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Editorial

The first national assessment of ecosystems services in New Zealand was recently released (Ecosystem Services in New Zealand – Conditions and Trends, 2013. Manaaki Whenua Press).This work provided an understanding of the science that underpins the functioning of our ecosystems, so that their management can be based on knowledge. I'm delighted to see that the National Land Resource Centre has provided the opportunity to further showcase developments in the field of ecosystem science.

The increasing interdisciplinary nature of ecosystem services is reflected in this year's Soil Horizons magazine. In this issue, scientists have come together from across the Crown Research Institutes and Universities to bring you current understanding of soil services in New Zealand. This includes AgResearch describing research on soil erosion and riparian management; Plant and Food on ecosystem services of orchards; SCION on ecosystem services in forests; NIWA on land use and water quality; ESR and Lincoln University on organic waste; Auckland University and Auckland Council on soil health; Universities of Otago and Auckland with Landcare Research on impacts of climate change on ecosystem services; and Landcare Research on soil microbes, urban soils, plant selection, land use, and catchment-scale ecosystem services.

The work progressing in this area indicates positive contributions to soil management. It highlights increasing value in promoting a broader perspective of all the soil services that contribute to human well-being.

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Optimising ecosystem services of (urban) soils

Where soils are used to mitigate effluent or stormwater they must provide key ecosystems services of water detention, water retention, and contaminant removal (Figure 1). **Detention** lowers the peak rate of discharge to surface waters, helping reduce stream erosion and flooding. It may also enhance groundwater recharge. **Retention** reduces the volume of effluent or stormwater entering surface or ground water. Retention improves **contaminant removal** by allowing time for plant uptake (with evapotranspiration), adsorption to soil particles, or contaminant transformation (denaturing chemicals to innocuous derivatives). Plants rely on this retained water to sustain them between rainfall events.

Resource consents for areas (or devices) receiving effluent / stormwater should specify minimum soil criteria to increase the certainty that an acceptable level of performance can be achieved. Soil physical criteria include minimum (and maximum) infiltration. They may also require a minimum water storage volume (within a defined depth). Sometimes favourable conditions are assumed if soil textures are coarse, i.e. sand to sandy loam, or meet specific particle-size distributions. Natural soils may be modified, or new soils engineered, to meet specific performance criteria. The growing media used in rain gardens and swales are examples. In cities with few natural sandy soils, such as Auckland and Wellington, growing media are manufactured.

In Auckland, adding up to 50% sand to Ultic Soils (silty clays) to create sandy loam led to slumping, infiltration < 10 mm/h (below the minimum standard), and extended periods of anaerobic conditions. Wellington and Christchurch also report problems selecting suitable media. The soil physics laboratory at Landcare Research, Palmerston North, has developed a three-step method for screening potential rain garden media. This builds on joint research with the University of Auckland for Auckland Council (Fassman-Beck et al. 2013). First, the range of moisture contents a medium can contain

FIGURE 1 Rain gardens at Karanga Plaza, Auckland City intercept, retain and cleanse runoff from adjacent paved surfaces before discharge to the harbour. The rain gardens are functional landscaping using local plants.

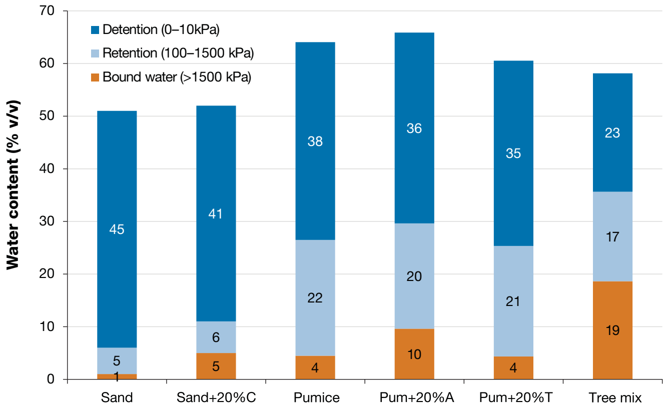

FIGURE 2 Water content of different rain garden media. 'Sand' has no internal porosity, 'C' is compost, Pumice is a pumice sand, 'A' is allophane (volcanic subsoil), 'T' is Allophanic topsoil, and Tree mix is a loam blend designed for tree pits made from pumice sand, topsoil and compost.

is established. Second, the susceptibility of the medium to a standard level of compaction is measured at several moisture contents, including likely delivery moisture content and a relatively high moisture content. A resilient rain garden mix maintains a similar bulk density under a range of moisture contents. Finally, the permeability and water stored for plant growth in the medium are measured.

Suitable media have infiltration rates >50 mm/h and high water retention (at 100–1500 kPa tension). Pumice sand is an ideal base for rain garden mixes. It can hold up to four times more water than 'standard' sands ('pumice' vs 'aggregate' columns in Figure 2). Adding 20% v/v organic matter (composts) does not necessarily increase retention of pumice but slightly improves retention of sands. This is because the additional water is in pores drained at >1500 kPa (nominal wilting point) or tightly held to organic particles. Adding 20% v/v sandy-textured allophane (P+20%A) or an Allophanic Soil (P+20%T) to improve metal and P attenuation did not change retention. Measuring retention is useful to show arborists that very coarse textured media can supply as much water as their standard landscaping mixes, while being resilient to compaction. Pumice-based mixes also have much higher detention than standard tree mixes, providing greater stormwater benefits.

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Using an ecosystem services approach to assess the cost of soil erosion

FIGURE 1 Three scenarios: Scenario A – typical east coast hill country sheep and beef grazing; Scenario B – Shallow mass movement erosion followed by recovery; Scenario C – Soil conservation in hill country.

Soil degradation from farmland is a significant issue across New Zealand. This study investigates an ecosystem services (ES) approach to estimate the long-term environmental cost of shallow mass movement erosion, and to evaluate the wider environmental and social benefits of soil conservation practices.

The study considers a typical East Coast hill country sheep and beef operation under three scenarios (Figure 1). To quantify the provision of ES from a permanent pasture grazed by sheep and cattle in hill country, information from planners in the region was used. Neoclassical economic valuation techniques (market prices, defensive expenditures, replacement and provision costs) were used to determine the economic value of each service.

We looked at (1) the provisioning of food, wood and support for infrastructures and animals, and (2) regulating services: flood mitigation, filtering of nutrients, decomposition of wastes, net carbon accumulation, nitrous oxide, methane oxidation, and pest populations. The study followed the steps below:

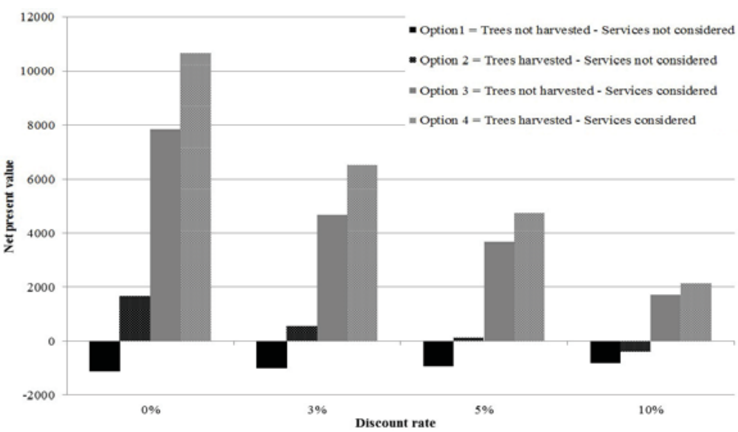

FIGURE 2 Economic value (NZ$/ha/yr) of ecosystem services provided by pasture grazed by sheep and cattle, on uneroded rolling and steep land, steep land immediately after a shallow landslide and following 20 and 50 years of recovery, and steep land planted with 10- and 20-year-old wide-spaced trees.

- Quantification and economic valuation of the provision of ES, to assess the baseline flows of ES under current land use. The assessment was done for rolling and steep landscape units.
- Quantification and valuation of the provision of ES following shallow mass movement erosion on steep land to evaluate the loss of services compared with intact pastures.
- Characterisation, based on soil recovery data, of the recovery profile of the provision of ES in the 20 years following a landslide on steep land to assess how far the provision of ES recovers.
- Assessment of the provision of ES over 20 years from the uneroded steep pasture planted with wide-spaced poplars for soil conservation, to see how trees impact on the provision of services.
- Cost–benefit analysis of soil conservation on steep pasture prone to erosion using an ES approach, to assess the return on investment from the soil conservation policy.

The economic value of the services (Figure 2) provided by an uneroded steep pasture grazed by sheep and cattle was estimated at $3,717/ha/yr. Regulating services, usually not considered in decision making, had an economic value four to six times that of the provisioning services for the rolling and steep landscape unit respectively. The economic value of the services dropped by 65% when the topsoil was lost in a single instance of shallow mass movement. Fifty years after erosion, the services only recovered to 61% of the un-eroded value. In contrast, the same land planted with soil conservation trees provided, after 20 years, additional (+22% in dollar value) services from the similar unprotected landscape.

A classical cost–benefit analysis (CBA) of soil conservation practices showed planting conservation trees is only profitable if the trees are harvested for timber (at age 20), and low discount rates (<5%) are used. When the economic value of the extra services from conservation trees is included in the CBA, the net present value of the investment is greatly positive at discount rates ranging from 0 to 10% (Figure 3).

This analysis offers new insights on how to integrate an ES approach and use it on the ground to advance existing governance frameworks for resource management.

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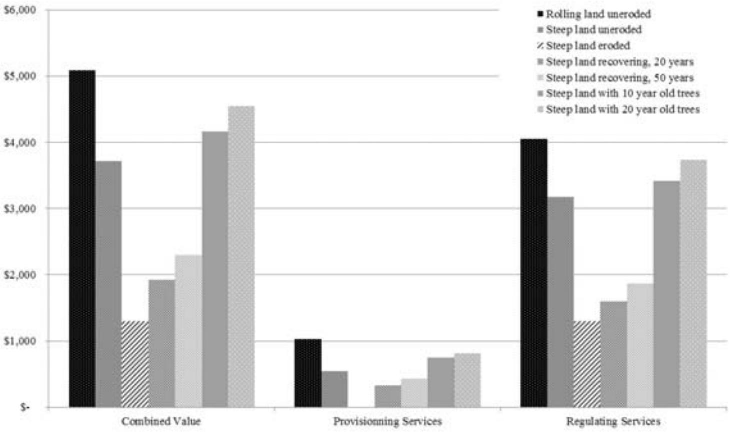

FIGURE 3 Net present value (NPV; NZ$/ha) over 20 years of four different management options at four discount rates.

Mapping soil health from microbial genes

Soil scientists from regionals councils (Northland RC, Auckland Council, Waikato RC, Hawke's Bay RC, Greater Wellington RC, Tasman District Council, Marlborough District Council, Environment Canterbury and Environment Southland), the University of Auckland (Dr Gavin Lear) and Landcare Research (Dr Bryan Stevenson) have joined together to take soil quality monitoring to a higher level.

Using soil that regional councils annually collect from different land uses and soil types throughout New Zealand, a soil microbial component is being trialled in addition to the standard suite of sampling analyses, as an indicator of soil quality. The intention is to record variation in the abundance and diversity of microbial genes that are known to provide vital ecosystem services, including nutrient storage and cycling. Our research is intended to provide substantial added value to regional councils' soil quality monitoring programmes that to date have focused on soil physicochemical data such as measures of organic carbon, total nitrogen, pH, Olsen P, macroporosity, and trace elements.

The inclusion of a microbial component to monitoring may provide advances over traditional strategies used by councils to report on the long-term status of New Zealand's natural soil resource. Importantly, the delayed response of soil physicochemical measures to land-use change means current soil monitoring strategies can overlook the onset of serious soil degradation. In contrast, bacterial communities respond very rapidly to environmental change, allowing declines in soil health and fertility to be detected at a far earlier stage, before degradation is severe or perhaps irreversible. Modern molecular (DNA) methods allow us to reliably target specific ecosystem processes for inclusion in monitoring networks (e.g. targeting genes of particular interest, such as those involved in the nitrogen cycle, or originating from particular soil pathogens). Furthermore, microbial measures may provide a relevant bioindicator of soil status compared with standard chemical measures. This is because, similar to plant roots, soil microorganisms respond to bioavailable fractions of contaminants or nutrients.

FIGURE 1 Extracting and analysing DNA from samples collected for soil quality assessment can provide information on the variation, abundance and diversity of microbial genes that provide vital ecosystem services.

What this means for the future is that we'll be able to inform land managers and landowners more quickly about the status of their soil resource and what they can do in terms of land management practice. Further, the information collected will also inform policy and science direction in regional councils, which will help maintain and improve soil health around New Zealand. Without the collaboration and coordination of the regional councils, the University of Auckland and Landcare Research, this project would not be possible. It demonstrates the importance of using the resources different parties can offer.

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Soil microbes – bacteria, archaea, and fungi

Soils harbour enormous microbial diversity, comprising bacteria, archaea, and fungi. The total fresh weight mass of organisms in grassland soils can exceed 45 tonnes per hectare, equalling or exceeding above-ground biomass. Bacteria are present in greatest numbers, with archaea 10-fold less. The numbers of species of bacteria per gram of soil have been estimated to range from 2000 to 18 000. Fungi, however, often contribute the largest part of the total microbial biomass in soils. The activities of soil microbes drive or contribute to the cycling of all major elements (e.g. C, N, P), and this cycling affects the structure and functions of soil, as well as the ability of soils to provide ecosystem services.

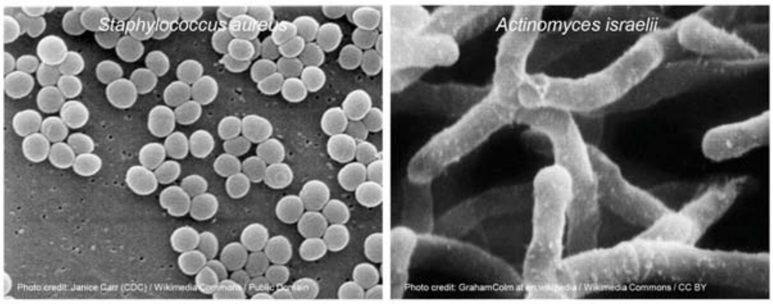

FIGURE 1 Examples of the structure of bacteria.

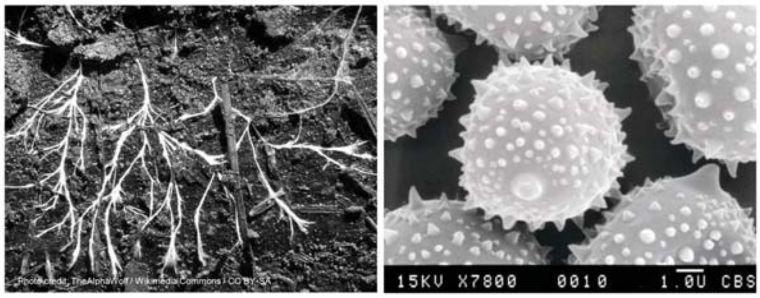

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FIGURE 2 Examples of (A) fungal hyphae in soil, (B) fungal spores.

What are bacteria, archaea, and fungi?

Bacteria and archaea are the smallest independently-living, single-celled organisms on earth. Typical cells range from 0.5 to 1.0 µm in diameter. Bacteria and archaea may occur as cocci, rods, or spirals, and some bacteria common in soils, such as the Actinomycetales, can form branching filaments (Figure 1). Most lack a true membrane-bound nucleus, so their DNA lies free in the cell cytoplasm. Their genome typically consists of a single circular molecule of double-stranded DNA. A cell membrane made of phospholipids surrounds the cell. Outside this is the cell wall, usually made up of proteins, carbohydrates and lipids. Many microbes can move, using flagella (whip-like extensions from the cell). They can also form fine filaments called pili that can attach the cells to each other or to soil surfaces. Usually they undergo asexual reproduction, typically by dividing in half; some cells can divide every 12–20 minutes, while others take much longer.

As with all organisms, bacteria and archaea require carbon to provide the building blocks for cell materials. They also require energy to drive the reactions involved in cell synthesis and metabolism. To grow, some bacteria require oxygen, while other bacteria and most archaea use alternative electron acceptors, including nitrate and sulphate (i.e. they respire nitrate and sulphate). For these anaerobic organisms oxygen may be toxic. Broadly, microbes are classed as autotrophs or heterotrophs. Autotrophs use energy from sunlight or inorganic compounds (e.g. Fe^{2+}, nitrate or nitrite) to fix atmospheric carbon dioxide to produce carbohydrates, fats and proteins, whereas heterotrophs use organic carbon compounds as a source of carbon and energy.

Archaea were originally thought to exist only in harsh environments, but we now know they are widely distributed and are found alongside bacteria in many environments, including soil. Recently Archaea belonging to Crenarchaeota have been implicated in nitrogen cycling in soils. Archaea and bacteria are difficult to distinguish on the basis of their morphology. However, molecular phylogenetic tools that compare 16S ribosomal rRNA sequences have revealed that all life can be divided into three domains, with Archaea being more closely related to Eukarya (all multicellular organisms) than those two are to the Bacteria.

Fungi are eukarya and hence more closely related to plants and animals than to bacteria or archaea. Like all eukarya, fungal cells contain membrane-bound nuclei with chromosomes that contain DNA. They also have membrane-bound organelles such as mitochondria. Fungi have a cell wall composed of glucans and chitin. Fungi are heterotrophic organisms, and they feed on decaying matter. While some fungi occur as single-celled organisms, generally referred to as yeasts, many grow as hyphae, which are cylindrical thread-like structures, 2–10 µm in diameter (Figure 2). The hyphae may be either septate – divided into compartments separated by cross walls – or non-septate. Fungi grow from the tips of the hyphae. Many intertwined hyphae constitute a mycelium, the main body of the fungus. Finely and complexly branched, the mycelium occupies a large volume of soil and produces a wide variety of enzymes that act on soil organic matter and mineral compounds to release the nutrients and energy the fungus needs for growth. Fungi reproduce by both sexual and asexual means. Both processes produce spores, a general term for resistant resting structures. Yeasts reproduce by budding or binary fission.

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Impact of climate change on the diversity and functioning of soil microbial communities

Microorganisms comprise the majority of soil biomass and diversity and provide vital ecosystem services such as the breakdown of soil organic matter and cycling of available nitrogen. However, despite the importance of microbial communities for soil health and fertility, we know remarkably little about their response to changing climatic conditions.

In partnership with researchers at the University of Auckland and the University of Otago, scientists at Landcare Research are exploring attributes of soil microbial communities within the tussock grasslands of New Zealand's Southern Alps. Across this varied landscape, fine-scale gradients in microclimate conditions are detectable across short distances, caused by variability in site elevation or aspect. These steep temperature gradients along and around the mountain ridge are used to provide valuable insights as to the importance of thermal microclimates on various soil microbial attributes.

An extensive network of 405 sampling locations has been established at Mount Cardrona in Central Otago, and soil collected to cover the varied landscape topology, which includes a gradient in elevation from 500 to over 1900 metres above sea level (a.s.l.; corresponding to an average temperature change of ~8.5°C). Using advanced next-generation DNA sequence analysis, researchers are identifying tens of thousands of the most dominant bacterial and fungal species in each soil sample. Fine-scale differences in microbial community composition can then be mapped across the microclimate gradient. By comparing this microbial community data with temperature data collected at each sampling location, Landcare Research scientists hope to provide better predictions of future microbial community composition under a range of climate scenarios.

FIGURE 1 Main ridge of study site, Mount Cardrona.

Source: BJA

Source: BJA

FIGURE 2 Soil core from shady-side plot at 1800 m a.s.l.

Modern molecular methods are also being used to quantify the abundance of key functional genes (e.g. nitrogen-cycling genes) and their relationship to variation in microclimate conditions across all study sites. This information will shed new light on how variations in climatic conditions may impact key indicators of soil health and fertility, and even alter the balance of CO_2, N_2O and CH_4 production and degradation, processes that could further exacerbate future rates of climate change.

The outcomes of this project will increase understanding of (1) the likely resilience/fragility of indigenous tussock grassland ecosystems to the threat of climate change, (2) the likely impact of climate change on nitrogen cycling by soil microbes in tussock grasslands and its potential to affect concentrations of plant available N and soil N_2O emissions, and (3) the importance of the relationship between grassland plants and the microorganisms that surround them.

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On-farm riparian zones and ecosystem services valuation

In response to the growing concerns about surface water quality, the voluntary approach to fencing riparian zones on dairy farms is now becoming a mandatory requirement from regional authorities in some dairying regions, and a condition of supply by milk companies. This has intensified the debate on the value of riparian zones, and the degree to which they are actively managed.

The introduction of a planted riparian zone has the potential to increase filtering of overland flows carrying nutrients, sediments and pathogens and improve in-stream aquatic life through the provision of shade. Reasons why riparian zone fencing has not been adopted more widely on-farm include set-up and ongoing maintenance costs, weed control, and the perceived loss of productive land.

The objectives of this study were to explore the potential environmental, economic and social benefits of riparian zones within a New Zealand dairy farm by (1) identifying, quantifying and valuing ecosystem services (ES) provided by riparian zones, (2) exploring innovative ways of integrating riparian zones to the farm system, and (3) completing a cost–benefit analysis of riparian planting and fencing including the economic value of ES.

A trans-disciplinary group composed of dairy farmers, scientists, industry and regional council representatives had the opportunity to 'think outside the box'. Productive uses such as planting trees for shade and shelter, as well as sustainable harvests of timber, firewood, fodder, fruit or honey, were identified. Productive opportunities for waterways with improved water quality, such as harvesting watercress, koura or eels, were also identified. Cultural experiences for the farmer's family and the wider community were also mentioned, including creating pleasant aesthetic environments, opportunities for hunting, and recognising local history.

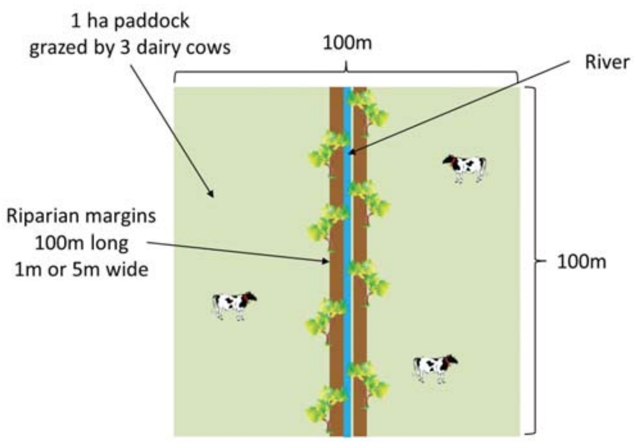

FIGURE 1 Farming system modelled.

The economic valuation of ecosystem services was realised for 1 hectare of grazed Waikato dairy pasture (Figure 1) with either: No riparian zone; 100 metres of 1-m-wide grass strip with temporary electric fence; 100 metres of 5-m-wide multi-tier system planted with poplar trees and native bushes, permanently fenced.

With the introduction of riparian zones into a dairy system, the quality and hence economic value of some ES declined (pasture quantity, recycling of wastes), some stayed stable (support to animals), and some increased (raw material, flood mitigation, filtering of nutrients). Inclusion of either a grass strip or a multi-tier system both increased the value of the ES provided, by 3–5% and 7–9% respectively, over the unfenced dairy pasture.

A traditional cost–benefit analysis (CBA) showed the net present value (NPV) over 20 years of an investment in riparian zones was negative. When the economic value of ES, especially regulating services, is included into the CBA, the NPV of the investment is always positive (Figure 2). The costs of externalities were not included in the CBA.

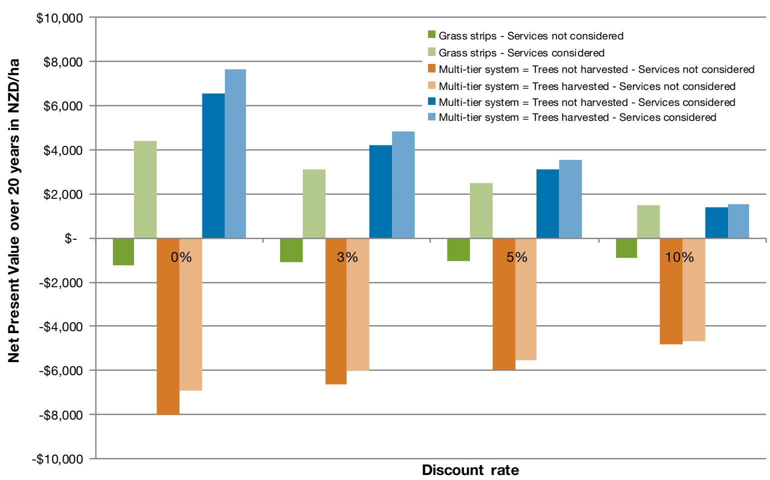

FIGURE 2 Results of the cost–benefit analysis (CBA): Net present value ($/ha) over 20 years of the two types of riparian zones, with and without considering the value of ecosystem services in the CBA, and with and without harvesting trees in the multi-tier system.

This shows that the change in the ES balance following fencing and planting has the potential, with only a small decline in pasture production, to put farmers in a more sustainable position.

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An overview of water quality in relation to land use in New Zealand

Much information on the water quality of New Zealand rivers at national scale has come from monitoring at the 77 sites of the National Rivers Water Quality Network (NRWQN) operated by NIWA for 25 years. A much larger number of water quality sites are operated by regional councils, although almost all have been running for shorter periods and there are difficulties with aggregating the regional data to provide a coherent national picture.

Four main categories of attributes that are measured in the NRWQN together define water quality:

- dissolved oxygen, temperature
- **optical properties** (e.g. visual clarity – Figure 1)
- the major **nutrient elements**, nitrogen (N) and phosphorus (P), which promote plant growth including nuisance algae (nitrate-N and ammoniacal-N are also toxic to aquatic life)
- **faecal microbial contaminants** indicating the possible presence of infectious disease agents.

Sources of pollutants arising from discharge at a point may be usefully distinguished from 'diffuse' pollution arising from land use. Improved point-source (wastewater) treatment over several decades has resulted in New Zealand water quality issues being related predominantly to diffuse sources – which are much more difficult to manage than point sources.

Dissolved oxygen and visual clarity are fairly high in New Zealand rivers, indicating good water quality overall.

Photo - Graham Timpany

FIGURE 1 Measuring visual water clarity at a river site in the NRWQN. The technician is using an underwater periscope (black item in his left hand) fitted with a 45 degree mirror to view horizontally under the water surface. Visual clarity is the distance (measured by tape measure) at which the visual target (black disc on the left of the image) disappears. The black disc is fixed to a steel pole driven into the river gravel.

Photo – Janice Meadows

FIGURE 2 Measuring nitrogen and phosphorus in river water samples from the NRWQN on the Flow Injection Analyser (FIA) in NIWA Hamilton's water quality laboratory.

Water quality is very high at 'reference' sites on rivers draining conservation lands. Conversely, there is widespread diffuse pollution from developed land, particularly pastoral agriculture. which mobilises fine sediment, faecal microbial contaminants, and nutrients. These diffuse pollutants all tend to increase with pastoral intensification.

River water quality can vary greatly from day to day. Even rivers that have good water quality most of the time may be turbid and polluted by faecal microbes during floods. Typically, diffuse pollutants move mainly during storm flows, whereas contaminants from wastewater are highest at low flow when dilution in receiving rivers is least.

Gradual improvements in the visual clarity of New Zealand rivers over 25 years possibly reflects soil conservation work and exclusion of livestock from channels by riparian fencing. However, a strong increase in nutrients, particularly N, has occurred over the same period in many rivers, reflecting intensification of pastoral agriculture.

Fortunately, there have been encouraging signs that decline in river water quality can be reversed. Nutrient enrichment appears to have slowed or decreased in recent years in certain catchments and regions of New Zealand where there has been major effort improved land management (e.g. riparian fencing and planting), soil conservation and nutrient controls.

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Downscaling ecosystem services to catchment scale – a case study in the Ruamahanga catchment

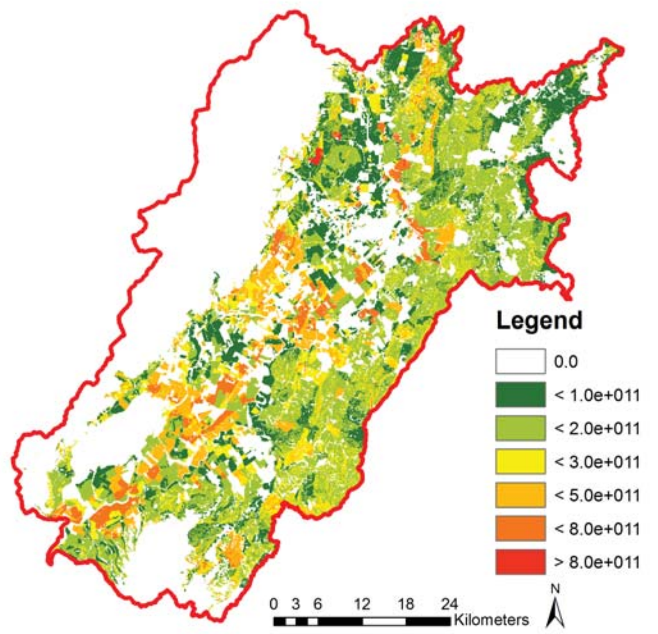
The Ruamahanga catchment in the Wairarapa is important for productive, cultural, recreational and natural values. It comprises 350 000 hectares with mountains covered in native forest in the north-west, and a mosaic of pastoral farming and viticulture in the lowlands. The water draining the mountains is of high quality, but somewhat compromised as it flows through grazing land in the hill country and Wairarapa lowlands, to the sea at Palliser Bay in the south. A community-based group, the Whaitua, is being set up to establish water quality and quantity limits for the catchment. In setting these limits, the Whaitua will have to take into account competing demands for land. There is also a proposal to build large storage dams to enhance summer water supply over much of the lowlands.

An ecosystem services framework can help depict a broad picture of impacts of land use or land management in the catchment. National models already exist for certain ecosystem services: provision of food, timber and wool; fresh water natural habitat; regulation of climate; soil erosion and water flow. However, when local issues are being addressed, downscaling to local detail becomes important. We used detailed soil maps to produce maps of overland flow and drainage. From these, we were able to produce catchment-wide maps of pathogen sources (*E. coli*) connected to streams (Figure 1). These maps provide useful context to those setting water quality limits for the Ruamahanga catchment.

We have also produced detailed maps of floral resources for assessing pollination services. We used Landcover Database version 3 and visually interpreted satellite information (SPOT) to improve the land cover classes (mānuka, gorse, riparian vegetation). Each land cover class was characterised, using expert knowledge, with estimates of nectar production and flowering time. We then designed a spatial model to combine floral resources with nectar requirement for sustaining hives and bee flying distances to produce a map of hive-carrying capacity (Figure 2).

The ecosystem services approach permits the assessment of catchment-wide mitigation strategies. For example, preventing direct stream access by cattle through fencing could reduce total *E. coli* sources by about 35%. Furthermore, fencing in combination with riparian management could provide additional floral resources that honey bees can feed on, and hence increase the capacity of the landscape to sustain hives.

Other scenarios are being developed, including wetland enhancement, soil conservation in the hill country, and implementation of best management practices for farm and municipal effluent. We are also investigating limits and trade-offs in managing agricultural intensification using potential irrigation schemes as the basis. We use multi-objective spatial optimisation to integrate economic, social, and environmental criteria to assess the potential effects of different on-farm management practices and spatial land-use configurations (i.e. irrigable areas) on soil natural capital and the provision of catchment-wide ecosystem services and economic returns.



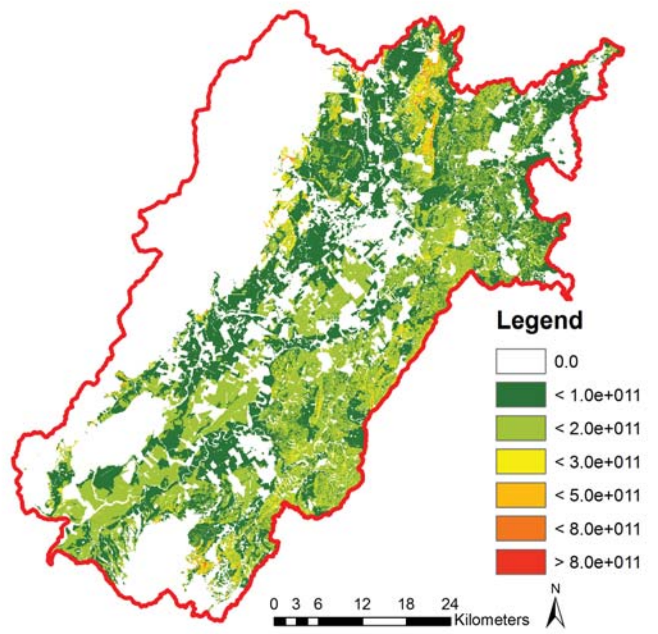


FIGURE 1 *E. coli* sources in Ruamahanga catchment. Left: current baseline; Right: with fencing everywhere.

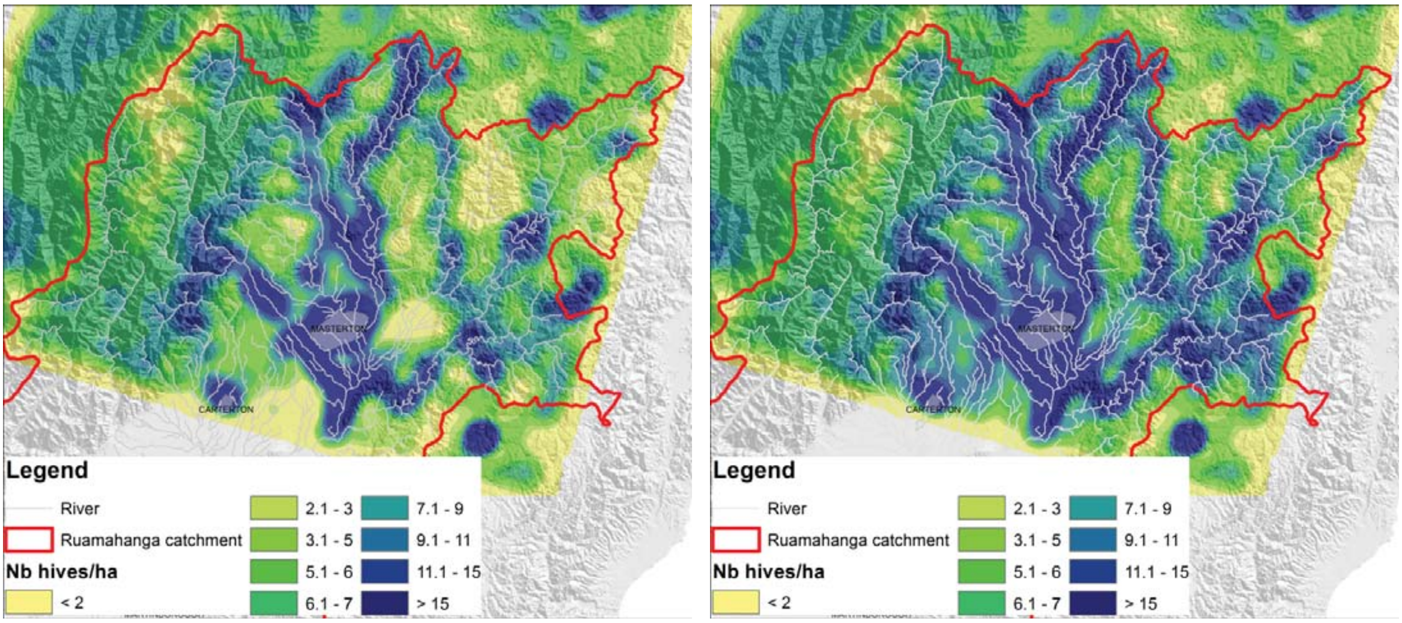


FIGURE 2 Hive carrying capacity (hives per hectare). Left: current baseline; Right: with fencing everywhere.

Our work aims to help decision makers by using ecosystem services as a framework for thinking about trade-offs and co-benefits of mitigation options in a catchment context.

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Orchard ecosystem services: bounty from the fruit bowl

The ecological infrastructures that underpin the production of New Zealand's fruit comprise valuable natural-capital assets. From these stocks flow ecosystem services that are valuable to the whole community. The Millennium Ecosystem Assessment classified ecosystem services into four typologies:

1 The provisioning services of food, fuel and fibre production

2 The supporting services of soil formation and nutrient cycling

3 The regulating services around the buffering and filtering of water, carbon and gases

4 The cultural services of heritage, recreation and spiritual well-being.

Horticulture generates NZ$3.5 billion of export revenues for New Zealand annually and sustains a NZ$2.9 billion domestic economy. All of this provisioning service comes from just 70 000 hectares of orchards and vineyards. Certainly there is provisioning bounty coming from the orchards of New Zealand's regional fruit bowls.

And the three other types of ecosystem services generated by orchards are not simply of value only to the orchardists and growers, as the wider community also benefits. Indeed they depend on them. In terms of the buffering of water, we have found that every bottle of Marlborough wine, packed and ready for despatch at the winery gate, has a negative water footprint of –66.8 litres per bottle. In other words, as a result of the production of the average bottle of Marlborough wine there is a net contribution of 66.8 litres of water to underlying groundwaters. This is because, on average, the natural capital stock of annual rainfall exceeds the evaporative consumption of water. So the Marlborough community benefits from the drainage of water through the vineyard soil that replenishes groundwater, which eventually becomes surface water in streams near Springs Junction – a valuable regulating service from which everyone benefits.

We also discuss the value of the supporting processes operating within the soil of orchards and vineyards, along with the role and value of the cultural ecosystem services that flow from the ecological infrastructures of New Zealand's orchards and vineyards.

EXAMPLES OF THE CULTURAL ECOSYSTEM SERVICES DELIVERED BY VINEYARD NATURAL CAPITAL

Clothier BE, Green S, Müller K, Gentile R, Herath I, Mason K, Holmes A 2013. Orchard ecosystem services: Bounty from the fruit bowl. Chapter 1.7 in Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Lincoln, Manaaki Whenua Press. Pp. 94–101.

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Monitoring agricultural land use with time – series satellite images

New remote sensing technology has been developed at Landcare Research to map paddock boundaries and identify the agricultural land uses within them. Satellite images are used, so a large area (approximately 60 x 60 km) is covered in a single map (Figure 1). If suitable time series of images can be acquired, regular update and change-tracking of land uses are possible.

The aim is to enable regional statistics to be gathered, such as the areas of various land-use types and their change over time. The maps of land use and crops can also be laid over other spatial data, for example soil maps, to see what land uses are occurring on what soils, or to carry out other environmental modelling.

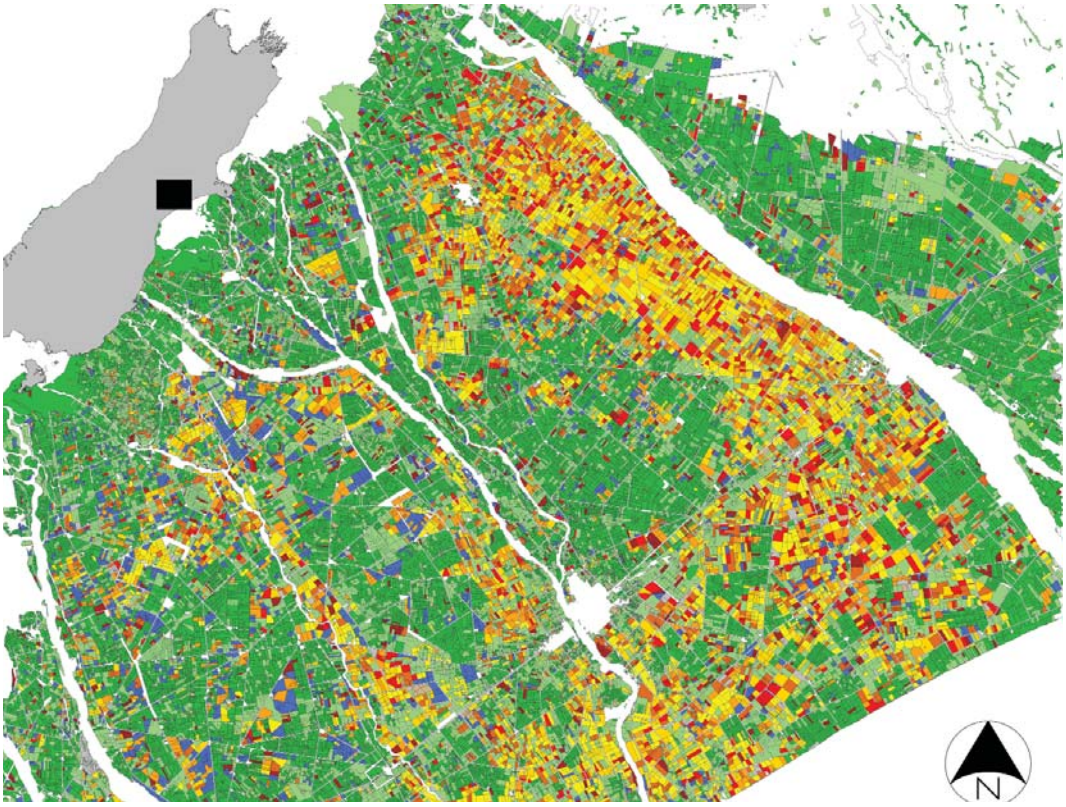

FIGURE 1 Land use classification for Summer 2011/12, Mid-Canterbury. Shades of green are pastoral types, yellow/orange/red shades are single-season crops, and blue indicates winter forage paddocks already planted in November–December. Rivers, towns, etc., are masked out (white).

With support from Environment Canterbury, researchers have so far mapped the Mid-Canterbury area around Ashburton on three dates: Summer 2010/11, Winter 2011, and Summer 2011/12 (this is shown in Figure 1). Image sequences are currently being acquired in South and North Canterbury for further mapping. In a separate project, winter forage paddocks have been mapped for a study site in Southland.

Figure 2 shows the paddock-level detail within the maps, and also the map legends for a summer classification. The groups of narrow (100-m-wide) pasture paddocks (green) are characteristic of modern dairy farms in Canterbury, and the larger paddocks in the yellow-red colours are cropping paddocks. Rivers, towns, forests, sea, and hill-country have been masked out (white). The full map area contains some 58 000 paddocks.

The land use picture in Canterbury is complex, with a huge range of grain and seed crops, forages, and pastoral farming. The new methods enable broad land uses to be mapped: permanent pasture, summer arable crop, winter forage crop, and bare soil (for an extended period). These can then be further broken down into crop groups (e.g. grain crops, grass seed + barley, maize for silage, peas + brassica/radish seed, forage brassica) and by timing (e.g. planted in early autumn, late autumn, winter, spring, or summer).

Crops often cannot be identified reliably from an individual satellite image because, at any given date, many look very similar – green vegetation with only subtle differences. Therefore, we use a time series of satellite images to track the timing of planting (bare soil), full leaf cover, and harvest (stubble or bare soil) in each paddock, and then refine the identification using the spectral appearance when the crop is at full leaf cover. In the case of permanent pasture (or lucerne), we expect the paddock to remain largely green over at least 12 months, with occasional, short dips in 'green-ness' due to grazing, mowing, or lack of moisture.

The researchers believe these land 'use' classes are more relevant to questions of environmental impact than are specific 'crop' classes. For example, oats may be grown as a summer arable crop for grain, OR it may be grown as a winter livestock forage. The possible impacts on soil and/or groundwater of a summer arable crop are quite different from those of a winter forage crop, so there is more value in this distinction than in specifically knowing that the crop is oats.

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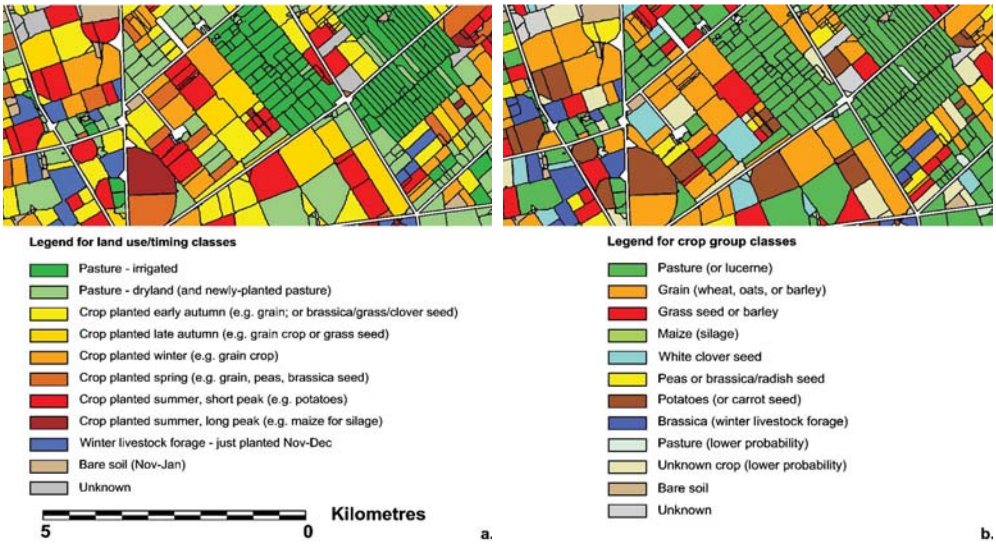

FIGURE 2 Enlargement of the Summer 2011/12 classification, showing paddock-level detail, and the two types of information produced by the classification: (a) land use timing, as also shown in Figure 1; (b) crop group.

Climate change impacts on ecosystem services

Research is showing that climate change has and will continue to alter provision, timing, and location of ecosystem functions across landscapes. These changes will impact on the benefits people get from nature, in both positive and negative ways. For example, climate change can alter primary production (increasing or decreasing biomass production of crops, pastures, forests) and influence future land-use changes. But it can also increase pest invasion, fire and erosion risks, and change water supply. Landcare Research, in partnership with other Crown Research Institutes and universities, is involved in several research initiatives looking at climate change impacts on ecosystems and their services.

First, we are investigating the likely impact of increased storminess on soil erosion and sedimentation in rivers. This work has led to an Envirolink project with Horizons Regional Council to look at the impacts of climate change on its Sustainable Land Use Initiative. This programme is designed to reduce soil erosion and sedimentation in rivers in the Manawatu-Wanganui Region through the implementation of farm plans. These farm plans involve a mixture of soil conservation tree planting, afforestation, and land retirement.

Second, we are developing case studies (Climate Changes Impacts and Implications research programme) to understand likely impacts and implications of future climates. Case studies include alpine, upland, lowland, estuarine and marine areas. In the lowland environment, consensus was reached to choose the lower Kaituna catchment in the Bay of Plenty for its mosaic of land uses (kiwifruit, dairy, forestry, cropping), natural ecosystems (native forests, wetlands), and issues of urban growth, land-use intensification, and the impact of sea-level rise on coastal settlements. Researchers from Landcare Research, NIWA, AgResearch, Plant & Food Research, Scion, Motu, and Victoria University of Wellington are teaming up to model various aspects of this complex system and to give insight into potential futures for this area. For instance, we are looking at climate change and associated land-use change impacts on primary production (maize, pasture, wood), water supply, pest and fire risks, erosion, and ecological integrity of wetlands. We are also engaging with local stakeholders through workshops to understand their issues and how our research outputs could help inform their decisions.

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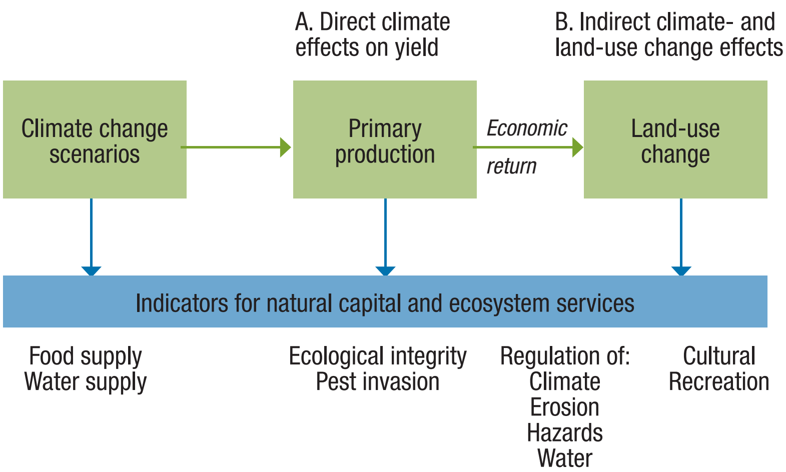

FIGURE 1 Modelling approach for assessing climate change impacts on ecosystem services.

New Zealand's planted forests provide important services to society

New Zealand's 1.72 million hectares of planted forests constitute a productive ecosystem mainly recognised for the provision of wood and fibre. The New Zealand planted forest ecosystem is also increasingly recognised for its contribution to the country's economic prosperity, environmental conservation and human well-being. The above services can be categorised into four groups: provisioning, regulating, cultural, and supporting services (Figure 1).

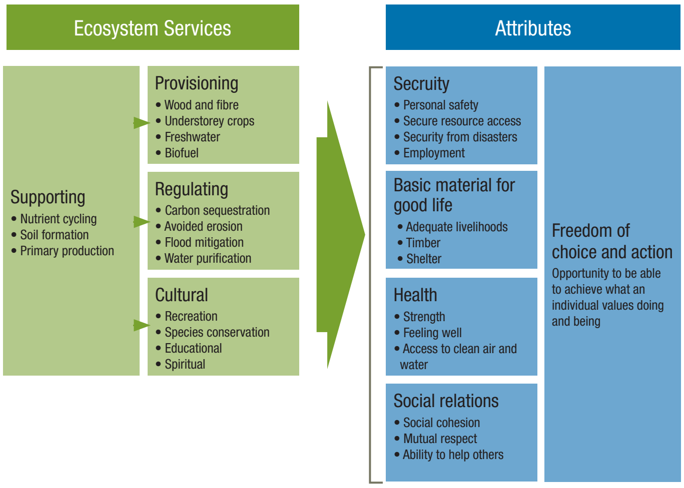

FIGURE 1 Ecosystem services provided by New Zealand's planted forests (adapted from the Millennium Ecosystem Assessment (2005))

Provisioning services refer to the products derived from a planted forest ecosystem such as logs, processed wood, fibre, and fuel. Forest products contribute directly to gross domestic product (GDP) mainly through export earnings and domestic sales. Planted forests also provide a place to grow high value crops, for example, simulated wild ginseng is grown underneath pine forests in the Central North Island region. Ginseng is a Chinese medicinal herb that has been used for thousands of years. The simulated wild ginseng is organically grown and dug by hand. This makes it labour intensive to produce, therefore creating employment opportunities in the region (Scion 2013). Planted forests also provide local benefits such as water filtration to help provide drinking water to some rural communities and raw materials that can be used to generate heat and power for other primary industries.

Regulating services are 'the benefits obtained from the regulation of ecosystem processes'. Planted forests provide regulating services such as reducing erosion, carbon sequestration, improved water quality, and flood mitigation. For example, a site in the central North Island can sequester 918 tonnes of carbon dioxide per hectare over a 28-year harvesting rotation, including above- and below-ground biomass and the litter layer. Studies provide strong evidence that planted forests stabilise soil (especially on steep slopes) and consequently reduce soil erosion.

Source: Rotorua Mountain Bike Club Facebook page

FIGURE 2 Mountain biking in the Whakarewarewa forest in Rotorua.

Cultural services are the non-material benefits obtained from an ecosystem, such as recreation, aesthetic experience, spiritual enrichment, appreciation of biodiversity, and conservation. Several planted forests in New Zealand provide recreational opportunities to the local people and tourists who visit them, including walking, mountain biking, horse riding, running, and exercising dogs (Figure 2). Some businesses have invested in new facilities for four-wheel driving, paintballing, and flying-fox adventures in the Woodhill Forest, a planted forest in West Auckland. This 12 500-hectare planted forest is also popular for hunting, horse riding and motocross.

Supporting services are the biological, chemical, and physical processes that underlie the provision of the other three groups of services described above. Examples of these supporting services include soil formation, nutrient cycling, water regulation, and oxygen production. Supporting services indirectly affect society, as their impacts on people occur over a very long time. These services can be quantified and valued, but care should be considered in adding these values with the first three ecosystem services (provisioning, regulating and cultural) to avoided double counting.

New Zealand's planted forest ecosystem is more than just a source of products such as timber and pulp that have market values. It also offers other important services to society such as recreation, reduced erosion, and habitat provision that do not have market values. The book chapter by Yao et al. (2013) highlights that planted forests provide both market and non-market values and that these values should be recognised and sustained in order to enhance human well-being and conserve the environment while improving economic prosperity.

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Mānuka and organic waste – uncovering a potential partnership

The ever-increasing need for environmentally sound waste disposal has put pressure on society to investigate the recycling of organic wastes such as biosolids. Biosolids, a product of human excreta, are carbon-rich and contain high concentrations of valuable nutrients that can have high fertiliser value. They are effective for rebuilding degraded soil, e.g. in land converted to pine forests. Disadvantages are that biosolids can be a vehicle for numerous contaminants, including human pathogens, and this helps to explain why in New Zealand most biosolids are placed in landfills. Forests are considered suitable for receiving biosolids because this land use is not directly linked to the human food chain, and applications can be made year-round.

Potentially, plants with antiseptic qualities could be grown in waste-amended soil to mitigate microbial contamination. Although there is much research into the source of the antimicrobial activity of oils and honey from New Zealand native *Leptospermum scoparium* (mānuka), there have been no studies into the impacts of these antimicrobial properties on the wider soil environment. Preliminary studies conducted by the Centre for Integrated Biowaste Research (CIBR) indicate inhibition of pathogen growth and accelerated die-off of pathogens when in contact with mānuka components. In the current project we have been further investigating the potential for antimicrobial properties of mānuka to mitigate environmental contamination from biosolids-borne pathogens in situ.

Mānuka is already widely used in land restoration projects in New Zealand due to its hardy, tolerant nature. Both mānuka and a morphologically-similar species, kānuka (*Kunzea ericoides*), are pioneer species that colonise disturbed environments in New Zealand and South Australia. This, together with its antimicrobial properties, makes establishment of mānuka plantations a viable option, and if achieved on low quality or degraded land, where biosolids can be recycled, then this system has added potential to generate an economic return.

Pot trials were established containing perennial ryegrass (*Lolium perenne*), mānuka and kānuka (Figure 1), which were subsequently spiked with the pathogen indicator species *E. coli* and *Salmonella*, in two separate experiments. Die-off of these pathogens in the soil underneath growing plants was assessed over time. Results show that *E. coli* and Salmonella survival is reduced in soil underneath mānuka (and kānuka) when compared to a pasture control. Further , the time taken to achieve 90% reduction in *E. coli* (decimal reduction time) was just 5 and 8 days for kānuka and mānuka respectively compared with 93 days for rye grass. These observed inhibitory effects may be due to mānuka antimicrobial properties, the nature of which requires further investigation. In addition to this work, CIBR is currently investigating the mechanisms behind how mixing biosolids with degraded soils can improve mānuka growth, as well as the effects of mānuka (and other indigenous plants) on nitrogen cycling and other processes in soils.

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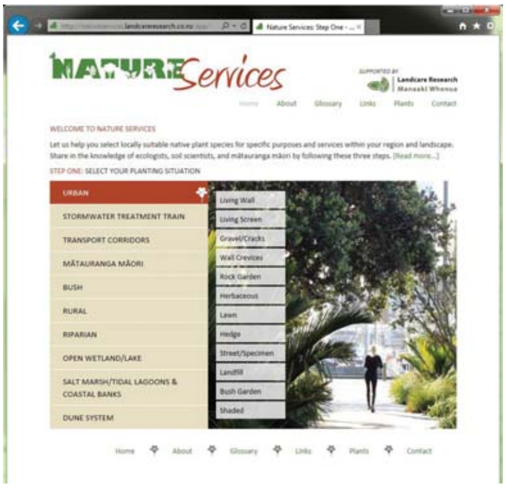
FIGURE 1 Potted plants of perennial ryegrass (*Lolium perenne*), mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea ericoides*) used to investigate die-off of pathogens in soil.

Nature services: a new green tool box

A new decision support tool for selecting plants for restoration and landscaping in New Zealand is now up and running. NZ Nature Services is a one-stop shop for choosing native plants that are regionally, environmentally, and purpose appropriate. Plant selections are initially prioritised by 'use': shelter belts (including under irrigators), stormwater mitigation, cultural uses, dune stabilisation, riparian protection, or landscaping (including native lawns, noble trees and roof gardens). Plants are then tailored to a location by clicking on a zoom-able map. This defines the Ecological Region, hence the naturally occurring native plants of the area.

NZ Nature Services recognises that soil conditions underpin successful plant selection. Species are matched to soils using three methods. First, the 'clicked' location identifies the likely Soil Order (in rural areas). Second, each use has a typical cross-section diagram identifying zones with similar soil drainage, frequency of flooding or disturbance, level of exposure or shelter, and overriding functional needs. For example, a stormwater swale has an 'edge' zone abutting a road (requiring short plants needing little edge trimming) and a wet or dry swale 'base' through which water periodically flows (requiring dense filtering plants). Third, each plant is given a Wet (poorly drained), Mesic, or Dry ranking. This allows the user to cross-check the generated plant list with site drainage. Soil Order is disabled for stormwater 'uses' and most urban landscaping, recognising the prevalence of Anthropic Soils in these situations. NZ Nature Services also has weblinks to technical guides and brochures produced by councils, for example, *Plant Me Instead* pamphlets and guides to riparian restoration, shelter belt planting and stormwater treatment devices. Bringing this information together highlights the variety of ecological (nature) services that native plants can provide. Species and uses are linked to New Zealand databases and on-the-ground experience in which Landcare Research and other publicly-funded agencies have invested over many decades. For example, information on Māori customary plant uses for food, fibre, construction, and medicines comes from the fascinating Ngā Tipu Whakaroanga database.



NZ Nature Services aims to increase the values and success of planting efforts, and expand the conventional range of native plants used in restoration and landscaping. Over 1000 native species are included, compared with 350 (mainly woody) species in its predecessor, the Green Toolbox. Combined with NatureWatch NZ (for species recording, identification and performance monitoring) and Nature Space (support for restoration groups), the information generated by NZ Nature Services will refine people's familiarity with biodiversity, place-based plant choices, planting techniques, and maintenance.

NZ Nature Services is prototype software supported by Landcare Research core funding, Selwyn and Nelson district councils, and Canterbury, Horizons, and Wellington regional councils. Feedback has been fantastic, assisting the development of the product. More funding will help refine the website and its information, e.g. tailoring sections to specific users. Priorities include:

- Populating case studies, identifying demonstration sites nationwide that people can safely visit
- Enhancing information on each Factsheet with more web resources, hotlinks and FAQs
- Enhancing the diagrams of each use (ecosystem service).

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