). Despite these events being rated highly by Māori in terms of encouraging sustainable management practices, Māori farmers have felt more isolated from support from other Māori as well as from the dairy industry (Clough *u.d.*). One of the underlying reasons relates to the different methods of group learning that take place within Māori culture, which uses hui as a forum for information extension and exchange.

## Scientific and local knowledge

Knowledge is both dynamic and context dependent, and background experience, values and personal aspirations are critical factors in shaping the outlook of each farmer. Farmer methods of learning are diverse, ranging from conscious activities to on-going observations of cause and effect which are tightly woven to the landscape. In this respect, the distinction between experiential learning and experimental learning are blurred.

*“...if you turn the dirt up you gotta have the thing right to plant...we had such a bad wet spell... there was no way we could get it dry enough to direct drill it so um we just blew the seed on straight out of the fert sprayer and um R. and I spent all night one night just harrowing... shaking the seed down into the grass, bloody stuff worked a dream... we’d had 3 fine days, then it come in really warm drizzly northerly rain and it was really, really mild and I said to R. if anything’s gonna grow, tonight’s the night so we went for it, went all night... and it worked perfectly...”*

The rapid pace of technological and social change within the agricultural sector greatly strengthens the need for an integrated base of knowledges to address issues of soil degradation and to design pathways toward sustainable systems. Understanding similarity and difference between knowledges is a critical step toward developing mutually beneficial collaborations between cultures. A key difference for example is that local knowledge and fact are often uncontestable:

*“These are stories what are told by me, by people of the past, plus with Māori that was the way, it was said, it wasn’t written, it was passed on that way, knowledge, most of the knowledge that Māori has, well it can’t be questioned.”*

Temporal and spatial scales also differ. Local knowledge may be “embedded” in the landscape and therefore not available or usable until it is needed:

*“...it’s good soil, what’s down in there, the gardens of the past, there seems to be a microclimate in there [...] these gardens you’re going back 5 or 600 years plus... I didn’t realise it ‘till I had a look a couple of years later...I was always told they were there but ...either you want to look or you don’t want to look... I was told and you can see and that’s enough [...]*

## Research methodology

Codes of conduct were drawn from Māori protocol were used to underpin and guide the interviewing. Critical reflections on the methods used are rarely detailed in the literature and

therefore have been emphasized to inform other researchers navigating similar transcultural terrain. These underscore the function of research as a learning process, a need for self-reflection on methodology and feedback from the participants.

Recommendations for future research included:

- What are the barriers and opportunities for Māori farmers to improve SQ and productivity on Māori land?
- In which ways do information needs for Māori farmers differ from that of non-Māori farmers?
- How can traditional knowledge be used to underpin scientific experimentation in order to determine best practice techniques for SQ conservation within pastoral agriculture?

General research questions (i.e. non-culturally specific) include:

- How can information pathways between farmers and industry/researchers be strengthened to facilitate the flow of knowledge from “bottom to top”?
- Do the SQ assessment tools developed for farmers meet their stated goals in terms of measuring SQ and empowering, educating and stimulating the farmer into action?

Several of these themes will be taken up in the next phase of ARGOS and as part of strengthening overlap between *He Whenua Whakatipu* and the other ARGOS objectives.

#### **b) Increasing the linkage between the High Country Farm Research and other ARGOS sectors.**

The comparatively huge size of the High Country runs participating in ARGOS and lack of complementary systems of converting and IM farms has forced a very different approach to environmental research there. All the Kiwifruit orchards participating in ARGOS could easily fit in a single paddock of one high country run; and all the sheep/beef and dairy farms would fit within one run. We have doubled the investment per property in High Country compared to elsewhere but inevitably the ecological coverage has had to be very thin.

Our primary focus on the eight ARGOS high country properties has been to undertake a baseline environmental assessment of each property and from this to establish a comprehensive land-cover, aquatic and soil monitoring programme. This has now been achieved across all eight properties (Table 5). We have also been working with the farmers to build accurate maps of paddock/block boundaries and stock utilisation for these blocks, as well as utilising publically available information as well as ARGOS specific survey data that we have collected (vegetation mapping). We are using these different information sources to develop detailed management and environmental maps of each property, although this work is still incomplete because of the scale of the properties involved.

	Land cover	Soil	Aquatic	Area (ha)
Ben Ohau	23	12	7	4,335
Flock Hill	33	12	9	14,607
Lake Hawea	44	12	7	11,578
Linnburn	31	12	7	7,132
Glenmore	48	12	10	19,200
Muller	44	12	12	38,833
Otematata	57	12	10	40,000
Redcliffs	25	12	5	2,113

**Table 5.** Environmental monitoring sites established on ARGOS high country properties

In addition, there has been a major emphasis on building a strong postgraduate research programme centred on the ARGOS properties involving MSc and PhD students exploring a range of research questions relating to the interaction between farm management and native biodiversity. Current research projects include including an assessment of the role of native shrubland and tussock for shelter during lambing, the effects of intensification on ecosystem resilience and soluble soil carbon, interaction between hawkweed invasion and spatial patterning of plants in tussock grassland, and the ecology and restoration of remnant woodland ecosystems.

We are planning to undertake our first re-measurement of the monitoring sites in 2008/09 which will allow an initial assessment of change in the monitored variables on these properties. We are working closely with the farmers on our study properties to complete the block/paddock mapping and collating of stock utilisation information, as a basis for finalising detailed reports on spatial patterns of stocking and environmental variables. There will be a continuing emphasis on supporting postgraduate research projects on these properties, while it is intended to seek new funding to increase our work on understanding the effects of intensification on native biodiversity, to explore some of the implications of climate change for property management, and to work further on the interaction between invasive species and economic and biodiversity values.

## **Cross-sector conclusions and meta-hypotheses**

### **ARGOS's farming systems null hypothesis**

The ARGOS programme has selected a range of species and systems that are indicators of environmental sustainability and socio-ecological resilience, and has applied these to the investigation of the relative performance of organic, integrated management and conventional farming systems in sheep/beef and dairy farms and kiwifruit orchards. As a first step we simply compared our resilience indicators across differing management systems within each sector. A number of significant differences have been identified, especially in soil indicators where most of the research investment has been focused (Table 5). However it is very important to not interpret the non-significant differences between systems for some indicators as showing no real differences. Until a power analysis is completed for any particular indicator, we can not be sure whether there was simply not enough statistical power to detect even quite large differences that are nevertheless present between systems, or whether

actually little difference in that indicator exists out there on the farms. In the meantime our broad-brush approach at the meta-level leaves no doubt that the farming systems null hypothesis is often rejected for specific indicators, and the quasi-experimental design of the ARGOS study has successfully captured enough power to detect average changes between farming systems.

It is fundamentally important to distinguish between rejection of a null hypothesis of equivalent indicators between organic, IM and conventional farms, and an actual test of the original and more encompassing farming systems! The latter stated:  $H_0$ : *environmental outcomes from Organic, Integrated Management and conventional farming are the same*. This implies that different farming accreditation systems cause change in environmental outcomes [Moller 2004]. Causation is a necessary condition for our goal to evaluate (and help enhance) different pathways to sustainable agriculture in New Zealand. Our findings of average differences in indicators from different farming systems is indeed consistent with organic and IM farming systems causing environmental change. Indeed, had our initial three years of sampling accepted the null hypothesis of equivalent environmental indicators, ARGOS's environmental research job would already have been done – we could stop environmental monitoring and research secure in the knowledge that existing eco-verification and associate farming practices are not delivering different environmental consequences. First descriptions of several environmental differences has therefore helped settle part of a national debate in which protagonists and antagonists of alternative agricultural systems have variously asserted major differences, or no differences at all in environmental outcomes. A relatively high proportion of significant differences between systems has been found by ARGOS, so potential exists to now exploit these differences for strengthening market access and promoting national support for farmers and their land stewardship.

The remaining dilemma is that observed differences in indicators between farming systems may result from differences in the quality and values of the farmers themselves before they went into organic or IM farming; or that farmers seeking organic or IM accreditation already had land (or deliberately bought land) that was environmentally enriched before they imposed their new farming practices. Over and over our research has emphasized the huge spatial variation in environmental indicators within and between farms belonging to the same farming system. This is not surprising to ecologists, whose stock and trade is quantification of spatial and temporal variation in the abundance and diversity of life, and attempting to understand what drives that variation. Our farm-cluster research design has greatly assisted the power of statistical tests of the farm systems null hypothesis (many of the differences summarized in Table 6 are not apparent in ANOVAs that do not incorporate farm cluster as a 'blocking' variable).

Differences observed now in average indicators of farming systems can be interpreted as having emerged only since conversion, and therefore to have been caused by conversion, only if we can safely assume that all environmental indicators were the same on organic, IM and conventional farms at the time the former two converted. Several clues suggest that this assumption cannot be defended. If those farmers prone or predisposed to establish organic farming were already managing the land in a different way (for example, had promoted a diversity of native woody vegetation on their conventional farm), then the higher biodiversity currently present will not have been triggered by or caused by the organic farming protocols themselves. Similarly, if land is selected as already environmentally different and therefore suitable for organic practices or philosophy, change in indicators will not have been caused by the organic practices themselves. The original ARGOS research design sought to better identify causation of environmental impacts by including farms about to undergo conversion but this had to be abandoned because very few farms were considering this option. The

subsequent addition of the dairy sector has however given us an opportunity to address this specific issue in at least one sector.

ARGOS must now disentangle cause from simple correlation of indicators resulting from prior inherent qualities of the farmers or their land before reliable prediction is possible. If changed environmental outcomes are not caused by the accredited farming practices themselves, any accelerated adoption of eco-verification systems will not result in real environmental gains for New Zealand's production landscapes. Therefore ARGOS's environmental team will now adjust its focus to test causation of a smaller number of focal species and ecological processes that have been shown to differ between farming systems. Enlisting the help of the social and economic objective teams will be crucial in this quest, because they can help test causation by examining why farmers have chosen to convert, or set up accreditation on different parcels of land, and how the farmers' environmental subjectivities have changed through being associated with organic and IM eco-verification schemes and associated changed practices. In the meantime, our finding of a wide variety of average ecological differences between the systems is promising and offers the prospect of real gains in sustainability once we understand better why the changes are present, and which enablers and constraints must be managed and promoted nationally to trigger improved environmental, social and economic outcomes.

### **Intensification as a driver of different environmental outcomes between farming systems**

Intensification has been identified as a potential major threat to New Zealand agricultural sustainability [PCE 2004, MacLeod & Moller 2006]. Here we are broadly defining intensification by the volumes of nutrients and other 'ecological subsidies' applied per unit land area per year, and the rate at which food and fibre are removed per unit land area per year. However, confusion is created by how exactly intensification is defined by different disciplines, and consequently how exactly one might measure it. A widespread belief that ongoing intensification of agriculture is continuing to degrade biodiversity in New Zealand's production landscapes is apparently based partly on conflation of two issues: the whole-scale ecological change wrought by conversion of forests to pastoral farmland (when huge shifts in biodiversity were triggered), and ongoing degradation from 'pushing' the land harder to gain increased efficiency (normally defined as production or profit per unit land area). With the exception of farm intensification impacts on aquatic health and biodiversity, there is actually little evidence for the second driver [Moller et al. in press].

It is important that New Zealand ecologists find out whether ongoing intensification is indeed a driver of land and ecosystem degradation, mainly because intensification has been prolonged and is accelerating, and also because it is often asserted to be a keystone of New Zealand's international competitive margin against other agricultural commodity producing countries. Tight regulation of carrying capacity of stock in Europe is motivated by demand to cap intensification in the local environment. The prospect of stocking limits or nutrient input limits finding their way into eco-verification schemes is perhaps unpalatable for most New Zealand agricultural industries, and growing local concerns about ecological costs of ongoing intensification adds to the urgency for rigorous investigation of the intensification question.

ARGOS at this stage can only formally report on existing 'intensity' of farms, not on 'intensification' per se. Eventually the longitudinal study design can link current and changing levels of farming intensity to changes in sustainability indicators. At that point, perhaps 10 years from now, we can directly test drivers of the process of intensification and its putative consequences.

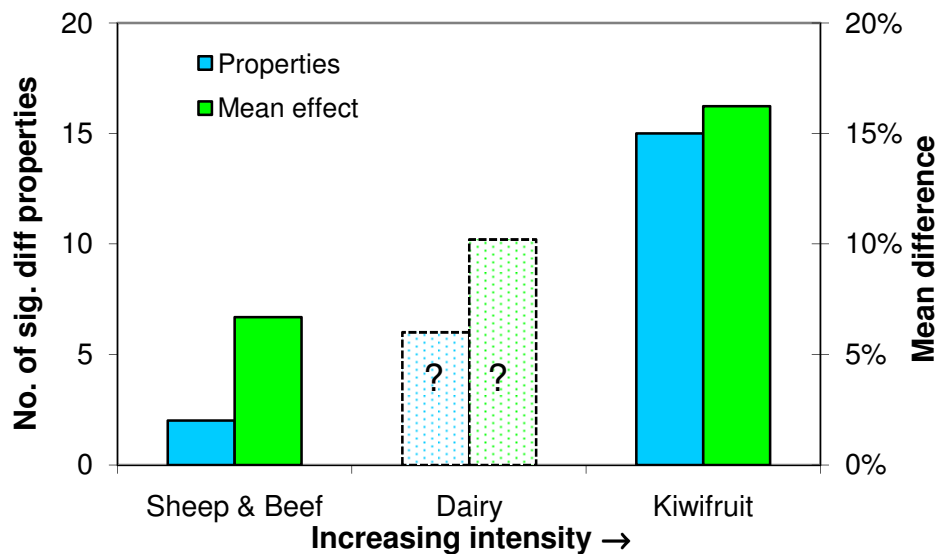


The ARGOS environment team urges that intensification as a potential driver of unsustainable outcomes becomes the major thrust of transdisciplinary fusion in the next few years of research, (i) beginning with a transdisciplinary debate of how to define and perhaps measure it; (ii) moving to comparing it across farming systems, sectors and between farms within each system; and (iii) evaluation of its environmental, economic and social effects by linking intensification metrics and qualitative variables to the sustainability indicators so far gained for all the ARGOS farms; before leading to (iv) transdisciplinary investigation of why intensification is such a permanent and pervasive feature of New Zealand farming; and (v) searching for practical ways to ameliorate any unwanted effects or threats to sustainability.

After rejection of the null hypothesis, the first major transdisciplinary meta-hypothesis could therefore be stated as: *H<sub>1</sub>: Agriculture intensification is a background driver of increasing risk and opportunity for the social-ecological resilience of New Zealand agriculture.* This could be tested first by relating intensity of different farm enterprises within each ARGOS farming system to their current sustainability indicator levels. Corollaries give rise to questions like: are more intensive farms more profitable and economically resilient? Are stress levels of farmers related to intensification of their farming operation? Does the amount and nature of the ecological refuges for biodiversity vary with intensification?

In calling for emphasis on intensification as a key driver of risk and opportunity for New Zealand agriculture, we are not advocating abandonment of the ARGOS farming systems null hypothesis. Indeed, if we are right in suspecting intensification is a key driver of outcomes, many of the system effects emerging from the ARGOS research may be explained. For example, a second meta-hypothesis across the entire study is that: *H<sub>2</sub> organic agriculture causes changes in environmental outcomes primarily by being less intensive.* This can be tested first by comparing average intensification indicators between farming systems in the same sector.

If H<sub>2</sub> is true, we might also predict that: *H<sub>3</sub> : The more intensive the agricultural sector, the greater the difference there will be in sustainability outcomes between organic, IM and conventional systems.* Kiwifruit farming is undoubtedly more intensive than sheep/beef farming; and we expect dairy farming to also be more intensive than sheep/beef; but transdisciplinary debate, definition and measurement of measures of intensity are now needed. We recommend this as an urgent priority in the transdisciplinary fusion across the ARGOS objectives. The relative intensification of dairy compared to kiwifruit farming in particular requires further study and clarification of terms. Our preliminary finding of more differences between organic and IM systems in kiwifruit (67%) compared to sheep/beef (25%) is consistent with H<sub>3</sub> (Table 6). This hypothesis can be tested by long term, more extensive and more equivalent comparisons of indicators across systems than we so far have mustered (Table 5 shows that the main comparable data sets are for soil systems and birds). The soil results in particular support H<sub>3</sub> ( Figure 16). However, the coarseness of the bird count method, or the confounding effect of wider variation in habitat amongst sheep/beef farms than amongst kiwifruit orchards could have further obscured real differences in birds on organic, IM and conventional sheep/beef farms. However, the comparative absence of differences in birds between farming systems in sheep/beef compared to kiwifruit is consistent with an ARGOS hypothesis that differences between farming systems will be greater for the more intensive agricultural sectors like kiwifruit.



**Figure 16:** Number of significantly different chemical soil properties between Conventional and Organic systems for each sector and the average size of the differences (expressed as a % change in either direction between systems). Results for dairy systems are notional, showing predicted future divergence as the BACI unfolds.

The Before-After-Control-Impact (BACI) experiment emerging within the dairy sector can also potentially provide a cogent test of H3. We would expect the number of significant differences between management systems to increase over time to a level between sheep/beef and kiwifruit in the intermediate-intensity sector (dairy) as the organic conversion farms commence full organic production.

More generally and simply, the greater variability and size of sheep/beef farms compared to kiwifruit and dairy farms may be driving the apparent differences in degree of differentiation of farming systems between sectors (Table 5, Figure 14). First ecological principles predict that ecological variability (and so variation in indicators) will be higher in the more varied topography and larger sheep/beef farms. It might therefore simply be that the ARGOS panel design has insufficient power to measure real differences within sheep/beef farms, but excellent power to detect them in kiwifruit. Future work will test this alternative explanation in opposition to H3.

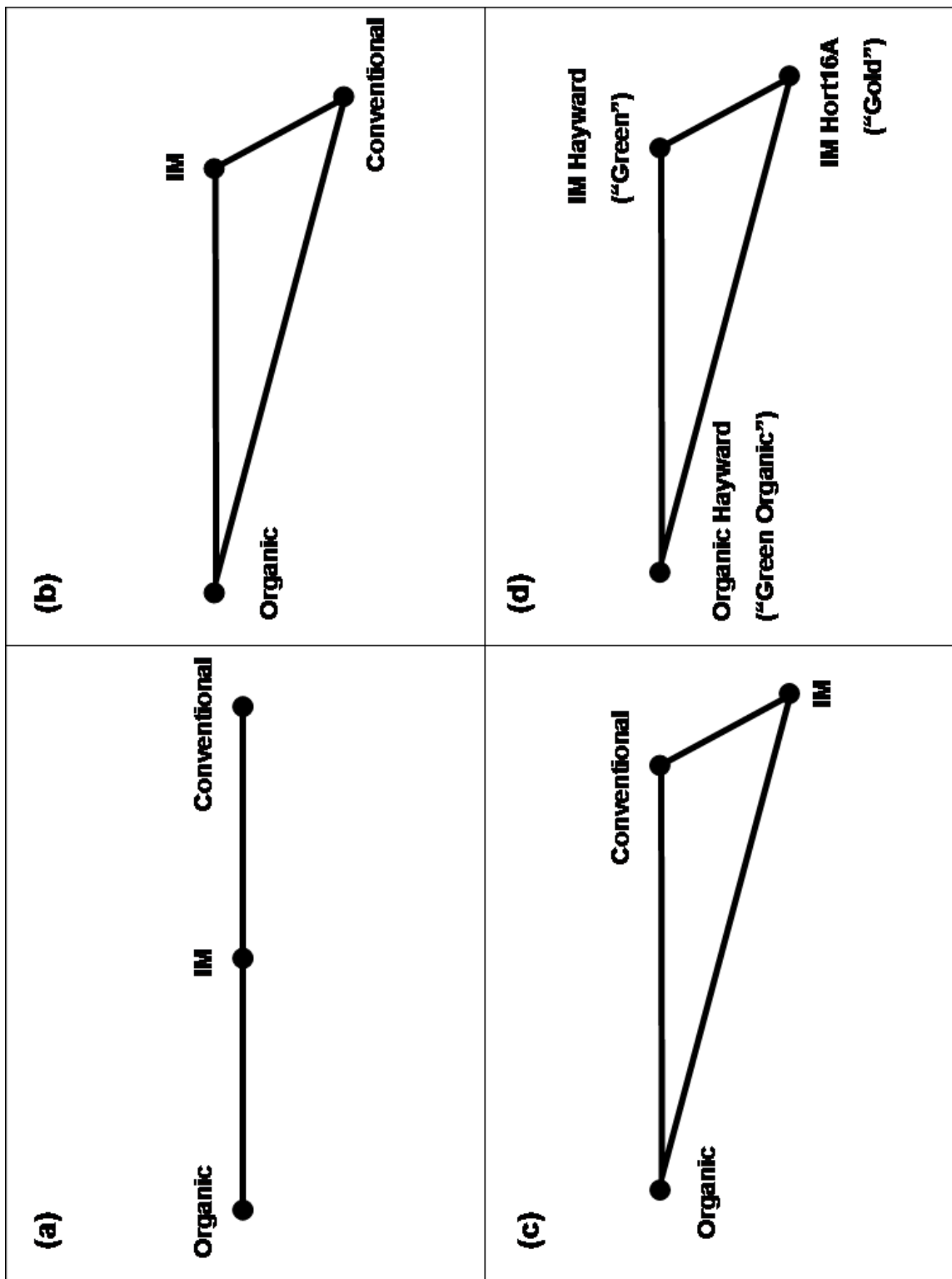
### **Clarifying the relative positions of conventional, IM and organic farmers**

Another way of unifying the findings of the different research objectives in ARGOS is to search for higher order pattern in features that may have little to do with intensification. For example, informal transdisciplinary discourse in the ARGOS team meetings has often implied that IM is in some senses an ‘intermediate’ approach to farming that is positioned between organics and conventional in philosophy and sustainability outcomes. This is vehemently opposed by some organic farmers who assert that you can not be “half-pie” organic: for them it’s a binary opposition and any protocols that are more ‘dilute’ than organic rules will undoubtedly trigger unsustainable farming. In trying to guide future farmers on the relative efficacy of alternative pathways to sustainability, we think it would be useful to examine the hypothesis that *H<sub>4</sub>: IM farming is intermediate in approach and outcomes between organics and conventional farming*. This could be tested by several multivariate and multidimensional

scaling methods using quantitative and semi-quantitative data. Complementary qualitative research methods, especially comparatively “thick” descriptions of particular farming families’ subjectivities and experiences can help verify and test the quantitative approaches. The emerging ARGOS experience is that each approach greatly helps the other. This can be depicted by multi-dimensional scaling as in Figure 17a based at this stage on completely notional data.

An early indication from the environmental indicators is that being organic is associated with much greater differences than being IM (Table 6). A useful post hoc hypothesis might be: *H<sub>5</sub>: Differences between organic and conventional, and between organic and IM are larger than differences between conventional and IM.* This can be depicted by multi-dimensional scaling as Figure 17b or, if H<sub>4</sub> is false, as in Figure 17c.

A full organic/IM/conventional experimental comparison was not possible within the kiwifruit sector because very few and probably atypical orchards remained unaccredited in some form of eco-verification scheme. After much debate, the ARGOS team substituted Hort16A kiwifruit (a separate species) as a second IM system. On purely ecological grounds then, we would predict that IM Hort16A ("Gold") will be very different in sustainability outcomes than IM Hayward ("Green"); and if H<sub>4</sub> is true, the outcome will be as shown in Figure 17(d)."



**Figure 17:** Notional multi-dimensional scaling of farming systems to evaluate the relative positioning of organic, IM and conventional farmers/growers.

**Table 6:** Summary of significant differences between management systems for ARGOS sheep/beef, dairy and kiwifruit sectors.

*For each biological system, the table indicates whether any significant differences were found, and in brackets the number of significant test results and the total number of tests performed in that system. For example, 21 tests of differences between management systems were conducted on soil chemistry for sheep/beef and dairy farms, and 15 on kiwifruit orchards, and 8, 4 and 13 significant results were found for sheep/beef, dairy and kiwifruit respectively. Farms are only currently undergoing conversion to organic production in the dairy sector, so the proportion of significant differences may change as farms achieve full certification and follow organic management for a number of years.*

Increasing “intensity” →				
		Sheep/beef	Dairy	Kiwifruit
System		Difference (count)?	Difference (count)?	Difference (count)?
Soil	Chemistry	Yes (8/21)	Yes (4/21)	Yes (13/15)
	Biology	Yes (2/5)	Yes (1/5)	Yes (3/10)
	Structure	No (0/5)	No (0/5)	Yes (4/4)
Terrestrial invertebrates	Pests	NA	NA	Yes (2/3)
	Beneficials	NA	NA	Yes (5/5)
	Insects/mites	NA	NA	Yes (7/12)
Terrestrial vertebrates	Birds	No (0/3)	Yes (1/4)	Yes (1/3)
	Bats	No	NA	No
Aquatic ecosystems	Physio-chemical	Yes (3/19)	Yes (2/19)	NA
	Periphyton	Yes (1/2)	No (0/2)	NA
	Insects	Yes (1/4)	No (0/4)	NA
	Vegetation	No (0/2)	Yes (1/2)	NA
Landcover	Within farm	NA	No (0/3)	Yes (1/2)
	Surrounding landscape	NA	No (0/4)	NA
Total significant differences/ total investigations		15/61	9/69	36/54
Percent of significant differences		24.5	13.0	66.7



## **Conclusion: Progress so far and priorities for the next two years**

An extensive environmental monitoring and research framework has been established over 105 farms in 5 sectors. Baseline ecological surveys and landuse mapping has been completed to allow augmentation and measuring of changes on the farms over the next 30 years for a powerful longitudinal study of sustainability indicators. We have (i) trialed and compared the cost-effectiveness and scientific robustness of techniques, (ii) abandoned some proposed monitoring methods altogether because they were not practical, (iii) trimmed others now that reasonably consistent results have been found in a second cycle of monitoring. This will now allow investment priorities to be readjusted by:

- Sampling less frequently where indicators are stable
- Focussing sampling on key variables
- Restriction of attention to focal species as industry flagships (eg. fantails), ecological indicators (eg. cicadas, spiders, soil microbes, birds) and ecological keystones (eg. earthworms)
- Digging deeper in areas of particular interest or importance for resilience, or where early results have demonstrated likely panel effects
- Shifting emphasis to discovery of why ecological indicators differ (thus far we have only being able to concentrate on what differs)
- Testing causation of change from the organic and IM market accreditation schemes
- Expanding inquiry into different spatial scales (thus far most indicators have been assessed at whole farm scales and reported as means – the variation in indicators in different parts of each farm, and in the wider landscapes within which each farm is situated will be the next emphasises)
- Grounding components of our research in more direct and tactical outcomes (eg. like the weed research example) now that the bigger picture discovery framework is in place
- Moving more from an ‘external assessor’ (passive observer) role to a more active ‘involved assistor’ role where we will give more direct environmental advice to farmers and study why that advice was or was not useful (a Participatory Action Research framework)
- Providing more structured help and education outreach tools for the agriculture/industry sectors’ facilitators
- Consideration of transdisciplinary needs and emphasis to better assist the overall project

The latter of these goals is expected to generate a quantum leap in excitement, surprise and innovation. Our somewhat ‘thin’ but ‘extensive’ ecological sampling approach is unusual for ecological research of this nature in New Zealand. Design of the study was partly a compromise to match available funds, but also a deliberate choice to match the potential capability limits of farm management, economics and social researchers all struggling with similar resource constraints. We expect that what we have lost in depth of the environmental research we will have more than gained from the transdisciplinary fusion that will now be possible, and the strong replication at the whole farm enterprise level. It is the individual farming family and owners that is likely to be the key site of action to trigger (or stall)

changes for improved social-ecological resilience and sustainability. In the meantime we are confident that the environmental sampling framework itself has delivered sufficient power to at least detect major shifts in sustainability indicators even in its first 3 years of field sampling – and increased power from the future longitudinal study should allow discovery of even smaller steps in alternative pathways to more sustainable primary production in New Zealand.



## 4 ACKNOWLEDGEMENTS

Jeff Reid and Andrea Pearson (Crop & Food Research Limited), David Steven (IPM Research Ltd) and Amanda Phillips (The Agribusiness Group) were earlier contributors to the ARGOS environmental research programme. We are grateful for their vision and advice and continue to reap the rewards of their inputs to the fundamental design of the ARGOS sampling frame.

We thank David Wharton (UoO Zoology), Jim Williams (UoO, Te Tumu), Nigel Bell (AgResearch) and Roger Littlejohn (AgResearch Statistician) for supervision of student thesis work that has contributed to this report.

ARGOS environment team field work has been greatly assisted by the the energy and sweat of several research students, Vacation Bursars, agriculture student Interns, seasonal wage workers and volunteers, and we thank them all. These included: Anna Lucock, Bevan Cameron, Caela O'Connell, Dean Clarke, Eloi Thibault, Erin O'Neill, Francesca Buzzi, Gaia Gnanalingam, Jennifer Techer, Jeroen Lurling, Jess Seipe, Jessica Lach, Jo Wright, Julia Haggerty, Kate Hewson, Louise Davidson, Natasha Percey, Marcia Green, Marion Mondot, Mark Haggerty, Noemie Opatowski, Robin Mitchell, Sharon Lucock, Steve Rate, Susan McGuire, Suzanne Burns, Tracey Dearlove.

David Lucock and Jayson Benge are actually stationed in the Farm Management objective of ARGOS. We would prefer to redefine them as our field ecologists and gain the credit for their energetic and professionalism that underlies the results synthesised here! They are key authors of this report while being funded from Objective 1. The anchors in that support team are Martin Emanuelsson and Jon Manhire who have advised and grounded our research efforts, helped with interpretation and supported us through the thinner moments of the first 4 years of ARGOS work.

ARGOS is funded mainly by The Foundation for Research Science and Technology by award of a Public Good Science Fund grant (AgRB-0301) and provision of a Postdoctoral Fellowship for Marion Johnson (and now Yuki Fukuda who will start in September 2007). Substantial extra financial support has been provided by the ministry of Agriculture and Forestry Sustainable Farming Fund (Grant numbers L05/002 and L05/003), Fonterra, a private meat packing company, ZESPRI International Ltd, the Certified Organic Kiwifruit Growers Association, Meat and Wool NZ and Merino New Zealand Inc. The University of Otago has also contributed enormously by provision of four Vacation Bursaries for student training while placed in field teams, waiving overheads to allow Tanja Maegli to provide GIS support and Sarah Richards to help manage the research team.

Our order of authorship is reverse alphabetical by Christian name. This choice is partly to combat Zed-ism, but mainly to reflect a spirit of full team work that has characterised the objectives first four years.



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