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ENVIRONMENTAL MONITORING AND RESEARCH FOR IMPROVED RESILIENCE ON ARGOS FARMS

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EXECUTIVE SUMMARY

This report outlines a rationale for proposed environmental monitoring on 136 farms participating in the Agriculture Research Group on Sustainability (ARGOS) project. A transdisciplinary research team of around 20 researchers, including sociologists, economists, farm management experts and ecologists will assess the sustainability and socio-ecological resilience of farms and orchards participating in organic, Integrated Management (IM), conventional farming systems and Māori farming systems. The farming sectors represented range from (i) high-input:high-output agriculture for dairy and kiwifruit production (mainly in North Island New Zealand), through (ii) medium-input:medium-output sheep and beef farming on the plains or rolling low hill country of South Island, to (iii) very low-input-low-output sheep/beef farming in the South Island High Country. A parallel study of Māori land use and sustainable development amongst Ngāi Tahu Rūnanga will include a variety of other farming approaches. A meta-analysis over all farm sectors and farming systems will attempt to identify key drivers of change and barriers to improved resilience. Researchers will monitor social, economic and environmental changes on farms over the next 20 to 30 years as part of an 'independent assessor' role, but they will also seek to help the participating farmers improve the sustainability and resilience of their enterprise by acting as 'involved assistors'. This report identifies fundamental approaches and ecological processes to be researched mainly from an ecological point of view. Subsequent discussions amongst the whole ARGOS team are likely to adjust the priorities to get the maximum advantage from our expert sociological, economic, farm management and Māori colleagues.

The fundamental stance of the research team is that a systems approach is needed to understand and help manage farming and farmscapes. This allows for transdisciplinarity, multiple scales, incorporates uncertainty, includes the farmer's local knowledge and sees people as embedded within nature. Some of our specific research questions focus on understanding smaller parts of the problem, but the overall research project will be holistic in approach and application – otherwise we see no prospect of really helping farmers, their families and communities, their land or New Zealand. We prefer to guide the programme with 'Resilience Theory' rather than sustainability theory, because resilience shifts emphasis from study of ecosystem vulnerability to discovery of what makes socio-ecological systems strong enough to withstand perturbations by new threats. Rather than aiming for some mythical fixed goal of 'sustainability', which is defined very differently by different stakeholders, the goal is to aim for robust farming systems that can go with change or be taken in new directions by future generations of New Zealanders.

The major opportunity for NZ biodiversity conservation in the new millennium is 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 will flourish in greater variety and abundance than in upland national parks, provided they are appropriately managed in an integrated way with profitable and sustainable agriculture. There is every prospect that many threatened species, especially cryptic invertebrate taxa and rare plants can by nurtured on working farms. Ecological flows between reserves and production areas can either help or hinder national efforts to reverse the decline of indigenous biota. The aim of this research is to convert farmed landscapes from 'sinks' (areas where recruits from nursery areas can not survive long enough to replace themselves) into 'sources' (areas with viable populations that export excess offspring to surrounding areas). Current conservation research and management predominantly focuses on reserve areas, whereas for some species that effort may be undermined by unmanaged flows across reserves to the production part of the ecological matrix. The high level goal to reverse New Zealand's declining biodiversity must therefore use complementary strategies for

stewardship of both ‘natural ecosystems’ and surrounding more modified landscapes. ARGOS seeks to water the biodiversity desert (production land) as the key means of supporting the vulnerable oases.

A critical barrier to successful deployment of environmental restoration activities is the current barrier between multiple users of farmland and the actions of environmental scientists and environmental agencies. Our team wants to help farmers and kaitiaki assert their rightful place as stewards of the land and build their capacity to make a huge contribution to reducing the present decline of indigenous biota. ARGOS will also focus on defusing a damaging divide between some regulatory agencies and farmers by facilitating dialogue, sharing information and creating tools that build mutual respect and co-operation between land owners, regional councils and national institutions (MAF, DoC, MfE).

Ecological processes and biodiversity on New Zealand’s farmed landscapes has received very little study so far because most environmental endeavour has been focused on threatened species and Protected Natural Areas. We can not effectively manage a system that we do not understand. Therefore we need to invest time and resources into studying general ecological processes in agro-ecosystems rather than simply monitoring the effects of different farming systems. We propose that 20% of resources are dedicated to researching ecological processes in years 1 and 2; 30% in years 3 and 4; and 40% in years 5 and 6. This allows the basic monitoring systems for sustainability and resilience indicators to be tested and perfected, before gradual escalation of research into understanding why the indicators are or are not changing. Identifying the reasons for the observed changes or lack of them is the key to better advice on how to bring the desired improvements in sustainability and resilience.

The first step is to complete baseline ecological surveys on the ARGOS farms to learn what we have to work with. A baseline survey of landforms and habitats will be supplemented by biodiversity surveys of bats, birds, lizards, frogs, fish, insects, soil biota and plants in the first two years. These surveys will also test monitoring methods, so that by year three we can select a small group of ‘focal species’ for efficient long-term monitoring. These will be species judged to be particularly important to farming and ecological processes in farmscapes, for example species that provide ecosystem services (pollination, soil formation, predator biocontrol, seed dispersal), ones that are important pests, or ones that are especially loved and valued by the farmers or kaitiaki (‘flagship’ or ‘taonga’ species). We can not possibly measure all the biodiversity on farms so it is important that we choose focal species that are practical to measure, reasonably common and widespread, and particularly sensitive indicators to ecological practice. Naturally we will focus on species that are most likely to respond to conversion from conventional to IM and organic farming. A check for threatened species is very unlikely to find any, but if they are present, special monitoring and management will be put in place to support the farmers to find ways to nurture the populations without undue disruption to normal farming practice. We will invest 70% of our monitoring and research on supporting ‘agricultural biodiversity’, i.e. the plants, microbes, fungi and animals that have some direct role in affecting crops or livestock. The remainder will focus on general biodiversity on farms.

Initial surveys of landforms and habitats will create maps of each participating farm and key features (shelterbelts, fences, houses, drains and streams etc.). These will provide baselines from which to monitor future changes. Remote sensing imagery will be ‘ground-truthed’ and then used to derive long-term indices of habitat complexity and diversity. A Geographic Information System (GIS) and database of all ecological descriptors will be generated to facilitate consistent long-term monitoring and analysis of environmental changes of farms by a research team that is itself likely to change.

Lizards will be monitored using directed searches, pitfall traps of use of ‘Lizard Lounges’ (tiles and overlayed corrugated sheets which we provide for the lizards take cover in). Birds and bats

will be surveyed in spring and early summer when most species breed so we can better distinguish residents from seasonal visitors to farms. Small introduced mammalian predators (cats, ferrets, stoats, weasels, rats, mice, hedgehogs) will also be monitored because they potentially reduce the numbers of some native animals on farms, or even eliminate some altogether. If our feasibility study confirms it is practical and funding can be found, we will control these predators for three years on farms with high habitat diversity and structure, and other farms with low habitat diversity and structure, and then monitor whether the native animals respond. The aim is to determine whether the main way to get more native animals onto working farms is to create more suitable habitat, or to control predators, or to do a mixture of both.

Pest and beneficial insects will be monitored, and the effectiveness of current control will be measured with a view to making control more cost effective and less harmful to beneficial insects. We will also measure a general index of the abundance and diversity on night-flying insects on farms.

Wetlands and stream quality will be monitored on ARGOS farms. If funding can be found, we will measure the maximum amount of nutrients, sediment and pesticides that can find its way into streams without there being significant harm to stream invertebrates, fish and downstream values. If farming is shown to discharge more than these 'ecological damage thresholds' we will work with farmers to find ways of reducing inputs in future. The feasibility of restoring native fish and native crayfish to farm streams will also be researched.

Soil health monitoring and research will be a very high priority in the programme. This is because good soil quality is the key to sustaining production, livelihoods and diverse and abundant ecological communities on farms. Soils and associated microbes and animals are also the fundamental pedestal across all farming sectors and farming systems, so it provides a common ground to compare across all the ARGOS farms. Standard soil physical and chemical measures of topsoils will be supplemented with Visual Soil Assessments to track general changes in soil condition. Assays of microbial activity will index the vitality of the soils cycling processes. Altogether nearly 17,000 measurements of soil will be taken in just one years' soil survey of kiwifruit and lowland sheep/beef farms.

If further funding can be secured, ARGOS will use a standard and simple 'bio-assay' of soil quality that works by comparing the growth rate of standard plants grown in glass houses under constant conditions in the soil gathered from different ARGOS farms. This technique puts the samples onto a 'level playing field' so the relative quality of the soils can be measured. Other additional soil research would measure the standard soil characteristics at deeper parts of the soil profile and tests the ability of soils to breakdown standard substrates (measures of the soil food webs and cycling rates).

Regular year-round measures of pasture standing crops will be supplemented by less regular measures of pasture production and sward composition. The latter will monitor herbaceous weeds, but the more woody weeds will be assessed from baseline habitat surveys and remote sensing.

A prioritised ARGOS ecological research agenda has been drawn up that characterises management and investment levels into *'Core Projects'* (essential for ARGOS agenda and funded and done entirely by our team), *'Priority Partnerships'* (other larger need-to-know answers but where additional funding and expertise is needed to do the research), *'Partnerships'* (nice-to-know answers where ARGOS gives limited resources, logistical support to other researchers and students), and *'Support projects'* (other researchers and students get access to data and farms). Projects are ranked mainly on their importance (less so their urgency) for achieving the ARGOS goals, their transdisciplinary strength, ability to test differences between

farming systems, and the chance that they will be successfully completed to support the farmers and biodiversity on their land. Already 34 desired research topics have been identified. The top eight research themes (first as most important) from an ecology perspective are:

1. Evaluation and refinement of environmental indicators
2. Gathering historical data from farms
3. Adding soil quality and biodiversity predictions to the Lincoln University Trade and Environment model (an economics model that assesses the impact of market access policy changes, global economy trends, conversion to organics or IM etc. on New Zealand farmers)
4. Shelter belt management
5. Development of whole-farm biodiversity plans
6. Working from land use capability and ecological potential assessments of different parts of the farm, identify changes in land use that can simultaneously improve economic return and social and environmental values of the whole farm enterprise.
7. Assess the options for creating small reserves from grazing on farms, or ways of adding ecological value to existing ones
8. Modelling soil processes.

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Acknowledgements

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1. Goals, Guiding Concepts and Overall Design

1.1 Goals of the Agriculture Research Group on Sustainability and need for monitoring Environmental Changes on farms

The Agricultural Research Group on Sustainability (ARGOS) is an unincorporated joint venture between the Agribusiness Group, Lincoln University, and the University of Otago. It is funded by the Foundation for Research and Technology (FRST). ARGOS has started a programme to examine the environmental, social and economic sustainability of New Zealand's farming systems. A better understanding of the environmental effects, and the social and economic consequences of different farming practices will help New Zealanders and their land-use systems achieve more appropriate and enduring accommodations with the New Zealand environment. The goal of ARGOS research is to facilitate innovation and performance in primary production systems and to maintain or create multifunctional landscapes, where people and their actions are rooted in, rather than grafted on to, the New Zealand environment.

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The project has secured 'long-term' funding for six years from FRST as a first step in a 20 to 30 year project.

ARGOS will investigate the environmental, social and, economic effects of farming within five different farm[1] '***sectors'***: (i) lowland and hill country sheep and cattle farming in South Island (Te Wai Pounamu), (ii) kiwifruit farms situated mainly in the Bay of Plenty, North Island (Te Ika a Maui), (iii) a variety of types of farming on Ngāi Tahu land holdings in Te Wai Pounamu (Reid 2004) [2], (iv) 24 dairy farms from the Waikato and Taupo region (to be added to the study in 2005/06, along with (v) at least 8 High Country sheep/beef runs spread between Marlborough and Southland.

Within each sector, '***clusters***' of farms are arranged in matched pairs or triplets, each with a different '***farming system***'[3]. For the sheep-beef farm sector there will be replicates of three different farming practices: '***conventional***', which in the context of contemporary land management will act a control; and two alternative management strategies, '***Integrated Management'*** (IM) and '***organic***'. The kiwifruit cohorts will be an IM (Zespri Green™) and certified organic Hayward growers and IM Hort 16A (Zespri Gold™) crops. Half the dairy farms will be organic, and half conventional. The exact nature of the differences between farming systems within the High Country and Ngāi Tahu farms is yet to be determined, so planning monitoring on these holdings has not yet been possible and is given scant regard in the remainder of this report. If parallel monitoring is wanted by the kaitiaki, many of the protocols outline here may be appropriate for He Whenua Whakatipu and some Māori indicators or research topics can potentially be extended onto the kiwifruit, dairy and sheep/beef farms already identified.

Organic farms follow strict protocols laid down by Bio-Gro or CertNZ that use no artificial fertilisers or pesticides. Integrated Management follows a somewhat more varied protocol where a wider range of chemicals can be applied but inputs are minimised by a variety of strategies (Wharfe & Manhire, 2004). A major part of the ARGOS programme centres on testing the '***farming systems null hypothesis***' that is, that there are no differences in environmental, social and economic outcomes between organic, integrated, conventional and Māori farming. This test will evaluate whether either one provides a more effective pathway to sustainable land use in New Zealand.

An ***Integrated Pest Management*** (IPM) approach is part of the wider IM approach being followed by some growers. It claims to result in a more sustainable management of pest populations, thereby preventing pest outbreaks occurring to damaging levels (e.g. Smith *et al.* 1997, Way and van Emden 2000). Similar claims are made for organic systems, such as "Internal balance and stability of an organic system will be achieved by fostering the beneficial processes and interactions that occur in natural ecosystems thereby minimising reliance on external control measures." (Bio-Gro 2001). Neither side has substantiative evidence that such more sustainable management does in fact occur, although it is based on the logical premise that improved biological control reduces the need for other interventions (*loc. sit.*).

The ARGOS project provides a unique opportunity to test these assumptions over the extended time period necessary. To achieve this both the principal pests and the beneficials attacking them would need to be monitored on ARGOS farms.

The scope of the environment team's research of agriculture on Māori land holdings will not be known for another year or so when the kaitiaki will have completed their project plans.

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[1] 'Farm' is used as generic terms for farms and orchards in this report, and 'farming' refers to pastoral, cropping and horticulture.

[2] This part of the project is called *He Whenua Wakatipu*.

[3] We have fallen in to calling these cohorts, but this is a hang-over from the initial plan to follow three cohorts within a BACI design. Farming systems is not a very satisfactory term either – can the group please discuss this and settle on a fixed term to embed it from now on?

In future years converting farms will be included to test whether the change in farm practice associated with IM and organic certification actually caused the differences we may observe between already converted and control farms (Fairweather & Moller 2004). This experimental test uses a Before-After-Control-Impact (BACI) design.

The protocols described in this report will be broadly applied to allow as many comparisons and generalisations between farms as possible, but some adjustment of sampling to ecological conditions and scale of farm management within each farm sector and farm system is inevitable.

Environmental sustainability issues will be researched as Objective 4 of the overall ARGOS project (refer to contract). This 'Environmental Changes on Farms' objective will help answer some of the questions pertaining to approaches to, or departures from sustainability, specifically in terms of the different farming systems and management practices studied in the ARGOS project, and more generally, with respect to the sustainability of New Zealand's agricultural systems. ARGOS Environmental Changes on Farms research questions include:

- Whether IM, Organic, Conventional or Māori farming leads to similar or different sustainability outcomes.
- What are the pressures on different agricultural landscapes and their component ecosystems?
- Are the qualities and quantities (i.e. states) of different agricultural landscapes and their component ecosystems changing?
- What must be measured in the long-term?
- What are the key indicators of environmental sustainability and how are they best monitored in the long-term?
- What degree of environmental change matters in environmental terms?
- What degree of environmental change matters in social and economic terms?
- Where and when is it particularly important to intervene for sustainability gains?
- What are the main barriers to improved management of the farm environments and how might they be removed?

Policy formation and adaptive management would be aided if a group of environmental indicators can be delineated to monitor progress and consequences of various interventions. A proximate goal of our research will be to develop, test and, if necessary refine a practical set of environmental indicators for New Zealand primary production landscapes. The ARGOS monitoring programme must match and complement the agriculture sustainability indicators used by EUREGAP, OECD, and several food distributors in Europe, USA, and Asia. However, ecological processes and management priorities are in many respects very different in New Zealand compared to overseas (Perley *et al.* 2001). ARGOS environmental sustainability indicators may therefore reframe or augment those required to meet overseas market demands.

1.2 Structure and aims of this Report

Section 1 of this report now introduces the background conceptual framework that guides the environmental monitoring and research, outlines criteria for selection of 'focal species' for longer-term and more intensive research, and briefly describes some general research tools (e.g. geographic information databases from satellite imagery, use of photo-points). Section 1 describes the aims and methods of a baseline ecological survey of habitat on ARGOS farms. Descriptions of specialised sampling protocols for terrestrial vertebrates and invertebrates are included in Sections 3 and 4, aquatic biodiversity and wetland health in Section 5, soil health in

Section 6, and farm management in Section 7. The report ends with a general discussion and prioritised future research agenda (Section 8).

Some sections of this report (especially sampling strategies) will eventually be shifted to a more detailed set of field manuals written to complement the strategic overview presented here. They are needed to link database entries to precise field sampling protocols so that new people in the team in years to come can reliably interpret the historical data. In the meantime the overview given here will help students, newly appointed postdoctoral fellows, and other short-term contributors to grip the overall context into which they will fit their more specialised environmental research. More immediately, this report can help the lead researchers in all the disciplines forge a trans-disciplinary design for the project as a whole.

In 20 years time, when the project may have a very different form, this document will probably offer a hilarious eulogy to best made plans gone bad – but hopefully also a background insight into why particular design was chosen. We need to remain flexible and adjust research priorities as our own discoveries or external perturbations dictate.

1.3 Agro-ecosystems

An agro-ecosystem is a socio-ecological system, encompassing both cultural and natural relationships. The concept of a socio-ecological agro-ecosystem relates closely to the concept of 'ecosystem management' (Grumbine 1994, Christensen *et al.* 1996, Park 2000) where ecosystems are understood to be complex and dynamic, organised across different hierarchies in space and time, and with humans as integral ecosystem components. Ecosystem management itself is based on an emerging paradigm that encompasses landscape ecological processes and hierarchical interactions rather than the 'balance of nature' paradigm (Wu & Loucks 1995).

Patterns on a farm are the product of processes interacting on it, the farm surroundings and beyond. Every farm is a place; a location invested with multiple meanings, which can be described by ecologists and the farmers themselves in terms of local or regional landscapes, watersheds, and bioregions. The ARGOS farm monitoring will emphasise a landscape approach as one level of analysis within the wider Agro-ecosystems paradigm. Landscape is defined as "... a spatial configuration of patches of dimensions relevant for the phenomenon under consideration" (Farina, 2000: 295). Patches are defined as discrete elements of a landscape which occupy a bounded area on the Earth's surface and which have structures and compositions different from adjoining areas (Farina, 2000: 46). Patch sizes can range from a few millimetres to thousands of hectares depending on the functional ecological scale for a given organism, population or community. The lifespan of a patch can range from a few seconds to many years.

Within such a landscape systems perspective, any existing environmental attribute on a farm may be explained by any one or combination of four domains (or subsystems):

1. On-farm and surrounding *landform* on various scales
2. On-farm *soils & climate*, with particular regard for microsites
3. Farmscape and surrounding *landscape ecological patterns and processes* on a variety of hierarchical scales, both 'upstream' and 'downstream' of the farm, both historical and current; and,
4. Historical and current on-farm and surrounding *farm management practices*, on various spatial scales down to microsites.

Each of these domains are complex systems in themselves. All interact through a web of cause and effect within the whole agro-ecosystem. For example, the landform in combination with the

vegetative patterns may influence the choice of particular farm management practices, which in turn may influence farm soils, microclimate, even landform; eventually completing a feedback loop to influence some future state in landscape vegetative pattern, etc. – which then further influences management. Such a complex system is characterised by: the inseparability of culture and nature; dynamism; complex relationships (processes) between parts (or subsystems); varying sensitivity to initial conditions; multiple hierarchical levels of organisation (Bergandi 2000); the 'emergence' of specific new characteristics between hierarchies not explainable by analysis of component parts (Odum 1971: 5); chance and indeterminism; self-organisation through feedback processes; and non-linear reactions.

This is not a complete representation of the agro-ecosystem. *Human values and learning systems* are integral to choice of management practice, and these values and management practices change in response to knowledge and environment. In addition, wider *socio-political* and *socio-economic* drivers and pressures – operating at scales extending from family, through local, regional, national and global influences – also influence human actions. They act on agricultural environmental performance through their direct and indirect influence on choice and implementation of farm management practices. A conceptual representation of the complex relationship between subsystems in the agro-ecosystem is provided in Figure 1.1.

The goal of a socially-inclusive sustainable land management requires a systems perspective to grapple adequately with the complexity recognised above. A systems approach is associated with a number of additional attributes. Some of these attributes as they relate to socio-ecological systems are outlined in Table 1.1 below.

A particular challenge issued by a systems approach is that land cannot be considered as discrete bits, treated in isolation from its wider context. Ecological processes occur across property boundaries, and many of those processes have a cultural component. A systems approach recognises the inseparability of culture and nature, and also recognises that land cannot be allocated in areas where the primary purpose is either economic or environmental. The so-called productive lands have an essential ecological role within a landscape context (Norton 1998; Knight 1999, Norton 2000). Unfortunately, mechanistic assumptions underlie New Zealand's current 'allocative' model of environmental policy where land is thought of as *either* providing solely ecological functions in exclusion from social and economic functions, or conversely as providing solely economic functions in exclusion from environmental, and often social, functions. This current allocative model is highly criticised (Norton 1998; Craig *et al.* 2000, Perley *et al.* 2001, Perley 2003) as being a source of conservation under-achievement. This problem arises because the allocative model is underpinned by a false set of assumptions about the way the environment works, and the way culture interacts with that environment. The ARGOS team will instead use an 'integrative' model where any one piece of land is recognised as having potential ecological, social and economic functions. In addition, an important recognition is that cultural activities – including the harvest and use of outputs from the land – are not necessarily harmful toward the environment. Use and protection can be part of one approach to land management (Botkin 1990), rather than viewed as mutually exclusive goals on discrete areas of land.

Table 1.1. Comparisons of systemic and mechanistic approaches to ecology and management.

Attribute	*Mechanistic/Analytical*	*Systemic/Integrative*
Philosophy	Narrow & targeted Disproof by experiment Teleological/Deterministic	Broad & exploratory Multiple lines of converging evidence Indeterministic/stochastic
Perceived Organisation	Biotic interactions Fixed environment Single scale Focus on components/entities	Biophysical interactions Self-organisation Multiple scales with cross-scale interactions Focus on processes/relationships
Causation	Single and separable	Multiple and only partially separable
Uncertainty	Eliminate (reject) uncertainty	Incorporate (accept) uncertainty
Human-Nature relationship	Culture separates *Homo sapiens* from nature	*Homo sapiens* part of and embedded within Nature
Decision making	From authority down	Incorporating local knowledge

Partly sourced from Holling 1998 & Callicott et al. *1999*

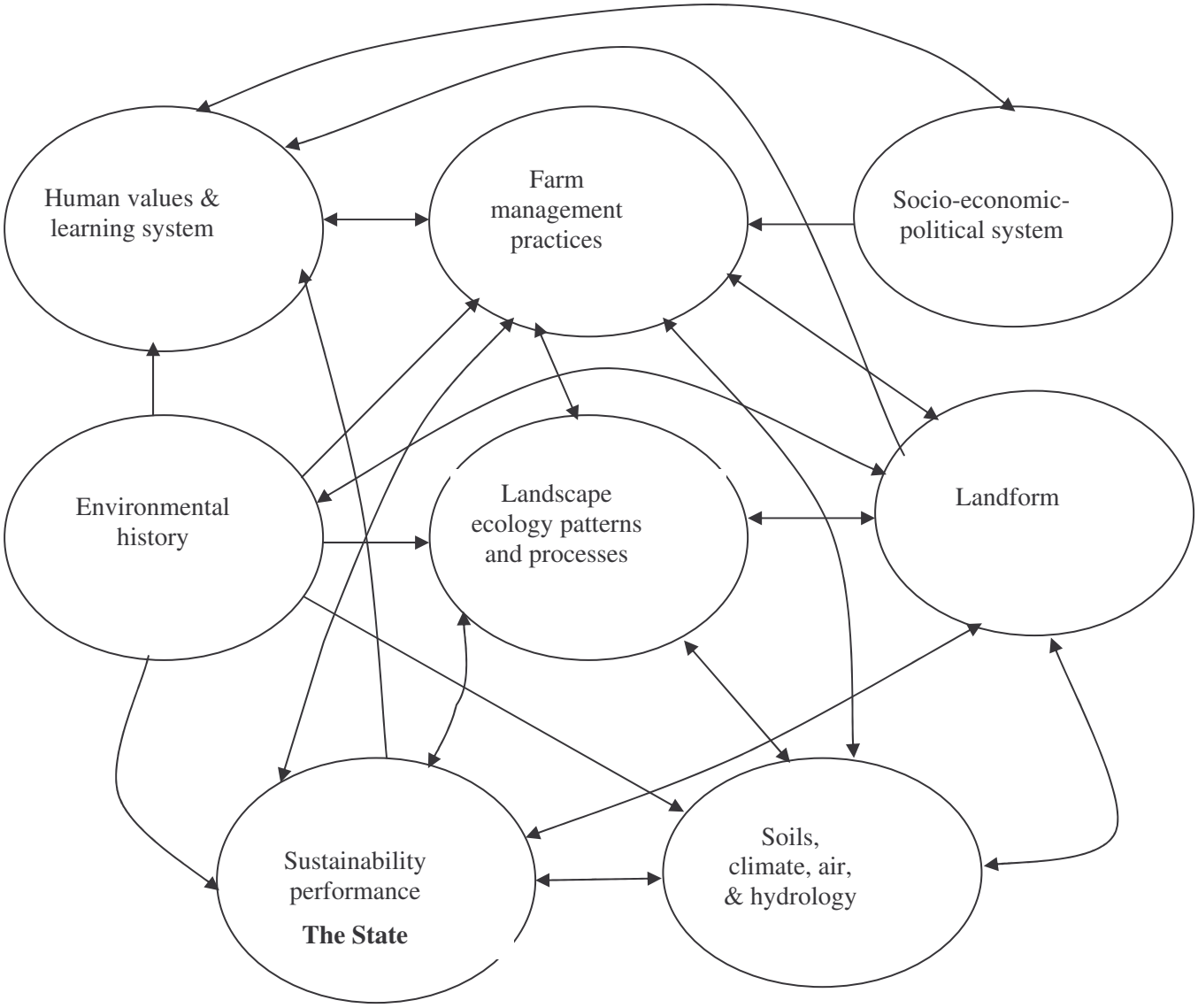

Figure 1.1. The Agroecological system: domains and interrelationships.

This report and our research on environmental variables *per se* must therefore be joined to economic and social research objectives as soon as possible. The ARGOS team must anticipate the transdisciplinary linkages that will be of most interest (Moller 2004b) and if necessary augment or substitute the environmental monitoring described here. Once ARGOS's detailed sociological and economic research results are available, many changes in environmental monitoring should occur. Similarly the Māori research will add a further cultural dimension and texture to the social agenda in ways that force changes in environmental monitoring. A need for flexibility must therefore be built into all of ARGOS's institutions and research planning.

1.4 Balancing investment in monitoring compared to research of ecological processes

An immediate goal of ARGOS is to compare the sustainability of conventional, IM and organic approaches. However, it is also committed to discovering determinants of sustainability in general, irrespective of farming sector and the particular type of farming being applied. Several of these 'bigger picture' issues raised in this report relate most directly to these general determinants of sustainability or understanding the ecological processes at work on all farm cohorts. They potentially divert time and financial resources to the extent that a less powerful test of differences between organic, IM and conventional agriculture can be achieved by the ARGOS research. Nevertheless, we see considerable advantages in mixing research and monitoring rather than simply focussing on monitoring environmental changes between farming systems: for example,

- Understanding the underlying ecological, economic and social processes will focus where to search for differences between farming systems, how to interpret them and how best to test causality. For example, we need to know if the presence of a forest patch near a farm might alter natural levels of insects on the farm. If such a patch is present near the conventional but not the organic farm in a cluster, any effect of conventional agriculture per se would be obscured. Therefore we need to factor out these important confounding variables in order to test the farming systems null hypothesis more effectively, and this demands research and understanding of the ecological processes and patterns.
- The IM/organic/conventional comparisons of the study is a useful subset of a more fundamental and 'big picture' evaluation of sustainability. Testing the farming systems null hypothesis is a focussed and practical first agenda, but it is potentially insufficient in the long-run to define the project.
- The IM/organic/conventional framework was weakened by the lack of organic gold cohort option and substitution of a new cultivar (Hort 16A) comparison – this makes the overall project less cohesive if we are simply framing the focus on testing the original null hypothesis. Similarly, the organic or IM options are not available in the High Country sector, only organic and conventional are available within dairying, and the He Whenua Whakatipu project may not have any different farming systems to compare. Choosing a framework to look at more general determinants of sustainability and the ecological, social and economic processes underlying them would build back more potential fusion across sectors within the project.
- The meta-analysis across sectors will depend on deeper understanding of general processes than on simple comparisons between cohorts within sectors
- There may be much more variation within outcomes for sustainability within farming systems of each sector than between farming systems. We may have little left of a timeless nature to report if we find little difference between averages for farming systems.

- The definition of organic and IM, and the constellation of social and ecological variables around them seems to be very varied (at least when comparing internationally). We expect the IM protocols to continually tighten and restrict farm management. If we just focus on organic cf IM cf conventional comparisons, our findings will not be very relevant in 20 years time when the definition of an IM and organic and conventional farm may be very different.
- The results are more relevant to all New Zealand farmers if we work on the general models and underlying processes of resilience and sustainability.

The ARGOS project is hamstrung by a comparative lack of research on key ecological processes in farmed landscapes. A large number of predominantly single species ecological studies in New Zealand farmland exist (Moller *et al.* 2001), but there have been few long-term studies of ecological interactions and processes, or of indigenous biodiversity living in farmscapes. Perley *et al.* (2001) identified a large number of important gaps in knowledge, especially on issues of soil biodiversity. Generally, there has been insufficient research to help sustain indigenous biodiversity on private land (Norton 2000) where agricultural and forestry activities offer both opportunities and threats. Our agro-ecosystems are potentially very different from those overseas (Perley *et al.* 2001), so the information on ecological processes needed to interpret observed changes can not be simply imported from overseas research.

Accordingly, to balance the competing needs for monitoring and more general ecological process research, we propose close management to achieve a target for year 1 and 2 in the environmental portfolio to spend 80% of the time and energy on the organic/IM/Conventional comparison and 20% on underlying processes and forces leading to sustainability. In years 3 – 4 we hope to shift this to 70% vs. 30%; and in years 5 & 6 to 60% vs. 40%.

We believe that all the other researchers in ARGOS face the same dilemma to balance monitoring and process-oriented research, but that the social researchers (Objective 5) in particular will struggle if monitoring were to be the sole orientation of the ARGOS project. The 'bigger picture' sections of the original FRST contract for ARGOS squarely acknowledges the need for understanding determinants of sustainability and provides a warrant to engage in process oriented research that transcends the farming systems comparisons. An initial tight focus around establishing the longitudinal monitoring of different farming systems can then give way to broadening of research focus to test why differences emerge between organic, IM and conventional farms (Moller & Fairweather 2004).

1.5 Balancing assessment and assisting on ARGOS farms

The ARGOS project will combine an 'Independent Assessor' role to evaluate sustainability with an 'Involved Assistor' approach that actually assists growers to change to more sustainable practices (Duignan 2003). The ARGOS environmental group shares the passion expressed by our colleagues to be involved assistors for the farmers, but we urge that the group closely manages a balance between helping by active intervention and independently evaluating the farmer's own performance. Even a middle strategy between the two roles could compromise independent assessment. For example, if the ARGOS team facilitates uptake of an innovation that only affected say conventional, then the environmental indicators on conventional farms might move relative to the others mainly because of our intervention. Unless ARGOS assistance is even-handed in every respect, it could destroy the ability of the team to be independent assisters. Also involved assistance requires a lot of time, time which currently is not budgeted. We urge consensus decision-making on a case-by-case basis before any active intervention to ensure that one objective team's reliance of independent assessment is not compromised.

1.6 Agricultural biodiversity: a special case?

Environmental sustainability of agriculture in New Zealand has usually been seen mainly in terms of maintaining the ecosystem services (e.g. pollination, biological pest control, soil formation) required to allow indefinite production of crops. For example, much of the thrust of the Convention on Biological Diversity (CBD) stemmed from 'Agenda 21', a policy statement upheld by the 1992 Rio Conference. Chapter 14 of Agenda 21 concerns Agricultural Biodiversity, which it defines thus[4]:

> "… ***agricultural biological diversity*** *means the variability among living organisms associated with cultivating crops and rearing animals and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems. The unique feature of agricultural biological diversity is the emphasis on its utility to human beings*".

The CBD emphasises the need to conserve biodiversity partly for its own sake (the intrinsic value motivation) but also to support the bio-economy of humans. The need to feed burgeoning human populations by fostering highly productive agriculture is repeatedly stated as a prime motivation for the CBD, along with recognition that this is the source of part of the global environmental crisis. For example[5]:

> *"… overwhelming evidence leads to the conclusion that modern commercial agriculture has had a direct negative impact on biodiversity at all levels: ecosystem, species and genetic; and on both natural and domestic diversity. On the other hand, modern intensive agriculture has made it possible for the ever-increasing human population to be fed without the extensive destruction of habitats to provide the needed food. While agriculture has both positive and negative impacts, it also depends upon biological diversity for its continued existence. Hence, promoting sustainable agriculture requires the conservation and sustainable use of biological diversity. But this diversity is currently being threatened by the very activities that depend upon it".*

Intensive agricultural productivity is thus seen by some as an essential strategy to minimise the amount of conversion of 'natural' habitats to agricultural land. An alternative view is that such an approach increases the risks of particularly small-scale farmers, with both adverse social and environmental effects. The Indian economist Vandana Shiva argues that the Green Revolution displaced a socially and ecologically robust and diverse food productive system with a more risky and monocultural system dependent upon off-farm capital. This benefited those with access to capital to the detriment to those without (Shiva 1993).

Irrespective of the alternative views on intensive agricultural productivity, there is an emerging emphasis on integrating use with biodiversity protection within agricultural landscapes so that a genuinely ecologically sustainable but profitable harvest is taken. This is to be achieved in two ways - by caring for the biodiversity living on the actual land used for growing crops or grazing stock, and by ensuring that sufficient integrated reserves of less intensively managed, unmodified and more 'natural' habitats are retained within the overall ecological landscape. This often involves retention of wetlands, riparian areas, hedgerows, herbaceous leys, and forest patches irrespective of whether exotic or indigenous species predominate. Such areas provide many more benefits besides biodiversity, many of which have direct economic relevance. Conserving biodiversity in agricultural landscapes is seen as essential to maintaining production

[4] *UNEP/CBD/COP/3/14, page 2.*
[5] COP/3/14, page 9.

of foods and fibre for human use at the same time as supporting ecosystem health and resilience to future changes (e.g., climate change).

There is also a growing awareness in New Zealand that even highly modified ecological landscapes also have an intrinsic, ecological, and social value (Norton 1998, Park 2000, Meurk & Swaffield 2000, Perley *et al.* 2001). We will use this wider agro-ecosystems view as the guiding rationale for our research of environmental changes on farms. However, we recognise the need for the majority of research in Objective 4 of the ARGOS project to centre on agricultural biodiversity and maintenance of crop production. We will invest 70 % of our effort and expenditure on environmental monitoring and research to understanding agricultural biodiversity, and 30 % to non-agricultural biodiversity. However, slightly more than 30 % will have to be spent on wider biodiversity in the initial one to two years to determine what biodiversity exists on ARGOS farms.

1.7 Other Environmental Management Frameworks

Several other frameworks for guiding environmental management have been promulgated around the world. Some have slightly different emphases in environmental philosophy, or they aim at different levels or employ different methods for problem solving.

The ARGOS environmental group will review and contrast these different frameworks, including:

- Social-ecological Resilience Theory
- Pressure-State-Response Indicator Framework
- Ecological Footprints
- The Six Pillar basis for Environmental Indicators
- The Natural Step
- Holistic Management
- The Biodiversity Paradigm
- Ecosystem Services

The aim of our review is to identify complementarities and differences between frameworks so that we can choose which are the most useful for ARGOS[6].

A preliminary assessment highlights the utility of the Social-ecological Resilience Theory framework. Resilience theory shifts emphasis from study of ecosystem vulnerability to discovery of what makes socio-ecological systems strong enough to withstand perturbations by new threats. Rather than aiming for some mythical fixed goal of ‘sustainability’, which is defined very differently by different stakeholders, the goal is to aim for robust farming systems that can go with change or be taken in new directions by future generations of New Zealanders. We will use resilience theory to identify social, economic, ecological and agricultural community institutions that lock-in management for long-term improvement of biodiversity in farmscapes. Initially we will seek to learn how the agro-ecosystem works and which sites of action are most likely to trigger positive change. Then we will measure whether our proposed remedies to reverse decline of biodiversity in production landscapes are effective. If funding can be found, we will also test the resilience framework by researching a new theme, that of climate change. The ability, or otherwise, of New Zealand farming to withstand climate change and enhance ecological, social and economic sustainability in the face of the crisis will be a useful case study.

[6] This review will form a chapter in Chris Perley’s PhD thesis.

1.8 Choice of Indicators

The ARGOS project will invest a large amount of effort in measuring 'Indicators' of sustainability.

Broadly speaking, indicators that measure outcomes are better than ones simply measuring inputs. So far the justification for Organic and IM farming systems is predicated on the assumption that if farm inputs are controlled to be more benign, the outcomes for the environment must necessarily be more benign.

Research and monitoring is traditionally focused on indicators that are considered likely, from first principles, to be affected most by the different farming systems. This is a sensible first step, because if few or slight differences are detected for such sensitive indicators, then it is most likely that overall outcomes are similar for all farming systems. However, it is important to realise that focusing on just the sensitive indicators could give a biased overview. If strong differences are found in those variables, it is possible to lose sight of the possibility that most other aspects of farming and farm environments are much more similar for less sensitive variables.

It is important to realise that this term 'indicators' is used in a wider context by the ARGOS group than the normal use of 'indicator species' by ecologists (see section on focal species following).

1.9 The need for a comprehensive baseline survey of ARGOS farms

The first step in designing an environmental monitoring programme must be to find out what we have to work with on ARGOS farms. We therefore propose to place considerable resources and energy into a baseline ecological study of the farms. This survey will assess the main landforms and habitats currently present on the farms (Chapter 1), begin a compilation of species presence/absence and in some instances provide a baseline single measure of their abundance (Chapters 1 – 8). Comparisons of broad-scale features like landforms and habitats between farming systems within and between clusters will act as a first check of the utility and tightness of the ecological matching between farms in clusters. This is an important test of whether farm matching allows *a priori* choice of paired or unpaired statistical testing of null hypotheses that a particular ecological variable is the same across farming systems. The survey will also provide a first test of our proposed long-term monitoring protocols.

We expect that baseline surveying and testing monitoring protocols will take 80% of our time in years one and two[7]; but from year three that this has reduced to 15%. Regular monitoring and ecological process research will take 75% and then 90% of the investment in years three and four onwards.

Discovery of any differences in species abundance in our baseline surveys and initial monitoring will be used to predict the size of the differences that will emerge after conversion to IM or organic, on the assumption that the spatial comparisons reflect causality. Power analyses will then be performed to predict sample size and intensity needed to be certain to detect differences of that magnitude in the delayed Before-After-Control-Impact (BACI) experiment (Moller & Fairweather 2004).

1.10 Species Diversity Indices

General understanding of ecological communities can come from calculating 'diversity indices' from the animal and plant data to give a single measure of biodiversity. A simple count of the number of different species encountered is one potential option, but usually an index is derived that combines both the number of species and their relative abundance (see Begon *et al.* 1996: 681 – 683). Intuitively, a community of 10 species with equal numbers in each is more diverse than another, again consisting of 10 species, with more

[7] the remainder is needed for choice of farms, overall design and administration

than 50% of the individuals belonging to the most common species and less than 5% in each of the other nine. We will calculate Margalef's Species Richness indices and a Simpson's Index and/or Shannon Diversity indices that combine species richness and distribution of abundance between them. The data from the baseline ecological survey will also be boiled down into a habitat diversity index that incorporates both the structural complexity and spatial variation in landforms and vegetation types.

We will then search for correlations between species diversity and habitat diversity scores to summarise overall pattern. If correlations are present we will determine whether (i) organic, IM and conventional farms have the same level of biodiversity, (ii) organic, IM and conventional farms have the same level of habitat diversity, and (iii) biodiversity is higher or lower for a given level of habitat diversity in organic, IM and conventional farms (using a co-variance analysis).

1.11 Narrowing the chase: choosing 'focal species' for longer term monitoring on ARGOS farms

Use of these biodiversity indices can force a rather abstract analysis of biodiversity variation because they value all species equally and encapsulate the distribution of abundances of the different species. Our research on ecological impacts of farming must therefore go further to focus on individual species valued for their ecosystem services or intrinsic value as defined by the farmers and the wider community.

Given the great diversity of species, monitoring of all the biological components of managed ecosystems is impossible. Based solely on pragmatic considerations, management of biological systems may be simplified and made more cost-effective by considering only a small group of 'indicator species' as surrogates for the complete system (Szaro & Balda 1982, Landres *et al.* 1988). The concept of an indicator species is one of a species that is associated highly with a specific habitat type or component of the habitat, and a species that can be monitored to determine the possible reaction of the species to changes in this habitat type or farm management. Moreover, if this species is associated positively with a number of other species, then one may assume that habitat needs of the other species are also being met. Indicator species may be plant or animal species and in some cases may be used to refer to groups of species. Usually more than one indicator species must be selected because a single species can only serve as an ecological indicator for a narrow range of conditions within a habitat type.

Use of indicator species to guide ecological management has been controversial (Hutcheson *et al.* 1999). The general consensus has become that no species is likely to be a wholly satisfactory indicator of the viability of other species because of important differences in dynamics of individual species. However, this does not say that some species do not provide an integrated indication of the status of some portion of the farm system. We recommend that the ARGOS project adopts the United States Forest Service strategy of changing to a 'focal species' concept which would allow a variety of approaches to selecting species to monitor and assess for viability. The term focal includes several existing categories of species used to assess ecological integrity including: indicator species, keystone species, ecological engineers, umbrella species, flagship species, link species and species of special concern. 'Taonga species', species that are of special concern to Māori, are a local variant of the latter. The key characteristic of a focal species is that its status and time trend provide insights to the integrity of the larger ecological system. These focal species chosen for future work will be those judged most sensitive to farming practice and practical to monitor to track long term sustainability of the farms.

Choice of the important focal species will consider its significance in the landscape. It could be extended to include plant and animal species, soils and water bodies. Such an assignment may be for ecological, economic and cultural reasons, separately or in combination. The expression of this importance varies. For example, plant species 'x' may be an ecosystem defining ecological keystone, whereas plant species 'y' may rank as a serious ecological and/or economic weed. Both are likely to influence approaches to or departures from sustainable land management, and therefore be useful for monitoring.

It would be unwise to choose a focal species and rigid monitoring protocol for an ARGOS farm monitoring project before the preliminary ecological survey has been completed. Some more focused research on ecologically important parameters may also be needed to ensure that the focal species will serve their proposed function and that scientifically defensible monitoring regimes can be devised. A few focal species should be monitored by a standardised protocol from spring 2005 onwards, but other long-term indicators and their optimal measurement protocol may not be finalised until 2006.

We will give priority to choosing those focal species that could be most influenced by the major differences in farm management practice of the different farming systems. For example, a significant difference between systems is the quantity of nitrogen used, so monitoring soil fauna that are most sensitive to nitrogen application would be prudent. Also anthelmintics (i.e. sheep drench) might particularly affect soil beetles for example, or soil nematodes. Review of the international literature will help identify particularly sensitive indicator species, but our baseline surveys are likely to be the main lead for New Zealand conditions of the most useful species for ARGOS. A related priority is to preferentially choose species which move on small spatial scales (at or smaller than the whole farm area) so that they are more likely to respond to the local conditions on an organic, IM or conventional farm. Wider ranging species are more likely to be (though not necessarily) influenced by far-flung resources and therefore their abundance is less likely to be influenced by farming system.

1.12 Threatened species on farms

Threatened species, if present on farms, are a special category of focal species that will demand high priority research and management.

Although New Zealand has an extremely high number of threatened species per unit area, most of them exist outside the highly modified farming landscapes to be studied by ARGOS (Perley *et al.* 2000). With a few notable exceptions (brown kiwi in Northland and kea in South island high country), most currently threatened birds in New Zealand occur in forested or high alpine regions which are not farmed and where there are conservation reserves. Some sheep/beef farms may impact on threatened bird species breeding on adjacent braided rivers of South Island. 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 (Molloy 1995, O'Donnell 2000 a,b). Several threatened native fish occur in South Island streams and rivers (McDowall 2000; Waters & Wallis 2001a & b; McDowall & Waters 2002, 2003). Two species of giant skink persist in farmland in the Macraes Flat and Lindis Pass regions of Otago and 11 other species are declining in South Island farmland (Hitchmough 2002). The existence of widespread localised endemism amongst New Zealand invertebrates suggests that some threatened invertebrates will occur in farmland (Perley *et al.* 2000). The Mohenui 'giant weta', which persists only in a gorse stand upon a sheep/beef farm in central North Island (Sherley & Hayes 1993), is a spectacular example. Many of New Zealand's invertebrates remain undescribed and there is no systematic monitoring of their distributions. It is estimated that 20%

of threatened vascular plants are confined to private land while a further 60% occur on both public and private land (P. de Lange, pers. comm. in Norton & Miller 2000).

It is probable that no threatened plants or animals persist in the 136 ARGOS farms. However the national biodiversity crisis dictates that we must thoroughly check for them, and if present, identify potential impacts on them from farm management. Any decision to ignore them would immediately contradict our commitment to a holistic agro-ecosystem approach to ARGOS.

We will assess management priorities for any threatened species found in the vicinity of the farms by reference to the most recent New Zealand Department of Conservation (DoC) threat listings (Hitchmough 2002, Molloy *et al.* 2002) that supersede most of the published rankings (determined by the system devised by Molloy *et al.* 1994). Threatened species distribution maps will be sought from DoC and researchers before we begin our own baseline ecological survey of ARGOS farms so that a more focused search for threatened species can be performed when on the farm.

The presence or absence of threatened species is unlikely to be linked to organic, IM or conventional farm management. The sparse and fragmented nature of threatened species leads to persistence in refugia of quite distinct habitats or where predator/competitor conditions favour persistence, or where some historical serendipity has operated (Gray & Craig 1991). We expect ecological differences between organic and conventional farms to be relatively slight compared to the regional variations that allowed rare species to persist in some areas and not at others. Therefore the focus on threatened species identification and subsequent management should be seen as part of the over-arching quest for ecological sustainability running throughout the ARGOS project rather than being a fundamental test of the relative sustainability of the different farm cohorts.

It is most likely that threatened species cease to be an issue in ARGOS work after the baseline surveys, or if they persist, they would only be a consideration on a small number of ARGOS farms. In the longer run within the 20 – 30 year project, reintroduction of threatened plants and animals may be a possibility.

1.13 Taonga Species

Tangata Whenua have developed a special relationship with many Mahinga Kai species. Centuries of customary use has lead to those species having a particularly important culturally defining role for Māori and consequent aspiration by many Māori to co-manage the species (Moller 1996, Roberts *et al.* 1995, Moller *et al.* 2000, Howard & Moller 2001). The Ngāi Tahu Settlement Act 1988 formalised a list of Taonga Species for special attention. These include 49 bird species and 54 plant species, several of which may occur on ARGOS farms (Appendix 1).

There is much more to Kaitiakitanga than special care of taonga species, but choosing some of them as focal species for long-term monitoring is a first step to supporting Māori environmental aspirations in general and particularly He Whenua Whakatipu (Objective 2).

1.14 Initial milestones and objectives for environmental research

The initial goal of Objective 4 of the ARGOS project is to determine the effect of management system on farm biodiversity and environment. This will involve an initial emphasis on establishing indicators of environmental sustainability, followed by increasing research on more fundamental ecological processes to allow analysis of determinants of sustainability and whether the indicators reliably measure them.

Biophysical indicators are typically well defined and will be established on the farms in the first year. For biological indicators, the first year's research (2003/04) will concentrate on evaluation and careful selection of practical but robust and interpretable indices of biodiversity and

ecological processes. From year two (2004/05), regular measurement and analysis of the selected environment indicators on treatment and control farms will compare performance of all farm cohorts with known standards at other locations within New Zealand and overseas.

Initial testing for significant differences between the treatment and control groups in year two will be a first indication of whether conversion to organics and/or IM leads to environmental changes on farms. Any differences observed will then be monitored in a delayed Before-After-Control-Impact (BACI) experiment. Those differences will be used to predict targets for desired long-term environmental changes on intervention groups. We will also test whether the putative response variable changes with time-since-conversion to indirectly test whether the conversion caused the change. However we will also use a combination of environmental history, interviews of farmers and check for confounded ecological variables on farms between the cohorts. For example, growers that go organic may have very different land than ones choosing not to convert (as well as very different social and economic characteristics). If these differences cause ecological flow-on effects, we will observe differences between organic and other farms that do not relate to the change in farm management *per se*. Perhaps farms going organic have more and diverse trees, or are smaller areas overall. If so, they may have more or fewer birds before conversion, and the differences we see on long-converted farms are therefore not caused by any change in farming having triggering increased or decrease bird numbers or diversity (see Moller 2004a for a discussion of these potentially confounding variables).

In year two, we will assess the feasibility of superimposing an experiment on the overall project's design to assess the relative importance of habitat cf. pests in limiting indigenous biodiversity on farms. If practicable, such an experiment will be initiated late in year two and will be maintained for the next three or four years.

Outputs from this objective will also contribute to syntheses across all objectives so that farmers and their sector representatives can identify the best pathways to achieve sustainability. This will be achieved by showing how the different dimensions of sustainability are related and which synergies or trade-offs are involved when multiple dimensions are considered. Priorities for policy will be identified with input from sectoral leaders and industry policymakers.

The following milestones have been nominated for the first two years:

1. In conjunction with participating farmers, field workers and environmental scientists, evaluate and select environment indicator methods for all farms. (Finish Date: June 2004).
2. Establish a prioritised research agenda to fill gaps in knowledge about the utility and interpretation of environmental indicators. (Finish Date: June 2004)
3. Record baseline biophysical data for the farms. (Finish Date: June 2004)
4. Record selected environment indicators for all farms for the 04/05 year and compare results for treatment and control farms and test for significant differences. (Finish Date: June 2005)
5. Select methods, study areas and assess experimental power for testing the relative importance of pest control and habitat quality enhancement for promoting indigenous biodiversity on farms. (Finish Date: June 2005).

The following specific outputs have been promised for the first 2 years:

a) Production of an instruction manual for participating farmers and field officers to monitor environment changes on farms. (Finish Date: June 2004)
b) Paper on environment monitoring methods to sector conference. (Finish Date: June 2004)

c) Biophysical indicator summaries for each cohort provided to farmers, posted on web and given to industry partners. (Finish Date: June 2004).
d) Environmental summaries for each cohort provided to participating farmers, posted on web and given to Merino New Zealand Inc., Canterbury Meat Packers, Certified Organic Kiwifruit Growers and Zespri. (Finish Date: June 2005).
e) Paper on potential predator control and habitat quality enhancement to sector conference. (Finish Date: June 2005).
f) Paper on environmental change to cross-sectoral conference. (Finish Date: June 2005).

The objective's 'Specific Tangible Outcome', to be achieved by June 2005, was stated as:

> *Practical, robust and interpretable indices of biodiversity and ecological processes for the two production systems will be established. An objective assessment of the environmental performance against selected indicators of the participating farms/orchards under different management systems. Participating farmers, and their sector representatives, know the environmental effects of different management systems and adjust their farm practices accordingly. This will lead to broader use of environmentally enhanced production systems, initially within the study farms and then more broadly among farmers in New Zealand. The key indicator will be an increasing proportion of farms within each sector studied that can demonstrate improved sustainability over time using internationally and nationally agreed criteria.*

2. Baseline Survey of Land Forms and Ecological Habitats on ARGOS farms

2.1 Introduction

To achieve the goals of ARGOS it is necessary establish secure, robust baselines from which it possible to measure, map and explain environmental change in meaningful ways. Eventually we hope determine whether the changes observed stem from particular farming practices or reflect external ecological forces unrelated to farming per se. The baselines will be obtained by inventories of farm environments and land-use practices occurring within the farmscapes. These surveys which have been designed to describe ARGOS farms at multiple spatial and temporal scales, in terms of their physical landscapes, component ecosystems and ecosystem services, habitat structures, biodiversity, agricultural land-uses, agricultural productivity and farm structures.

The baseline survey will provide initial baseline data to compare with future measurements. It will also compare environmental attributes and land management practices on conventional, already converted IM and already converted organic farms. However we will use environmental history techniques, historical data, and interviews with current farmers to learn whether the farms already converted to IM or organic were different even before they changed to the new farming regime (Moller 2004a). If so, any environmental differences we now observe between conventional, IPM, and organic farms may be partly of wholly driven by different starting conditions rather than by the different farming practices *per se*.

This chapter introduces the baseline survey which will provide the information underpinning assessments of agricultural sustainability and facilitate anticipations of landscape futures. It:

1. describes the organizing framework of the initial farm surveys, and the utility of the sampling with respect to describing patterns and processes, detecting change, and facilitating inter cohort comparisons,
2. identifies the requirements for, and method(s) of, data collection,
3. lists the types and sources - and limitations - of the data to be collected, and
4. indicates time and money costs of data collection.

Our baseline survey must cast a wide net with a fine mesh if it is to adequately describe multifunctional landscapes at multiple spatial and temporal scales and integrate ecological, social and economic dimensions. To be effective, the net has to be constructed of the appropriate materials. This section first reviews previous approaches before prescribing the best methods to achieve these goals.

2.2 Targeting Measurement

What should ARGOS be measuring? There is a bewildering array of environmental variables for potential inclusion. Decisions need to be made regarding data deemed crucial (need to know), desirable (nice to know) or non-essential (of interest but not relevant to sustainable land management.

The baseline survey design has to be flexible enough to be able to range widely across scales, and to accommodate changes in scale dynamics. Land management may fail if the scale of the element / unit or species is not identified and matched (Walters and Holling 1990). A temptation to manage at the whole farm level may be ineffectual if the functional scale is larger than the farm, and wasteful if the functional scale is more fine-scaled than the farm level. Appropriate land management may involve sampling or understanding ecological flows that cross farm

ownership boundaries. Different elements of the agro-ecosystem may have to be managed at different spatial and temporal scales within farm boundaries or throughout the landscape(s) within which the farm is embedded. The functional of scale of some native insects may be individual trees or rock outcrops. For rivers and streams the functional scale is the watershed / catchment. This may encompass thousands of km^2. The functional scales of many features are dynamic. For some flows and transfers the functional scales are likely to be subtle and/or difficult to discern.

2.2.1 Unpacking the landscape

The baseline survey will "unpack the landscape" by identifying, locating and delimiting the ***physical landscape*** (geology, geomorphology, climate, soils, and water), the ***biological landscap***e (above and below ground flora and fauna and its expression as land cover), and ***cultural landscape*** (e.g. farm buildings, fences, tracks, gardens, ditches, water tanks, hedgerows, and shelterbelts) features of the ARGOS farmscapes. All three combined must be considered to interpret pattern and processes, explain habitat structure and to characterise farm functioning and productivity.

The patterns of farmscapes and their component elements will be described in order to provide a multi-scale baseline for determining current conditions, an understanding of the processes producing the observed patterns, and to track future changes. A description and mapping of the farmscape facilitates its characterization in terms of land-cover, biodiversity and productivity, and their susceptibility to and ability to recover from disturbances impacting on environmental and farm management systems.

Some ecological landscape features can be characterized only after a baseline survey is completed (e.g. fragmentation, landscape connectivity, landscape permeability, landscape potential, natural hazard context (e.g., flooding, flood control, fire, rabbits, etc). The baseline survey might also provide a basis for any landscape health index that might be used (e.g., resilience, persistence, tenacity, fragility, vulnerability, naturalness, buffering, simplicity versus complexity).

2.2.2 Priority rankings and units of measurement

Some parts of any landscape will have greater importance to farmers or the wider community. There is a need to determine which of these important landscape elements are unique to or rare in the farmscape and which are abundant and/or widely distributed. Landscape importance may have an areal expression (e.g., a wetland, a moist gully with a native woody shrubland not found in the wider farmscape), or may take the form of isolated points (e.g. scattered rimu *Dacrydium cupressinum*) in a paddock). Importance in the landscape may also take the form of structural features such as edges, ecotones, and corridors.

The spatial expression of such features is likely to exhibit inter-taxa variation. Human use and appreciation of the landscape also leads to the designation of some parts of the landscape as possessing greater significance so social and economic dimensions need to be taken into consideration. Therefore, our baseline surveys should be used by social and economic teams within ARGOS to evaluate farmer perceptions and value of different elements of the landscape. Ecological and agricultural production landscape views need to be melded with visual aspects of farmscape. A concentration on land-cover and its productivity to the exclusion of what it looks like would diminish our study of sustainability.

2.3 Land Systems Derived From a Landform Classification as a Basis for a Baseline Survey of ARGOS Farms

2.3.1 Previous categorisation

Land systems are areas or groups of areas with recurrent, consistent patterns of topography, soils, geology, climate and vegetation (Christian & Stewart 1953). Differences in physiography are the primary criteria for delineating land systems, which may comprise spatially disjunct areas. '***Land systems***' divide farms into areas with similar inherent physical properties, and by extension delineate areas with similar ecosystems and landscapes. Lynn and Hewitt (1990) used a land systems approach to delineate areas likely to have similar responses to rabbit and land management. Land systems can also be conveniently sub-divided into smaller units on the basis of the '***landforms***' present.

There have been a number of New Zealand classification systems devised to integrate physical landscape, climate and ecological features. The Land Use Capability Survey (LUCS) approach was to promote

> *"the planned treatment and efficient use of each area of land so that its inherent qualities for sustained primary production or other uses in accordance with the multiple use concept are unimpaired; and whereby the uses of all the areas within a river catchment are balanced for the greatest overall benefit of the land and the people in that catchment or associated catchments" (Anon.. 1969; 11: Soil Conservation and Rivers Control Act 1941).*

The LUC surveys classified land "according to its capability for permanent sustained production" (Anon. 1969: 11), with 'capability' defined as "suitability for productive use taking into account the physical limitations" (Anon., 1969: 12) of an area of land. Their nationally sanctioned objective was to produce maps and text that integrated soil, erosion severity, potential erosion, slope, wetness or droughtiness of soil, climate, and land-uses information in order describe opportunities for and limitations to production-oriented land-uses (Anon. 1969). The catchment (or 'watershed') approach of the LUC surveys was commendable in that systems could be envisaged in terms of permanent, periodic, or occasional sources, transfers or flows, and sinks. More debatable were the scheme's disregard of indigenous biota and the effective acceptance of supplementing or replacing of existing systems with new systems that required externally derived inputs of seed, fertilizer and energy.

The Protected Natural Areas Programme (PNAP) used a regional ecological framework based on geological, climate and vegetation features, and making conspicuous use of river boundaries (McEwen 1987). Its main objective was to identify representative areas of particular value for indigenous biodiversity with a view to preservation and reservation. By implication and by design it supported a separation of New Zealand's conservation and production-oriented landscapes. It ignored or discounted hybrid and synthetic landscapes comprised of a mix of indigenous and introduced elements, and promoted the notion that agricultural sustainability and indigenous biodiversity are separate realms (Wearing 1999). The 2001 Biodiversity on Private Land Strategy represents a government acceptance that biodiversity initiatives have to extend beyond the conservation estate, but biodiversity and agriculture are still couched in terms of spatial separation (usually by a fenceline).

Harding and Winterbourn (1997) proposed an '***ecoregion***' classification of the South Island based on known determinants of ecosystem structure and function. They used six macroenvironmental variables: vegetation cover, bedrock geology, soils, relief, rainfall normals and New Zealand Meteorological climate regions. Twelve ecoregions were produced and

mapped as 1:1 000 000 and 1:2 000 000 scales. The LUCS, PNAP, and Harding and Winterbourn (1997) classifications all recognize the underlying importance of landscape, climate and ecology but place an emphasis on specific management goals.

2.3.2 Mapping landforms

Landforms are relatively easy to map and as features in the humanised landscape they tend to be durable. Compared to measurable features such as vegetation cover and animal densities, landforms are a conservative feature in the landscape. Individual landforms or parts of landforms do disappear or are modified. For example, a severe flood may lead to the removal of a section of river terrace. But a new terrace will form. Landforms also have a strong influence on vegetation cover (which is usually the most visible feature of a landscape after its physical from), soils, and microclimate. Landforms can also be represented in terms of the ecological and economic opportunities and threats that concomitant with their characteristics. In other words, landforms are a good template on which to drape all other features of interest in a landscape, whether they are spatially specific or diffuse. The theme of farming to the land can be extended to farming to the landform in order to achieve a better and more durable match between the environmental qualities / attributes of an area of land and the use(s) to which it is put.

We recommend that ‘landforms’ are chosen as the fundamental unit for the baseline survey of ARGOS farms.

Whitehouse *et al*. (1992) devised a hierarchical (nested) landform description scheme for use in PNAP surveys in the eastern Southern Alps. Landforms were sequentially sub-divided into macro-, meso-, and component landforms. Macro-landforms (e.g., a fluvial valley floor) were differentiated on the basis of relief, topographic position and substrate. Meso-landforms (e.g., terrace, fan, riverbed) were differentiated on the basis of substrate, topographic form and origin. Component landforms (e.g., footslope) were differentiated on the basis of topographic position and form.

Sets of descriptors (e.g., scattered rock outcrop, gully, wetland) describe the size, shape, arrangement, composition, or other properties of landforms. A large number of possible descriptors can be applied to particular landforms. Descriptors can also be used to delineate and describe ecologically important features occurring on individual meso-landforms and component landforms. Descriptors may exhibit considerable variation in dimensions, from, for example, a 2x2x2 metre rock in a paddock to a one hectare deep-seated slump on a hillslope. For ARGOS a set of lists of meso-landform, component landform, and landform descriptors have been devised for each potential macro-landform category: mountain slopes, ‘hard rock ‘ hillslopes, ‘soft rock’ hillslopes, fluvial valley floors, and alluvial plains. The descriptors lists are open-ended and will be influenced by what is recorded on the ARGOS farms.

A hierarchical approach to delineating the landscape has a number of advantages. The farmscape can be studied at multiple scales. Farm attributes of interest can be considered at fine and coarse scales, or across scales. The descriptors can be used to identify, locate, count, describe and track features of particular ecological interest (e.g., the role of rocks as refugia for native invertebrates). Landform based descriptors can be integrated with ecological and cultural feature descriptors that characterize landscapes in terms of animal and plant perceptions (Farina 2000) or ‘eye-views’. For example, a terrace tread and riser sequence on light soils in a sparsely vegetated fluvial valley floor with a dry climate and a 100-year history of farming will constitute a hostile landscape in terms of kowhai (*Sophora microphylla*) and its prospects for recruitment. Conversely, it may be an ideal landscape for rabbits. Culturally, the landscape may be seen in ambivalent terms. The openness of the landscape makes for high visibility, but the sparseness of the vegetation and the evidence of rabbits promote a reading of the landscape as bearing testament to exploitative use.

Basic land system differences pertaining to macro-landforms and – in some landscapes – meso-landforms can be identified on remote sensing imagery and on aerial photographs. Remote sensing and aerial photographs represent the only practical means of obtaining information beyond ARGOS farm boundaries and to situate the farms in the context of the whole landscape. The baseline survey has to work within these limitations.

One of the outputs of the ARGOS baseline survey will be a farm landform map. Computer databases held by central and local government authorities and by other organizations will be used to generate basic maps of the terrain features of the ARGOS farms. We will gradually add layers to these maps as more data are gathered in subsequent visits to the farms.

Boundaries are not always clear-cut. In particular there will be difficulties when delimiting and describing slopes. Terms tend to describe variation either down the profile, or along the contour, but do not describe area. Information on both is necessary in order to describe landscape structure and by extension the physical attributes of plant and animal habitats. Different parts of a slope often merge into one another. A fan may have clearly defined boundaries, but a spur crest grades into a slope shoulder which grades into a sideslope, which grades into a footslope. An element of subjectivity will be involved when locating different slope components if judgment is required to distinguish between different slope components and several survey personnel are employed. It will desirable to keep the survey personnel as constant as possible.

A preliminary landform map will be made before a farm visit. This will be ground-truthed and, if necessary, modified during the field visit. Field survey will be necessary to map meso-landforms, component landforms and descriptors. Subsequent visits in the field can be used to refine the mapping process on individual farms if the terrain is complex and/or varied, or if differentiation is subtle. This may result in a fine-tuning of the map.

It is the intention of the ARGOS baseline surveys to produce accurate landform maps, but it is not essential that the first farm visit results in the production of a completely accurate map, and the exact location of every boundary, unless the boundaries themselves are features of interest[8]. For example, ARGOS might wish to investigate short tussock (*Poa* spp., *Festuca* spp.) density and recruitment on different component landforms. The sampling strategy would be formulated to ensure that individual sampled tussocks are definitely located on a particular landform.

The resulting landform maps can be interpreted with reference to soil, climate, hydrological, vegetation, land sub-division and land management patterns (See the matching farming to ecology within farms research in Section 8).

2.4 Ecological landscape perspectives

The dilemma we face in the ARGOS team is that we have insufficient resource to fully monitor ARGOS farms, let alone the surrounding farms making up the ecological landscape. The farm boundary/whole farm unit was the necessary choice of measurement unit and replication for several practical and socio-political reasons, but this is inadequate for ecological processes. The only practical solution is to rely on remote sensing tools, all measuring habitat variables, for up-scaling beyond farm boundaries. These databases are not ideal because they are configured on course scales for many broad-brush agendas. An important early priority is to review all the available databases, test their efficacy during the baseline survey, and then settle in to use the best of them for longer-term monitoring.

[8] Landform boundaries may be sharp or gradual, as are ecological boundaries, which may be sharp, or ecotonal or zonal. The coincidence or otherwise of landform/soil/hydrological boundaries and ecological boundaries merits further investigation.

2.4.1 Using existing vegetation cover databases for a landscape perspective

The vegetative (land cover) pattern scaled down within the farm and scaled up to include the surrounding landscape provides the basis for future evaluation of many key biotic and abiotic processes. Processes include disturbance, nutrient cycling rates, energy flow rates, patch persistence and turnover rates. Combined with physical structure and community ecology, land cover provides the matrix for evaluation of other biological processes in a landscape: presence/absence of particular biota; reproduction; competition; recruitment; dispersal & migration; predation, etc.

It is proposed to rely on existing spatial information to provide the land cover benchmarks for farms, but to develop a remote sensing protocol for long-term monitoring (see future research in section 8).

The Ministry for the Environment (MfE) Land Cover Database (LCDB) provides countrywide spatial data on a range of land cover types. Its primary purpose was to evaluate vegetative change as part of New Zealand's Kyoto Protocol requirements. This will require an iterative process of land cover evaluation, with the intention to produce new land cover inventory every five years enabling the land cover change to be assessed and reported on. The first series (LCDB 1) was based on 1997 satellite imagery, using 18 land cover types. The final maps were produced in 2000. This series was based on three colour bands with resolution below one hectare.

MfE are currently working on the second Land Cover Database (LCDB 2), based on 2001 satellite data. LCDB 2 has a considerably better resolution than LCDB 1, with the analytical unit being a high resolution 15m x 15m pixel, using six colour bands. The maps are not produced to this fine a resolution, using a one-hectare polygon. A major advance in LCDB 2 is the increase in land cover types identified, increasing the land cover types to 43. There is considerably greater detail provided in the grasslands and shrubland categories, of most importance for the ARGOS project. Table 2.1 provides a comparison between the land cover types covered in LCDB 1 and LCDB 2.

Many of the regions in New Zealand are already mapped using LCDB 2, with ground-truthing complete. The whole series is projected to be completed by early July 2004. Costs will be based on CD production and distribution, with a full set estimated to be priced between $200 and $300.

2.4.2 Land Cover Types

The LCDB 2 grassland and shrub vegetation types outlined in Table2.1 provide a useful basis for vegetation. However, while the data was ground-truthed by MfE, it is unlikely that they will be completely accurate within farms. A confirmation of the general classification through ground inspection will be required. However, we will first ground-truth the Land Cover Database by comparing its records for ARGOS farms with data from our preliminary ecological surveys. This will test the limits of any interpretation that we may subsequently attempt across wider spatial scales. We will cross-reference our plant mapping for the baseline survey to the LCDB categories.

An inspection will also provide greater detail on the vegetative composition of any particular land cover patch. Many of the ecological qualities associated with individual patches depend on the species present. For instance, an area classified as a closed canopy pine forest may have important sub-canopy shrub and herbaceous layers, while other similarly classified pine forests may not. Similarly a wider shelterbelt with a mix of vegetative types – trees, shrubs, herbaceous plants, nectar producers, fruit producers – is qualitatively different from a shelterbelt with no foliage connection between ground and tree canopy.

The one other potential deficiency with the Land Cover Database relates to the differentiation of "exotic grassland" only into "high-producing" and "low-producing" types. "High producing" grasses are described in the LCDB 2 as intensively managed, rotationally-grazed grasslands typically located within smaller paddocks on land that can be cultivated (indicating high fertility, and plains and downlands). "Low producing" grasslands are described as extensively grazed, located on harder country, and intermixed with areas of "high producing" pasture on more fertile sites. This suggests that a species composition is inferred from landform and other factors such as paddock size, and that the Exotic Grassland land cover information is not nearly detailed enough on its own for the ARGOS project. From an ecological perspective grassland species composition (including whether woody species are present), the grassland growth habit (e.g. whether grasses are ever allowed to go rank), are important. The LCDB provides a less than desirable baseline for future monitoring. We will cover this gap with our own more intensive sampling of pasture within farms (see Section 7) but will only be able to use crude pasture measures for landscape analyses.

Despite the limitations of the LCDB resolution, the packages are inexpensive and they can give a valuable relative index of landcover on ARGOS farms in our different sectors and farming systems. Provided that accuracy is not biased in ways that interact with different types of cover predominating on organic cf. IM or conventional farms, the relative index can coarsely evaluate current differences between farm systems and track them through time. The system allows ARGOS to greatly increase the power of comparisons by adding farms outside the ARGOS panel to the comparison.

2.4.3 LCDB Wetlands

The LCDB 2 does assess 'freshwater sedgeland/rushland', 'flaxland', and 'lake and pond water bodies', but it does not provide a class describing wetland extent. This is because wetlands are usually complex systems consisting of a number of different land cover classes. For example, a single freshwater wetland may comprise areas of open water classed as lakes and ponds, areas of freshwater sedgland/rushland, flaxland, and areas classified into one of the shrub classes. Defining the extent of a wetland system would require further spatial analysis and subsequent groupings of the land cover components by MfE and their Land Cover Database team. However, this may be incorporated as a separate layer of LCDB 2 in the future.

Wetlands are significant landscape features in the ARGOS farms, providing major functions in mitigating the detrimental effects of farm run-off associated with soil sediment, nutrients, and faecal coliforms and microbial levels. In addition, they provide important ecological habitat in themselves.

Given the limitations of the LCDB, and the environmental importance of wetlands, some fieldwork-based description and monitoring of wetland extent will be required on the ARGOS farms.

Table 2.1. Target Classes for Land Cover Database Version 2

Ist Order Class	*LCDB1 Class*		*LCDB2 Class*	
Artificial Surfaces	1	Urban Area	1	Built-up Area
	2	Urban Open Space	2	Urban Parkland / Open Space
	3	Mines and Dumps	3	Surface Mine
			4	Dump
			5	Rural Infrastructure
Bare or Lightly Vegetated Surfaces	4	Coastal Sand	10	Coastal Sand and Gravel
	5	Bare Ground	11	River and Lakeshore Gravel and Rock
			12	Landslide
			13	Alpine Gravel and Rock
			14	Permanent Snow and Ice
			15	Alpine Grass-/ Herbfield
Water Bodies	6	Inland Water	20	Lake and Pond
			21	River
			22	Estuarine Open Water
Cropland	9	Primarily Horticulture	30	Short-rotation Cropland
			31	Vineyard
			32	Orchard and Other Perennial Crops
Grassland	10	Primarily Pastoral	40	High Producing Exotic Grassland
			41	Low Producing Exotic Grassland
	11	Tussock Grassland	42	Short Tussock Grassland
			43	Tall Tussock Grassland
			44	Depleted Grassland
Sedgeland	7	Inland Wetland	45	Freshwater Sedgeland / Rushland
Saltmarsh	8	Coastal Wetland	46	Saltmarsh
			47	Flaxland
Scrub and/or Shrubland	12	Scrub	50	Fernland
			51	Gorse and or Broom
			52	Manuka and or Kanuka
			53	Matagouri
			54	Broadleaved Indigenous Hardwoods
			55	Sub Alpine Shrubland
			56	Mixed Exotic Shrubland
			57	Grey Scrub
Forest	13	Mangroves	60	Mangrove
	14	Major Shelterbelts	61	Major Shelterbelts
	15	Planted Forest	62	Afforestation (not imaged)
			63	Afforestation (imaged, post LCDB 1)
			64	Forest - Harvested
			65	Pine Forest - Open Canopy
			66	Pine Forest - Closed Canopy
			67	Other Exotic Forest
	16	Willows and Poplars	68	Deciduous Hardwoods
	17	Indigenous Forest	69a - 69u	Indigenous Forest Classes to be derived from NVS Database, CMS Plots, Landsat imagery and other ancillary data.
Unclassified	18	Unclassified	70	Unclassified

2.5 Microsite Soil and Climatic Data

2.5.1 Land Environments of New Zealand (LENZ)

The Land Environments of New Zealand (LENZ) is an environmental classification system of New Zealand developed by Landcare Research with funding and support from the Ministry for the Environment. It provides GIS compatible layers covering climate, landforms, and soils, which can be both used as a framework for a range of conservation and resource management issues, and used as a tool to underpin indicator-based monitoring of the state of New Zealand's environment (Leathwick *et al.* 2002). LENZ is a complementary national data set to the LCDB.

The climatic, land form and soil data layers work on a range of scales from 1: 5,000,000 to 1: 50,000, and allow a number of analyses such as:

- changes to ecosystems (loss, fragmentation, restoration),
- the ability to evaluate risks from pests and diseases,
- the optimisation of land management through the identification of particular sites that may be associated with either economic, social and environmental opportunities and threats,
- identify the geographic extent over which results from site-specific studies can be reliably extended, and
- identifying environments throughout the world that are similar to New Zealand's environment to assist with predicting threats, and evaluating opportunities.

LENZ is available as a full colour atlas ($50) showing the Level I and Level II classification scales. The database version comes in two CDs, one containing the classification data layers, and the other the underlying climate, soils and land form variables that make up the classification system. The CDs are available under license to Landcare Research for a cost of $350 dollars each ($700 for the set) to "public good agencies". Cost to commercial agencies is $1250 for each CD if buying the set of two, or $1500 for each CD if purchased separately.

2.5.2 Regional Data Sources

A number of regional organisations within New Zealand have developed high resolution climatic and soil information integrated on to terrain maps. As an example, Otago Regional Council's GrowOtago™ initiative will provide spatially-digitised data on a number of climatic variables including exposure, last frost, rainfall, growing degree days (above 10^{o}), earliest frost, etc. Most of the maps have been produced using modelling techniques that extrapolate data from the existing network of climate stations and soil maps. Each of the variables will be available in map form (compatible with the NZ 1:50 000 topographical series), as well as a GIS-compatible data layer. Otago Regional Council expects to have its GrowOtago™ climatic data available on a set of CDs by May 2004, but costing strategy has yet to be finalised.

The Council has collected all the soil maps within the region (ranging from 1:250 000 to 1:10 000 farm scale maps). They are less detailed than the climatic series and will be produced in 2005-2006.

Topoclimate South is a similar initiative to GrowOtago™, though with less emphasis on climatic variables, and a greater emphasis on soil quality suitable for potential commercial opportunities. The driver for the initiative includes a local regional development group. The data only cover the higher producing lands in Southland and South Otago, and information is available at 'commercial' rates.

Agribase (MAF) has farms by farm type, has stock numbers, crops grown, production forestry area, and is regularly updated by field staff. With Agribase it is possible to get a map centred on the target farm with a 10 km circle, for example, mapped according to terrain and farm types. The farm type/terrain/land-cover/soil class data can be matched to social data.

It is proposed to evaluate the use of such data once we know whether they exist for the regions of most the ARGOS farms. They may only be affordable to support detailed case studies on a subset of farms.

2.6 Geographic Information Systems

The Land Cover Database spatial information is available as GIS-compatible data. It is also essential that all the other environmental monitoring data are linked to a GIS system from the outset.

The analysis of the data will require a GIS software system, such as ArcView 3.2 (approximately $3 000). We will make enquiries with Otago University Surveying Department to evaluate the potential for their provision of GIS services.

A major advantage of a GIS system is the ability to synthesis many data layers including: vegetation cover; the New Zealand 1:50 000 topographic series (providing information on slope, aspect, altitude, etc.); key landscape features such as roads, rivers; recent and historic aerial maps; cadastral information providing property boundaries; and other data sources such as the soil and climatic data as provided by such regional initiatives as GrowOtago™ and Topoclimate South.

More sophisticated GIS systems are integrated with historic management data relating to a particular management unit (costs, returns, land & crop descriptions, operation descriptions and dates, etc.). This is a common feature within forest growing enterprises where the traditional stand record systems are now incorporated with GIS technology. Similar systems may already be available for farming enterprises. Alan Somerville (ex Forest Research scientist and TUMONZ developer) has developed integrated software incorporating such GIS and stand record systems, and may already have considered similar applications for farms.

We recommend that ARGOS uses as many of the remote sensing databases (reviewed above) as possible. They are very inexpensive considering the potential wealth of data represented there and it seems likely that each will be stronger than the other for some of the research agendas.

An easily overlooked consideration is the cost and time required to extract GIS analyses. It can be a complicated procedure requiring specialised expertise. The ARGOS environmental researchers will try to find the time to learn how to use the GIS packages in the first instance. GIS is also needed for biodiversity and pest research.

2.7 Aerial Photographs and Photo Points

Photographs provide a very useful comparative record for such processes as soil erosion and vegetative change (Hunter & Scott 1997, Start & Handesyde 2002), and for identifying cultural and natural landscape structures. They can take the form of repeat photography of scenes depicted in historical photographs, fixed photo-points (Mark 1978) located around farms, or aerial photographs of farms. Photo-sequences are particularly useful estimating changes in visually dominant species such as woody and tussock plants, and changes in woody plant distribution with altitude and landscape type.

Aerial photographs also integrate well with such data sets as the LCDB by providing better edge resolution and patch definition. They are also compatible with GIS systems. Many regional

councils have a full set of aerial photographs, often on 1:25 000 scale. New Zealand Aerial Mapping, the country's longest established aerial mapping firm, is also a major source of historic photographs. There is potential once the ARGOS farms are finalised to tap into the historic photographic records covering particular properties relatively cheaply ($100s).

Photo points provide potentially excellent benchmarks, especially for those sites and processes that are identified as critical within a farm from an environmental point of view. Digital cameras have increased the flexibility and convenience of this monitoring tool. It is proposed to establish photo points within farms to examine particular sites or processes. A strict archive of the photos must be established and linked to the ARGOS database to maximise the use of the photographs by the entire team.

2.8 Background conceptual challenges to understanding vegetation dynamics

Land managers seek to influence which species will occur and the abundances of individual species, but still vegetation pattern is usually complex and determined by several forces. The following quotes illustrate a few of such complexities:

> "*Species are not team players – they tend to look after themselves*" (Gee 1996: 24).
>
> "*It cannot be assumed that two environments which were initially similar would subsequently support similar vegetation*" (Roberts 1987: 31).
>
> "*The relationship between vegetation and environment is relational rather than functional. The environment determines which plant species can occur, but it does not determine which species will occur; the environment determines the maximum possible abundance of species which do occur, but it does not determine their actual abundance*" (Roberts 1987: 32).
>
> "*In many vegetation types, the position of a site in vegetation space, and its trajectory through time, will be partly determined by herbivory from insects, and larger animals, or pathog*ens" (Roberts 1987: 30).

The environmental history of the farm may have lingering effects on the current state of its vegetation and may still be influencing ongoing successional processes at work there. The degree of vegetation modification from the pre-European cover ranges from moderate to extensive, but the vegetation cover of most farms has been extensively modified. The transformation of agricultural landscapes has been an ongoing process (Challenger 1974). On ARGOS farms, total plant species diversity, indigenous plant species diversity, and the structural complexity of the current vegetation cover, reflects the differing influences of a combination of factors: environmental history, physical characteristics and climate. For most ARGOS farms, there are few records to indicate the nature of the pre-European vegetation cover and where there are early descriptions, these tend to focus on the vegetation in terms of the opportunities for, and likely difficulties associated with its use for productive purposes. On the other hand, unusual and/or conspicuous vegetation features (e.g. a stand of trees in a tussock grassland landscape) were generally noted. There have been few detailed studies tracking vegetation change in New Zealand's agricultural landscapes, whether at the farm or landscape scale. A notable exception is the work of Holland (1988), who traced patterns of vegetation change in the lowland landscapes of the Waimate district of South Canterbury. Holland (1983, 1988) also examined the social and economic drivers of vegetation change, and their ecological, social and economic consequences. He demonstrated that vegetation change was not a linear process, and that the cost of labour has had a profound influence on vegetation cover (e.g. replacement of hedgerows by fences). Price (1993) focused on changes in hedgerow and shelterbelt networks in Mid-Canterbury.

Three major drivers and explanatory categories have been proposed for vegetation dynamics: site availability (resource availability, spatial availability, and temporal availability), differential species availability (survival of site-opening disturbances, the condition of seed pools and the dispersal of propagules), and differential species performance (environment and species factors that operate following initiation of successional sequence) (Brand & Parker 1995). Agricultural systems endeavour to manipulate these drivers to promote desired successional end-points.

The causes of particular successional pathways are complex and multiple. Perspectives on vegetation systems should therefore:

- Be oriented to process and not endpoint.
- Consider environmental and species drivers as fundamental to an understanding of vegetation dynamics
- Use explanatory schemes that are applicable to all systems and at all spatial and temporal scales.
- Recognise individual species roles, and that their individuality is evolutionarily derived and genetically based (Pickett & McDonnell 1989).

An alternative approach is to consider species in terms of their vital attributes, i.e. attributes that determine the species' role in a vegetation replacement sequence at a given time since a disturbance event (Noble & Slayter 1980). The most important vital attributes are: the method of arrival or persistence of the species at the site during and after a disturbance; its ability to establish and grow to maturity; and the time taken for species to reach critical life ages (Noble & Salyter 1980: 6). For example, Hall's totara (*Podocarpus hallii*), fescue tussock (*Festuca novae-zelandiae),* sweet vernal (*Anthoxantum odoratum*) and mouse-ear hawkweed (*Hieracium pilosella*) can co-occur in one paddock, but they have very different vital attributes that can drive vegetation change in different directions, and they respond differently to disturbance events.

Agricultural landscapes are changing in many ways. Variability of plant species and vegetation covers in space and time is a particularly critical factor in grazing-oriented agricultural systems. Grazing, like predation, is seen by many ecologists as a type of disturbance that can release or intensify competition between different species in the ecological community. Therefore linking vegetation cover to grazing intensity and seasonal rhythms will be an important theme in ARGOS research. It may be that organic farming reduces stocking rate and that this indirectly has considerable impact on current vegetation and associated fauna and successional changes underway.

There is a need to track both plant population and habitat changes across taxonomic groups and a range of spatial scales. Different mechanisms might be driving habitat loss, as opposed to the loss or simplification of populations within extant habitats, and there is a danger of conflating habitat losses with population declines. This makes it difficult to discern the mechanisms threatening species persistence.

There is also a need develop measures that distinguish the processes and move beyond simple records of habitat and population loss to reflect significant shifts in plant community composition or structure, and the resulting changes in patch dynamics (see Farm 'Y' example below). Measuring vegetation change at one scale does not mean that changes occurring at other scales will be discerned. Ideally, land managers could apply synthetic indicators of habitat and population losses, but the scale, scope and consistency of possible indicators pose problems. Comprehensive, robust baselines and ongoing monitoring schemes are the only way to identify, test and use indicators of change and to research why those changes are happening.

Studies of plant populations in many agricultural systems reveal declines and losses of indigenous species, especially habitat specialists, and increases in introduced species with

weedy propensities. The replacement of habitat specialists by habitat generalists is a widespread trend in New Zealand's agricultural landscapes. A population near its species' abiotic environmental optimum will support a greater biomass, density and reproduction than a population near the species' minimum environmental requirements (Roberts 1987). Stressed populations often occur near the extremes of the species distribution, and flourishing populations are more likely to be near the distributions middle. In many agricultural landscapes, indigenous plant species are more likely to be found at sites with conditions nearer to a species' minimum requirements.

Biotic homogenization may be as widespread as habitat and species losses, but it is clearly a distinct phenomenon that demands separate monitoring. The consequences of homogenization for agricultural production systems, in the context of sustainable land management, needs to be researched.

Any vegetation sampling design has to be flexible enough to cope with the range of variation of sample sites in a farm's vegetation cover, of both species and sites. It has to be sensitive enough to track spatial and temporal changes in the cover-abundances of individual species, patches and paddock and farm-scale vegetation associations. To illustrate some of the issues involved in vegetation survey, two hypothetical examples (Farms 'X' and 'Y') are outlined below.

Farm 'X' is a sheep and beef farm 'X' comprising a suite of extensive river terraces a few kilometres from hill country. The terraces are crossed by two streams, which have cut deep incisions into terrace scarps. Farm X has several paddocks of different dimensions. Most of these paddocks are completely dominated by introduced pasture species, but some have a residual element of indigenous short tussock vegetation. There is one large paddock, which is dominated by indigenous tussocks, but it also contains significant elements of introduced grasses. The paddock with indigenous tussock species also has a significant tree and shrub component of remnant indigenous and actively spreading introduced species, which occurs as clumps on patches with surface rocks, as discontinuous strips along both streams, and as scattered shrubs in the tussock grassland. One strip along an incised section of a stream is an open remnant stand of black beech (*Nothofagus solandri* var, *solandri*). Indigenous woody plants also occur as scattered shrubs on roadside margins of the minor road that passes that runs along the north and east boundaries of the farm. Woody plants on the rest of farm consist of several isolated shelterbelts and one long hedgerow which runs along the northern boundary. All these features consist of introduced species. There are several old isolated cabbage trees/ti (*Cordyline australis*) scattered around the farm, and five over-mature black beech trees in the front paddock between the homestead and the road. A mistletoe species, which is nationally threatened, occurs on some of the beech trees on this farm. Some of the woody shrubs are also host species to regionally endemic insects. Bats have been recorded on this farm.

2. Farm 'Y' is a 1500 hectare rectangular paddock, which straddles a broad east to west trending ridge. The paddock is used for sheep grazing. Rabbits are also present in low numbers. Introduced grasses and herbs dominate the vegetation. Indigenous short tussock grasses occur throughout, but they are only abundant on south-facing slopes. The south–facing slope also has mature clumps of indigenous woody shrubs growing in moist gullies and there are also individual woody plants scattered across the slope. On the north side of the summit ridge there are several sheep camps. The vegetation structure and the resulting patch mosaic of the paddock, with the partial exception of south-facing slopes, is strongly influenced by sheep grazing preferences and farm management decisions directing stock to areas of the paddock with palatable biomass. The plant species pool of the paddock, with the exception of woody plants, occurs in all

patches but cover–abundance and plant vigour values exhibit considerable variation. The vegetation patches are characterized by grazing induced shifts in the cover-abundance values of the species present, and may lead to new mixes of the plant species that constitute the regional landscape species pool. Vegetation shifts would occur in response to a rapid increase in rabbit numbers. At any time, there are multiple potential botanic landscape outcomes: e.g. more introduced grasses, fewer indigenous short tussock grasses, more hawkweeds (*Hieracium* spp.), or more indigenous woody plants. Different vegetation trajectories will lead to alterations of patch traits, or the creation of 'new' patches. Substantial shifts in the traits of individual patches will produce vegetation switches and alterations of the paddock-scale patch mosaic. This has cascading consequences for the botanic futures of individual patches, the vegetation of the paddock as a whole, its value as a grazing resource, and wider ecological and cultural landscape values. There are also likely to be ripple effects into the surrounding landscape.

The implications of vegetation changes such as might occur on farms 'X' and 'Y', and whether they are desirable or not with respect to long-term agricultural sustainability need to be assessed in terms of spatial and temporal dynamics of vegetation shifts and switches in the patch mosaics of individual paddocks, landforms and up-scaled to the entire farm. The vegetation sampling design needs to list both the species present and the spatial and temporal characteristics of cover-abundance. The paddock has to be sampled to include the range of physical and botanical attributes present. In addition, 'special features' need to be included in the picture. In the case of the paddock on farm 'Y' the woody vegetation in gullies constitutes a potential point of departure for future landscapes, with consequences, both positive and negative, both for production systems and conservation values. The vegetation data then has to be married with information on soil health, animal grazing behaviour, and paddock management and then up-scaled to the farm scale, in order to obtain an accurate determination of the component parts that make up the landscape, and to assess whether the individual parts, as well as the whole unit approaches in social-ecological terms a sustainable system.

2.9 ARGOS Vegetation Sampling

The sampling design has two aims. First, to describe the vegetation in compositional and distributional terms, and to relate vegetation patterns to landform, soil, water and management factors. Second, to describe the patterns and attributes of focal plant species, plant species of significance in the farm production systems, weed species, and geo-botanic landscape features of special interest (e.g. rock outcrops, gorges and gullies, hedgerows, shelterbelts, roadsides and tracks) in relation to farm environments and farm management practices.

Vegetation data will be collected by a number of operators working on very different farms of very different sizes. The approach to vegetation data collection has to be consistent between ARGOS farms, be easy to repeat, and record information in way that ensures that all data are comparable. The sampling design has to be simple and robust. Initially, data will be collected by direct approaches. Subsequent field visits may incorporate data obtained from inferential approaches and the use of index values. The first step is to undertake a vegetation survey in order to get a picture of overall vegetation composition, and the cover-abundance and health of species involved in production systems, and of the other species present on the farm with ecological or conservation values, or which pose threats to ecological, economic and conservation values.

The vegetation survey uses the ARGOS farm landform and soil maps as a framework to select individual sampling sites and points. It is desirable to classify and ordinate the vegetation both in terms of individual plant species and the complete vegetation cover that is adding or detracting from the farm enterprise. Ideally, the vegetation cover should also be assessed in terms of its

harvestable biomass, and the actual and potential amounts of biomass as sub-sets of the total that is being harvested.

The vegetation cover will be stratified on the basis of the landform arrangements and soil sets occurring on individual farms. Within these areas, sample sites and points are randomly located. It will not be feasible to use a single, uniform plant sampling strategy to collect the presence/absence, cover-abundance, distribution and other attributes of a farm's vegetation cover. Some aspects of a farm's vegetation mantle are not amenable to stratified random sampling. The distribution of some focal species[9] may render stratified random sampling strategies inappropriate. In such instances, purposive or directed sampling will be necessary. For example, a farm may have 20 trees that are known to host a species of tree weta. To collect meaningful data and to situate it an appropriate landscape context it will be necessary to take a plant-oriented sampling approach is needed. Each tree will need to be located and then sampled with reference to its traits and site factors. This type of more spatially directed sampling will follow the baseline surveys once focal species have been selected.

Efficient vegetation sampling is best achieved by use of either line or banded transects. They are generally easy to lay down, and if required, to mark their starting points, with a stake or permanent marker, or description of the starting point with reference to a durable farm feature (e.g. a fenceline). Permanent marking of the start of a transect makes it possible to undertake repeat surveys. Depending on the information being collected along a transect can be marked by a tape, string, or be walked. Transect length will reflect information requirements and local site conditions. Vegetation sampling can be either continuous or at set intervals. In some situations a banded transect will facilitate a more explicitly spatial approach to vegetation. For example, across patch boundaries where there is considerable variations in plant sizes on and data collection and is useful when plants of wide range of sizes are encountered. The use of a tape measure introduces a greater degree of spatial control and acts a baseline from which any subsequent change of species and vegetation attributes can be measured.

An alternative approach is to undertake quadrat sampling of a stratified sample of patches in the study area. This would involve a preliminary survey to map the patches of a study area to create a sampling grid. Some patch boundaries will be difficult to locate by eye. Different vegetation types are most accurately sampled by different-sized quadrats. It would be possible to produce species-areas curves for all the vegetation types encountered on the ARGOS farms, but this would necessitate a pilot survey. Decision-making with respect to locating quadrats on the ground and laying them out presents opportunities for inter-operator divergence and potentially lessons the value of the data recorded. Comparing data for 1x1 metre (e.g. grassland) and 20 x 20 metre (e.g. forest) quadrats raises a number of statistical issues.

All plants should be identified to species level if at all possible. If plants cannot be identified in the field then two reference samples will be taken and be assigned a tag name: one for subsequent identification and the other to be used a reference sample in the field. Species frequency measures will be difficult to obtain in swards or if the species are clonal and/or stoloniferous. Biomass (site production, site production potential, plant vigour, and proportions of palatable plants) may be a more appropriate measure.

Cover-abundance measures derived from discontinuous measurements pose problems as plant dimensions (e.g. large trees and shrubs versus small grasses growing at the same site) exert an influence on what is sampled. Some plants at some sites will have distribution patterns (e.g clumped, regular) that are not efficiently recorded by sampling at set intervals. Ideally, cover-

[9] e.g. rare or endangered species; not threatened, but rare or uncommon species on a farm and in the landscape of which it is a part; or nationally iconic species.

abundance measures should relate to discrete patches, but it is going to be difficult to match plant data from a line to an area.

Collecting good sets of vegetation data is time-consuming and expensive. It is much more effective to sample most vegetation types in pairs. If the species pool is large and surveyor taxonomic knowledge is limited, much time could be spent involved in post-fieldwork plant identification. Creating a computer database will also be time-consuming and expensive. There are likely to be some very divergent data sets (e.g. lowland kiwifruit farms versus high country stations). Plant species with low frequencies could be excluded, but that would mean making an assumption that frequencies will remain low, which could be wrong. Low frequencies could represent decline or recent entry into a farmscape.

3. Surveying and Monitoring Terrestrial Vertebrates

3.1 Lizards and frogs on farms

A national database on the distribution of herpetofauna (frogs, lizards and tuatara) is maintained by DoC[10] and will be consulted by the ARGOS team to focus search strategies onto the most likely areas on farms to find them. The ARGOS data will be contributed back to the database using their standardised record sheets. There are at least 18 threatened or declining New Zealand lizards living on farmland, 13 of which are in the South Island (Hitchmough 2002; Table 2.1). More common lizards and frogs may be valuable bio-indicators for long-term monitoring and currently unthreatened species may become locally threatened if farming is intensified.

Table 3.1. Threatened lizards found on New Zealand farmland. (After Hitchmough 2002). (CD = Conservation Dependent; DP = Data Poor; HI = Human Induced).

Common name	Taxon	Threat classification	Qualifier	Notes	Island
Grand skink	*Oligosoma grande*	2 Nationally endangered	CD, HI		S
Otago skink	*Oligosoma otagense*	2 Nationally endangered	CD, HI		S
Small-scaled skink	*Oligosoma microlepis*	4 Serious decline	DP	Almost all populations threatened by farming activity	N
Canterbury gecko	*Hoplodactylus* "Canterbury"	5 Gradual decline	HI		S
Large Otago gecko	*Hoplodactylus* "Otago large"	5 Gradual decline	DP		S
Southern forest gecko	*Hoplodactylus* "Southern forest gecko"	5 Gradual decline	DP, HI		S
Pacific gecko	*Hoplodactylus pacificus*	5 Gradual decline	HI		N
Auckland green gecko	*Naultinus e. elegans*	5 Gradual decline	HI		N
Wellington green gecko	*Naultinus e. punctatus*	5 Gradual decline	HI		N
Jewelled gecko	*Naultinus gemmeus*	5 Gradual decline	HI		S
Northland green gecko	*Naultinus grayii*	5 Gradual decline	HI		N

[10] see http://www.doc.govt.nz/Conservation/001~Plants-and-Animals/001~Native-Animals/Herpetofauna/005~About-Bioweb-and-Herpetofauna.asp

Rough gecko	*Naultinus rudis*	5 Gradual decline	DP, HI		S
Nelson green gecko	*Naultinus stellatus*	5 Gradual decline	DP, HI		S
Green skink	*Oligosoma chloronoton*	5 Gradual decline	HI	Taxonomy?	S
Cryptic skink	*Oligosoma inconspicuum*	5 Gradual decline	DP, HI	Decline may be less than 5%/10 years?	S
Speckled skink	*Oligosoma infrapunctatum*	5 Gradual decline	HI	Appears to be declining more rapidly in North Island	N+S
Spotted skink	*Oligosoma lineoocellatum*	5 Gradual decline	HI	Appears to be declining more rapidly in North Island; taxonomy?	N+S
Scree skink	*Oligosoma waimatense*	5 Gradual decline	HI	Taxonomy?	S
Kaikouras gecko	*Hoplodactylus* “Kaikouras”	6 Sparse	DP		S
Matapia gecko	*Hoplodactylus* “Matapia Island”	6 Sparse	HI	Now known to occur on mainland	N
North Cape Pacific gecko	*Hoplodactylus* “North Cape Pacific gecko”	6 Sparse	HI		N
Goldstripe gecko	*Hoplodactylus chrysosireticus*	6 Sparse	DP, HI		N
Marlborough green gecko	*Naultinus manukanus*	6 Sparse	DP, HI		S
West Coast green gecko	*Naultinus tuberculatus*	6 Sparse	DP		S
Long-toed skink	*Oligosoma longipes*	6 Sparse	DP	Waimakariri, Arthur’s Pass	S
Grey Valley skink	*Oligosoma* “Grey Valley”	7 Range restricted	DP	3 small populations known; included in "West Coast skinks" in Molloy & Davis	S

Copper skink	*Cyclodina aenea*	Not threatened			N
Ornate skink	*Cyclodina ornata*	Not threatened	DP	Decline on mainland offset by increases on islands	N
Central Otago gecko	*Hoplodactylus* "Central Otago"	Not threatened		Continuous population in single geographic area	S
Cromwell gecko	*Hoplodactylus* "Cromwell"	Not threatened			S
Marlborough mini gecko	*Hoplodactylus* "Marlborough mini"	Not threatened		Possible cryptic taxa	S
Southern Alps gecko	*Hoplodactylus* "Southern Alps"	Not threatened			S
Common gecko	*Hoplodactylus maculatus*	Not threatened		Increasing on islands from which rats eradicated, declining in some placeas on mainland	N+S
McCann's skink	*Oligosoma maccanni*	Not threatened			S
Common skink	*Oligosoma n. polychroma*	Not threatened			N+S
Brown skink	*Oligosoma zelandicum*	Not threatened			N+S

All lizards can be found by searching under cover items such as rocks. Skinks and green geckos are also found by scanning suitable habitat for basking animals. Brown geckos are found by spotlighting for eye shine at night. Skinks can be sampled by pitfall trapping. A combination of directed searching and pitfall trapping will be used to estimate a catch per unit effort and catch per pitfall per day index of skink and gecko abundance (following Towns 1991). We will also investigate the placement of 'Artificial Cover Objects' (ACOs) for indexing lizard abundance. Squares of material with refuge spaces underneath are attached to the ground to attract lizards. These can then be rolled and numbers estimated. It is a useful technique in that it is not weather dependent. Each method will be biased for different species, so several techniques should be run in parallel for the preliminary survey, and then a more targeted sampling protocol can be devised if a lizard is chosen as a focal species for long-term monitoring.

Frogs have been declining throughout the world and are considered potentially sensitive as environmental indicator species (a recent issue of Diversity and Distributions [Vol 9, number 2, 2003] is dedicated to "*Amphibian declines: Untangling the complexity*"). Standardised international protocols for frogs (Heyer *et al.* 1994) will be assessed for application to the farm ponds and riparian strips 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.

3.2 Birds on farms

3.2.1 Bird distribution, abundance and activity

Ecologists and wildlife managers commonly focus on two levels of population performance – the distribution (presence/absence) of a species and the abundance of the species where it does exist. Distribution is an inexpensive and quick measure that will signal some broad ecological influences over wide areas. We will use some crude distribution analyses to estimate ecological landscape level effects stretching beyond each ARGOS study farm. Abundance measures are harder to obtain but can lead us to more important and fine-scale information of what each species needs to prosper in the farm landscapes. We will also measure habitat use and individual's activity to help us identify critical places or resources that are needed for survival and reproduction in the farmland landscape.

3.2.2 Using the New Zealand Bird Atlas

The 'New Zealand Bird Atlas' (Bull *et al.* 1985) is a scheme operated by the Ornithological Society of New Zealand (OSNZ) that collates bird sightings by its members and volunteers from throughout New Zealand. Observations are aggregated for each 10 Km grid square on the SM1 Map series. The database is periodically updated so that broad scale shifts in species distribution can be monitored. Publication of a revised atlas is planned for 2005 (Robertson & Taylor 1999).

We propose that all records from the preliminary survey of ARGOS farms are submitted to the bird atlas scheme and if practicable, that the field officers also note birds seen or heard whenever they visit the farms in the course of their other work. Nearly all kiwifruit orchards will fall in only a single 10 km square, but sheep/beef and especially the high country runs will cover several 10 km squares (separate sighting lists for different parts of the farm will then be needed). The atlas will be used to predict which species we might expect to find in the vicinity of each farm. This will be compared with the actual presence/absence we score on each farm to assess whether ecological conditions are suitable there. We can then generate a list of "missing" species that might be encouraged onto each farm with appropriate restoration management. Contributions to the bird atlas scheme should take less than an hour per farm per year provided that the bird lists are generated in the course of other more essential work. A minimum of one-hour per square is sufficient to detect most species (McKinlay 2001).

The expensive and intensive surveys of bird abundance described below can initially only be done in spring. We propose that the field officers or Postdoctoral Fellows generate a separate list of birds recently noted on each farm by the farmer and/or his family at all times of the year. The farmers' degree of awareness and knowledge about the birds will in itself be of interest to our socio-ecological research, but the augmentation of the lists by the farmers helps the distributional study by providing a year-round perspective.

The distributional study will probably be far too coarse to compare bird communities on organic, IM and conventional farms unless ecological differences are huge. Nevertheless we will build multiple logistic regression models for each species to test whether presence/absence relates to any of the habitat and farm descriptors measured in the ecological survey of ARGOS farms.

3.2.3 Describing the ballpark in terms of abundance: a few relative measures of abundance to compare with other New Zealand studies

Most bird abundance monitoring in New Zealand has been done in forested habitats, using a 'relative index' method (see Dawson 1981 or Sutherland 2000 for a discussion of the relative merits of relative and absolute measures of abundance). Usually this involves "5-minute-bird-counts" (the number of birds seen or heard in 5 minutes from count stations spaced 200m apart; Dawson & Bull 1975) or the number of birds seen and heard when continuously moving down a transect (O'Donnell & Dilks 1986, 1994). For comparability reasons we propose to do a small number of 5-minute bird counts on the ARGOS farms to provide a collective benchmark of farmland to forest bird abundance. We will begin by doing 10 such 5-minute bird counts per farm on the first visit and review at the end of the baseline survey to see if more are needed in follow-up work. Small indigenous forest or grass reserves and any pine forests will have an additional set of 10 counts done.

The five minute bird counts must be done in reasonably ideal conditions, and so temperature, wind speed, humidity and cloud cover will be recorded for each site. Surveys should not undertaken if it is raining or if the wind speed is too high (>20km/h^{-1} average) so as to maximize the detection of birds (Dawson & Bull 1975). All counts should be done between 0800 and 1400 hours to minimize rapid changes in detectability that can occur with some species around dawn and dusk. The open-space nature of the farmland in some sectors will probably increase the detectability of the birds there compared to in forest, so the relative index will be biased upwards in farmland. For most species, very much lower bird counts are expected in farmland than in forest, so this detectability bias will reduce the apparent difference between the habitats.

3.2.4 Distance sampling is best for comparing between farms

The problems of differential detectability of animals in different habitats or at different seasons has led to the development of sophisticated 'Distance sampling' methods to directly measure and thereby factor-out the influence of these detectability changes (Buckland *et al.* 2001). In this approach, the observer notes the distance out from a predetermined transect line, or from a fixed sampling point, that each individual bird or flock was seen. It is assumed that all the birds located on the transect (or at the observation point) are seen, and a 'detectability function' is calculated that describes the way in which probability of detection declines at increasing distance from the transect or observer. If the sampling unit is defined as a flock, a separate score of the number of birds per flock is made and the distance sampling procedure estimates the density of flocks.

The DISTANCE™ software is available (free of charge) to fit best models to observed frequency distributions to pick the best detectability function. This allows calculation of the area surveyed and thereby the 'absolute density' of each species (birds per km^2). The supreme advantage of the method is that variation in detectability does not interfere with the estimates. The method is particularly appropriate for the open space type habitats predominating on ARGOS pastoral farms, but may be less robust in the kiwifruit orchards where vision of the observer is seriously occluded by the vines and shelterbelts between blocks.

The only other method used for estimating absolute densities in farmland is the British Common Bird Census method (Bibby *et al.* 2000). This relies on plotting the location of sightings of unmarked birds and interpreting clusters as territories. The method is extremely subjective and has already given wild swings in bird abundance in successive years that are most unlikely to represent ecology reality (Wratten 2003) – instead the differences inferred are almost certainly a result of different observers or interpreters of the data. We believe the method should be abandoned altogether. It is not sufficiently robust to detect any differences between organic, IM or conventional farms. The distance sampling method may yet also fail to estimate bird abundance sufficiently to compare between ARGOS farm cohorts, but at least it is a more objective and repeatable analysis method.

Dr Catriona McLeod (Landcare research) is estimating bird abundance using distance sampling methods on arable farms in Canterbury so some comparable data will be available to compare with our sheep/beef farms.

3.2.4 Distance sampling intensity

At least 30 observations of a given species are needed to adequately estimate a distance detectability function, but naturally more observations allow more accurate estimation (lower confidence intervals). This may be readily achieved for some relatively abundant species, but it is inevitable that we will not even reach this minimum target for the sparse ones. In such cases we can either (i) select the detectability function of a related species judged to have about the same conspicuousness and calculate an absolute density anyway, or (ii) we use the raw interception rates as a relative index only and make comparisons between farms (on the assumption that detectability remains about constant).

We will aim to achieve 50 observations for the most common species per farm or habitat within each farm, but it is impossible to predict whether this is practicable until after we have tried it in the spring of 2004. We will make repeated passes over the same or different transects.

Each farm in a matched triple (or pairs in the case of the High Country farms) will be visited on a given day for bird counts, on three separate (probably successive) days between 10 September and 15 November). The order of doing the counts within each triple will be rotated regularly so that any effects of time of day on detectability are evened out. All up this will require 36 sampling days for lowland sheep/beef; 30 days for High country; and 36 for kiwifruit. Therefore we will need at least two observers for the survey.

Choice of sampling strategy is crucial to the success of any monitoring programme, probably even more important than the choice of survey method (Gregory 2000). Until we have seen the farms selected for the ARGOS cohorts we can not judge whether it would be prudent to divide the farm into particular habitat types. If large discontinuities exist, it will be prudent to stratify the farm into separate habitats and to try to achieve 50 detections within each block/habitat. Placement of transects for distance sampling will then be stratified random.

3.2.5 Placement of 5-minute counts within the distance sampling procedure

The ten 5-minute-bird-counts will be placed at random locations along the transects used for distance sampling with the proviso that they are more than 200m from their nearest neighbour (sheep/beef) or 50 m (kiwifruit).

In the kiwifruit case the counter will traverse from the most recent count station to another at least 200 m away, before doubling back to the intervening stations. In this way

maximum temporal independence will be achieved between successive counts even though this forces the observer to criss-cross back and forward over the orchard. This will force the observer to do the 5-minute bird counts as a separate exercise after having completed the distance sampling. The 5-minute bird counts could be more simply inserted into the sampling sequence while traversing the sheep/beef farm because at least 10 sites spaced at 200m from its nearest neighbour can be obtained.

3.2.6 Frequency of sampling

At this stage we should treat the bird sampling as a once-off exercise, measure the time and cost to achieve the information, and use the preliminary survey to estimate confidence intervals around estimates. The spring breeding time is the most important period for this first look if the farms are to be assessed as ecological 'nursery' or ecological 'source' areas (Pulliam 1988), rather than simply spill-over or 'sink' areas used for foraging outside the breeding season.

3.2.7 Linking bird locations to landforms, habitat and activity

Whenever practical we will also assign sightings of individual birds to the landforms and habitats defined in the baseline ecological surveys of ARGOS farms. Similar we will categorise the activity of the birds to general activity (e.g. foraging, territorial display, roosting, etc.) and note its position in the habitat to assess 'habitat use (O'Donnell & Dilks 1986). These observations give linking information on the habitat needs of each species ands may lead us to monitoring of particular foods or habitat requirements in the later stages of the ARGOS study. It is useful to measure abundance as a first step and subsequently to track trends in abundance, but research on why it varies depends on detailed observations of what the birds are doing on the farms and which elements in the landscape that they centre their activity. Studies of habitat use at both large and fine habitat scales has identified reasons for large declines in some United Kingdom farm landscapes and pinpointed local management actions to increase local populations (Potts 1986; Stowe *et al.* 1993; Green & Stowe 1993; Evans & Smith 1994; Green 1996, Gregory & Bailie 1998).

3.2.8 Selection of bird focal species

Having described the overall bird communities in the first year, we will select a subset of 'focal species' for further work on their ecological requirements, responses to predator control or correlations with habitat quality. After this narrowing down we can design a more finely tuned bird census programme that uses an optimum sampling effort. At that stage it may be possible to broaden the study out to measure the abundance and activity of the focal species in summer, autumn and winter; and to assess the number of years required for repeated censuses to be reasonably confident of detecting a given level of increase or decrease in bird abundance.

3.2.9 Bird pests on farms

There have been repeated comments by Kiwifruit growers that flocks of birds (probably finches) can sometimes attack shoot and flower buds in spring. This is apparently a particular problem for Hort 16A growers, presumably because these appear 3-4 weeks earlier than in Hayward and food is scarce then. Some growers believe that bird damage is more of a problem when hay or grains are fed to livestock within the surrounding 5 Km. These hypotheses will be checked as the monitoring of ARGOS kiwifruit orchards proceeds. If it appears to be a severe problem, intensified research will be initiated in later years.

There is a general low-level problem of 'bird liming' of fruit; that is, bird faeces being deposited on fruit and spoiling its marketability. Again a watching brief will be kept on this threat.

3.3 Bats on farms

Bats are being used in the United Kingdom as bioindicators of agricultural impacts (www.bio.bris.ac.uk/research/mammal/bioindicators.html), and significantly more bat activity and higher bat species richness occurs 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 (Wickramasinghe, in litt.).

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 that 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. 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 centred on large reserves or National Parks. A well-studied population of long-tailed bats covers about 100 km^2 of Southern Canterbury, in the Hanging Rock, Geraldine to Pleasant Point region (Sedgeley & O'Donnell 2004). Both short-tailed and long-tailed bats occur in high numbers in Fiordland National Park, so some may forage out onto the farmland of the Waiau Valley where one of the proposed clusters of ARGOS farms is located.

We propose that the ARGOS team searches for both long-tailed and short-tailed bats on all their farms in summer 2004/05. Research should only be intensified in later years if bats are detected. Studies have already demonstrated the importance of tall woody vegetation, shelter belts and riparian vegetation (e.g. willow trees) for bat roosting and availability of high quality roosts may be an important population regulator (O'Donnell, no date). Therefore should we find bats, tree management on the farms will become an important focus for sustainability. A greatly intensified monitoring programme would be needed to detect long-term trends in bat numbers (O'Donnell & Langton 2003).

Our survey will use the standard protocol devised by O'Donnell & Sedgeley (2001) and our information will be added to their informal bat database to allow a landscape evaluation of bat distribution in the vicinity of each ARGOS farm. The method involves walking along all the public roads within each square kilometre on foot at a slow walking pace (around 3 km per hour) while carrying a hand-held 'Bat Box III' bat detectors, manufactured by Stag Electronics, Sussex, UK. We will carry two bat detectors at once, one tuned to 40 kHz for detecting long-tailed bats and the other 27-28 kHz for short-tailed bats. The observer counts the number of 'bat passes' in each km grid square of the SM1 national map series. Ambient air temperature must be $\geq 7\ ^0C$ and there must not be any rain (it reduces detectability). Times of moderate or strong wind should also be avoided. The first two hours after dark are the best for detection, but we propose to count anytime till midnight as dictated by other work routines. Overcast nights are best, probably because temperatures are warmer. Standardised weather information and time will be recorded during each survey.

The surveys along public roads around the farm should also be augmented by a special walk over the ARGOS farm itself (separate records will be kept for this search so that the standardised search effort can be reported to the national distribution survey). This walk-through survey should last no more than two hours and deliberately seek out the parts of the farm where bats are most likely to occur i.e. shelter belts, riparian margins, ponds, forest margins and scrub (Sedgeley & O'Donnell, 1999). A rough plot of the location of the search path and all bat passes heard for each species will be recorded.

The bat survey around and on each farm should take no more than three hours and need only be done on a single night. The likelihood of detecting bats can be further increased by using automated bat-detecting stations as developed by O'Donnell & Sedgeley (2001). These have a Bat Box III, battery, talking clock (to announce the turn of each hour) and voice-activated tape-recorder so that an audio-recording of the number of bat passes each hour can be obtained for very long periods. We propose that as many as possible of these detectors are placed on all three farms in an ARGOS triplet on the first day the team arrives in the area, and left in place until the last day (probably 3-4 days later). Half of the detectors should be set to the long-tailed bat frequency and half for short-tailed bats.

The bat detectors cost approximately $250 each and the complete automated recording station equipment around $600. We therefore propose to borrow or lease as many as possible from DoC, Universities and other consultants for the preliminary survey. The bat detectors can only hear a long-tailed bat in the surrounding 44 ± 9 m (O'Donnell & Sedgeley 2001), and short-tailed bats within ca. 20 m (C. O'Donnell pers. comm.). Therefore fixed automatic recording stations offer poorer spatial coverage but longer temporal coverage than the walking surveys.

3.4 Introduced small mammals on farms

Possums, hedgehogs, rabbits, rodents, feral house cats and mustelids (ferrets, stoats, and weasels) are all potentially important introduced predators on ARGOS farms. Possums and ferrets have received a lot of study because of their role in transmitting bovine tuberculosis to livestock (Ragg *et al.* 1995a & b, Cowan & Coleman 1999), and rabbits have been studied intensively in the semi-arid regions where they have at times been a serious economic and conservation pest. However hedgehogs, rats, mice[11], stoats and weasels have been relatively neglected elements of the predator prey communities in pastoral landscapes, and no systematic studies of any of the introduced predators in kiwifruit orchards have been published.

Management of introduced predators and their prey is complex and intensified predation of valued indigenous biodiversity could result from well-meaning but misguided interventions (Moller 1989, Moller *et al.* 1996, Moller *et al.* 1997, Rebergen *et al.* 1997).

3.4.1 Initial survey of small mammals

Ink-print tracking (King & Edgar 1978, Ratz 1998) will be used in initial biodiversity surveys to detect the presence/absence of rodents, hedgehogs, stoats and weasels at ARGOS farms. If resources allow[12], follow-up index trapping using soft-jaw victor traps and standardised trap up-stands (Alterio & Moller 1997) will be used in autumn to index feral cat, possum, hedgehog and ferret abundance.

Rabbit abundance will be scored using a Mclean scale of pellet abundance which modified Gibb's *et al.*'s (1978) relative scores of the distribution and abundance of pellets. Although differential decay rates of pellets can preclude comparisons of rabbit abundance in different regions, the method can accurately and rapidly estimate pellet abundance itself (Moller *et al.* 1997) and differential decay rates should not prevent testing a null hypothesis that rabbit abundance is the same within farms of the same cluster.

[11] Foundation work by Brockie (1959, 1975) provided excellent descriptive ecology about hedgehogs in New Zealand but the critical studies of their impacts on biota are only just emerging (Jones et al. 2005.). Brockie (1977) also provided an early survey of rodents on pastoral farmland.
[12] Budget constraints mean that this survey will probably not be possible until Autumn 2006 or 2007.

3.4.2 An experiment to assess the relative importance of habitat and predator control for farmscape restoration

Enhancement of biodiversity on New Zealand farmed landscapes probably partly depends on building more habitat variety and structural complexity into our agro-ecosystems. However, this may not be enough in itself. Just as for intact forests, safe-guarding or enhancing biodiversity may also require control of several introduced animal and plant pests, which if left unchecked, will continue to drive persisting species locally extinct or prevent reestablishment of ones that have already gone (Perley *et al.* 2001). Feral cats, possums, ferrets, stoats, weasels, rats, mice and hedgehogs are all potentially limiting valued indigenous and introduced biota on farms. ARGOS therefore proposes to do an experiment as soon as possible to test whether (i) habitat features alone set biodiversity levels, (ii) introduced predators reduce biodiversity levels to such and extent that habitat quality is unimportant, or (iii) restoration of biodiversity is dependent on both habitat enhancement and ongoing control of predators. If practical, a 'predator press' (sustained control of predators; Moller & Raffaelli 1998, Raffaelli & Moller 2000) will be imposed on a replicated set of farms with a low habitat diversity and simple habitat structure, and also on a set of farms with varied and complex habitats. A Before-After-Control-Impact (BACI) design would be used to monitor changes in biodiversity on both sets of farms.

In 2004/05 (year 2), we will assess the feasibility of superimposing the experiment on the overall ARGOS project's design. Of critical concern is whether sufficient replication can be achieved and whether the predator press can be imposed on a sufficiently large spatial scale to make the experimental inference reliable (Raffaelli & Moller 2002). It may be that we can achieve better replication and spatial scales by centering the predator press on TB 'Vector Risk' areas where most of the predators are being controlled by the Regional Councils and Animal Health Board. Some Landcare groups also mount predator control programmes. Similarly, a new initiative by farmers, community groups and DoC is beginning to control predators in South Canterbury to protect and restore long-tailed bat populations (C. O'Donnell pers. comm.). An intensified predator press to protect giant skinks in the MacRaes Flat area of Otago is also currently being mooted. We may be able to use these areas for treatment replicates. Although use of management initiatives such as these can save funds and enhance statistical power by increasing replication, it can also force several distortions on the experimental design (Raffaelli & Moller 2001). For instance, duration and consistency of the experimental intervention will be driven mainly by management imperatives; there may be difficulties in finding matched non-treatment sites; choice of where and when to control predators will be determined by considerations other than ARGOS study needs. However, if we can mount the experiment on ARGOS study farms we can better integrate outcomes into the ARGOS project and draw on the overall database for contextual information about each farm. Therefore we will only shift the experiment to non-ARGOS farms if the practical constraints force this dislocation.

If practicable, such a predator control experiment will be initiated late in winter of 2005 and will be maintained for the next three or four years. We propose to apply to the Sustainable Farming Fund (MAF) in February 2005 for co-funding for the predator control project from July 2005. We invite collaboration from anyone in the team on this project. It would be exciting to have the sociological and economic perspectives embedded within this application and increase the chances of funding.

The experimental outcome will inform the relative importance of predator control and habitat enhancement for environmental sustainability interventions in the remaining decades of the ARGOS project.

4. Invertebrates on Farms

4.1 Why sample invertebrates?

Research and monitoring of invertebrates 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. They are often significant pests of crops and livestock. The arthropod fauna is a very rich source of diversity in terrestrial ecosystems and in many situations will be the most numerous and most diverse component of the animal life present. This holds for altered as well as indigenous environments. For example Kuschel (1990) working with just one order of insects, the beetles, recorded 982 species from an Auckland suburb, including 130 undescribed species.

The largest challenge for monitoring is to adequately measure their abundance and distribution. The practical difficulties of sampling invertebrates stem from their (a) extreme diversity (specialists are needed to separate species), (b) inadequately described taxonomy, (c) cryptic habitats, and (d) patchy distribution and abundance in time and space (and therefore present considerable statistical challenges for sampling). This extreme diversity makes it impractical to monitor the entire arthropod fauna - focusing of effort is needed. Several strategies are possible to achieve this. Most frequently a smaller taxonomic group is chosen to represent the wider communities, such as ants in Australia (Andersen 1990).

We single out some pest invertebrates for targeted monitoring in Section 3, and focus on nematodes and earthworms as potential focal species for monitoring soil health and soil formation in Sections 6 and 8. Aquatic insect abundance will be well-measured by our SHMAK protocols (Section 5). However, there are more generalized measures of terrestrial invertebrate abundance and diversity. These are considered briefly here.

This section sets out what research is intended to be undertaken within the general theme of “pests and beneficials”, and attempts to provide some of the background and rationale for the proposed work.

The ARGOS project was set up to evaluate the relative economic, environmental, and social performance of conventional and alternative production systems within a range of different farming sectors. It also aimed to make comparisons of these performance aspects across the sectors to derive fundamental principles that were applicable to primary production in general. The desired outcome is the broader use of environmentally-enhanced primary production systems in New Zealand, in order to meet enhanced environmental and quality standards. The two intentions, evaluating farming systems within a sector and comparing sectors, can require conflicting requirements, and this is particularly so at the level at which invertebrates and micro-organisms operate. This dichotomy between aims is further emphasised by the necessity that what is undertaken must be practical within the defined budget, so that options must be targeted.

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. This distinguishes them from most other environmental parameters and so is further discussed below.

In both kiwifruit and sheep/beef the main focus of the pest control measures are arthropods (Scott 1984, Zespri 2004). 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 that we intend to follow is 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 these studies.

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.

The chapter deals with the two main production sectors separately, firstly with kiwifruit and then with sheep and beef farming. The separation reflects three principal aspects that differ markedly between the sectors:

- The physical scale of individual operations, very small on kiwifruit orchards relative to sheep and beef farms,
- The intensity of production and thus the importance of pests and pesticides, and
- The spread and internal diversity of the clusters and farming systems.

These differences all impact on the possible value of pests and beneficials as focal species, and their potential use as indicator species of environmental impact.

4.1.1 Definitions

For simplicity the word ‘pest’ is used to include all organisms injurious to plants or to farmed animals or to trade in products derived from these. This is based on the FAO phytosanitary definition (FAO 2002), but is extended to encompass farmed animals as well as plants as hosts.

‘Beneficials’ includes predators and parasitoids, as well as pollinating agents.

The term ‘focal species’ is used in preference to ‘indicator species’ (Benge *et al*. 2004), since the latter term invites the question “indicative of what?”, and at this stage of the project we lack the information needed to provide any answer. Focal species are those of interest to the researchers or to the participating farmers for any one of a variety of reasons.

4.2 Pest and Beneficial Insects in Kiwifruit orchards

4.2.1 Monitoring orchard inputs

In managed ecosystems pests are important, but the degree of importance varies with the intensity of the production. The amount of active intervention that can be economically undertaken will reflect both these aspects. However the type of intervention employed will depend on the management system being followed. Conventional management has minimal restrictions on what is permitted, and has traditionally given rise to an intensive and repetitive “insurance-oriented” application of pesticides, to the extent of maintaining a level of insecticide residues on hosts that would be toxic to incoming pests (Suckling 1984).

A key feature of integrated management systems is to restrict intervention using pesticides to when it is needed (e.g. Brookbanks 2004, Max 2004) and giving preference to pesticides with specific rather than broad-spectrum activity (Way & van Emden 2000). Organic systems are

similar but set even stricter limits on the type and quantity of intervening responses that are permitted (e.g. Bio-Gro 2001). Both approaches use the practice of restricting spraying to when it is needed as a way of adapting the intervention applied to the local conditions occurring on, or even within, each farm or orchard. It confers considerable variability to what actually is done by growers following a particular management system. The system may be clearly defined, but actual practice can be highly variable. Steven *et al*. (1997a) recorded that kiwifruit growers following the KiwiGreen system used from zero to eight oil sprays in a single season.

It is thus necessary to measure the inputs employed against pests, and the pest pressures that give rise to these inputs, in order to better define and hence interpret the outcomes of following a particular system.

Intended data collection:

1. Spray diaries are mandatory for all pesticide sprays on kiwifruit produced for export (Zespri 2004), and are also required under other integrated or organic schemes. Thus in both the kiwifruit and sheep and beef sectors this data should be available and be collected. In the sheep and beef sector this information will include drenches and pour-on treatments for stock, pesticide use on pasture and crops and measures against vertebrate pests by the farmers or local government agencies.

   Spray data should be analysed by intended target, area treated, pesticide type, number of applications, rate, timing, and application technique used. Pest pressure should be factored in to some analyses to take this into account as a variable.

2. The farmers' perceptions as to what pests are present on their properties and their thoughts on the relative importance and pest pressure that these generate should be sought. This is necessary to derive basic incidence data for minor pests against which action may be taken, or those which have a limited geographical distribution. For kiwifruit a check list could be drawn up based on Steven (1990).

3. Any more objective data on pest pressure on which treatment decisions have been based should be collected. For kiwifruit orchards this will focus on monitoring data for the major pests, leafrollers and armoured scales, with some orchards also having information from Fuller's rose weevil, passion-vine hopper counts, or *Botrytis* management scores.

4.2.3 Monitoring effectiveness of arthropod control

This section covers those measurements which directly relate to how well the application of the imposed treatment regime achieved its target - the prevention of losses due to pests. In kiwifruit pests primarily affect the quality of production rather than sheer quantity, so that the intended effect of pest control is to maintain or enhance the quality achieved. These data are essential for comparing the outcomes of the management systems.

The main sampling tactic here and throughout the kiwifruit research is to sample from the middle sections of a kiwifruit block in order to avoid edge effects created by external influences such as adjacent gullies. The intent is not to ignore such external influences, but to give priority to determining whether the pest control operations directly give rise to different environmental impacts.

Intended data collection:

1. Packhouse data on reject rate for submitted fruit, due to pest damage or contamination. The data may include both quality control records and defect analyses of reject fruit.

The data collected, other than quality control records, will to vary from shed to shed as there is not a standardised system in place across the industry. We need to start with data for the 2004 harvest and see how useful the information is in describing and comparing outcomes across the cohorts. We may then be able to improve the standard of reporting by packhouses, which would also make it more useful to growers. An alternative in future would be to do a small 'bin-in' or pre-harvest sample ourselves following a standardised procedure.

2. Coolstore and export data on fruit quality. This information is required because, except for *Sclerotinia* which causes fruit drop and damage soon after flowering, the fungal pathogens of kiwifruit fruit cause latent disorders (Brook 1990). These only manifest after some time in cool storage or during ripening.

4.2.4 Monitoring major pests

The major pests of kiwifruit are the leafrollers and armoured scales (Steven 1999). Both of these are universal in New Zealand kiwifruit orchards and their attack determines the vast majority of canopy sprays applied, while *Sclerotinia* on Hayward vines and storage rots of Hort 16A require one fungicide application by most growers (Zespri 2004). Minor arthropod pests induce little crop spraying. Steven (1990) provides the most detailed account of the ecology of kiwifruit pests but is somewhat dated and in need of revision.

The extremely wide-spread occurrence of the major pests is an advantage for a focal species, but also means that it is abundance and not incidence that is important. This requires a standardised sampling system undertaken on all sites over a relatively short time span to minimise phenological fluctuations. The pest monitoring undertaken in kiwifruit provides incidence rather than enumerative data, and the timing of samples from orchards will vary, so that its suitability will be somewhat compromised.

There is also no recording of parasitism or predation in routine monitoring on kiwifruit (Zespri 2001). Beneficial arthropods merit serious consideration as focal species since the effect of pesticides on such non-target organisms has been known for a very long time (Newsom and Smith 1949). These unintended effects have been attributed as an important cause of pest resurgence and the rise of secondary pests, although other causes are known (Hardin *et al*. 1995). They are the major reason for preferring selective pesticides in integrated systems, and for prohibiting artificial pesticides in organic systems. Although most interest in biocontrol agents has centred on those beneficials strongly linked to particular pests, generalist predators should not be ignored (Symondson *et al.* 2002).

Intended data collection:

1. Armoured scales. A sample in autumn when populations peak would seem likely to provide both a reference point for pest pressure and the best chance of finding parasitoids. However a sample in January, at the end of the first generation, would also be of interest, if practical.

2. Leafrollers. A sample of leafroller parasitism in the spring, just before or at flowering, would be of most interest. The high mobility and wide polyphagy of the species in this pest group indicate that the pressure of this pest may be more impacted by influences outside the crop than is the case with armoured scales.

4.2.5 Impact parameters - minor pests

The minor pests include Fuller's rose weevil, passion-vine hopper, greenhouse thrips, mealy bug, cicadas, Collembola and both oribatid and two-spotted mites (Steven 1990, 1999). Many of

these are frequently present in low numbers and only occasionally become numerous enough to cause concern. Outbreaks of tetranychid mites such as two-spotted mite have frequently arisen as a side-effect from applications of broad-spectrum pesticides (Hardin *et al*. 1995, Helle and Sabelis 1985). However on kiwifruit in New Zealand two-spotted mite contamination of fruit has primarily arisen from a failure of predator mites to develop spring populations as rapidly as the pest mite rather than as a direct effect of sprays (Charles 1989).

Intended data collection:

1. Mite fauna. Oribatid, tydeid, tetranychid and predatory mites of several families can all be found on kiwifruit leaves (Steven *et al.* 1997b). A summer or autumn sample could be used to give both diversity and abundance counts.
2. Fuller's rose weevil. This weevil species is a contaminant pest of quarantine importance rather than causing damage to fruit or the host plant. Current controls involve use of barrier or repellent sticky bands around the trunks and posts to prevent the flightless adult weevils climbing into the canopy of the vines (Zespri 2004). However, not all growers use banding as it is time-consuming to establish and maintain. If initial surveys show most of the Argos participants undertake banding, it could be exploited as a monitoring technique; otherwise an alternative approach will need to be considered, such as monitor bands on a few vines.
3. Passion-vine hoppers. These hemipterans are a common insect in kiwifruit orchards that normally require controlling when large numbers immigrate into kiwifruit blocks from adjacent reservoirs of host plants. However a potential for this pest to build up populations resident in orchards under organic management has been identified. A technique to monitor this which would provide information on parasitism will be investigated using egg-laying.
4. Cicadas. Preliminary studies have shown that counting pupal exuviae of cicadas remaining on trunks of vines and posts in kiwifruit orchards can give interesting data (Benge *et al.* 2004). This study should be continued.
5. Leaf insects. The same leaf samples used for mites could be assessed for the numbers and species of Collembola and mealy bugs present, as well as for greenhouse thrips. Timing of sampling for such insects, especially greenhouse thrips, may be best undertaken in autumn.
6. General predators. Generalist predators may impact on both major and minor pests (Symondson *et al.* 2002, Pearce *et al.* 2004). Several groups are of particular note, including spiders and Coccinellidae. Spiders are known to be affected by synthetic pyrethroid insecticides (Bajwa and AliNiazee 2001) which have been used on kiwifruit. Spider faunas have also been used in ecological characterisation (Riecken 1999). Spider webs are conspicuous and relatively easily counted. Spiders are important foods of birds, at least in forests (Moeed & Fitzgerald 1982). They may also benefit kiwifruit growers because they prey upon pest insects. We therefore propose to count spider webs as a one-off fast comparison of biodiversity in organic and IM orchards. We may also score the presence/absence of spiders associated with each web and catch some of them for identification. Web counts will miss hunting spiders (which stalk passion-vine hoppers) and temporary-web spiders such as the interesting "bird-dropping" spiders. A preliminary survey indicates large differences between the cohorts, so more intensified research of spiders will probably follow. Spider webs can be common under T-bars and differences may occur between training structures. Sampling will have to be stratified carefully to make any comparisons across training structures as they provide very different sampling

universes - and the upper canopy is largely un-observable in pergolas. Given the insects associated with decomposition cycles, especially Diptera and Lepidoptera, we expect more spiders where compost is used, especially in the sub canopy zone. This may show that organic orchards have more spiders, but other growers do use some compost and mulch. An unmowed sward with high weeds also provides greater opportunity for web-spinning. Permethrin products used in the past (Attack, Averte) killed spiders but as only a single spray was used per year it may not have been terribly limiting. These are no longer allowed (from 2004).

Coccinellids or lady-bird beetles include some very conspicuous and well-known predacious species, and have been used as marketing symbols for IPM systems in both Europe and the Americas.

Techniques will be investigated and tried to derive numerical estimates for specific groups of generalist predators, for example web counts will estimate some spiders. In future vacuum sampling should be considered to extend the range of spider types studied. Direct counts of adult ladybirds will be attempted, although these could also be vacuum sampled (Lo 2000).

Removal of host material e.g. insect eggs as a technique to indicate overall predator impact will be considered on a small scale in the first season, if possible (Berry *et al.* 1995).

4.2.6 Monitoring pollinators

The pollinators are a distinct functional group of beneficial arthropods. Kiwifruit is dioecious with separate male and female vines so that pollination is critical for fruit set (Ferguson 1990). Early studies on pollination showed that only members of the bee group were effective pollination agents in New Zealand (MacFarlane & Ferguson 1984). This included endemic species, the introduced bumble bees and both hive and feral honey bees, with the latter dominant. The more recent advent of the *Varroa* mite has largely eliminated feral honey bees (Goodwin 2003), but has not affected other species.

Intended data collection:

1. Monitoring is proposed using unbaited white pheromone traps since this colour trap has bees as a by-catch (Steven 2001, unpubl.).

4.2.7 Relative abundance of night-flying insects

New Zealand has very few native butterflies, but conversely has a superbly abundant moth and flying beetle fauna. We therefore propose to sample their diversity on organic, IM and conventional farms in all farm sectors. Insect nets will be mounted on four-wheel drive vehicles and the vehicle will be driven back and forth over the farms in each cluster for three nights in spring. A record of the distance of travel from the odometer, when multiplied by the area of the gape of the net, will calculate the volume of air swept out to catch the sample from the whole transect. A count of the number of large insects flaring in the vehicle headlamps will be kept for each kiwifruit block (or paddock within sheep/beef) will give some indication of spatial variation of the insects within the farm.

4.3 Invertebrate Pest Monitoring on Sheep/Beef and dairy farms

4.3.1 Grass grub and porina

Grass grub and porina remain the most widespread and serious pests of pastoral farming (Barrett 1990). However pasture pests now much less of a problem than in the 1970s and 1980s (Bertram 1999). In retrospect, this subsidence is seen as relating to banning of DDT in

the late 1960s (S. Goldson, pers. comm.). 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. Trevor Jackson has shown that pastures more than two years old 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. These expectations will first have to be checked by monitoring ARGOS farms in the first two years of the project. If the expected low threat on sheep/beef is confirmed, only very low intensity monitoring of pasture pests will follow. If not, priorities will be adjusted accordingly.

Dr Steve Goldson (AgResearch, pers. comm.) thinks that even though pasture pests are below economic damage thresholds, a hidden effect is that grass grub and Argentine Stem Weevil (ASW) shorten life of the pastures; that is, "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. Many other factors will influence this; for example, stocking rate, landform, climate, seed stock, etc. These other factors might vary between organic and IM and conventional farms. Therefore, we may not necessarily find a clear signal for this indirect pasture pest damage, but the distribution of ages of paddocks on IM, organic and conventional farms will be a useful variable to investigate. A background ARGOS question might therefore be how long does pasture quality last in the different farming systems.

The 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 production limit of the system. This widespread and often repeated perception should be quantified by ARGOS because it has several implications for social and economic as well as ecological resilience. If so we should analyse impact and intervention thresholds in relation to some measure of farming intensity. Such an index could incorporate the ratio of productivity per stock unit. If so, is it yearly average or ratio at a winter bottleneck, or a summer drought bottleneck that counts most? Such an index can be used for all manner of model building beyond the pasture pest concern.

Grass grub and Porina density

Porina is more 'condition dependant' than grass grub (i.e. more sporadic in distribution) but even grass grub can be patchy. Bruce Chapman (Lincoln University, pers. comm.) once detected a Porina invasion-front sweeping over a farm in a three year period. This implies a reasonably limited rate of spread.

Several interacting variables and signals will accompany pasture impacts from pest insects, for example:

- Weediness is often indicative of invertebrate pest pressure
- Free-draining soils have many more grass grubs
- Younger pastures more prone to grass grubs
- Stressed plants will be impacted more by the same level of invertebrate pests
- Stock management is key (stocking rate impacts on vegetation, degree of bare ground, and trampling)
- Soil type
- Paddock history.

We will search for these correlations and treat the predictors as covariates so as to obtain a more powerful test of the farming system null hypothesis.

Grass grub and Porina Monitoring

Both grass grub and Porina are best monitored in autumn or winter. This is the traditional time for most monitoring in that it gives time to respond with inputs before soil freezes. ARGOS will initially trial a very simple method of scoring larvae abundance was devised by van Toor & Willoughby (1995). The surface of the pasture is sliced off with a spade and a square of hardboard pegged out over it –the grub just stops and returns back down the tunnel when it hits the board. Two to three days later the board is lifted and the number of larval tunnels counted.

Aerial surveys of grass grub (Barrett *et al.* 1990) have been discontinued for years now.

If grass grub and porina emerge as significant pests they will probably be selected as one of our focal species for long-term monitoring and studies of seasonal dynamics. Sifting grubs from 15 x 15 x 15-20 cm deep soil samples is the usual standard for grub counts. Each takes three to five minutes to search for grubs, and around 20 per paddock is the norm. This suggests that about one and a half hours would be needed per paddock. A few other scarabs will turn up in the samples but 95% are instantly recognisable as belonging to the two main species. They can be rapidly assigned to instars (Barrett *et al.* 1990). A useful first check of differences between the dynamics on organic, IM and conventional farms will be to compare the 'stage-structures' of their populations.

Grass grub and Porina Control

The complexity of the system, especially pest patchiness in time and space makes it hard to set sensible trigger points for control intervention[13]. However a standardised grass grub and porina monitoring system has been devised to give early warning of outbreaks so that farmers can only invest in control when economically justified (Barrett *et al.* 1990). Relatively few farmers seem to have taken up the practice (B. Barrett, B. Chapman, pers. comm.), but a survey of ARGOS farmers should be completed to confirm this. It requires some time in January to establish test strips with and without chemical pesticides, so it can not be used as easily on organic farms as elsewhere[14]. The method has considerable potential to help IM systems if grass grub and porina are a serious threat there.

Parasitoids have now been released and dispersed targeting grass grub and porina, so not much management imperative left here[15]. However research of parasitism rates may be warranted later if they remain a significant threat on some farms.

Serratia biocide against grass grub had reasonably slow uptake, mainly because it requires critical timing and specialised contracting equipment. Recently a granulated/encapsulated delivery has been perfected to allow it to be drilled in with seed.

4.3.2 Other pasture pests

The Asian Stem Weevil (ASW) threat has also changed dramatically over recent decades. New pasture cultivars with endophyte differences have been developed. The endophyte makes the ryegrass toxic to stock and so introduced varieties with less endophyte have been introduced. ASW preferentially attacks endophyte-free stems, so eventually ASW browsing changes quality

[13] Steve Goldson states: "To be honest there is not much a farmer can do other than to farm around the problem".
[14] Presumably control using *Serratia* is permitted on organic farms?
[15] This conclusion must be checked with Barbara Barrett.

of the sward. Endophyte frequency can be assayed but this is time consuming and should only be attempted by ARGOS if ASW appears to be a serious pest.

Sitona Weevil damages the clovers' nodules and so has several flow-on soil and pasture effects. It is unlikely to be much of a problem in South Island sheep/beef. The Clover Root Weevil (CRW) – another Sitona – is spreading south fast and should reach Wellington in the next few years. Infestation can be very bad, up to 300/m^2. It de-nodulates legumes and so disrupts N fixation causing the clover to yellow and not be able to compete with grasses. The problem is less in dry areas but severe in irrigated or naturally wet areas. This probably arises from switch in life-cycle at the pupal stage. If conditions are dry, most of grubs' energy goes into forming flight musculature and few eggs are laid, but if conditions are wet the reverse occurs. This is an adaptation to exploit patches of legume when in them and conditions are ideal, but to disperse to find new areas when conditions are deteriorating. ARGOS should keep a watching brief on CRW and scale up research and monitoring if it is found on ARGOS farms. It may be a particular threat in dairy farms in North Island and eventually in irrigated dairy conversions in South Island.

Mealy bug maybe another rising problem on South Island to be monitored on ARGOS farms.

4.3.3 Fly-strike and parasites

For sheep and beef farms faecal egg counts of internal parasites are the data estimating pest pressure which are most likely to be encountered.

4.4 Monitoring non-pest invertebrate biodiversity on Sheep/Beef and Dairy farms

Aside from the night-flying insect netting described above for kiwifruit, there will be some additional sampling of invertebrates on sheep/beef farms, especially targeting native bees and spiders. Spiders are well represented in the New Zealand agricultural landscapes and recent studies have shown that the species composition changes depending on land use regimes (McLaughlan & Wratten, 2003; Clark *et al.*, 2004; Vink *et al.*, 2004). Spiders are a dominant invertebrate predator in these systems.

The importance of native bees in the pollination of native plants is little understood in New Zealand but they are likely to play a substantial role in this process. Native bees (mainly from the Halictidae family) are generally solitary through to semi-social. Halictidae bee densities and species compositions are known to respond to changes in land use regimes (Klein *et al.*, 2003). In addition, habitat loss and fragmentation is likely to impact on plant-pollinator interactions affecting fruit set of plants (Klein *et al.*, 2003; Tscharntke and Brandl, 2004). There is growing international interest in native bee guilds now that spread of Varroa mite has eliminated feral honey bees from many agro-ecosystems and made beekeeping more difficult (Perley *et al.* 2001).

The same white 'DeSIRe' sticky traps used for monitoring pollinators in Kiwifruit orchards will be trialled on sheep/beef farms. Steve Wratten uses simple bright yellow ice-cream containers (filled with water and detergent to trap the insects) to collect insects, especially to target native bees, at Kowhai Farm. These are left in place for three days. Both systems may be trialled in initial years and a choice of the optimum method made if native bees become focal species for long term monitoring. All other considerations being equal, we will try to keep the trapping systems equivalent between sectors, in which case the DeSIRe sticky traps will be retained on sheep/beef and dairy farms to match their use in kiwifruit.

5. Aquatic Habitats and Their Biodiversity

5.1 *Why monitor stream health?*

We advocate a moderate investment by ARGOS in monitoring stream health for several reasons. There is a large body of evidence linking water biodiversity and water quality to adjacent land use (recently reviewed for New Zealand freshwater by Van Roon & Knight 2004). In many cases conversion to agriculture is seen as degrading waterways, but conversion of tussock grassland to 'developed pasture' actually increases invertebrate biodiversity in the streams, perhaps as a result of increased nutrient loading in the stream (Riley *et al.* 2003). The streams are also of intense interest to the wider community for recreation, fishing and down-stream uses. Māori have often espoused intense spiritual value from wai ora (healthy living water) and distress from its degradation to wai mate (dead water). Maintenance of water quality is the focus of increasing regulation and conflict between farmers, the Fish & Game movement and wider society so many of the upcoming community debates about sustainability of farming will centre on water. Many regional councils actively facilitate improved riparian management by farmers. There is a growing perception that stream health is a valuable cumulative index of sustainable land management because it effectively indicates runoff of chemicals and sediments. Monitoring streams is therefore rather like monitoring "the toilet" of the farm and a litmus test for sound land-water management. More subtly, degraded stream health is an obvious example of the ecological flows where the costs of mismanagement are transferred beyond the farm boundary. Several other such flows will be occurring but are more cryptic, especially in the cases of pests and fragmentation of habitats to make wider metapopulations of valued biodiversity vulnerable to extinction in the wider farmed landscape. Streams are more obvious examples of ecological landscape level connections because the main habitat medium (water) itself flows. Stream restoration is therefore a powerful social model for examining large scale ecological processes and full social cost accounting of individual farm's land management. Most farmers are likely to understand and see it as an important remediation issue. Monitoring of stream health is reasonably practical and inexpensive and several well-tried tools exist to make robust comparisons.

Most research on anthropogenic impacts on streams in New Zealand and overseas has focused on the consequences of broad land use changes, especially mediated through altered nutrient and sediment inputs or changes in the vegetative cover overhanging the stream. Prediction of changes to stream health by organic and IM agriculture through altered nutrient and sediment inputs are therefore supported by a large body of corroborating knowledge about stream processes. The key determinant of outcomes for ARGOS will be whether the altered farming practice generates sufficiently reduced or increased nutrient or sediment inputs to the streams to cause any appreciable effect on stream health. We plan to measure water nutrient content as well as biodiversity in streams flowing through organic, IM and conventional farms. A key issue for interpreting these data will be scale. It is not clear whether nutrient, colliform and sediment levels fluctuate markedly within the reach of individual farms, or whether damped changes will occur so that aggregated effects of surrounding landscapes have the dominant influence on what is measured on each farm. If rapid changes in indicators occur with local land use, we will be able to assess potential impacts of conversion of agriculture to IM or organic in two ways – by monitoring changed nutrient and sediment loads in the water, and by monitoring stream biodiversity. If landscape level effects dominate, there may be little power to test the effects of farming systems in this way.

5.2 A need for more intensive research on impacts of pesticides on stream health

Any effect on stream health from reduced pesticide applications on organic and IM farms will be harder to assess than putative effects from altered nutrient and sediment inputs. This is because so little fundamental research on pesticide impacts on streams has been done either in New Zealand or overseas (G. Closs, pers. comm.). Measuring levels of pesticides in water is extremely specialised and therefore expensive and we are unlikely to be able to predict the impact of any measured pesticide levels found on stream plants, invertebrates, or fish. We therefore recommend that ARGOS does not attempt such measurements until other corroborating evidence suggests that such monitoring is interpretable or more resources can be found. An option for more intensive research later is described in 'Future Research' of Section 8.

5.3 Using the Stream Health Monitoring and Assessment Kit

We propose that ARGOS uses the simplified monitoring protocol called the 'Stream Health Monitoring and Assessment Kit' (SHMAK) that was designed for use by farmers (Biggs *et al.* 1998)[16]. This method avoids the extremely time-consuming stream invertebrate sampling methods for a complete 'Quantitative Macroinvertebrate Community Index' (QMCI), which was developed by Stark (1993). Several calibrations of SHMAK and QMCI invertebrate scores have underscored the robustness of the former's rapid assessment method. A recent study also demonstrated that the SHMAK invertebrate index was sufficiently sensitive to detect significant improvements in stream invertebrate communities within a few years of reserving riparian buffer vegetation along streams running through Southland deer farms (Rhodes 2004). We are therefore confident that the SHMAK is a cost-effective yet defendable monitoring tool for the ARGOS project.

The SHMAK protocol measures/scores:

1. Recent flow conditions
2. Recent farm conditions and activities
3. Habitat quality
    a. Flow velocity
    b. Water pH
    c. Water temperature
    d. Water conductivity
    e. Water clarity
    f. Composition of stream bed
    g. Deposits on stream bottom
    h. Bank vegetation
4. Stream bed life (a count of indicator invertebrates and estimate of percentage cover of periphyton (algae) on: stones and woody debris; amongst gravel, sand and silt and; on water plants.

The Taieri River research team are extremely skeptical that once-off measures of temperature as prescribed by the SHMAK protocol can be interpreted meaningfully. Temperature is indeed an important determinant of stream health, but it varies so much diurnally and seasonally that a single measure at the time of the sampling is too unreliable. We advise that it is measured

[16] See http://www.landcare.org.nz/SHMAK/summary.html for a more detailed description of the kit.

nevertheless because repeated SHMAK measures over the 20 to 30 years of the ARGOS project will eventually allow general comparisons from pooled samples.

One SHMAK kit would be needed for each field officer. The full equipment kit costs around $395 but the only specialised piece of equipment is the water clarity tube and conductivity meter which can be purchased separately for $170 and $135. The manuals can be downloaded for free from www.landcare.org.nz/SHMAK/manual.html.

The SHMAK is superbly designed and supported for farmers to make measurements themselves, should they so wish. There would be scope here for a more Participatory Action Research Approach should we decide it is wanted and valuable. Otherwise the ARGOS field officers could easily and efficiently do the repeated measures and thereby improve consistency of long-term monitoring.

5.3.1 SHMAK sampling frequency

Each SHMAK sample is likely to take one to two hours. Time required is longer if muddy, shorter if clear water, and facilitated if an assistant is available to record.

Ideally we should obtain some measure of variability in stream health within each farm to see if it is just as large as variation between farms in different cohorts. Provided that each SHMAK sample takes less than 90 minutes, we urge at least 3 sites are sampled per farm. We prefer to use the Level 2+ sampling protocol for streambed life (Biggs *et al.* 1998), but if the more intense sampling adds too much time, Level 2 should be used instead in the interests of increased spatial replication of measures within each farm.

The SHMAK and nutrient analyses gave very different results in summer than in winter in one study of the effects of riparian planting on stream quality in Southland deer farms (Rhodes 2004). We therefore propose that the SHMAK measures are made quarterly on all ARGOS farms in the first year, starting in June 2004 if resources allow. Otherwise the first priority is to measure in summer at the time of minimum water flow so that water nutrient concentrations coming from farming are likely to be highest. A second priority would be to measure at the other extreme (i.e. winter), when high flows may trigger a lot of sediment release from the banks. An analysis of the first year's results from several seasons will be performed to select an optimum single time of the year to do annual measures for the remaining years of the project.

5.3.2 Placement of SHMAK sampling sites

The SHMAK and nutrient sampling will be repeated at exactly the same sites each time so that seasonal and then annual trends are more likely to be discerned. A GPS will be used to maintain this consistency.

It will be important to choose sampling sites so as to closely standardise both the streambed characteristics and the immediately surrounding riparian vegetation within each triplet farm (organic, IPM, conventional). The preliminary ecological survey and Land Cover Database maps will be used to pre-select the most likely sites for each SHMAK survey within each triplet. In an ideal world, habitat and stream characteristics in the vicinity of the stream would be consistent and we would select at least one of the survey sites to be as close as possible to the downstream point of exit of the stream from each farm. Stream quality at this extreme site will probably be the most affected if conversion to IM or organics has any influence (or any effect of farm conversion may even extend downstream of the farm for some unknown distance). However several other considerations will taken into account when determining placement, as follows in rough priority order:

1. If a major tributary enters the watercourse from a subcatchment stretching well beyond the study farm, we should position the SHMAK sites just upstream of the confluence so as to minimise the risk of land use impacts on this side stream swamping the more localised impact of farm cohort.
2. We will try to place the sample sites just above any ponding or swamp areas within the waterway, because these will potentially have an enormous impact on water and biodiversity. If ponds or swamps occur at all three farms, it may be possible to work below all of them to neutralise their impact on treatment differences.
3. Similarly, if a major habitat discontinuity occurs within a farm (e.g. a forest or riparian plantings in the middle) the sample sites should be placed just upstream of where the discontinuity occurs.
4. People-made waterways or straightened natural waterways are potentially very different ecologically. They should be factored out of the study as for tributaries and habitat discontinuities in bullet points 1 and 3.
5. The stream's physical characteristics and substrate should be standardised across the three farms in each triplet
6. The closest site to the downstream boundary of each farm that meets the above standardisations should be chosen to maximise the reach of stream potentially affected by the local conversion to organic or IM agriculture. Two further sites should be chosen at least 100m from its nearest neighbour upstream from this farm edge site.

The most stringent matching of stream sampling sites will occur within each farm triplet. It is unrealistic to expect that similar types of stream could be selected between triplets, but where there is a choice, we recommend that medium sized, relatively shallow stream. All streams must be flow year-round.

5.4 Nutrient Measurements

The SHMAK habitat and invertebrate sampling protocols will be supplemented by direct measures of nutrients in the water column to test whether conversion to organics or IM reduces or increases the stressors to stream health. Nutrient concentrations will be measured from water samples that have been vacuum filtered through pre-ashed and weighed glass microfibre filters (Whatman GF/F) before being transported on ice and then frozen on the same day of collection. Thawed samples will be auto-analysed calorimetrically for nitrate, nitrite, ammoniacal nitrogen and dissolved reactive phosphorus using standard methods (APHA 1998). The auto-analyser will be calibrated every morning before each day's analysis (of around 100 samples per day). Filter papers and accumulated sediments will also be frozen before drying to a constant weight at 65^{o} C for calculation of suspended solids. Analyses will be performed free of charge by Debra Gauntlett, the University of Otago's Department of Zoology laboratory technician, provided that a reasonable number of samples (<300 per annum) are all that is needed.

We propose that water samples for nutrient analyses are collected at the upstream starting point of each SHMAK site (before sampling has disrupted the substrate). This will allow correlation of the biodiversity indices to nutrient measures taken at the very same place. Another water sample should also be collected (at about the same time) from as far upstream on the same farm as possible without any of the interfering influences (1-6) listed in the above section within the reach between the sites. The change in nutrient levels from the upstream to the SHMAK site is therefore the main response variable to be tested for difference between the farm cohorts. We will use the GIS to calculate the area of the farm draining into this intervening reach of stream to standardise the expected change in nutrient levels between farms.

The nutrient measures will probably be more sensitive to farm practice because our response variable is *change in nutrient level within a farm*. The SHMAK biodiversity measures (and fish monitoring, see below) are simply point measures. Several background variables will potentially affect these in addition to farm conversion to organics or IPM. Such background variation may severely reduce the power of our test for farm effects despite our best attempts to reduce their disruptive influence by close matching within triples. We hope to consult with an experienced stream ecologist to achieve the very best matching of sample sites within farms once ARGOS farms are chosen.

It is important to realise that because of the complex trans-disciplinary nature of the ARGOS sustainability study, stream quality is considered important but in the end secondary to more overarching matching criteria for the choice of study farms. We would have achieved better matching for interpreting stream quality impacts had we been able to drive study design only to meet that end. Some decoupling of the stream sampling from the main ARGOS farms may therefore be prudent, provided we then do not lose the connection to key background measures of farm practice (e.g. stocking rate, fertiliser inputs, etc.) that we hope to correlate with stream health measures. For example, it is possible that matched streams cannot be located within all three farms within a triplet. We suggest that we still proceed to measure stream health at two of the farms even if the third does not have matching stream habitats. Although this makes the design unbalanced, the more essential need to gain statistical power by increased samples of what will then be pairs (conventional vs. IPM; conventional vs. organic; or IM vs. organic). If the ARGOS conventional or IM farm is the missing one within a triplet, consideration should be given to asking nearby non-ARGOS farmers if we could measure stream characteristics in their conventional or IM farm. This would be once-off interventions to increase sample size. Such an adjustment will not be possible for organic farms because so few of them exist.

5.5 Faecal coliform Counts/Bacterial Counts

The presence of faecal coliforms or E. coli are indicators of other potential pathogens harmful to people and stock through drinking, bathing and other recreational pursuits, and food gathering in downstream rivers, lakes and estuaries. Pathogens include protozoa such as Giardia, enteric viruses such as typhus, and bacteria such as streptococci. Farm and stock drinking water are particular concerns. Faecal coliforms levels are not usually high enough to significantly affect biological oxygen demand (BOD) or eutrophication. The presence of faecal coliforms is related to stock access to waterways, rain events increasing overland flow, with mitigation through riparian buffer zones and on-farm ponds and wetlands (Ottováa *et al.* 1997, Perkins & Hunter 2000, Duggan *et al.* 2001, Falabi *et al.* 2002).

As part of their water quality management, regional councils generally sample main river systems, with more detailed assessments being carried out within farms. Sampling methodology is prescribed by the laboratory, which also supply sterilised 300 ml sampling containers. Faecal coliforms and bacterial assays require samples to be delivered to the labs within 24 hours (by courier), and kept at low temperatures in transit. Contract lab fees for one regional council per individual analyse run from $16 per sample for bacterial assay to $7 to $8 per sample for pH, metals and nutrients.

5.6 Stream health measurements may not be useful within the kiwifruit sector

Requirement for flat land to grow kiwifruit will lead to many of the ARGOS study orchards in the Bay of Plenty being quite some distance from streams. Sometimes thick forest covers intervening gullies and this may buffer the streams from orchard applications of fertiliser and pesticides. Also many orchards applying different farming styles are often immediately adjacent to one-another and the length of stream passing near a kiwifruit orchard of around five to ten ha will be much shorter than sheep and beef farms of around 500 to 1000 ha, or high country runs

of several 1000s of hectares. These spatial scales may make it particularly difficult to register localised effects of conversion to organic or IM on streams in most of the ARGOS kiwifruit orchards. We will consider whether it is even worthwhile to monitor stream health in association with kiwifruit growing once the final selection of farms has been completed and a preliminary ecological survey has determined whether sufficient equivalent streams flow sufficiently near or within organic Hayward, IM Hayward or Hort 16A orchards.

5.7 A Māori Cultural Stream Health Index

Recent work by Gail Tipa, Laurel Tierney and Colin Townsend has highlighted the robustness and utility of a Māori stream health index (Townsend *et al.* 2004). A set of cultural values assigned by the kaitiaki in one-off visits to streams in the Taieri catchment aligned very closely to the detailed QMCI and SHMAK scores of stream health measured at the same sites. There is exciting potential here to bridge measures in Objective 2 (Māori land) and Objective 4 (Environmental changes on farms) if the kaitiaki wish to apply both stream health monitoring protocols to either Māori land, the non-Māori land or to both for benchmarking and pooling inferences. However potential logistical problems arise from application of the Cultural Stream Index at such widely spaced sites throughout Te Wai Pounamu. Presumably different groups of kaitiaki from each local rohe would be involved and part of the cultural index criteria consider past use of the area for mahinga kai. If the land on ARGOS farms has been in private ownership for several generations there may have been little opportunity for the kaitiaki to have maintained ahi kā in recent times. A decision about whether or not to mount a parallel Māori cultural stream health index or to substitute it for the SHMAK index in some places will best be made in the second year of the project when the Objective 2 work programme is more certain.

5.8 Fish and koura distribution and abundance

McDowell (2002) has a complete description of the migratory galaxiids and introduced fish, but recent research has augmented the lists of non-migratory galaxiids, some of which are threatened (Waters & Wallis 2001a, 2001b; McDowall & Waters 2002, 2003).

Electric fishing takes specialised equipment, requires two trained personnel to operate at once, can take a long time and disturbs the fish and the environment. Its supreme advantage is that repeated electric fishing of a reach can cumulatively remove the resident fish so that an absolute population abundance measure is obtained by a ‘Zippen removal’ estimate and detectability biases are at least partly neutralised. However, a thorough search of streams at night using a torch and standardised search protocol is likely to be almost as good at detecting the presence or absence of fish and koura and it can provide a relative index of abundance. This approach was used by David *et al.* (2002) to establish the distribution of both introduced and native fish in the Taieri and Waipori Rivers and calibrated against absolute density of banded kokopu by McCullough & Hicks (2002). An MSc student at the University of Otago is also currently testing the calibration between spotlight counts and actual density of fish, so more information on the reliability of the technique will be available soon. The McCullough & Hicks (2002) calibration showed a remarkably linear relationship between the total number of banded kokopu seen and their abundance provided that all size classes were pooled (smaller fish were under represented). The biggest advantage of the spotlight counts is speed (around six times faster) and simplicity, thereby allowing a much longer reach of stream to be sampled than by electric fishing. Some species are very patchily distributed within the streams so increased length of stream surveyed allows much improved representativeness. Repeated counts on the same stretch of stream can also be done without disturbance, so the precision of the spotlight index can be improved with added effort. Fish are active during daylight but are much less prone to disturbance at night. Spotlight counts work best in moderately flowing relatively shallow reaches without dense vegetation, but the same bias also applies to electric fishing. The experience of

the Otago limnologists is that a good observer can learn to distinguish the trout, different native fish and most of the introduced ones (G. Closs, pers. comm.). There may be difficulty in distinguishing adult common and redfinned bullies unless water clarity is high and the observer is experienced. It will be impossible to confidently separate juveniles. However we will probably only get large numbers of commons in a system with a large river or coastal lake downstream. Most smaller coastal streams seem to only hold redfins (G. Closs, pers. comm.). Koura are readily counted at the same time (McCullough & Hicks 2002).

We recommend that the spotlight method be used in the ARGOS project, but with strict standardisation of the following:

- Train observers closely on count technique and species identification
- Keep the same observers if possible
- If observers vary, make sure that their spotlight counts are cross-calibrated against different observers
- Standardise spotlight type and brightness
- Use a red-filtered light (wavelength > 600 nm) because it minimises back-scatter of the light in presence of suspended material such as clay particles, and thus gives a clearer view of the fish increases the visibility of the fish
- Make sure observers are not colour blind
- The observer should tread as softly as possible while approaching the stream and walking along it
- Observers should not talk, nor whistle a merry tramping song during the survey
- Move slowly and steadily along the transect
- Make each count last around half an hour (longer impairs concentration of the observer)
- Try to do the counts between dusk and around 2200 h when activity of fish is relatively high and tendency to disturbance lowest. Counting in the two to three hours before dawn would also be possible but the middle of the night should be avoided (a dawn peak in activity follows a middle of night nadir in activity for some species)

We will calculate the relative index as the number of fish of each species spotted per m^2 of stream searched. Some hand netting to confirm identifications would be needed at first but then the count must be restarted only after x minutes since such a disturbance.

The same reach should be surveyed in successive nights, seasons or years to maximise detection of temporal shifts. The start and end points should be marked with a reflective stake, and exact locations recorded by GPS. We propose that the initial survey counts fish on three nights (probably successive nights unless heavy rain intervenes to alter conditions). It would be logistically ideal to do these counts on the same nights as bat and flying invertebrate sampling in November to March. The sequence of visits to each farm should be rotated within the three nights so that any influences of diel activity of the animals are evened out between the farm cohorts.

The ideal would be to link the fish survey with the very same reach sampled by the SHMAK. However the latter disturbs the substrate and potentially also the fish, so the spotlight counts must be done just prior to the SHMAK sampling. A separate count should be taken for the reach sampled by the SHMAK compared to counts on any additional reach searched by spotlight. This will allow the correlative analysis of fish abundance to invertebrate and stream habitat scores to be restricted to exactly the same area.

If a focal fish species is identified for continuous monitoring from year 2 onwards, it may be necessary to adjust sampling to cover other times of the year or to minimise variance in counts for that species. A separate study to calibration of spotlight counts against absolute density for that species should also then be considered. Redfinned bullies and Giant kokopu have already been suggested by the Ministry for Environment (MfE) as useful indicator species (G. Closs, pers. comm.).

We will assess variances in standardised fish counts from the three nights and between different farms after completion of the first survey. A formal power analysis will then be used to estimate whether more or less sampling is needed to detect long-term trends. Any subsequent annual surveys of fish may therefore have adjusted sample intensity.

5.9 Biodiversity associated with farm ponds and swamps

Some farms will have natural or artificially created areas of lentic (standing) water which may be very important sites of biodiversity that is quite different from biodiversity associated with the lotic (flowing) water. There is a background concern that the extent (number, area) of the shallower wetlands is still decreasing in farmed landscapes (Prof. Carolyn Burns, pers. comm.). We argue that this is part of a much wider trend for intensified agriculture 'dewatering' the landscape (see baseline ecological survey in Section 2)

There is no SHMAK equivalent for monitoring lentic environments, but there is a Lake SPI index for rooted macrophytes (water weeds) in lakes for use by regional councils. There is also a 'Trophic State Index' (Burns *et al.* 1999) which may be usable, and picophytoplankton have been suggested to be useful biological indicators, being sensitive to contaminants and increased nutrients. Lisa Galbraith is currently writing up her MSc thesis data on physico-chemical and biological correlates in 45 ponds, lakes and wetlands throughout Otago. She is using land use/cover in the catchments (GIS-mapped data) as one predictor and finding strong signals that land use alters pond health. Our ARGOS sampling should aim to monitor only those factors identified by her study to be important determinants of pond health. We could also simply transfer some of the measures taken on streams to ponds (e.g. use of the water clarity tube and water conductivity). The size, depth, riparian vegetation, stock access, substrate and, in the case of artificial ponds, years-since–creation are all probably important predictors of water quality and biodiversity.

Measurements of water nutrient levels (nitrate, nitrite, ammoniacal nitrogen, dissolved reactive phosphorus) should be taken at the same time as stream water monitoring.

The distance sampling protocol used for birds will monitor some waterfowl, but this is unlikely to thoroughly monitor the more cryptic wetland avifauna, especially if it is a relatively big wetland. Waterfowl are notoriously mobile (Williams 1981, Caithness 1982) and counts at a local pond therefore too variable to discern trends without greatly increased effort. If sufficient ponds and swamps are present on the ARGOS farms, we will probably do a separate survey of their birdlife from year two onwards using standard procedures like those designed for farmers, hunters and Fish & Game officers by Bevers *et al.* (1997).

5.10 Accounting for ecological landscape influences on waterways and their biodiversity using the Land Cover Database

Stream and pond quality measures are enormously variable in time and space, partly because effects of localised variation of inputs to waterways can be swamped by background influences from very large spatial scales like land use over the entire upstream catchment area or the underlying geomorphology (Closs *et al.* 2004). Conversion to organics or IM might indeed alter inputs to local streams, but the influence of other background landscape features may obliterate the signal that we seek by comparing water quality at nearby conventional farms. Matching of

clusters of farms is designed to minimise this threat and paired (or tripled) comparisons between farms is therefore the most powerful option to test our null hypothesis of equal stream/pond quality between farm cohorts. However we may be able to further minimise the effects of these background sources of variation by upscaling using data from remote sensing. We will use the Land Cover database to calculate various indices of land use upstream from any one of our SHMAK or water nutrient measures. The power of this approach has been demonstrated recently by Allan (2004, unpubl.). They were able to explain over 70% of the variation in local water quality indicators from a combination of landscape, local habitat and stream reach characteristics in a Michigan catchment. We will attempt the same general approach using the New Zealand Land Cover Database

6. Monitoring soil quality in ARGOS

6.1 The importance of soil quality and soil sampling

Soil quality can be elusive to define, but Karlen *et al.* (1995) gave a good description that we will adopt here:

> "*the fitness of a specific kind of soil, to function within its capacity and within natural and managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation*."

In the minds of most in the agricultural industry "soil testing" is important, but it amounts to collecting relatively shallow samples, bulking them and sending them off to a laboratory for a suite of chemical tests. New Zealand is blessed with both a well-accepted basic set of chemical test methods and a reliable group of accredited laboratories to do this task. However, as the above definition suggests, there is so much more to characterising how suitable the soil it is for various uses, and how management influences those characteristics.

The standard chemical tests made in the laboratory should be carefully supplemented by observations of soil biology and physics. In many cases visual and tactile observations of the soil in the field can be *more* important than the chemical tests. Encouragingly, these field observations are not the exclusive domain of specialised technical staff. Growers and other field staff are more than capable of making these observations, but close attention must be paid to training and consistency if we wish to make meaningful comparisons between farms, land uses and sampling times.

In the ARGOS project, soil health monitoring consists of a suite of chemical, biological and physical tests made in the field and laboratory. Visual and tactile examination of the soil in the field is the prime tool. It is complemented with a combination of standard and innovative laboratory techniques. The choice of indicators, and the techniques used for those indicators, is strongly influenced by:

- The need to cover biological, physical and chemical aspects of soil quality with techniques that can withstand scientific scrutiny;
- The need for continuity, so wherever possible results can be compared to historical information for New Zealand soils;
- A desire to encourage growers and consultants to use low-tech but reliable and meaningful soil quality indicators throughout their operations.

6.2 Soil quality in organic and conventional production

6.2.1 Pastoral farms

The largest effect on pastoral soils of changing to an organic management system is likely to be associated with soil nutrient status (different fertilizers may be used) and stocking rate. Under organic production there is a restricted fertiliser range available for organic production, and soil chemical analyses are important to determine if soil nutrient status is being sustained.

Depending on the amount and scale of decline in soil nutrient status, pasture production or composition may also be affected. If stocking rate is changed to accommodate changes in feed availability, then soil bulk density and treading damage may be also affected.

During the 1950s and 60s there was effort spent introducing earthworms to improve pastoral soils in the South Island hill country (Stockdill 1982). In uncultivated soils, earthworms play an important role incorporating organic inputs. If organic inputs are higher than the rate of earthworm incorporation (e.g. if earthworm populations are low), an organic thatch may develop on the soil surface (van de Westeringh 1972). With the improved thatch incorporation and nutrient cycling as a result of introducing earthworms, large increases in pasture production (28 – 120 %) were found. Assessment of earthworm populations may help in interpreting changes in pasture production. Visual soil inspection (thatching and aggregation) will also indicate the efficiency of the resident earthworm population.

6.2.2 Orchards

The effects of management on soil quality on orchards will be linked mainly to weed management and plant nutrition.

Other vegetation growing in the orchard such as grass has been demonstrated to compete with the fruit crop for water and nutrients, leading to a decline in fruit production if no action is taken to ameliorate the effect (Haynes 1980, Hogue & Neilsen 1987). Fruit production may be adversely affected in other ways, for example some common orchard weeds can host pests and disease (Suckling *et al.* 1998).

Cultivation was used to maintain bare ground until herbicides become widely available in the 1950s and now herbicides are used widely on orchards for weed control (Pearson 2003). Changing to an organic fruit production system removes herbicides as a vegetation management tool. Rather than revert to cultivation (which can damage soil and crop roots) swing-arm mowers are generally preferred for established organic orchards as the most cost-effective vegetation control (Hughes *et al.* 2002). In New Zealand, alternative non-competitive species has also been assessed to replace grass as understorey vegetation on orchards (Hartley *et al*. 2000).

Establishing a permanent sward on soil previously kept bare by herbicides is likely to alter many soil properties. An orchard sward can produce around 11 t DM/ha/yr[17] (Haynes & Goh 1980a) and organic inputs from turnover of shoot and roots are likely to increase soil organic matter levels. The permanent grass contributes to soil respiration through a dense and actively growing root system and by supplying leaf and root residues and exudates which can support larger soil biological populations. Lower biological activity under herbicide treated bare ground results mainly from removal of vegetation rather than any toxic effects of herbicides (Hartley *et al.* 1996, Wardle *et al.* 2001).

Increased earthworm populations under a permanent sward and the rooting action of the sward may improve thatch incorporation, soil aggregation and infiltration (Haynes 1981). A vegetative cover protects the soil surface from impact energy of water droplets. Bare soil is exposed raindrop impact, the force of which can disintegrate soil aggregates leading to surface sealing and the formation of a crust which limits infiltration (Merwin *et al.* 1994, Haynes 1981a).

Increased earthworm and rooting activity may lower soil bulk density (increase total porosity of the soil) where a permanent sward is introduced to an orchard soil. However the number of vehicle passes on organic orchards tends to be higher due to an increased spraying requirement (Scarrow *et al.* 2004). This increases the potential for soil compaction, decreasing soil porosity and increasing soil bulk density.

A permanent sward will require water and nutrients. Adverse effects of competition between the trees and the sward for soil water uptake may be offset by improved water infiltration as a result

[17] Tonnes dry matter (DM)

of increased soil porosity (Glenn & Welker 1989). As the sward takes up nutrients from the soil, soil nutrient availability is likely to decrease (Goh & Haynes 1983). The sward will contain significant quantities of nutrient nutrients which will eventually be returned to the soil as decomposing plant material. In particular, soil mineral nitrogen levels are adversely affected by the introduction of a permanent sward (Haynes & Goh 1980b).

6.3 Choosing measures of soil quality

We reviewed the extensive literature on measures of soil quality, searching for techniques to use. We gave priority to techniques that were:

- Appropriate for *all* the management systems to be studied in ARGOS;
- Precise, reproducible and scientifically defensible;
- Biologically, physically and chemically meaningful in an agricultural context;
- Rapid and affordable, so that good levels of replication could be achieved;
- Readily adoptable for routine use by land managers
- Already well-used in the literature, so that comparisons could be made readily published results in New Zealand and overseas.

A range of qualitative and quantitative soil quality indicators were chosen and prioritised. The higher the priority the more essential the index is. From 2003 onwards, indicators in priorities 1, 2 and 3 will be monitored on a regular basis at all sites. Some lower priority indicators may be used only for detailed studies at selected sites and time, to help our interpretation of trends observed in other measurements. All of the chosen indicators are summarised in Table 6.1. The priority 1 to 3 indicators are described in more detail below.

Table 6.1. Full Listing of Chosen Soil indicators. All measurements should be made in winter.

Priority	Indicator	Depth (cm)	Measured how?	Rationale	Possible values
1	Field soil assessment, combination of nine indicators	0 - 30	Spade sampling and visual inspection[18]	Field measurements form a suite of meaningful observations that can be integrated into one or more soil quality scores. Involvement of field research managers *and* growers will have positive spin-offs.	Will develop and compare a range of methods of integrating the scores from the different measurements
1	Field soil dry bulk density	0 - 7.5 7.5 - 15	Samples taken using soil corer, and sent to laboratory	Values and time trends are a useful indicator of compaction. Values are essential to convert soil chemical results into nutrient contents in kg/ha	Continuous scale of values
2	Chemical properties[19]	standard[20]	Samples taken using soil corer, then sent to laboratory	Values have considerable use as indicators of soil chemical fertility. Useful to assist soils fitness for present and other uses. Substantial literature available to assist interpretation.	Continuous scale of values
2	Total organic C and N	standard[3]	Same samples as for chemical properties	Values have considerable use as indicators of soil biological condition, and contribution to global CO_2 balance. Useful to assess soils fitness for present and other uses. Substantial literature available to assist interpretation.	Continuous scale of values

18 Measurements should be made at the same date and locations. Good training is crucial!
19 Soil pH, Olsen P, exchangeable cations and cation exchange capacity, P retention %, potentially mineralisable N, measured using New Zealand standard techniques.
20 The standard depth is 0-7.5 cm for pastoral and 0-15 cm for horticultural or cropping situations.

Priority	Indicator	Depth (cm)	Measured how?	Rationale	Possible values
3	Microbial biomass C	standard	Representative samples taken from paddock or block using soil corer, and sent to laboratory. May use same samples as for chemical analysis	Useful and well-accepted indicator of the amount of living material in the soil.	Continuous scale of values
3	Basal respiration	standard	Samples taken using soil corer, and sent to laboratory. May use same samples as for chemical analysis (will be checked).	Useful indicator of the rate of microbial activity in the soil under standardised conditions. Time trends could be especially useful to track impacts of management changes.	Continuous scale of values
3	Metabolic quotient	standard	Simple ratio of values obtained for biomass C and basal respiration	Useful indicator of the metabolic efficiency of the microbial population	Continuous scale of values
4	Soil fertility by bioassay	0-30 or whole topsoil21	Samples taken using spade or corer, sent to laboratory. Samples sieved and potted for bioassay using fully fertilised and watered plants as control.	Potentially very useful as a means of comparing the fertility of soils under contrasting land uses and management regimes.	Continuous scale of values, expressed as % of a control where the plants received adequate nutrients, water and air with no pathogens.
5	Chemical properties (as above)	from standard depth to 30 cm22	As above for standard depth	Combined with standard depth samples yields a figure that can be compared across land uses	Continuous scale of values
5	Total organic C and N	from standard depth to 30 cm	Same samples as for chemical properties	Combined with standard depth samples yields a figure that can be compared across land uses	Continuous scale of values

21 Whichever is the most shallow
22 Standard depth is 0-7.5 cm for pastoral and 0-15cm for horticultural or cropping situations.

Priority	Indicator	Depth (cm)	Measured how?	Rationale	Possible values
5	Microbial biomass C	from standard depth to 30 cm	As above for standard depth	Combined with standard depth samples yields a figure that can be compared across land uses	Continuous scale of values
5	Basal respiration	from standard depth to 30 cm	As above for standard depth	Combined with standard depth samples yields a figure that can be compared across land uses	Continuous scale of values
5	Metabolic quotient	from standard depth to 30 cm	Simple ratio of values obtained for biomass C and basal respiration	Combined with standard depth samples yields a figure that can be used to compare across land uses	Continuous scale of values
6	BIOLOG™	standard depth	Sub-samples taken from samples used for biomass C. Extracted in water, series diluted, applied to substrate wells on special plates and incubated. Colour changes in the wells are measured at intervals and related to activity of different classes of micro-organisms.	Has good potential for comparisons of functional diversity of soil microbial communities. However, much technique refinement and development is needed, and the technique is costly.	An array or matrix of values for micro-organism activity versus substrate type.

6.4 Priority 1 Indicators

The first priority indicators are a suite of meaningful field observations that can be integrated into one or more soil quality scores. Most are qualitative soil assessments rather than quantitative and will be undertaken by the two field officers. To ensure repeatability, the field officers were trained in the same manner and calibrated against each other. Regular standardization the field officers soil assessment (as paired observations) will be required to ensure consistency.

We used '***Visual Soil Assessments***' (VSAs) to provide semi-quantitative measures of the following soil characteristics against the quantitative measures determined from laboratory analyses. The VSAs provide our only opportunity to replicate extensively within farms because the cost of laboratory analyses forces pooling of soil from several different places on the farm. The VSA scores show remarkably strong correlations with soil physico-chemical analyses when compared across a wide variety of soil types (Shepard 2004), but it is unknown how sensitive they will be to detect the more subtle changes expected between farming systems within each cluster.

The visual soil assessment sheet given in Appendix 3 shows the detail of the scoring methods.

VSA variables were scored from digging a hole dug to 30 cm and have straight sides[23].

- Area of exposed soil (%)
- Amount of soil covered in live vegetation (%)
- Area of crusted soil (%) and thickness of crust
- Area damaged by vehicles, stock or erosion (%) and approximate depth
- Amount of pasture (kg DM/ha) for sheep and beef
- Canopy cover (%) for kiwifruit
- Presence and thickness of surface organic thatch build up
- Soil porosity
- Soil discolouration (mottles and gleying)
- Soil aggregation

The background justification for using these VSA scores and also earthworms and soil bulk density include:

Surface crusting

Organic matter plays an important role in maintaining soil strength. Saline soils (high Na+ content) are more likely to exhibit soil crusting. Surface crusting may be a result of stock treading, mechanical damage or water impact from rainfall or irrigation. Generally crusting is evident only in the top few cm of soil so soil bulk density measurements unlikely to be sensitive enough to determine level of crusting.

[23] A small spade was used to define the dimensions of the hole (xx cm square).

Surface smoothness

This reflects damage to soil by animal treading or vehicular passes, especially in wet conditions. Soil bulk density is likely to be affected if soil surface smoothness is badly damaged. On pastoral farms, treading damage has a direct impact on pasture utilization.

Organic matter thatch

In uncultivated soils, earthworms play an important role incorporating organic matter inputs. If these inputs are higher than the rate of earthworm incorporation (e.g. if earthworm populations are low), an organic thatch may develop on the soil surface. Earthworm populations will be assessed as part of this project.

Soil structure and aggregation

This indicates level of structural development of the soil. An older clay soil is likely to have stronger developed aggregates than a young sandy soil (link to soil cation exchange capacity measured as part of chemical suite). However poorly managed soil that has been compacted (assess through bulk density and visual inspection) and has low organic matter content (measure total C) may also have poor structure and aggregation.

Soil colour

The dark brown colour of topsoil is derived from organic matter (measured as organic C). Red-brown (in topsoils) or orange (in sub-soils) colours are mainly caused by oxidised iron (Fe3+) compound. The distribution of orange coloured mottles indicate how quickly the soil drains after water logging and is related to structure. Presence of grey/blue mottles indicates anaerobic soil conditions (soil moisture measured as part of bulk density).

Earthworms

Soil removed for the last four assessments is to be used for measuring earthworm populations. Earthworms give an indication of the biological, chemical and physical fertility of a soil (Fraser *et al.* 1999). Earthworms 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.

Soil bulk density

Soil bulk density is a measure of soil compaction and defined by weight per unit volume Blake *et al.* (1986). As weight is dependent on moisture content, samples are oven-dried at 105 ^{o}C to remove all moisture, giving dry bulk densities that can be compared between locations.

6.5 Priority 2 Indicators

Soil physico-chemical analyses for the topsoil make up the Priority 2 indicators. They are mostly a standard suite of measurements contracted out to commercial soil testing laboratories (Blakemore *et al.* 1987). There is a substantial literature available to assist interpretation. Additional measurements useful for interpretation are being conducted by Crop & Food Research.

The following measures will be conducted from soil samples taken from the top 7.5 cm (pastoral) and top 15 cm (orchard) of the soil:

- Soil pH indicates the level of acidity or alkalinity of the soil sample. Soil pH can influence the availability of nutrients to the plant. The normal pH range for kiwifruit is between 5.8 and 6.5
- Olsen P (µg/ml) is a measure of the phosphorus readily available to plant. The normal range for kiwifruit is 30 – 60 µg/ml, in productive pastoral soils values less than 15µg/ml are common.
- Exchangeable cations (Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Potassium (K^{+}) and Sodium (Na^{+})) are major nutrients for plant growth. Exchangeable cations are reported in two ways, as MAF quick test or as milli-equivalents per 100g (me/100g).
- Cation exchange capacity (CEC, measured in me/100g) is a measure of the soil's capacity to hold cations. A larger value indicates a soil with a higher capacity for cation nutrients. Soils with high clay and organic matter have high CEC. Sandy soils with low organic matter have low CEC.
- Phosphate retention (%) is a function of the soils parent material and the amount of clay minerals present that immobilise phosphorus. A high phosphate retention soil will need a higher phosphorus content in maintenance fertiliser than a soil with lower phosphate retention
- Anaerobic mineralisable N is an indication of the nitrogen that may become available to plants through mineralisation of organic matter.
- Volume weight (g/ml) is the weight per volume of air dried and ground of the soil sample used by laboratory for analysis
- Total organic C and N. Organic matter is important as it supplies nutrients to the soil, improves soil physical fertility and moisture retention. Samples are analysed by the Dumas Method for percentage carbon and percentage nitrogen in a LECO CNS-2000 Analyser (Laboratory Equipment Corporation Ltd, U.S.A.) After samples have been combusted at 1050 ^{o}C in a stream of pure oxygen, the resulting carbon dioxide gas is analysed by an infrared analyser. The nitrogen gas from the reduced nitrogen oxide gases is analysed by a thermal conductivity analyser. Soil organic matter content is directly proportional to the organic carbon content of the soil (to a good approximation, soil organic matter equals 1.72 x total organic carbon).
- Percentage of stones present in the soil sample by weight. Stones hold no nutrients or water, thus causing a dilution effect in the soil. Nutrient availability per volume of soil can be more accurately determined if stone content is known.

Lack of finance precludes replication of these priority 2 measures within each management unit. On Sheep/beef farms the soils from all three SMSs are pooled and mixed thoroughly to obtain a representative sample for a single analysis. On kiwifruit orchards the vineline samples from the 3 SMSs are pooled, and the alleyway samples are gathered in a separate sample. By sampling management units separately, we can filter out radical changes in one of those management units (e.g. cultivation, flood), but with only 3 management units sampled per farm, the replication may be inadequate to describe an average for all of each farm.

6.6 Priority 3 Indicators

The third tier of measures described below assesses biotic activity in the soil profile. It is often claimed that conversion to organics triggers a general increase in soil

biodiversity and activity, so inclusion of some measures of their joint activity was considered a bottom line selection of soil parameters for long-term monitoring.

6.6.1 Microbial biomass carbon

Microbial biomass carbon is a measure of the total amount of living microbes in the soil (Vance *et al.* 1987). Microbial biomass usually constitutes around 1 to 4% of total soil organic matter. In temperate climates the fast rate of microbial turnover suggests that microbial biomass is a more sensitive indicator of changes in total soil organic matter than total soil carbon content. The laboratory test is a relatively simple and rapid chloroform fumigation method. Microbial biomass levels will differ between soil types and land use history.

6.6.2 Basal respiration

Soil micro-organisms recycle essential nutrients when they decompose dead plant and animal material. Hence an active microbial population is a key component of good soil quality (Rice *et al.* 1996). Measured in the laboratory, microbial respiration is a process that reflects the potential activity of the soil microbial population. Measurements are conducted on sieved soil packed to a bulk density of 1.0 g/ml, wetted to a soil moisture of 60% of field capacity, and incubated at a temperature of 22°C (Parkin *et al.* 1996). Microbial respiration is the amount of carbon dioxide production over a fixed period.

6.6.3 Metabolic quotient

This is a simple ratio of values obtained for biomass C and basal respiration. It is a useful indicator of the metabolic efficiency of the microbial population.

6.7 Priority 4 to 6 Indicators

The available budget in year one and two precludes sampling in additional ways that would be highly desirable. Further funding will be sought to allow these additional measures once the baseline monitoring has been established.

The Priority 4 indicator is the development of a plant growth bioassay to measure the 'fit for future use' of the soils and to compare across sectors and farming systems. One or two standard plants would be planted in soils taken from each SMS and brought into standard glass house conditions. The relative growth rate of the standard plants under constant environmental conditions will potentially provide a robust holistic measure of soil quality that can allow aggregation of results from divergent soil types.

Priority 5 was assessed as a repeat of the soil physico-chemical and microbial assays at greater depths (7.5 – 30 cm for pastoral, 15 – 30 cm for kiwifruit). This would test that surface soil indications used in standard tests is reflecting properties of the deeper soils which may in turn be affecting grass and fruit growth, as well as soil biota abundance and diversity.

BIOLOG™ plates to assay soil chemical activity is a Priority 6 indicator. A pre-prepared matrix of 96 wells of 32 different chemical substrates is inoculated with soil. Colour changes are used to assess reactivity between the soil and each type of chemical substrate to provide a profile of its potential bioactivity. The BIOLOG™ plates were developed for medical research rather than soil work per se. They are expensive and setting up the system to adequately assay ARGOS soil reactivities may be time consuming. Nevertheless the system shows promise as a type of generic comparison between the soils under different farming systems' management.

6.8 Argos Field soil sampling strategy

The prime aim of the field soil sampling is to compare between two agricultural systems *and* between the three management systems for those agricultural systems.

Agricultural systems, management systems and individual farms are complex entities to compare, and soil quality can vary a great deal in time and space. Therefore, in order to achieve our prime aim on a limited budget we must be very careful to specify the levels of focus for sampling. In particular, we must be very careful to focus our sampling efforts at appropriate scales. The location and number of individual samples strongly dictates:

- How well a single years' results can be used to compare agricultural and management systems, and
- Whether meaningful or detailed comparisons can be made between individual farms or paddocks within farms.

A measurement strategy that is effective at characterising whole farms is very intensive and expensive if it is also to be used to compare agricultural and management systems.

The overall ARGOS approach, which we must fit into, is to concentrate on groups (clusters) of commercial farms that are under the target management systems and are in close proximity. Given this, and the likely large spatial variability in soil quality we chose to monitor the dominant landforms within each cluster using permanent soil monitoring sites (SMS). This scheme is especially good for comparisons between agricultural and management systems (the prime aim), but it is weak for characterising whole farms.

Guidelines for establishment of soil monitoring sites have been developed for both sheep and beef farms and kiwifruit orchards. A similar strategy is expected for ARGOS dairy properties. Details for setting up the protocols are in Appendix 2 & 3, but the general principles and rationale for them is described below.

6.7.1 Frequency and timing of sampling

We intend to repeat routine monitoring on an annual basis for at least five years, and possibly up to 20 years. Time trends that may appear in the results will help us to make the more detailed comparisons mentioned above. Also, in some years it may be possible to carry out some more intensive measures on specific farms to test sharp hypotheses about the effects of the management systems and differences between individual farms.

The ideal time to sample soils is mid winter (June – July), but sampling until mid September may be forced in some years due to work load. This time is chosen because the soil has usually been wet for a long period and therefore more uniform results between properties can be expected, thereby giving the best opportunity to detect background differences between farming systems.

6.7.2 Landforms for soil sampling

The next requirement is to stratify soil sampling to particular landforms in an attempt to control for some dominant variables expected to influence soil parameters. This means that the combined soil samples will not be immediately representative of the whole farm, but it does strengthen our ability to compare across farming systems and to detect trends in soil parameters from repeated sampling in the coming decades.

For sheep and beef, three predominating land forms are present: Flat river terraces, Mid slopes and Hill crests. However, in clusters on the Canterbury Plains only flat river terraces predominate, so only this single landform will be studied. For sheep

and beef clusters on hill country, the dominant two of the three landforms be studied. In nearly all cases these will be mid-slope and hill crest. Within a cluster the same landforms will be studied.

On orchards, management of the vine line (within row) and 'alleyway' (between rows) are expected to have very different soils and will be treated as two separate landforms. The two landforms will be selected in a 'paired' manner. That is, having found and sampled soil from a random location on the vine line, the adjacent alleyway is also sampled (Appendix 2).

6.7.3 Management units

On kiwifruit orchards, the property is managed by the grower in separate blocks. On sheep and beef farms, the property is managed by the farmer in separate paddocks. On sheep and beef properties, individual management units (paddocks) may have specific functions or be monitored and fertilised according to very different strategies. For example, some paddocks have specific functions on the property, such as:

- Long-term hay paddocks
- Access paddocks
- Airstrips
- Regular cropping paddocks
- Grazing style (extensive or set stocking vs. intensive or break feeding).

Similar paddock functions to be chosen across the three properties within each cluster. Three paddocks will be chosen at random within each farm per landform from all paddocks of the target type (i.e. all paddocks present with each landform and management unit function).

On orchards with only one block, sampling on a sub-block basis will provide an indication of within block variation *and* if there is any natural stratification within that block. If there is an obvious shift in landform or ecology within such large single blocks, the boundary of sub-blocks will be aligned to the natural change. Otherwise the sub-blocks will have about equal size.

On orchards with two blocks, we will sample two sub-blocks and one full block. Again, if there is any stratification within the split block, the boundary will be placed there. If the two blocks are about equal size, the one to be split into two sub-blocks will be allocated randommly. If one of the two blocks is conspicuously larger than the other, the largest will be assigned two have two sub-blocks.

On orchards with three or more blocks, sampling individual blocks separately will assess between-block variation of chemical status. By sampling blocks separately, we can filter out radical changes in one of those management units (e.g. cultivation, flood, etc.).

6.7.4 Soil monitoring sites

At a single sampling time, soil properties can be quite variable within a small area. To achieve reliable monitoring that spatial variation must be recognised and accommodated, so that time trends can be distinguished from random noise generated by sampling different areas of soil. Most of the hypotheses relating to farming system effects on soil will be tested by detection of trends between successive years, rather than spatial comparisons. Our approach to this problem is to establish within each management unit permanent '***Soil Monitoring Sites***' (SMS) where all samples are gathered.

There will be three SMS placed at random within each randomly chosen management unit (paddock or block) on each property (see

Figure 10.1 and Figure 10.2 in Appendix 2). However, some randomly chosen sites will be disallowed for SMSs. That is, on sheep/beef farms we will avoid unusual areas and keep *at least* 30 m away from trees, fences, gateways, and water troughs. A further check of suitability of SMS will involve sampling the soil profile to one metre with a soil auger. After checking at least three SMSs per paddock, we will discard sites if the soil profile is obviously different to all others, or if unusual layers like old fire sites or isolated soil disturbance (e.g. old cow shed/shelter belt, etc.) are found. A new random SMS site will be used to replace the sites censored from the sample in this way.

The outer rows of kiwifruit blocks will be avoided to exclude edge effects. Similarly, bays with male vines and sign of dead or decaying vines will be excluded[24]. On orchards with only one block, sampling on a sub-block basis will provide an indication of within block variation *and* if there is any stratification within that block. On orchards with two blocks, sampling two sub-blocks and one full block will provide some indication of within block variation, if there is any stratification within the split block, and the variation between the blocks.
On orchards with three or more blocks, sampling individual blocks separately will assess between-block variation of chemical status. By sampling blocks separately, we can filter out radical changes in one of those management units (e.g. cultivation, flood, etc.).

Each SMS in sheep/beef will be approximately 15 m x 15 m. In kiwifruit they are two 'bays' long and extend either side of the vine line to the middle of the adjacent alleyways (ca. 4-5m wide x 8-10 m long). These dimensions were chosen sufficient to allow soil cores to be taken from a different spot within it each year.

The location of each SMS is recorded by GPS so that it can be re-sampled each year.

6.7.5 Soil profile

The soil profile and depth will be described in the standard manner (see Appendix 3 for details).

6.7.6 Sample processing

When samples arrive at Crop & Food Research, they are immediately sieved fresh through a four mm sieve. The sieved soil is weighed and oven dried at 25° C for 5 days, then reweighed. Samples will be stored until all have been collected and processed (Ross 1991). For both types of microbial analysis, the soil will be rewet to 60% of water holding capacity.

6.7.7 Soil measure sample sizes

The protocol above results in 81 378 and 648 Priority 1 measures for Sheep/beef on the Canterbury Plains, other sheep/beef farms and kiwifruit respectively (Table 6.2). Pooling of soil samples for chemical and microbial analyses means that there are 27, 126 and 216 Priority 2 and 3 samples in these same groups. As there are several parameters measured from each soil sample (11, 10 and 3 for each of Priority 1, 2 and 3), the result is a database of 16,974 soil indicators. Preliminary analysis after

[24] If vines die after SMS establishment we will identify whether the death is a consequence of soil quality. If death is due to another reason (e.g. foliar disease or pests) it may be necessary to replace this SMS with another.

the first two to three years is highly desirable to focus the data collection for the long-term.

It is important to note that these sample sizes have been generated simply from combining our experience and defense of a minimum degree of replication with what can be afforded in the first years' budget. It may be that high natural variability in the measures will weaken the statistical power of the resulting analyses. The first year must be considered a pilot study and power analyses will be completed before the second year of soil sampling is undertaken.

Table 6.2. Number of soil samples for the sheep/beef and kiwifruit farms in winter 2004.

Measure	Canterbury Plains Sheep/Beef farms	Other Sheep/Beef farms	Kiwifruit farms	All sectors
Farming systems per cluster	3	3	3	3
Clusters	3	7	12	3 - 12
Landforms	1	2	2	1 - 2
Management Units per landform	3	3	3	3
SMSs per Mgt Unit	3	3	3	3
Number of priority 1 samples	81	378	648	1,107
Number of priority 2 and 3 samples	27	126	216	369
Number of priority 1 measures†	891	4,158	7,128	12,177
Number of priority 2 measures†	351	1,638	2,808	4,797

† There are 11, 10 and 3 parameters measured for Priority 1, 2 and 3 samples respectively.

7. Farm Management

7.1 Pasture assessment

Pasture assessment is potentially important to biodiversity and fundamental to the farm management and economic outcomes for sheep/beef and dairy farms[25]. We therefore propose that considerable emphasis is placed on regular assessments of pasture standing crop, and that cameo studies of the relative growth rates of pasture under organic, IM and conventional management are attempted. The composition of the sward should also be measured, but less regularly because it is a time consuming and specialised task. Pasture monitoring will mainly be the responsibility of the economics team but some brief discussion is included here because of overlaps with the environmental monitoring agenda.

7.1.1 Measuring pasture productivity

Measuring pastures well is enormously challenging, especially when ARGOS is attempting to monitor so many farms with such a limited budget (D. Lucas, pers. comm., Lincoln University). Measuring production is much harder than measuring standing crop of the sward. The most reliable method to measure production is to place cages on clipped areas of the pasture to act as exclosures[26] and then clip the new sward about 4 weeks later to measure intervening production (Lucas & Thompson 1990, Leaver 1982, Mannetje & Jones 2000). A local experiment measuring response of pastures to various treatments occupies a Lincoln technician for most of a year. That study is over three ha and involves 68 plots. Dick Lucas and team are doing an intensive study of pasture production on Lincoln University's Mt Grand Station (Hawea Flat). This is costing $100K per year for the one property. Much depends on choice of study question, but clearly this sort of investment is impossible for ARGOS.

One option is secure external funds to do a cameo study of comparative productivity on different farm systems using the exclosure method[27]. An alternative option is to take advantage of farmers' management to measure pasture production in paddocks where grazing has been removed (e.g. for hay making). It may be difficult to find sufficient such paddocks in all three farms within a cluster at about the same time, but gradually we may succeed in building up sufficient sample size by such means. If paddocks had been closely grazed before exclusion of the stock, only one visit to measure standing crop would be needed.

7.1.2 Measuring standing crop

A "rising plate meter" measures height of pasture and something of sward density[28]. Although quantitative, this still only offers a relative index of standing crop. A much better alternative if we can afford it is to use a capacitance meter. They measure pasture biomass indirectly by measuring water content around the probe[29]. They will underestimate total grass dry matter (D. Lucas, pers. comm.) so a calibration study would be needed to correct for this bias and check its constancy between different sward compositions.

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[25] There are some issues of sward management under orchards, but these are less central to production of produce.
[26] Cages have to be sturdy enough to keep cattle out and cost $100 each.
[27] A partnership with a student hosted by AERU might be able to overcome these logistic constraints.
[28] Care is needed in its application (e.g. it could land on a thistle).
[29] They cost around $2,000 each.

The most practical and rapid measure is to use 'Visual Pasture Assessment' (VPA) methods to estimate standing crop by eye. Sheep farmers usually do not visually or quantitatively assess pastures, but dairy farmers do this more regularly (D. Lucas, pers. comm.). The subjective nature of the measures dictates that our field officers would initially need to have their existing experience sharpened by a training session[30] and then regularly calibrate their scores against clipped samples of sward (perhaps in association with the spot measures of productivity mentioned above).

7.1.3 Pasture composition

Irregular (perhaps every 3 to 5 years) assessments of sward composition would be valuable from several points of view. Organic or IM farming may alter the competitive interactions between the species and trigger changes in the prominence and distribution of weeds. The key element in the pasture for productivity and competition outcomes will be the legumes[31]. Stocking rate and grazing pressure are also important covariates that will affect productivity and sward competition.

7.2 Feed management

Feed management is potentially crucial to several environmental and biodiversity outcomes on the farm. If nutrients in the form of supplementary feed are imported to overcome lean periods (e.g. during winter periods of low pasture production, drought periods, etc.) or peak demands of livestock, then stocking rate of the farm is largely decoupled from the *in situ* ecological carrying capacity of the farm. These 'ecological supplements' are effectively external additions to a local ecosystem. Stocking rate probably indirectly affects many environmental variables (e.g. soil compaction, grazing pressure, nutrient turnover, leaching, run-off, soil organic matter dynamics, etc.) and several flow-on farm land management regimes. Many putative differences between pastoral farming systems may be driven indirectly through altered stocking rate, so it becomes important to understand the motivations and tools used by farmers to regulate feed and stocking rate.

Stockpol™ is used to maintain a model of the feed supply and demand (stock policy) for each property[32]. A feed supply and demand model is typically created prior to commencement of the production year (July to June). Feed supply is calculated through establishing expected land use and resultant pasture growth rates, yield of supplementary feed and area conserved. Pasture growth can be manipulated through application of nitrogenous and other fertilisers. Feed demand is calculated through developing a profile of stock classes, monthly numbers, changes in live weight, timing of shearing, and breeding performance. Stockpol accounts for efficiency of feed conversion to live weight through breed type and efficiency within breeds (based on historical data). Actual feed demand and supply assumptions are revised using monthly farm data.

Applying the Stockpol™, UDDER™ or Endeavour™ models could provide a useful service for the growers to support our involved assistor roles, but they must be used with extreme care to test difference between farming systems. The expected relationships within the packages are not calibrated separately for organic, IM and conventional. Certainly the inputs will be different for the farm system audit

[30] Greg Lambert from AgResearch in Palmerston North has been putting a lot of work into visual assessments of pasture and training farmers and advisors to do it. Dick Lucas suggested that we commission him to train us, or that Dick himself could do the training or some of the actual work on ARGOS farms.

[31] According to D. Lucas (pers. comm.), "Grass is just blotting paper for nutrients". While we do not subscribe to this reductionist perspective, the quote highlights the fundamentally different ecological actions of the two fodder species.

[32] Endeavour™ and UDDER™ are competing models.

requirements, and this will allow some differentiation and prediction using the standard model. But if the farming style has some impact on, for example, mycorrhiza or other soil biota (as is so often claimed), and if these parameters affect pasture production, predictions using the model will be flawed as far as our testing of the farming systems' null hypothesis. The models would only then work for conventional systems. We can not be sure that say a predicted variable from the model can be used to test whether there are differences between organic, integrated and conventional farms. It would constitute a circular argument until we had tested whether the relationships within the model are different in the three types of farming[33].

For the above reasons we envision using the nutrient/feed and fertilisation packages only for preliminary predictions that must them be cross-checked by a variety of other measures: for example, did the expected relationships between say livestock weight gain and feed in Stockpol™ look the same in organic and IM and conventional? Forecast feed demand and supply assumptions must be reassessed monthly based on farmer expectations and historical trends. If these and other crosschecks are secured then we can accept the model's predictions. If there are systematic departures for the different farm systems from internal cross-checks, then we need to re-calibrate them for the different systems.

The models should not be used to advise organic or IM farmers until the above cross-checks are completed.

7.3 Fertilisation of soils

Overseer™ is a decision-support model for farmers and fertiliser advisors to design annual fertiliser applications Farm Environment Risk Assessment Maps (FERAMs) provides a more landscape level nutrient input decision-support system to design fertiliser application rates on different parts of the farm and whole catchment (Quin *et al.* 2004).

Comparing the predictions of these models for organic, IM and conventional systems will provide preliminary hypotheses for differences in soil health and leaching and potentially help the individual growers. However, the same constraint of models' calibration as discussed above for Stockpol and Endeavour will restrict the usefulness of Overseer and FERAMs as a predictive tool, at least until checks of the robustness of predictions can be completed.

Application of Stockpol, Endeavour, UDDER, Overseer and FERAMs requires considerable time input by farmers and/or our ARGOS team or consultants. This may not be a barrier for some farmers, but others will not be interested in doing it. A solution may be to invite a partnership with the manufacturers of the models and set up a research project to measure their relative strengths and weaknesses will being applied to ARGOS farms. An external grant may be secured to provide the package for all participating ARGOS pastoral farmers.

7.4 Weed Management

Weed management in pastoral lands in New Zealand is relatively straightforward, unless ARGOS ventures into the riverbed issues that could flank some of the ARGOS farms[34]. However weeds may be more of a problem for organic growers

[33] This scepticism is not shared by Jon Manhire's colleague, Geoff Dunham who is convinced that we can compare farms/systems etc. Similarly Prue Williams, Crop & Food, believes that the Overseer fertilizer application package with the same potential constraint, can be safely used to compare systems. The issue needs more investigation and discussion.

[34] A critical reassessment of priorities may be needed of these riverine habitats are important in the final panel of farms chosen.

(MacKay *et al.* 2002). We propose that the investment in management of weeds is monitored in the first two years of ARGOS and investigation is intensified only if serious problems are indicated. Effort will then be targeted on the most serious weeds; that is, those that are either listed as noxious or create significant farm management difficulties, biodiversity or economic concerns.

There are five main woody weeds and seven main herbaceous weeds in sheep/beef farming landscapes (Table 6.1).

Nassella Tussock and Mouse-eared Hawkweed are more prominent in drier areas, whereas Ragwort and King Devil are more prominent in wetter areas. *Hieracium* is a particularly intractable problem to manage on some High Country runs. Matagouri is an interesting case in that it is a native species and presumably has an associated fauna of native species. It is climate limited[35].

Weed prevalence is affected by many factors, including: pasture management, soil fertility, insect damage, stocking rate, fire management. Cattle are much more selective eaters than are sheep and especially goats. Cattle avoid thistles. In the High Country *Hieracium praealtum* is more erect than the other *Hieracium* species, so its leaves and especially flowers are eaten by stock. If dairy cows are forced to eat Ragwort, the milk becomes tainted. Sheep avoid many weeds and if they eat Ragwort they die young. The sheep/beef ratio is therefore sometimes managed to optimise weed control, and goats may be run mainly for weed control.

Thistles in general are poor competitors and so need disturbance (bare ground, cracks in soil, drought, grass grub, etc.) for establishment and persistence. The exception is Californian Thistle, which is rarely spread by seed. A Californian Thistle patch is a giant clone spreading from the margin by rhizomes (so no need for disturbance). Nassella Tussock and Ragwort are biennial. Scotch Thistle is annual. There is a 10 to 12-year seed bank for most of these herbaceous weeds, much longer for woody weeds.

Gorse is definitely currently more of an ecological and economic threat than broom but the reverse may be true in generations to come. Gorse has been a problem in New Zealand since about the 1880s and its distribution is probably nearing its ecological capacity. Broom has probably been in New Zealand as long as gorse, but unlike gorse, it was planted in domestic gardens and never spread around the countryside as a hedge. Broom did not reach critical mass for invasion until about 1950, since when it has been invading rapidly. Distribution is still quite limited, but broom probably has potential to be much more ecologically important than gorse[36].

Ecological urgency can sometimes influence priority setting after potential or realised ecological importance has been assessed. The gorse cf. broom research also illustrates this well. DSIR and then Landcare Research started the biocontrol fight against broom with seed-feeders to try to stem the rate of long-distance invasion (Paynter *et al.* 1996). This is usually not the preferred approach in biocontrol circles, but it became a priority after recognition of the urgent need to stem spread to prevent

[35] CLIMAX modelling has been done for it (R.L. Hill pers. comm..).
[36] For example, gorse rarely grows above about 1000m in the South Island, whereas broom can go much higher into the tussock lands. See Hill & Sandrey (1986) and Richardson & Hill (1998) for issues of lags in spread of gorse.

Table: 7.1. The Main Weeds of South Island Sheep/Beef Farms. Information sourced from Roy *et al.* (2004) and R.L. Hill (pers. comm.)

Weed Type	High Country	Hill Country	High Fertility Sheep/Beef Farms on Flats
Woody Weeds			
Matagouri	✓	✓	x
Broom	✓	✓	✓
Gorse	x	✓	✓
Wilding Pine	✓	✓	x
Sweet Briar	✓	✓	x
Herbaceous Weeds			
Mouse-eared Hawkweed	✓	✓	x
St John's Wort	✓	✓	x
Californian Thistle	✓	✓	✓
Nassella Tussock	✓	✓	✓
Ragwort	x	✓	✓
Winged Thistle			✓
Scotch Thistle			✓

the weed reaching its ecological potential. In general, stemming new organisms in their invasive phase will often force urgency to its research, potentially at the expense of current ecological importance of competing projects. Introduced animals often complete their spread throughout New Zealand very rapidly, but weeds can sometimes be more easily contained. Introduction of Biocontrol agents to ARGOS farms may be one way the team can support badly affected farmers.

The greater patchiness of the woody weeds has made them more of a 'public good' issue than herbaceous ones. This triggers more involvement by the regional councils to make sure individual farmers do not create problems for their neighbour –or one region for a neighbouring region. The main management strategy is to focus on limiting spread (patch edge management) or eliminating outliers, coupled with abandonment or conversion to forestry of the main long-standing woody weed patches.

There is no database for the herbaceous weeds because they are "nearly everywhere" (R.L. Hill, pers. comm.).

The regional councils have produced a lot of material in the Pest Management Plans (as required by the Biosecurity Act), but it is mainly on the woody weeds rather than herbaceous ones. Other than regional council publications and management advice, only the scientific literature is available for farmers. That is, there are currently no decision-support packages for farmers to choose weed-optimal management strategies.

Regular measures of sward composition and photo-points will monitor the prevalence of herbaceous weeds, but the more woody weeds will be assessed from baseline habitat surveys and remote sensing.

8. Synthesis: General Discussion of Current Research and Potential Themes for the future

8.1 Identified Future Research Themes

8.1.1 Gathering of historical data by the Field officers

Gathering of historical data on soil sampling, stocking rate, production, economic records, farm plans etc. is extremely important for the ARGOS study because a BACI design could not be mounted immediately. This compromises our ability to test whether the changes we observe between already converted farms were caused by the change in farming (Moller 2004a). One solution is to gather historical data, if possible stretching back to before organic and IM farms converted. We hope that the field officers will gather copies of any historical data as soon as possible because there is a risk that they will be lost or destroyed. Knowing how much historical data can be retrieved also helps us assess how much effort we should invest in the delayed BACI approach (number of farms etc.).

8.1.2 A need for research of environmental history

Ideally, the ARGOS Environmental Changes on Farms surveys will be allied to investigations concerned with narrating and understanding the environmental histories of the study farms and their local and regional landscapes, and relating these to contemporary patterns and processes of agro-ecosystems and landscapes, and anticipations of possible future landscapes under different scenarios. Researching the environmental histories of the ARGOS farms and their landscapes will aid the understanding of the changing expression of people-environment relationships and the landscape outcomes in terms of ecologies, production systems, and visual appearance, as well as the durability of wanted and unwanted elements. Researching environmental history will facilitate the consideration of the different tracks that that the ARGOS farms to get to starting date(s) of the ARGOS study. The environmental history of a farm will have ongoing ecological, social and economic consequences. Environmental history allied to contemporary landscape studies provides a better basis for a systematic approach to landscape futures; that is, the landscape impacts of policy, programmes and plans.

Working in Sweden and Norway, Emmelin (1996) has developed a method for analysis of the landscape impacts resulting from the interaction of human and natural systems, and for their presentation in visual terms. His method uses scenario techniques. These offer a different perspective from studies dependent on statistical analysis. Emmelin (1996) applied scenarios to the landscapes impacts in Norwegian agricultural policy. He reconstructed a landscape as it appeared in 1966, and then portrayed the landscape as it appeared in 1988, “the point of departures for the futures” (Emmelin 1996: 27). Emmelin then devised four ‘trend alternatives’ for the year 2000:

1. The mechanical extrapolation of the trends from 1966 to 1988 into the future;
2. The introduction of a requirement for an ecologically sufficient spread area for manure on each farm;
3. “Translating the environmental rhetoric of Norwegian agricultural policy into concrete action at the landscape level, with respect for the history and tradition of that landscape” (Emmelin 1996: 30); and
4. An unexpected future: “market response to stimuli outside the conventional agricultural sector” (Emmelin 1996: 31).

ARGOS could use this technique by visualising the landscape outcome of the different farm treatments. We recommend initiating an environmental history investigation of ARGOS farms in year two once the baseline surveys are complete. Potential future farm landscapes should then be generated to assist farmers to set their future goals for farmscapes.

8.1.3 Forest and grassland reserves within farms: are their ecological processes intact and how can more reservation be encouraged?

In general ecologists expect that restoration of biodiversity in New Zealand 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 (2000) to suggest a target of returning 25% 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.

New Zealand's indigenous woody vegetation evolved in the absence of browsing by mammals, so regeneration of forest is dependent on removing stock. Creation of reserves of indigenous vegetation within farms will therefore be important. Several farmers have worked with the Queen Elizabeth II Trust and regional councils to place covenants on small forested or natural grassland fragments within farmland. Costs of fencing of such reserves are often shared by the farmers, regional councils and Queen Elizabeth II Trust.

We propose that the ARGOS team, in collaboration with farmers and successive MSc of PhD research students examine the ecological processes operating within farm reserves to determine whether added management investment is needed and practicable to make them more effective cradles for valued biodiversity. It may be that predator control is needed to allow native birds or bats to use them for breeding or roosting. A planting programme may be needed if the absence of seed dispersers like kereru makes the reserve ecological disconnected from seed sources[37].

8.1.4 Farm Forestry

Farm forestry also offers potential opportunity for biodiversity, as well as a diversification of incomes for each land-holder. We request consideration of whether to build more farm forestry considerations into the ARGOS project after the final selection of the sheep/beef farms is completed and current land uses known. There is very little ecological information on the biodiversity values of farm forestry in southern parts of New Zealand in particular, so some follow-up research to the base-line ecological survey may be needed.

8.1.5 Shelterbelts

Aside from reservation or farm forestry, the main other way of reintroducing woody vegetation to pastoral farmland landscapes is through planting trees for shelter and/or erosion control and thereby indirectly gaining biodiversity. 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 (McLaughlan & 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, shelter belts may be conduits and

[37] Bert Rebergen, an ecologist with the Otago Regional Council, has expressed interest in doing a PhD thesis on these themes within the ARGOS project.

nursery areas for introduced mammalian predators and browsers in New Zealand farmland.

ARGOS therefore proposes a detailed cost benefit analysis of different types of shelter to identify barriers and opportunities for increased planting of optimal species in ideal microsites on farms and orchards. We expect that most of this research will take place in sheep/beef farms, but there will be some need to evaluate shelter within kiwifruit orchards from a different and more restrictive point of view. Shelterbelt roles in harbouring pests will be a special emphasis for the kiwifruit study.

We will interview growers to discover why the shelter is as now present (the wider environmental history research will assist here) and where they may wish to add or remove shelter, and which species they might use. Research of the main barriers to shelter creation or enhancement will be a prelude to an active intervention to removing or lessening such barriers. The national and international literature will be reviewed and consultation sought with researchers currently studying shelter benefits and costs (e.g. Dr Jo Pollard investigated the role of shelter for improved lambing, Pollard *et al.* 2004). We will probably need to mount several small research projects of our own (e.g. bird use of shelter). The cost-benefit analysis must be extremely wide-ranging, and include consideration of:

- Physiological benefit to stock in relation to size and placement of shelter (already reviewed by Gregory 1995)
- Behaviour of stock in relation to shelter
- Patterns of stock defecation, urination and soil compaction in relation to shelter, and the consequent long-term implications for soil quality, nutrients and runoff
- Reduction of soil water loss
- Reduction of wind erosion
- Interception of light, i.e. nutrients, and alteration of soil by shelter vegetation, leading to lost production
- Biodiversity benefits and threats of different shelter (use of shelterbelts as refuge or breeding sites by valued and pest biodiversity)
- Time required to grow or replace shelter
- Nutritional value of shelterbelts (willow silage has been investigated by AgResearch, A. McKay, pers. comm.)
- Potential anthelmintic values of shelter vegetation if browsed (see Novel plants)
- Value of shelter in critical storm or drought events
- Use of shelter trees for firewood

We will then work with ARGOS farmers who wish to modify or augment their shelter to design a planting strategy. Our analysis of current and potential future landscapes and detailed look at micro sites using GIS databases like that provided by GrowOtago™ will help guide decision-making. We will calculate the seasonal food requirements of focal species (e.g. kereru) and plan planting to reach specific wildlife restoration goals. A Sustainability Fund grant from MfE or another SFF application may be appropriate for this project.

Dr Alex McKay has suggested that packages like UDDER or Stockpol could be quickly modified to predict how much of each food species would have to be planted.

Research on shelter should begin late in 2004/05 (year 2) once the predator and habitat restoration experiment has been designed. We expect one to two years will

be needed to complete the initial review and identification of subsequent research priorities.

8.1.6 Novel plants for anti-parasitic effects

The consequences of parasite burdens are one of the major constraints in the transition from intensive to low input systems and resistance to parasitism is becoming an issue on intensive farms. Thus the starting point for this programme is to research a novel, natural and sustainable method of reducing anthelmintic inputs into the farmed environment, whilst contributing significantly to agricultural biodiversity on farmland. Dr Marion Johnson will therefore investigate the nutritive value of the plants to validate their inclusion as feed buffers or alternative feeds within a farm plan. The project is mainly funded by a FRST Post-Doctoral Fellowship to Dr Johnson, but will be co-hosted by AgResearch Invermay and ARGOS. Considerable co-funding is provided by AgResearch. ARGOS has provided a moderate contribution ($10,000) for her costs and the platform to trial her proposals within the ARGOS farms.

Deer and lungworm will be used as the experimental model species for *in vivo* tests of anthelmintic activity of selected plants because lungworm is the most important and well-studied parasite in deer and the lungworm results will not be confounded by the presence of other parasites. Nevertheless the model results will be applicable across all the livestock industries and lateral extension of trials to sheep and deer farms will be sought later if initial results for deer look promising. Dr Johnson will assess the ecological importance of the most promising novel plants in agricultural landscapes so that triple bottom line considerations can influence eventual choice of which plants to take to extensive field testing stage.

The main outcomes of this research will be:

- Evaluation of indigenous plants, trees, shrubs and herbs for their anthelmintic and nutritive qualities for red deer.
- A practical method of increasing agricultural biodiversity.
- Provision of a means of encouraging uptake of alternative sustainable management systems through the identification of multiple roles for plantings and thus providing a tangible return on investment.
- The development of a method to ease the transition to low chemical input farming by finding and validating alternative methods of parasite control.
- A contribution to government initiatives and direction to increase and enrich biodiversity on private lands
- The investigation of properties of native plants which maybe incorporated into Māori land use plans and eventually lead to the development of indigenous branding of product.
- Practical field-testing of novel plant strategies by the end-users themselves.

The specific objectives of this research are:

Objective 1: *Identification of plants selected from 3 categories ~ natives, herbs, trees and shrubs ~ which have anthelmintic or 'tonic' properties*. Three categories of plants will be used for selection purposes as each category has a unique role to play within a multipurpose sustainable management system.

Objective 2: *Testing of selected plants from each category for anti-parasitic activity, palatability and nutritive value.* Plants will initially be tested for anti-parasitic activity in the lab. The palatability of the plants will then be assessed in outdoor feeding trials using red deer. Palatable, anti-parasitic plants will then be field tested using red deer

infected with lungworm. Plants which pass the anthelmintic and palatability tests will then be analysed for nutritive value.

Objective 3: *The incorporation of selected plants into a sustainable management scheme.* All selected plants must have multiple functions. Consideration will be given as to the suitability of different species for different roles and how those species should be managed. For example, anti-parasitic herbs may be incorporated into pastures or grazed separately. They may be accessed for zoopharmacognosy or used as part of riparian management programmes and grazed at key times. If plants possess good nutritive value they may be used as a feed bank or as a tonic at key points in the production cycle. In addition they will attract other fauna. Native species, trees and shrubs can for example be harvested, browsed, used to provide shade and shelter, erosion control, for riparian management or for an eventual cash crop. They may also be used as mixed plantings on difficult areas.

This project has been chosen for its generic contribution to ARGOS goals. However it is also an example of the type of intervention we hope to facilitate on farms in several other areas. We will particularly study the uptake of the novel plants as a way to identify general lessons for improved innovation on all farms.

8.1.7 Evaluation of Environmental Indicators

ARGOS will place immediate emphasis on establishing an environmental indicators monitoring programme, partly to assess the comparative sustainability of organic, IM and conventional farming approaches. Although we have tried to choose indicators being used elsewhere, and/or ones with a proven utility, it is inevitable that some additional research will be needed to test, calibrate and improve indicators for New Zealand farming conditions. There is a particular need for inexpensive soil biota indicators.

An MSc thesis study by Ms Sarah Richards will commence in April 2004 to investigate the potential for nematodes as bio-indicators of soil health in New Zealand's agricultural systems. Specifically, the following objectives will be addressed.

Conduct a pilot study to compare and evaluate the different methods for extracting nematodes from soil samples.

- Determine whether current abundance and trophic diversity of nematodes in soil varies between integrated pest management and organic kiwifruit farms.
- Estimate the sample size required to be 95% sure of detecting a 10%, 25% or 50% change in nematode abundance and trophic diversity.
- Perfect a simple to use survey method that can be used to monitor soil health in farms and further, to cost the minimum required sampling regime, or any variations in sampling method for a follow-up experiment with the ARGOS project.
- Assess organic, IM and conventional farmers' attitudes to both earthworms and nematodes in order to determine the optimum and most practical choice for a bio-indicator species.

A parallel detailed study of earthworms as focal species will facilitate a more informed choice of either nematodes, or earthworms, or both for long-term monitoring on ARGOS farms from year two to three onwards.

Our practical experience with a several sustainability indicators in the first year is likely to suggest similar detailed research priorities like those proposed already for nematodes and earthworms for improved efficacy and methodology surrounding the indicators themselves. However, once indicators are instigated and researched,

there will be a growing emphasis on the ARGOS project for more analytical research on generic determinants of sustainability. The new priority will be to determine whether the indicator suite actually informs actual progress towards sustainability. The trans-disciplinary nature of the ARGOS research team provides an exciting opportunity for an agro-ecosystems synthesis that cross-references and evaluates the indicators against long-term sustainability outcomes. A recent OECD Workshop on farm management indicators[38] mainly focused on the practical choice of (often rudimentary) indicators. The first reports of tests of whether simple indicators reliably monitor environmental outcomes should be possible from ARGOS farms in three or four years, though more and better commentary is likely to emerge continually for a decade after that.

8.1.8 Biosystematics of mites, native bees and spiders

A major component of measuring biodiversity and comparing between sites is choosing an appropriate group of indicator species. The indicator species must be sensitive enough to respond to environmental perturbations, representative of the local flora and fauna, and widespread to allow comparisons between sites. There are several potential groups that could meet these criteria in New Zealand agricultural landscapes. Initially we will assess the utility of three groups: spiders, bees and mites.

Free-living mites are increasingly being used as indicators of levels of pollution (Ruf 1998), disturbance (Kinnear & Tongway 2004) and soil quality (Ruf *et al*. 2003). Mites are ubiquitous and often microhabitat specific. In New Zealand, for example, native Ologamasidae mites are found in undisturbed 'natural' sites whereas Parasitidae mites, which are mostly introduced, predominate in disturbed and/or modified landscapes (Cruickshank, pers. com.). Both of these are large predatory mites fulfilling similar roles in their ecosystems and transitions between these faunas can be very abrupt.

A collaborative study with Dr Adrian Patterson (Lincoln University) would aim to investigate the utility of these groups as markers of environmental quality and disturbance; that is, whether species distributions match other measures of quality that can be used throughout sites in New Zealand. The largest impediment to the achievement of this goal is the systematics of these groups. While some species are well studied in these three taxa there are still issues of species identification to be worked through. It is important that species considered at different sample sites are actually the same species; that is, that morphological variation represents genetic variation, so that researchers are using the same units. For example, wolf spiders (Lycosidae) represent a widespread group found in modified landscapes in New Zealand. Recent molecular work on this group showed that some species were morphologically variable (and had been mistaken for different species) while others contained cryptic species (Vink & Paterson, 2003). The use of molecular data will also allow for the estimation of gene flow, or isolation, between populations of the same species at different sites.

The target taxa will be collected from a range of ARGOS sites. The initial emphasis will be on sampling short sequences (<600bp) from many different genes for relatively few taxa. This will allow us to identify three to five suitable candidate genes for constructing more comprehensive phylogenies. Genes will include ribosomal and protein-coding genes from both the mitochondrial and nuclear genomes in an attempt to cover the broadest possible spectrum of evolutionary rates but will be restricted to those that have proven phylogenetic utility (Caterino *et al*. 2000, Cruickshank 2002). To maximise the general utility of the results, one of the genes used will be COI,

[38] See www.oecd.org/agr/env/indicators

which is being used globally as the marker for barcoding research to allow for species identification (Hebert *et al*. 2003).

Once the species statuses of these groups are determined we will use density and distribution data of the taxa at our sites to examine the correlation with indices of habitat quality and disturbance as determined by ongoing research in the ARGOS project.

8.1.9 Habitat manipulation for biological control of introduced predators

Longer-term management of predator threats to native species in production landscapes will require the development and application of a toolkit of management options, including biological control. One approach is to manipulate habitat structure and complexity to deter or discourage access by predators, by reducing favoured habitat, removing access corridors, and by creating habitat barriers. However, habitat manipulation as a biological control of priority pests can proceed only from a detailed understanding of the fine-scale spatial ecology of key animal pest species. Consequently, a potential collaboration with Dr Phil Seddon (Zoology Dept., University of Otago) aims to apply state-of-the-art remote sensing (high resolution satellite imagery) and wildlife tracking technology (Global Positioning System devices with dataloggers attached to predators) to quantify fine-scale habitat use by mammalian predators in production landscapes. He will work intensively in four sites encompassing two to four habitat types (potentially within ARGOS farms), and focus initially on cats (*Felis catus*), as they are known to be significant predators within highly modified landscapes. We envision that up to 40 individual cats will be fitted with GPS-collars and their fine-scale habitat use and response to habitat manipulation will be quantified. Work will then be extended to include, among others, ferrets and hedgehogs. Habitat selection data will be used to construct predictive models of predator movements, simulate predator response to habitat manipulation, and to thereby derive guidelines for manipulation of habitat structural complexity to reduce predator access to, and movements within, key areas, thus reducing threats to indigenous biodiversity. The predictions of the models built from intensive study sites will be tested by more extensive predator trapping and predation studies on other ARGOS farms.

ARGOS will also investigate the interactions between exotic mammal predation and habitat complexity in limiting indigenous biodiversity as part of its proposed predator press experiment (Section 3).

8.1.10 Soil systems modelling

Monitoring activities on ARGOS farms will provide the key information needed for testing for differences between farming systems. However, interpretation of the differences and getting a predictive base for guiding innovative soil management requires a more systems approach. If extra funding can be found, a collaboration between Jeff Reid (Crop & Food) and Henrik Moller will research the processes that must be recognised and manipulated in order to enhance soil quality, the diversity and resilience of the soil biota, and the wider impacts of agricultural management by building an integrative model of soil system function and management influences**.** We will use data gathered in the routine ARGOS monitoring of farms to build a summary model of how soil quality varies with management practices, time and weather. This model will be used in at least four ways: (a) integrated with a catchment water quality model: (b) to interpret, interpolate and extrapolate existing information on how management activities influence soil quality and the sustainability of management systems; (c) as a starting point for developing mechanistic models of how management systems affect biodiversity and resilience; and (d) to provide inputs for

the Lincoln Trade & Environment Model to explore the interactions between economic and environmental sustainability.

Providing more information on biodiversity to the Trade & Environment Model has several advantages. The enhanced model will then be able to link global market economics and international agricultural policies to what is happening to farming families and to biodiversity on their farms. Generic lessons will emerge from comparisons across a wide continuum of study farms; for example, from (i) low-input-output farming in High Country, (ii) intermediate-input-output sheep/beef farming in lowlands, to (iii) high-input-high-output agro-ecosystems like dairy and kiwifruit. Dairying is high intensity on relatively simplified ecological landscapes, whereas kiwifruit are grown in a highly varied and structured habitat matrix. We can learn from widely divergent philosophies of organic and conventional growers, with Integrated Management farmers taking up the middle ground. We also will have large samples of intensively studied households that range from wealthy to poor. Our database of all financial and production records of farms, records of the main farm management acts (tillage, fertilisation, stocking rates, grazing management, etc.) and in-depth interviews with farmers will now be supplemented by detailed measures of biodiversity and its trends. We will search for generic drivers that are degrading or enhancing biodiversity in agro-ecosystems so that overall solutions can be identified at a big-picture level. For example, does farm intensification threaten biodiversity? Is a sense of place or a family farm that will be transferred to offspring a key determinant of investment in biodiversity management? Is equity level an important predictor of biodiversity gains on individual farms? Could economic tools and valuation of biodiversity act as incentives to accelerate restoration? How can the farmers' local ecological knowledge of farmers be better integrated with ecological research to capture improved management for biodiversity on farms?

8.1.11 Catchment water quality and riparian soil quality.

Many farming practices can alter soil quality, hastening transfer of both sediment and essential nutrients to surface water. This can jeopardise the sustainability of both farming systems and waterways. Research has demonstrated that surface water chemistry can be related to soil quality indicators both within the catchment and the riparian zone. Collaboration is being sought with Dr Carol Smith (Lincoln University) to model these processes. If funding can be found, we will collect data on surface water quality and riparian-zone soil quality from selected ARGOS farms, expanding the existing soil quality monitoring as appropriate. Using these data, we will build predictive models with a blend of statistical and mechanistic approaches. We will take the integrative model of soil system function (see above) and expand it with models of nutrient and sediment fluxes in the catchment. This will enable us to assess the sustainability of farming practices within the greater physical landscape.

8.1.12 Mycorrhiza and other fungi

Fungi play many important roles in the agricultural environment, mainly associated with nutrient recycling. As decomposers, fungi break down organic and inorganic nutrients and make them available to plants. As mycorrhizal symbionts, fungi increase the uptake of nutrients (especially phosphorus) by plants, often resulting in increased productivity. As disease agents, fungi can result in loss of productivity through diversion of energy resources to the pathogen, or more simply, through plant death. As beneficial agents, some fungi can reduce threats from pests by imposing biological control on fungal, plant and invertebrate pests. Focusing on the soils and fungi, a ubiquitous and functionally important group of organisms within soils, is an ideal system for testing the utility or otherwise of the organic and conventional farming approaches.

It has long been known that mycorrhizal associations can facilitate plant species co-existence, and therefore promote biodiversity. Only more recently has it become clear, however, that mycorrhizal associations can also impair species co-existence through both positive and negative impacts on plants. Some agricultural practices, such as fertilizer application, can select for increasingly negative mycorrhizal associations, potentially leading to negative impacts on plant communities. We will use the existing ARGOS farms to identify the links between plant community structure and mycorrhizal species/functional diversity in New Zealand's agricultural landscapes. We anticipate that in turn this will lead to experimental introductions of tailored mycorrhizal inoculation into controlled microcosms. The intent is to develop ways to promote facilitation (native species) and reduced dominance (aliens), and to develop and test mycorrhizal biological control agents. The research will lead to the development of management tools for end users to gauge agro-ecosystem health, and to promote re-establishment and selection of positive mycorrhizal associations, leading to reversals of biodiversity decline in degraded landscapes.

A full understanding of interactions amongst soil fungi in agricultural systems is impossible without knowledge of the genetic and functional diversity of fungi involved. A research partnership is therefore being sought with Dr David Orlovich (Botany Department, University of Otago). If funding can be found, we hope to develop tools for the assessment of genetic diversity in samples of soil, plant roots, and animal dung collected from farms managed under the three management regimes within a sector. A further meta-analysis will possible by comparing fungi on farming sectors ranging from high overall chemical inputs (kiwifruit, dairying), intermediate inputs (lowland sheep/cattle), and low intensity farming (high country sheep & beef). The examination of animal dung could also be used as a model system to compare genetic diversity assessment with diversity assessed by traditional incubation and culturing. The proposed research will provide baseline information to ARGOS about the levels of fungal diversity in each type of farming system, will permit comparisons of diversity between different farming systems, and correlations between diversity and other environmental factors as well as complete information on recent chemical inputs and soil management.

The assessment of fungal genetic diversity at this scale will be the first study of its type in a New Zealand agricultural context, and will contribute a deeper understanding of the dynamics of soil microflora, and the relationship of soil fungi to farming practice and sustainability.

The research will use two general approaches to monitoring fungi on farms and orchards: a standard ecological survey of abundance of fungi fruiting bodies (obvious to the naked eye) and a DNA extraction and analysis method for characterisation of microscopic fungal diversity. The genetic techniques we propose to use (terminal restriction fragment polymorphism analysis (T-RFLP) and denaturing gradient gel electrophoresis (DGGE)) have proven valuable in studies of community structure in other systems (e.g. decaying wood fungi: Vainio & Hantula 2000; coastal forest soil fungi: Klamer *et al*. 2002; grassland mycorrhizal fungi: Johnson *et al.* 2004; freshwater leaf decay fungi: Nikolcheva *et al*. 2003), but have not been applied to such a detailed comparison of organic, IPM and conventional farm soils, as proposed here. Understanding the relationships between mycorrhizal and non-mycorrhizal fungi in the soil will provide new insights into the functioning of agricultural ecosystems in New Zealand and overseas.

8.1.13 Developing soil quality and biodiversity modules for the Lincoln Trade & Environment Model

From the broader ARGOS program we will study at least two representative managed farmscapes that offer the best combination of existing information, and

environmental, economic and social significance. Then we will develop mechanistic models of the key on- and off-farm processes that influence soil biodiversity, resilience, primary productivity and environmental footprint of those systems. These models will then be integrated into a form ready for use with the Lincoln Trade & Environment Model, so economists and social scientists can explore the consequences of management system impacts on, for example, nitrate leaching, earthworm abundance, long-term changes in soil quality and total farmscape biodiversity.

8.1.14 Restoration of native fish

If funding can be obtained, a long-term collaboration with Dr Gerry Closs (Zoology Department, University of Otago) will focus on restoration of native fish. Giant, banded and shortjaw kokopu, and koaro and inanga migrate between marine and freshwater. Appropriate management and restoration of coastal rivers and streams across public and private lands is crucial to the restoration of these diadromous species. The mode (diadromous or non-diadromous) and frequency of recruitment is likely to vary with coastal oceanic currents, catchment morphology, barriers to migration and habitat availability as affected by farming. We will develop species recovery plans using a transdisciplinary approach incorporating scientific studies of population structure and distribution, otolith microchemical analysis and genetics, and the ARGOS team of sociologists, economists and farm advisers will identify and seek to remove farm management barriers to native fish restoration. Our models will improve the current *ad hoc* approach to native fish restoration to a more targeted approach that identifies sites most likely to support sustainable galaxiid populations following restoration. It will also identify where diadromous recruitment of depleted populations has been interrupted so that supplementation of recruitment by captive reared or transfers of wild-caught fish between catchments is justified. The work will concentrate on galaxiids as model species, but then extend to taonga mahinga kai species (lamprey, eels) and other estuarine fish and crustacea. Active involvement of the rūnanga in this mahinga kai restoration will be sought.

8.1.15 Remote sensing for monitoring habitat change

It is envisioned that the on-farm habitat manipulations undertaken within ARGOS will have large-scale effects on biodiversity across the broader landscape. Consequently, there is a requirement for accurate, reliable, repeatable and cost-effective tools to monitor resulting changes in habitat structure and complexity, and in overall biodiversity levels. We are seeking a collaboration with Dr Renaud Mathieu, the director of a newly-created spatial ecology research laboratory at the University of Otago and Dr Peter Whigham (the Director of the Spatial Information Research Centre, UoO) for spatial modeling work. This will use data gathered at intensive study sites to predict outcomes on the entire ARGOS monitoring farm suite. We hope to develop remote sensing technologies that can be used to correlate on- and between-farm changes in management practices with landscape-scale changes in habitat complexity and biodiversity. Relationships between satellite-based indicators and ground biodiversity surveys will be modelled to produce landscape-scale biodiversity indicators and to predict the regional distribution of species richness and abundance. Biodiversity changes will be quantified using a sequence of calibrated images. Historic changes will also be considered where archives images are available. The resulting indicator has enormous scope for regional councils and MfE for State of Environment reporting.

Active land management decisions made as part of on-farm practices may impact directly or indirectly on habitat quantity and quality underpinning indigenous biodiversity. In order to realise the ecological potential represented by farmscapes

we will seek to understand the linkages between the farm habitat matrix underpinning indigenous biodiversity, and the potential impacts on the farm's social and economic outcomes resulting from increasing the amount or quality of on-farm habitat complexity. We are especially interested in documenting and understanding situations where habitat restoration leads to improvements in the social, economic and ecological functions of a farm. This study, and the implementation of management strategies, is not performed in a static environment. Dynamism (changing markets, changing climate, changing social structure) lead to risk and the crucial importance of resilience in the agro-ecosystem. Theoretical modelling will be used in the later years of ARGOS to synthesise these aspects.

8.1.16 The ecological, economic and social opportunities through a farm systems view

A study of farm microsites as nested systems within a wider farm system has the potential to improve economic, environmental and social sustainability. The characteristics (or properties) of different subsystems within a farm vary across space and time in response to multiple causal pathways sourced either internally or externally from each subsystem. For instance, a property of one subsystem, such as woody plant reversion, may be caused by a multi-causal combination of: microclimate effects that occur either seasonally or during particular years; topography and aspect; grass production; feed quality; soil fertility; stock behaviour relative to climate, landform and feed; stock use of feed; stock management, paddock size; and proximity to a seed source either as a soil bank or offsite. Even within this relatively simple example there are systems nested within systems. For instance, the quality of feed is partly a response to stock use, which is itself partly a response to production as well as to stock demand and – completing the loop – feed quality. Understanding of these multi-causal links is not possible by analysing individual causal elements, because the causal property is not necessarily a feature of one element, but rather an 'emergent' property of the whole combination of elements.

A singular 'whole farm' view may fail to identify potential synergies across social, economic and environmental domains that is better appreciated by viewing the farm as an integrated, nested hierarchy of many subsystems – all relating to each other, and each with properties that contribute both to the wider system, and to their neighbouring interrelated subsystems. Potential synergies from understanding the properties and interrelationships between farm subsystems can include:

- A reduction in whole farm costs, *and*
- An improvement in the whole farm environmental performance, *and*
- An improvement in the whole farm profitability, *and*
- An improvement in the whole farm business risk, *and*
- Enhanced recreational, employment, aesthetic and food gathering opportunities for farm and local community.

These need not be 'either – or' (win – lose) trade-off options. They can all occur simultaneously, representing 'emergent' properties of a farm system configured and managed within a particular values context. A socio-ecological systems metaphysic is integral to the study of such potential outcomes on a farm. This must include a study of the values toward land that underpin farm management practices. Looking at a farm within a values context that focuses on some narrow definition of land – such as land as a 'crop producer' or 'manifestation of capital' (Perley 2003) – is incompatible with management for the win:win possibilities required for the achievement of socio-ecological sustainability.

Landform features that are of particular interest in this research are gullies, which can be associated with:

- Lower stock preference (decreasing use and encouraging weed growth),
- High farm costs (a pareto principle [80:20 rule] of farm cost distribution applies, which is often obscured because such costs are recorded as general overheads rather than directed to site – e.g. weed control, fence repairs and maintenance, high labour costs, capital loss through soil erosion [not accounted], fertility run-off [not accounted], and stock losses),
- Low productivity,
- Woody vegetation reversion,
- Landscape ecology centripetal processes associated with connectivity,
- A major interface between terrestrial and aquatic environments,
- Recreational and aesthetic values.

Many farmers are aware of the differences in the properties of their microsites, and manage these microsites to optimise their risk and returns, and to achieve multiple objectives. For instance, some farm microsites are recognised for their lambing shelter properties, their ability to grow grass in early spring or in high summer, or their detrimental properties such as proportionately high soil erosion or stock losses. One group in particular, farm foresters, have consistently chosen forestry sites with these land management issues in mind (Smaller & Meister 1983, Morey 1986). Much of this farmer understanding of the diversity of their land properties and interrelationships is implicit; a part of a 'sense of place' that is not easily quantified.

This sense of place is not always evident in professional analysis and advice. A presumption in many economic farm analyses is that the unit of study is the farm as a relatively homogenous state in space and time. Production figures are often averaged over the farm, and overheads are assumed to be independent of any particular microsite within a farm boundary, hence the use of gross margin analysis as arguably the most common economic analysis approach to farm management. Other studies have examined any change in land use out of pastoral production using marginal analysis (Jarvis & Perley 1989) – the assumptions being that any change in land cover will not change the overheads for the whole farm, and that there are no interrelationships between various microsite land subsystems. It is then simply a case of calculating the opportunity cost of land cover change, often using averaged farm production data irrespective of the properties of the subsystem that may be converted. In essence, such analysis views any part of the farm as a microcosm of the whole farm, and therefore without any particular properties that are not represented at the level of the farm macrocosm. These assumptions are often false and have lead to farm management recommendations and choices that are detrimental to the economic, social and environmental performance of farms, particularly in hill country areas. The errors consistent with such analyses are exacerbated by their use of average economic performance over time, rather than using stochastic variables relating to externally sourced perturbations on the farm system; including events relating to climate (storms, droughts, etc.), biology (pests, disease epidemics, pathogen resistance, etc.), society (labour skills, values & availability, political systems, legislation, etc.) and economy (changes in price, consumer preferences, input costs).

Analysis at just the 'holistic' farm level over short time periods of time fails to identify and characterise the many different subsystems that make up the complex adaptive system that is the whole farm. Such analysis also potentially decreases the 'resilience' – and therefore the socio-ecological sustainability – of a farm because potential variability over space and time are not part of the analytical framework.

The potential for sustainability on farms requires the evaluation of case study farms as socio-ecological systems. This research proposal looks to 'downscale' to evaluate the properties, processes and interrelationships of social, economic, and environmental subsystems internal to farms over space and time, and to 'upscale' to consider the external social, economic, and environmental factors acting on farms over space and time. A synthesis of these elements and relationships internal and external to the farm system provides a context for socio-ecological sustainability and sustainable land management.

Lack of appropriate fencing may provide a practical difficulty in applying this "downscaling'" strategy to manage different parts of the farm in very different ways. We therefore propose to study the match of current fencing within sheep/beef farms to localised opportunity and land-use capability. An environmental history and sociological as well as farm management perspective on why the fences are currently placed where they are now will allow us to consider opportunities and barriers to shifting them in future. It is easier for a farmer to gradually repair or upgrade a fence in sections while leaving the main fence lines in the same place, so we will have to search for creative solutions to capture the opportunity from a re-arrangement of the grazing units.

8.1.17 Comparison of Soil Food Web Institute and conventional soil testing

The Soil Foodweb Institutes (SFI) analysis of soil biota and associated advice of soil management[39] is fundamentally different form the standard soil laboratory assessments and advice. A growing number of farmers from all farming systems are beginning to use the SFI protocols in parallel with or as a substitute to conventional testing. A systematic and independent comparative study of the two systems and associated advice is overdue and could guide ARGOS farmers about the long-term utility of each for their needs.

8.1.18 Contaminants in soil

Investigation of levels of things DDE and Cadmium in soils may be a concern. Leo Whittle (pers. comm.) referred to several orchardists in his vicinity testing for DDE and being unpleasantly surprised about how much remained in the soils from the dairy farming that preceded their kiwifruit growing. These contaminants bio accumulate and are tested for at meat works, so we should first inquire about whether those results are available. Cadmium is found in Rock Phosphate and so could be at higher levels on some organic farms. Carol Smith (Lincoln University) is interested in researching Cd fluxes in farmscapes.

8.1.19 Pesticide impacts on stream biodiversity

Detection of real impacts of pesticides through spatial comparisons of stream health between matched conventional, organic and IM farms may be extremely difficult because of the background variation in other factors (land use, riparian management etc.) also influencing stream health. The most powerful tests of pesticide impacts would have to use experimental applications of pesticides under closely standardised or controlled conditions. Obtaining ethical and Resource Management Act consents for such experiments may be extremely difficult unless artificial stream channels are used. Clearly such process-oriented research is beyond the scope of the current ARGOS budget and team's expertise. We therefore approached the limnologists working at the Zoology Department of the University of Otago to invite collaboration on such a study. Some of them (Prof. Colin Townsend, Dr Christophe Matthaei and Sebastian Uhlmann) are currently studying the Taeiri River catchment (Otago) as part of a six-year FRST-funded project called 'Multiple Stressors in Streams'. Their

[39] www.soilfoodweb.com/sfi_html

resources are fully committed, at least in the next 2 years, to experimental tests of the role of sedimentation on stream health. However, they would be enthusiastic about mounting a joint application with ARGOS (probably to the upcoming FRST 'Ecosystems' investment portfolio) for new funds to study pesticide impacts. The collaborators could offer each other considerable leverage and complementary skills and data to make such an application more likely to succeed. Dr Gerry Closs, also from the University of Otago's Zoology Department, has considerable expertise on fish population ecology and conservation management and may be willing to become involved. We resolved to list potential student thesis topics in this area in the meantime in the hope of attracting an MSc or PhD student to begin temporary scoping studies. Some combination of sampling on ARGOS farms and experimental manipulations of artificial streams are likely.

8.1.20 Benchmarking to other farmers and growers

The environmental team would like to use parts of the wider biennial farmer survey mounted by John Fairweather and Hugh Campbell to explore environmental attitudes, farmer goals and knowledge levels. We recommend that the same questionnaire is answered by the ARGOS farmers themselves so that we can benchmark their responses to those of other growers in their agricultural sector, as well as to different sectors. These comparisons will help us assess the representativeness of the ARGOS farmer panel, but more importantly, to allow some tests on whether our findings are generalisable to other styles of agriculture. The MAF team at the recent OECD workshop on environmental indicators also indicated that they were revamping and potentially extending their farmer surveys in the coming years. We should consider whether to ask some of their questions in our own survey to achieve benchmarking.

8.1.21 Resilience of New Zealand Agriculture to Climate Change

If funding can be found, a transdisciplinary collaboration will be sought to assess the ability or otherwise of ARGOS farmers to withstand climate change and enhance ecological, social and economic sustainability in the face of the crisis. Climate change also presents a high-level, systems-level case study of agro-ecosystem resilience. Widespread, systematic change of climate norms and variability may directly impact on biodiversity, but stronger and more indirect effects are expected via stress on farming and farm families. Our examination of resilience to climate change can inform New Zealand's national and international policy regarding climate change mitigation and advise farmers in useful and very specific ways, but it will also provide more generic understanding of socio-ecological resilience which can be applied in other landscapes around New Zealand.

8.1.22 Whole-farm biodiversity plans

ARGOS will facilitate preparation of whole-farm biodiversity plans to assist farmers to restore indigenous biodiversity on their land while not compromising their economic returns or social goals. Our researchers will run and evaluate structured workshops and hui with several of the end user groups to deepen awareness of sustainability and resilience concepts and to underscore the need to take a whole-systems approach to problem and solution identification. But the primary outcome sought here is for stake-holders to self-identify practical small steps that they each can take to eventually safeguard and enhance biodiversity in production landscapes in the long run. We propose to start be a systematic review of farm plans to evaluate the environmental planning already in place (preliminary indications are that very little such planning is occurring). By year three or four we hope to develop more detailed biodiversity plans with willing farmers and then support and monitor their implementation in the subsequent years of the programme.

8.1.23 Disciplinary linkages

A growing emphasis on interdisciplinary linkages between environmental and social/cultural and economic determinants of sustainability will be sought. This will require lengthy discussion within the team and especially clarification of the bigger picture issues singled out for priority attention. Declaration of priorities for transdisciplinary work may also have to await establishment of core monitoring within each discipline. But in the meantime the environmentalists have started generating a list of potential topics that we see as potentially valuable for joint study (Moller 2004b). Among the topics already listed are:

- Characterising the farmers' sense of place and sense of self in relation to environmental, social and economic sustainability.
- How can we best help farmers "become native to their place"
- What is the farmers' definition of sustainability? Get some baselines here to measure changes?
- Categorisation of farming motivation/style in relation to economic, social and environmental priorities
- On farm cf 'social accounting' of inputs and outputs from environmental, social and economic perspectives
- If we are taking this ARGOS bicycle to the international market, what is the market's perception of environmental realities on New Zealand farms
- What is the farmer's perception of ecological risk and how does it square with an ecologist's risk assessment
- It may be interesting to provide a straight description/comparison of the way ecologists, sociologists and economists see the landscape and/or spatial scales operating; or the temporal scales at work. Presumably the local community and international flows and institutions are different in nature, but are we talking the same ballpark of scale – or do the disciplines talk past each other or focus on different parts of the system? So do you sociologists study the effects of neighbouring farm sociology on the focal farm (our equivalent of landscape effect), the wider regional community impacts, national hierarchies and international ones.
- Loss of artisanal knowledge; but also the regaining of it
- Local Knowledge and learning; attitudes of the Agri-experts to local knowledge
- Characterising the learning of local knowledge and its importance for matching farming to local ecology
- Attitudes of farmers to measurements and decision tools
- Do the big farm/small farm expectations from overseas work in New Zealand?
- How do ecologists cf. economists cf. sociologists measure intensification *per se?* Do those measures line up or are we talking past each other on this one?
- Measuring trends for intensification and its consequences
- Characterisation New Zealand farmers on the world scales of intensification and industrialisation
- Does resilience perception vary with age and financial security?
- What is the farmer's current level of knowledge of biodiversity and ecological processes on farms compared to what we found?

- What does a farmer see as the critical landforms and parts of the environment cf. the way we see then in a transdisciplinary way?
- Do farmers see the sustainability complex in a transdisciplinary way – do organic farmers have more of a holistic, transdisciplinary approach than IM or conventional growers?
- How do we choose focal species for longer-term attention when we use a transdisciplinary approach?
- Are organic growers more focused on soil characteristics and soil management than other growers?
- Do organic farmers have a "philosophical price tag?"
- What is the planning horizon (years?) used by the organic, IM cf conventional farmers in each of our economic, social and ecological corners? If they differ, what implications does this have for transdisciplinary studies; and for sustainability management planning by the farmers?

8.1.24 Establishing a Prioritised Research Agenda and Funding Strategies

We can not possibly do all the above suggestions, so a prioritisation framework is needed. We suggest that we:

1. Play to the ARGOS team strengths: let's pick off the trans-disciplinary topics or ones where we have particular linkages in the market place as highest priority.
2. Choose some clip-on topics of special relevance to our co-funders would build long-term support and be a just reward for their investment. So the co-funders' views should be considered when establishing the rankings.
3. Seek to make the biggest difference possible for the farmers and New Zealand Agriculture, so we should aim to pick emerging themes or strategies not being covered by other national research groups[40].
4. Primarily rank on the importance of the topic, urgency only as a secondary consideration.
5. Establish early baseline measures urgently, because parameters needed for long-term trend analysis may depend critically on number of years of data available.
6. Give precedence to research that helps test the null hypothesis of no change between farming systems over more analytical or process oriented research.
7. Seek some sure but not particularly innovative or spectacular outcomes; several investigations in the medium risk, medium gain part of the continuum; and a few high-risk, high-reward outcomes.
8. Scale realisability against value if the anticipated research outcome is achieved.
9. Restrict the ARGOS input of resources (funds, money, access to farms, use of ARGOS data) to higher risk projects.
10. Aim to provide a particularly useful and coherent result by around year five so that we can build trust with FRST at the time that our next 6-year funding bid is under consideration.

[40] Themes already gathering momentum and being applied should be left off our research agenda. For example riparian strip planting is very important for environmental impacts, but it is being facilitated strongly by the regional councils. It would help greatly to know how wide the buffer strips need to be, but we may be best to encourage them to research that rather than engage ourselves.

The projects should be categorised for management and investment within the ARGOS project as follows:

1. **Core projects**: these are done entirely by our paid staff and funded as part of our main programme. We need complete control and certainty to deliver the contracted outcomes.
2. **Priority partnership projects**: Other larger but 'need to know' research will receive some ARGOS funds and staff time, but they will we need substantive additional funding to achieve their goals. Sustainable Farming Fund (MAF), Sustainability Fund (MfE) or other FRST portfolios may assist. We can offer leverage, infrastructure and transdisciplinary interpretation, but the external funds are needed to hire contract staff to achieve the goals.
3. **Partnership projects**: The outcome of these projects will also be 'nice to know' rather than 'need to know' issues. Failure to attain the goal will therefore not seriously compromise the main ARGOS project, whereas success will greatly enhance ARGOS's outcomes and outputs. Most student projects would fall in this category. We may offer historical ARGOS data or controlled access to farms and a small amount of our time as collaborators, and some direct funding. Most such projects would be small in scope but nevertheless be picked to fit the bigger picture being assembled by ARGOS.
4. **Support projects**: A series of more peripheral nice-to-know topics could be supported simply by access to ARGOS data or farms. Demonstrating these lateral extensions to other groups is a matter of social responsibility, but it also helps gain further support from FRST.

Table 8.1 sets out our categorisations and priority scores for each of the potential future projects sketched out above. It does not consider the basic monitoring described in Chapters 1 – 6, but includes the completion of the predator press experiment currently undergoing a feasibility study (see Chapter 3). Table 7.1 also excludes detailed consideration of transdisciplinary questions which will be assessed by the research team in the near future. The farm management, social and economic teams' wishes will lead to readjustments and addition of new projects.

Student projects will nearly all be located within Partnership or Support projects. If they are occasionally used within Priority partnership work, their research goals must not become part of the contracted or essential outputs. This is because the teaching and research contract agendas can conflict, especially if things start to go wrong for the student. PhD students are ideal for the more challenging longer term projects (Table 8.1), but a series of MSc thesis investigations can be dovetailed to achieve a larger agenda.

We recommend that the ARGOS management team designate a plan for funding applications to support the research topics. It will need to balance the competing needs of the different parts of the team.

Table 8.1. Priority rankings for potential future research themes.

Rank	Topic	Level	Importance	Urgency	Testing farm systems null hypothesis	Transdisciplinary	Risk: Return	Comments
1	Evaluation of environmental indicators	Core	High	High	Yes	Yes	Low : High	
2	Gathering historical data (soils, financial records, stocking rates, farm plans)	Core	High	High	Yes	Yes	Medium : High	Costs little to gather info, but it is likely to be fragmented and therefore risk of not getting result is high.
3	Adding soil quality and biodiversity modules to the Lincoln University trade & Environment Model	Core	High	Medium	Yes	Yes	Medium : High	This is a key transdisciplinary fusion
4	Shelter belt management	Core	High	Medium	Potentially	Yes	Low : High	
5	Development of whole farm biodiversity plans	Core	High	Medium	Yes	Yes	Low : High	
6	Modelling soil processes	Priority Partnership	High	Medium	Yes	No	Medium : High	
7	Farm systems perspectives: downscaling to farm to ecology	Core	High	Medium	Yes	No	Low : High	

8	Reservation within farms; are they functioning and what are the barriers to their establishment?	Priority partnership	High	Medium	No	Yes	Medium: High	Only of relevance to sheep/beef and dairy
9	Modelling nutrient fluxes through farmscapes	Priority Partnership	High	Medium	Yes	No	Medium : High	
10	Predator press experiment	Priority partnership	High	Medium	No	No	Medium : High	
11	Development of remote sensing indices of habitat complexity and structure	Priority partnership	Medium	Medium	Yes	Potentially	Medium : High	Important to avoid duplication of effort by more traditional means and potentially increases sample size
12	Comparing pasture productivity between farming systems	Core	Medium	Medium	Yes	Yes	Medium : High	This may be mainly a priority for the economics team, but the finding has transdisciplinary implications
13	Benchmarking to other growers	Core	Medium	Low	Potentially	Yes	Low : Medium	
14	Priority 4 Soil indicators	Core	Medium	Low	Yes	No		
15	Nematodes as indicators	Partnership	Medium	High	Yes	No	High : Medium	
16	Comparing and testing utility of feed models	Priority partnership	Medium	Medium	Yes	No	Medium : High	
17	Comparing and testing utility of fertiliser application	Priority partnership	Medium	Medium	Yes	No	Medium : High	

	models							
18	Farm forestry impacts on biodiversity and farming	Partnership	Medium	Medium	No	Yes	Medium: High	Only of relevance to sheep/beef and dairy
19	Prey facsimile and Laminar bait decay rates	Priority Partnership	Medium	Medium	Yes	No	Low : High	Useful experimental techniques with guaranteed result, but generic indicator only (needs to be linked to actual focal species involved in prey/bait uptake.
20	Novel Plants	Priority Partnership	Medium	Medium	Yes	No	High : Medium	
21	Soil Mychorrhiza	Priority Partnership	Medium	Medium	Yes	No	Medium: Medium	
22	Priority 5 soil indicators (physico-chemistry at deeper levels)indicators	Priority partnership	Medium	Low	Yes	No	Low : Medium	
23	Priority 6 soil indicators (BIOLOG and bait laminars)	Priority partnership	Medium	Low	Yes	No	Low : Medium	
24	Comparing Soil Foodweb Institute and conventional soil testing	Priority partnership	Medium	Low	Yes	Yes	Medium : Medium	
25	Environmental history	Partnership	Medium	Medium	No	Yes	Medium : Medium	
26	Research of phylloplane on kiwifruit leaves	Partnership	Medium	Low	Yes	No	Medium : Medium	[Not sure of rankings for this project of David's – please assess and adjust David].
27	Introduction of	Priority	Medium	Low	No	No	High : Medium	

	rare or threatened plants to farms	Partnership						
28	Pesticide and nutrient inputs to streams	Priority partnership	Medium	Medium	Yes	No	Medium : Medium	
29	Contaminants in soil	Partnership	Medium	Low	Yes	No	Low : Medium	
30	Fish restoration	Partnership	Medium	Low	No	No	Medium : Medium	Highly valued by kaitiaki and an example of taonga species focus
31	Habitat biocontrols of predation	Partnership	Medium	Medium	No	No	High : Medium	
32	Taonga species restoration	Priority partnership	Medium	Medium	No	Yes	Medium: Medium	Important for kaitiaki and linkage to He Whenua Whakatipu
33	Resilience to climate change	Partnership	Medium	Low	Yes	No	Medium : Medium	Difficult to judge importance and priority because unclear what farmers face; excellent case study of resilience
34	Biosystematics of mites, native bees and spiders as indicator species	Partnership	Low	Medium	Yes	No	Medium : Low	This work is valuable nationally, but expensive. We probably have enough solid indicators to keep us busy without getting into long biosystematics chases first; there will also be delays before we establish any new indicators by this methos

9. References

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10. Appendices

Appendix 1: 'Taonga Species' Identified in the Ngāi Tahu Settlement Act 1988

Birds

Māori	English	Scientific
Hoiho	Yellow-eyed penguin	*Megadyptes antipodes*
Kāhu	Australasian harrier	*Circus approximans*
Kākā	South Island kākā	*Nestor meridionalis meridionalis*
Kākāpō	Kākāpō	*Strigops habroptilus*
Kākāriki	New Zealand parakeet	*Cyanoramphus* spp.
Kakaruai	South Island robin	*Petroica australis australis*
Kakī	Black stilt	*Himantopus novazelandiae*
Kāmana	Crested grebe	*Podiceps cristatus*
Kārearea	New Zealand falcon	*Falco novaseelandiae*
Karoro	Black-backed gull	*Larus dominicanus*
Kea	Kea	*Nestor notabilis*
Kōau	Black shag Pied shag Little shag	*Phalacrocorax carbo* *Phalacrocorax varius varius* *Phalacrocorax melanoleucos brevirostris*
Koekoeā	Long-tailed cuckoo	*Eudynamys taitensis*
Kōparapra or Korimako	Bellbird	*Anthornis melanura melanura*
Kororā	Blue penguin	*Eudyptula minor*
Kōtare	Kingfisher	*Halcyon sancta*
Kōtuku	White heron	*Egretta alba*
Kōwhiowhio	Blue duck	*Hymenolaimus malacorhynchos*
Kūaka	Bar-tailed godwit	*Limosa lapponica*
Kūkupa/Kererū	New Zealand wood pigeon	*Hemiphaga novaseelandiae*
Kuruwhengu/Kuruwhengi	New Zealand shoveller	*Anas rhynchotis*
Mātā	Fernbird	*Bowdleria punctata punctata* and *Bowdleria punctata stewartiana* and *Bowdleria punctata wilsoni* and *Bowdleria punctata candata*
Matuku moana	Reef heron	*Egretta sacra*
Miromiro	South Island tomtit	*Petroica macrocephala macrocephala*
Miromiro	Snares Island tomtit	*Petroica macrocephala dannefaerdi*
Mohua	Yellowhead	*Mohoua ochrocephala*
Pākura/Pūkeko	Swamp hen/ Pūkeko	*Porphyrio porphyrio*
Pārera	Grey duck	*Anas superciliosa*
Pateke	Brown teal	*Anas aucklandica*
Pīhoihoi	New Zealand pipit	*Anthus novaseelandiae*
Pīpīwharauroa	Shining cuckoo	*Chrysocccyx lucidus*
Pīwakawaka	South Island fantail	*Rhipidura fuliginosa fuliginosa*
Poaka	Pied stilt	*Himantopus himantopus*
Pokotiwha	Snares crested penguin	*Eudyptes robustus*
Pūtakitaki	Paradise shelduck	*Tadorna variegata*

Riroriro	Grey warbler	*Gerygone igata*
Roroa	Great spotted kiwi	*Apteryx haastii*
Rowi	Ōkārito brown kiwi	*Apteryx mantelli*
Ruru koukou	Morepork	*Ninox novaseelandiae*
Takahē	Takahē	*Porphyrio mantelli*
Tara	Terns	*Sterna* spp.
Tawaki	Fiordland crested penguin	*Eudyptes pachyrhynchus*
Tete	Grey teal	*Anas gracilis*
Tīeke	South Island saddleback	*Philesturnus carunculatus carunculatus*
Tītī	Sooty shearwater/Muttonbird/Hutton's shearwater Common diving petrel South Georgian diving petrel Westland petrel Fairy prion Broad-billed prion White-faced storm petrel Cook's petrel Mottled petrel	*Puffinus griseus* and *Puffinus huttoni* and *Pelecanoides georgicus* and *Procellaria westlandica* and *Pachyptila turtur* and *Pachyptila vittate* and *Pelegodroma marina* and *Pterodroma cookii* and *Pterodroma inexpectata*
Tititipounamu	South Island rifleman	*Acanthisitta chloris chloris*
Tokoeka	South Island brown kiwi	*Apteryx australis*
Toroa	Albatrosses and Mollymawks	*Diomedea* spp.
Toutouwai	Stewart Island robin	*Petroica australis rakiura*
Tūī	Tūī	*Prosthemadera novaseelandiae*
Tutukiwi	Snares Island snipe	*Coenocorypha aucklandica huegeli*
Weka	Western weka	*Gallirallus australis australis*
Weka	Stewart Island weka	*Gallirallus australis scotti*
Weka	Buff weka	*Gallirallus australis hectori*

Plants

Māori	**English**	**Scientific**
Akatorotoro	White rata	*Metrosideros perforata*
Aruhe	Fernroot (bracken)	*Pteridium aquilinum* var. *esculentum*
Harakeke	Flax	*Phormium tenax*
Horoeka	Lancewood	*Pseudopanax crassifolius*
Houhi	Mountain ribbonwood	*Hoheria lyalli* and *H. glabata*
Hakikatea	Kahikatea/White Pine	*Dacrycarpus dacrydioides*
Kāmahi	Kāmahi	*Weinmannia racemosa*
Kānuka	Kānuka	*Kunzia ericoides*
Kāpuka	Broadleaf	*Griselinia littoralis*
Karaeopirita	Supplejack	*Ripogonum scandens*
Karaka	New Zealand laurel/Karaka	*Corynocarpus laevigata*
Karamū	Coprosma	*Coprosma robusta, coprosma lucida, coprosma foetidissima*
Kātotoe	Tree fern	*Cyathea smithii*
Kiekie	Kiekie	*Freycinetia baueriana* subsp.

		banksii
Kōhia	NZ Passionfruit	*Passiflora tetranda*
Korokio	Korokio Wire-netting bush	*Corokia cotoneaster*
Koromiko /Kōkōmuka	Koromiko	*Hebe salicifolia*
Kōtukutuku	Tree fuchsia	*Fuchsia excorticata*
Kōwhai Kōhai	Kōwhai	*Sophora microphylla*
Mamaku	Tree fern	*Cyathea medullaris*
Mānia	Sedge	*Carex flagellifera*
Mānuka Kahikātoa	Tea-tree	*Leptospermum scoparium*
Māpou	Red matipo	*Myrsine australis*
Mataī	Mataī/Black pine	*Prumnopitys taxifolia*
Miro	Miro/Brown pine	*Podocarpus ferrugineus*
Ngaio	Ngaio	*Myoporum laetum*
Nīkau	New Zealand palm	*Rhopalostylis sapida*
Pānako	(Species of fern)	*Asplenium obtusatum*
Pānako	(Species of fern)	*Botrychium australe* and *B. biforme*
Pātōtara	Dwarf mingimingi	*Leucopogon fraseri*
Pīngao	Pīngao	*Desmoschoenus spiralis*
Pōkākā	Pōkākā	*Elaeocarpus hookerianus*
Ponga/Poka	Tree fern	*Cyathea dealbata*
Rātā	Southern rātā	*Metrosideros umbellata*
Raupō	Bulrush	*Typha angustifolia*
Rautāwhiri/Kōhūhū	Black matipo/Māpou	*Pittosporum tenuifolium*
Rimu	Rimu/Red pine	*Dacrydium cypressinum*
Rimurapa	Bull kelp	*Durvillaea antarctica*
Taramea	Speargrass, spaniard	*Aciphylla* spp.
Tarata	Lemonwood	*Pittosporum eugenioides*
Tawai	Beech	*Nothofagus* spp.
Tētēaweka	Muttonbird scrub	*Olearia angustifolia*
Tī rākau/Tī Kōuka	Cabbage tree	*Cordyline australis*
Tikumu	Mountain daisy	*Celmesia spectabilis* and *C. semicordata*
Titoki	New Zealand ash	*Alectryon excelsus*
Toatoa	Mountain Toatoa, Celery pine	*Phyllocladus alpinus*

Toetoe	Toetoe	*Cortaderia richardii*
Tōtara	Tōtara	*Podocarpus totara*
Tutu	Tutu	*Coriaria* spp.
Whararikī	Mountain flax	*Phormium cookianum*
Whīnau	Hīnau	*Elaeocarpus detatus*
Wī	Silver tussock	*Poa cita*
Wīwī	Rushes	*Juncus* all indigenous *Juncus spp.* and *J. maritimus*

Marine Mammals

Māori	**English**	**Scientific**
Ihupuku	Southern elephant seal	*Mirounga leonina*
Kekena	New Zealand fur seals	*Arctocephalus forsteri*
Paikea	Humpback whales	*Megaptera novaeangliae*
Parāoa	Sperm whale	*Physeter macrocephalus*
Rāpoka/Whakahao	New Zealand sea lion/Hooker's sea lion	*Phocarctos hookeri*
Tohorā	Southern right whale	*Balaena australis*

Fish Species

Māori	**English**	**Scientific**
Kāeo	Sea tulip	*Pyura pachydermatum*
Koeke	Common shrimp	*Palaemon affinis*
Kōkopu/Hawai	Giant bully	*Gobiomorphus gobioides*
Kōwaro	Canterbury mudfish	*Neochanna burrowsius*
Paraki/Ngaiore	Common smelt	*Retropinna retropinna*
Piripiripōhatu	Torrentfish	*Cheimarrichtys fosteri*
Taiwharu	Giant kōkup	*Galaxias argentus*

Appendix 2: Field Soil Sampling Strategy

Structure for describing levels of focus

Agricultural System

Two agricultural production systems are being monitored; sheep and beef (SB) and kiwifruit (KF).

Management System

- For sheep and been properties, the three management systems are:
    - A organic
    - B integrated
    - C conventional.
- For kiwifruit properties, the three management systems are:
    - A conventional green (Kiwigreen Hayward)
    - B organic green (Hayward)
    - C conventional gold (Hort16A).
- For cluster 1 of the kiwifruit a fourth property currently converting from conventional to organic has been added.

Cluster

A cluster is a set of three properties, one of each management system. The properties within a cluster are within close geographic proximity with similar landforms, soil type and climatic conditions. In the sheep and beef system there are 10 clusters. In kiwifruit there are 12 clusters.

Property

The individual farms or orchards that make up the cluster

- Sheep/Beef = 3 mgt systems x 10 clusters = 30 properties
- Kiwifruit = 3 mgt systems x 12 clusters = 36 properties

Landform

Landform describes the different geomorphology within a property

- *Geomorphic landforms for Sheep and Beef*
    - Terrace
    - Hill crest
    - Mid slope

For sheep and beef clusters on the Canterbury plains, one landform, flat river terraces, will be studied. For sheep and beef clusters on hill country, the dominant two of the three landforms be studied. Within a cluster the same landforms will be studied.

- *Geomorphic landforms for kiwifruit*
    - Vine line
    - Alleyway

On orchards, management of the vine line (within row) and alleyway (between row) can be very different and will be treated as two separate landforms within a soil monitoring site.

Management Unit

On kiwifruit orchards, the property is managed by the grower in separate blocks. On sheep and beef farms, the property is managed by the farmer in separate paddocks. On sheep and beef properties, individual management units (paddocks) may have a specific function (e.g. hay paddock, airstrip, cropping, etc.).

Soil Monitoring Site (SMS)

At a single sampling time, soil properties can be quite variable within a small area. To achieve reliable monitoring that spatial variation must be recognised and accommodated, so that time trends can be distinguished from random noise generated by sampling different areas of soil. Our approach to this problem is to establish within each management unit permanent soil monitoring sites (SMS) where all samples are gathered. There are three SMS within each management unit

Establishing soil monitoring sites and sample procedures

Sheep and beef farms

Landform selection for sheep/beef farms

- For farms on the Canterbury plains, only one landform will be monitored. Within a cluster, three paddocks on the same or similar terrace should be selected.
- For clusters on the hill country, two of the three most dominant landforms will be studied. The three landforms are terrace, hill crest and mid slope. Usual landforms for hill country properties are mid slope and crest. Within a cluster the same landforms will be studied.

Paddock (management unit) selection for sheep/beef farms

- Select three paddocks per landform at random, but be aware that some paddocks have specific functions on the property, such as:
    - Long term hay paddocks,
    - Access paddocks,
    - Airstrips,
    - Regular cropping paddocks,
    - Grazing style (extensive or set stocking vs intensive or break feeding).
- We require similar paddock functions to be chosen across the cluster.
- Some paddocks may contain more than one landform. The landform that the paddock is chosen to represent should be the predominant landform.

Soil monitoring sites (SMS) location for sheep/beef farms

- Location selected randomly within paddock (see
-
-
- ***Figure 10.1*** and Figure 10.2), but within the landform that paddock is chosen to represent.
- Avoid unusual areas and keep *at least* 30 m away from trees, fences, gateways, water troughs.
- Further check suitability of SMS by sampling the soil profile to 1 m with a soil auger (see below). Check at least three SMS's per paddock first before discarding any. Discard sites if:
    - Soil profile is obviously different to all others,

- Unusual layers like old fire sites or isolated soil disturbance (eg old cow shed/shelter belt),
- On the wrong landform for that paddock,
- If discarded regenerate new random SMS.

- Record the location of the site using GPS. As a backup, draw diagram and measure to fixed objects such as fence lines and trees
- Each SMS is approximately 15 m x 15 m

Scoring Visual soil assessment for priority 1 indicators for sheep/beef farms

See Appendix 3 for VSA scoring criteria. Always crry the card with you and reread the criteria every morning to try to maintain absolute consistency.

Scoring the soil profile for sheep/beef farms

- Depth marked up auger shaft.
- Use auger to remove soil in 10 cm increments.
- Remove loose soil from top and sides of sample.
- Lay out each sample in order on tarpaulin.
- Divide profile into common layers based on colour and textural changes.
- Record depth of layers.
- Record depth of mottling and gleying.
- Collect sub-sample of each layer (approx 1 handful), avoiding gradational changes, and send to Crop & Food Research for textural determination.
- Refill hole when finished.

Figure 10.1. Example of SMS layout for Canterbury plains sheep and beef farms with one landform, three paddocks per landform, and three soil monitoring sites per paddock. Total of nine SMS.

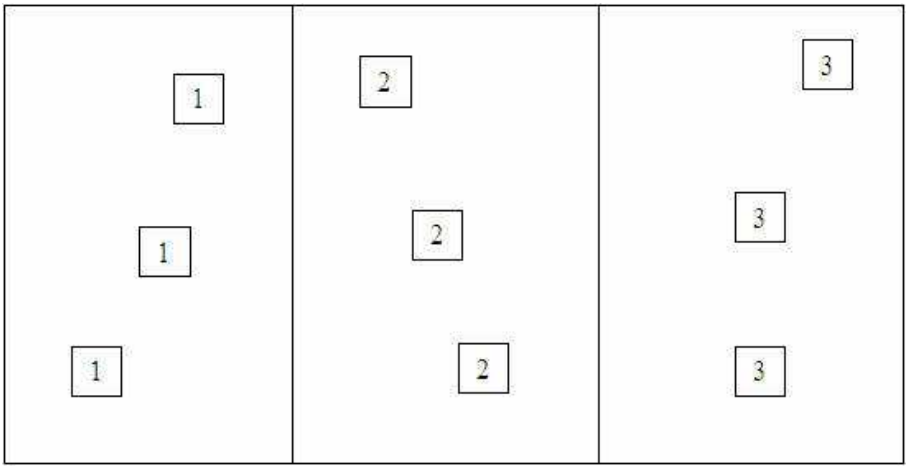
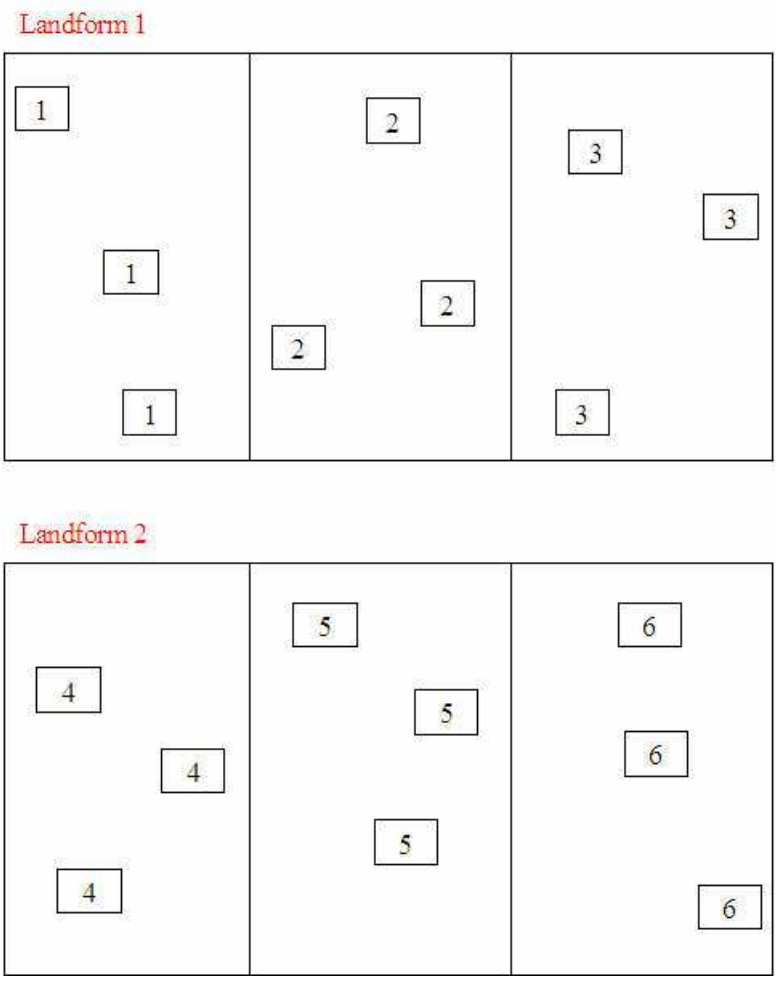


Figure 10.2. Example of SMS layout for hill country sheep and beef farms with two landforms, three paddocks per landform, and three soil monitoring sites per paddock. Total of 18 SMS.



Earthwom count for sheep/beef farms

- Earthworm measurements are conducted on soil that has been used for visual soil assessments.
- Measure the area of the hole that soil was collected from. The hole should be dug to 30 cm and have straight sides.
- Separate out any vegetation and shake over a tarpaulin to remove soil. Hand sort through vegetation to find worms and other soil fauna, then discard vegetation to avoid re-sorting.
- Hand sort through soil twice, removing worms and critters (put them in a container so they don't escape)
- 1st time thoroughly and methodically breaking up large soil aggregates
- 2nd time back sort taking particular note of the bottom layer
- Record whole and half worms numbers and total weight of worms (excluding other soil fauna)
- Preserve in 70% ethanol. Label pottle in pencil. Ethanol needs to be changed soon after preservation if several worms are present because earth in the gut absorbs a lot of it.

Soil bulk density for sheep/beef farms

- Soil bulk density is a measure of soil compaction and defined by weight per unit volume. As weight is dependent on moisture content, samples are oven-dried at 105 ^{o}C to remove all moisture, giving dry bulk densities that can be compared between locations.
- Two soil bulk density cores are collected at each soil monitoring site (four cores for kiwifruit, two each from the two landforms, vine line and alley way).
- Remove/cut away excess vegetation from soil surface without disturbing the soil
- Drive the corer into the soil to 7.5 cm depth (marked on corer).
- Twist to shear off bottom of soil core.
- Remove from soil and eject core into pre-labelled plastic bag.
- If a large amount falls out from the core then redo. It is okay to repack small amounts (< 10g).
- Watch out for large roots that penetrate into the core – make sure they are contained in the soil that is sampled.
- Repeat this process in same hole but this time core from 7.5 – 15 cm depth.
- Weigh both samples in the field to 1g, taring bag before weighing.
- Break up the soil sample in the bag and mix well by shaking.
- Sub-sample the soil sample by discarding roughly half back into the hole but keep all the non-soil material in bag (e.g. stones, big roots etc).
- If there is a large amount of root material it might be easier to sub sample by slicing the core in half lengthways.

Soil sample collection for priority 2 and 3 measures for Sheep/beef farms

- Collect eight cores per SMS at random within the SMS using a 7.5 cm (25 mm diameter) soil corer.
- Discard any broken/incomplete cores.
- Combine samples per paddock so there is one sample per paddock (total of 24 cores make up the sample).
- Put in bag – tie up and label well.
- Chill as soon as possible and/or store in fridge.
- Overnight courier to Crop & Food Research within one week.

Kiwifruit orchards

Landform selection for kiwifruit orchards

On orchards, management of the vine line (within row) and alleyway (between row) can be very different and will be treated as two separate landforms within a soil monitoring site.

Block (management unit) selection for kiwifruit orchards

- Use only blocks of the given variety (i.e. Hayward of Hort16A)
- For orchards with only one block:
    - Divide the block roughly into thirds to create three even sized sub-blocks
- For orchards with two blocks:
    - One block is kept whole, the other split in half to create two sub-blocks,
    - If there are no obvious discontinuities within the blocks, and one block is bigger than the other, choose the larger to subdivide,

- If there are no obvious discontinuities in a block, and they are the same size, chose at random which one gets subdivided,
- If one block has a major discontinuity (gully or crest) the block should be divided at that point.

- For orchards with three blocks:
  - Use all three.
- For orchards with more than three blocks
  - Select three blocks at random.

Soil monitoring sites (SMS) location for kiwifruit orchards

- Location selected randomly within block/sub-block according to row number and position along row, with only one soil monitoring site per any given row.
- Avoid the outer rows for both vine line and paired alleyway site.
- SMS locations are unsuitable if at the time of SMS establishment there are male vines or if there is no vine or a dead or decaying vine (require healthy female vines). [41]
- Further check suitability of SMS by sampling the soil profile with the 1m auger (see below). Do all 9 SMS's first before discarding any. Discard site if:
  - Soil profile is obviously different to all others,
  - Unusual layers like old fire sites or isolated soil disturbance (eg old cow shed/shelter belt),
  - If discarded regenerate new random SMS, but avoid choosing a single row twice.
- Record the location of the site, including property block, row number and distance and bay number from baseline end.
- Each site is 2 bays long.

Earthworms, bulk density, VSA and soil profile for Kiwifruit orchards

Follw the same protocols as described above for Sheep/beef SMSs.

Soil sample collection for priority 2 and 3 measures for Kiwifruit Orchards

The chemical samples will be collected using much the same way as for sheep/beef except that a 15 cm corer is used on orchards and the soil is aggregated in different ways for chemical anlyses (Priority 2 & 3 measures). Ochard samples will be collated by block (each sample should have soil from three SMS's).

Eight soil cores will be sampled per landform within each SMS (8 x 3 SMSs = 24 cores/sample) using the following protocols:

- Sample vine line and alleyway separately (two landforms).
- Collect eight cores per at random within each landform the SMS, combine soil from each landform from all three SMSs from that block.
- Discard any broken/incomplete cores.

[41] If vines die after SMS establishment you must identify if the death is a consequence of soil quality. If death is due to another reason (e.g. foliar disease or pests) it may be necessary to replace this SMS with another.

- Put in bag – tie up and label well.
- Chill as soon as possible and/or store in fridge.
- Overnight courier to Crop & Food Research within one week.

Appendix 3: Visual Soil Assessments

See separate Pdf file for descriptions.