

Ecosystem Services in Productive Landscapes

Mariska Anderson, Anna-Marie Barnes and Steve Wratten
Bio-Protection Research Centre, P.O. Box 84, Lincoln University, Lincoln 7647
New Zealand.

New Zealand's emerging agricultural pattern and land-use change.

It is considered that New Zealand has the greatest rate of land-use change in the Western world (Penman 2008 pers. comm.). Although New Zealand's land-use changes may be dynamic, reflecting overseas market needs in a business-agile way, the increase in agricultural intensification and in the diversity of crops grown over the last four decades is compounding the strain on the provision of ecosystem (nature's) services (Costanza 1997, Daily *et al* 1997) that are necessary for long-term sustainable and profitable production. Higher animal stocking rates and yields, conversion to more intensive forms of agriculture, conversion to forestry and deer farming, increased mechanisation and increased use of fertilizers, pesticides and feedstock inputs are all indications of this steady trend (MacLeod *et al* 2006).

In particular, the last decade has seen a rise in conversion from sheep and beef to dairy farming, a much more intensive activity. The dairy industry is currently striving to increase productivity by 4% per annum, to achieve a 50% increase in production by 2015 (MacLeod *et al* 2006). This policy depends increasingly on subsidies; more fertilizer, water, supplemental feeding – which may not be sourced from within the farm, or even from within New Zealand.

This current trend for intensification may not be ecologically viable for the long term. Increased carbon dioxide emissions from higher fossil fuel use in mechanised intensive farming practices cannot be easily offset (Rhodes *et al* 2007). Conversion of rough grassland to 'improved pasture' has seen losses in biodiversity. Biodiversity is very valuable to agriculture, although the exact figure is difficult to ascertain (Costanza *et al* 1997, Sandhu *et al* 2007, Tilman *et al* 1996).

New Zealand agriculture is diversifying as well as changing, examples being an increase in land use for vines and other specialty crops. Seed crops such as radish, have seen areas such as the Canterbury plains change markedly (MacLeod *et al* 2006). Forest plantations have seen a 110% increase in land area since 1980 (Brockhoff *et al* 2008). This increase in forestry (mainly *Pinus radiata*) may have some biodiversity benefits.

Plantation forestry in New Zealand

Worldwide, deforestation is the major cause of biodiversity loss. More than 50% of known terrestrial animal and plant species live in forest habitat, 13 million hectares of which are lost to agriculture annually (Brockhoff *et al* 2008). Plantation forestry has been suggested to be a 'lesser evil' in agricultural terms as it typically has a higher conservation value than intensively managed agricultural land – it provides habitat to generalist species and accelerates native forest succession at previously deforested

sites where persistent ecological barriers to succession might otherwise preclude reestablishment of native species. Plantation forestry can contribute to biodiversity conservation by providing habitat supplementation, forest habitat species may find shelter and food in exotic as well as native forests. Plantation forests can also provide connectivity between fragmented natural habitats and buffering edge effects (Brockerhoff *et al* 2008). In New Zealand, the Forest Accord (1991) prevents plantation forestry from being established in place of natural forest or areas being considered for protection, so in theory plantation forestry is seen as an improvement (environmentally) on whatever type of industry was practised on that land previously.

Unfortunately, most of New Zealand’s plantations are exotic species, predominantly *Pinus radiata*, (Monterey Pine) as it grows quickly and has many uses (Brockerhoff *et al* 2008). The USA has a similar proportion of its land area forested with *Pinus* species, but these are largely native to the USA.

Comparison of Plantation forestry in NZ and USA

	Forest cover	% land forested	Area	% Plantation forest	Million ha in <i>Pinus</i> spp
NZ	8.3 mill ha	31	1.8 mill ha	22.3	1.6
USA	303 mill ha	33	17.1 mill ha	5.6	15

Table 1. Adapted from Brockerhoff *et al* 2008.

Aside from the indications that plantation forestry may have some ecological benefits, in New Zealand it is still largely a monoculture of exotic flora and has implications for biodiversity and subsequent economically valuable ecosystem services that are lost when biodiversity is lost.

Over 30% of New Zealand land is publicly owned, and this degree of crown control has great benefits for biodiversity (Penman pers. comm. 2008). While our ‘clean and green’ image may no longer be deserved anymore, it may be achievable again, particularly given the new environmental awareness of sustainability in today’s markets. In October 2007, Stuart Smith, Chairman of New Zealand Winegrowers, referring to pesticide residues in wine, wrote in New Zealand Winegrower magazine: ‘...One day, and I believe that day is not too far away, the market will say no residues. No residues!’

New Zealand tourism and agriculture markets and the ‘clean and green’ image.

Tourism in New Zealand had an economic value of NZ\$8.3billion in 2006, a figure which continues to rise, and relies heavily on our image of being ‘100% Pure’ (Ministry for the Environment 2007). The country’s anti-nuclear stance, scenic imagery of Lord of the Rings movies, outdoor pursuits and natural environment are marketable assets for the tourism industry. Agriculture is

also worth a huge amount to our economy, agricultural exports amounted to NZ\$16.1 billion for 2007 (Ministry for the Environment 2007). Unfortunately, New Zealand's agricultural practises do not always support the image of being clean and green, and in some cases are particularly detrimental.

In 2008 for example, beef contaminated with the pesticide endosulfan was exported to South Korea, New Zealand's second largest beef market. This occurred just one week after the Environmental Risk Management Authority (ERMA) approved the use of the chemical for fodder crops (crops to feed livestock), and to kill earthworms in sports fields, parks and airport areas (Green Party Media Release 2007). Media coverage associated with these events can be damaging to the tourism industry.

"New Zealand sells its produce with a clean, green, pure, natural, branding image that is contradicted by actual practices, such as using one of the dirtiest pesticides in the world in our food supply. Sooner or later the global markets are going to catch on to this hypocrisy and New Zealand can expect a much tougher time making the image stick," said Dr Meriel Watts of Pesticide Action Network Aotearoa New Zealand (PANA NZ) (Joint Media Release – PANA NZ and Soil and Health Association NZ).

Endosulfan is currently banned or heavily restricted in more than 50 countries (Green Party Media Release 2007), including all the European Union countries. It is now being re-evaluated for its safety for use as a pesticide in New Zealand following reviews currently under way by the European Union (EU), US Environment Protection Agency (EPA), the Australian Pesticides and Veterinary Medicines Authority (APVMA) and the Canadian Pest Management Regulatory Agency (PMRA) (ERMA Endosulfan Reassessment report 2007). It is considered acutely toxic to humans, and very toxic to aquatic life.

New Zealand's growing popularity as a wine-producing nation could also be come under fire from criticism of the 'clean and green' image in the media, based on the rates of pesticide and herbicide use in viticulture.

For example, vineyard posts in New Zealand are routinely treated with a copper-chromium-arsenic mixture, known as CCA. This is a common practice and most non-organic vineyards use posts treated with this complex. The posts in each hectare of vineyard carry 12, 21 and 17kg of copper, chromium and arsenic respectively, based on a density of approximately 580 posts per hectare. Long-term simulations, with post-replacement, predicted that close to the post, and immediately under it, the concentration of arsenic in the soil would, after about 25 years meet, or exceed, the National Environmental Protection measures (NEPM)(1999) guideline values of 100 mg/kg (Vogeler 2005).

The use of toxic chemicals to manage pests, weeds and diseases has become more intensive as farming has. There was an increase of more than 25% in pesticide use between 1999 and 2003 in New Zealand and that number is expected to continue to rise (Manktelow *et al* 2004).

Human impacts on the environment

The effects of humans on the environment have been escalating for the last 300 years, which is not surprising given that the population has increased tenfold over that period and 30 – 50% of usable land is now exploited by humans (Crutzen 2002).

Examples include increased carbon dioxide, methane from the 18th century (Crutzen 2002) and atmospheric lead pollution from Greco-Roman times were being found in polar ice caps (Paula *et al* 2003), indicating how quickly and long-lasting human effects can be. Since those times, humans have placed more and more stress on the environment; 160 million tonnes of sulphur dioxide are released into the atmosphere each year (more than twice the natural amount), more nitrogen is applied as fertilizer in agriculture than is fixed in terrestrial ecosystems yearly, carbon dioxide emissions are over a third higher than in pre-industrial times, and are expected to double by the end of the century and methane emissions have already doubled since pre-industrial times (Zalasiewicz *et al* 2008). Acid rain, photochemical smog, climate warming (with increases of 1.4 – 5.8 degrees Celsius by the end of the century), and extinction rates up to 1000 times faster than those which occur naturally are all consequences of these imbalances that are caused by only 25% of the population (Crutzen 2002).

The ‘Anthropocene epoch’

Human effects may exacerbate global warming so that high temperatures not encountered since the Tertiary epoch may prevail and the already accelerated extinction rate may see extinctions on the same scale as the last major extinction event at the turn of the Cretaceous and Tertiary epochs (K-T boundary) (Zalasiewicz *et al* 2008). Such profound effects which have been brought about by humans have led scientists to call this, the end of the Holocene epoch, the ‘Anthropocene’, and geologists are currently debating formalising the name (Crutzen 2002, Zalasiewicz *et al* 2008).

The combination of extinctions, global species range shifts, replacement of natural plant and animal life and habitat with agricultural monocultures means that current levels of biodiversity are very quickly declining (Tilman 2002). These effects are permanent, as future evolution will take place from surviving and ‘anthropogenically relocated’ stocks (Zalasiewicz *et al* 2008). ‘New plant and animal species are emerging, but not fast enough to make up for human activity – that’s a 1-4million year long process – we are causing species to be lost at rates 1000 times faster’, Professor Tilman of the University of Minnesota states (MPR webpage 2005).

Human control over ecosystems has led extinction processes to develop extremely quickly, causing clear declines in biodiversity throughout the world

(Martens 2003). Human needs for food, energy, water and fuel can permanently reduce ecological capital such as varied species and habitats, so the quality and quantity of natural systems is much reduced, and this has implications for agriculture. 'Greater biodiversity generally leads to the more efficient use of the available natural resources because there is more chance that species will be present that are able to cope with specific circumstances in the habitat' (Martens 2003).

As long as agriculture replaces biodiversity rather than incorporating it, it will remain unsustainable. Sustainable healthy crop yields are only attainable from the most appropriate equilibrium between crops, soils, nutrients, the sun's energy, water and coexisting organisms. Nicholls and Altieri (2004) see the 'agroecological' objective as being 'balanced environmentally sustainable yields, biologically mediated soil fertility and natural pest regulation', and advocate exploiting the complementation of functional biodiversity that delivers ecological services, which naturally support agroecosystem processes that 'underlie agroecosystem health'.

Current practises and implications for the future in agriculture.

Humans use more than a third of the total productivity of terrestrial ecosystems, more than half of the usable freshwater supply, and increase the amount of nitrogen and phosphorus in the environment by twice as much as the amount that occurs naturally. (Tilman *et al* 2001).

The implications of the subsidies (for example irrigation, fertilizers and pesticides) that are added to agricultural systems are both positive, in that they increase production, and negative in that they have detrimental impacts on ecosystem services. It follows that ecosystems services may then not be able to support agricultural production, so that more and more subsidies are needed.

Subsidies in agriculture include human inputs to aid management, where the agricultural environment does not supply the ecosystem service. Irrigation increases salt and nutrient loading of downstream water systems, and soil salinity. Phosphorus causes eutrophication from fresh waters through to oceans. Increased nitrogen increases concentrations of the greenhouse gas nitrous oxide, increases nitrogen oxide, a major pollutant in tropospheric smog, causes soil and water acidification and cycles through to the atmosphere as ammonia and is then deposited regionally. These effects have impacts on plant and animal life and biodiversity is lost through reduced populations, and extinctions. Both nitrogen and phosphorus enter surface and groundwater supplies from agricultural run-off of fertilizer and animal wastes. The hypoxic dead zone of the Gulf of Mexico was probably caused by agricultural nutrient pollution (Tilman *et al* 2001).

Pesticides also subsidize agriculture, but high use of chemicals is detrimental to the functioning of ecosystems services, for example natural enemies of

pest species (Wratten pers comm. 2000) and may have implications for human health.

The next 50 years will probably see a demand for food by a wealthier and 50% larger population (Crutzen 2002, Tilman *et al* 2002). If past and current trends continue without improvements to existing practices, 10^9 hectares of natural ecosystems will have been converted to agriculture by 2050 accompanied by an almost 3-fold increase in nitrogen and phosphorus eutrophication of most large bodies of water and of use of pesticides (Tilman *et al* 2001). The resulting ecosystem simplification would cause extinctions and huge losses of biodiversity and ecosystem services.

Ecosystem services benefits to agriculture.

Ecosystem services (ES) are the benefits people obtain from ecosystems. Costanza (2008) sees this as a suitably broad definition as it encompasses both those benefits perceived and those not.

These ES have beneficial impacts on the environment as a whole and have particularly potent benefits to agriculture. For example, forests can minimise flooding by slowing water discharge and snowmelt, moderate local climate and remove and store carbon dioxide (Brockerhoff *et al* 2007, Tilman *et al* 2001, Tilman *et al* 2002). Both forests and grasslands create and regenerate fertile soils, degrade plant litter and animal wastes and purify water (Tilman *et al* 2002). Intact ecosystems provide potable water for 'little more than the cost of its extraction' (Tilman *et al* 2002).

Agricultural practices can make use of these ecosystems services to great benefit for agricultural production and long-term sustainability (Tilman *et al* 1996). Integrated pest management (the use of natural enemies and crop diversity), application of site and time appropriate amounts of agricultural chemicals and water, use of cover crops on fallow lands and buffer strips between cultivated fields and drainage areas and appropriate deployment of more productive crops can increase yields while reducing water, fertilizer and pesticide use and movement of non-agricultural habitats (Nicholls and Altieri 2004). Preservation and restoration of wetlands and riparian zones (interface between land and streams) can remove nitrogen by denitrification before it pollutes watercourses and can trap phosphorus (Tilman *et al* 2001).

The capability of remaining natural lands to supply ES and preserve biodiversity could be increased by planning and location of agricultural development, thereby saving biodiversity 'hot spots', minimise fragmentation of habitats, and maximise the range of ecosystem types preserved (Tilman *et al* 2002).

Biodiversity loss impacts ecosystem services functioning.

Land use and habitat conversion are huge factors in loss of biodiversity. Land converted to agriculture to meet global food demand comes from forests, grasslands and other natural habitats (Tilman *et al* 1996).

Ecosystems functioning and sustainability most likely depends on biodiversity (Tilman *et al* 1996). A study by David Tilman, published in Nature in 1996 demonstrates elegantly the relationship between biodiversity and functionality in a grassland ecosystem. Tilman showed that ecosystem productivity increased significantly with higher plant diversity, soil mineral nitrogen was utilised more, and there was less nitrogen leaching from the ecosystem. In the control plots, in nearby native grassland, the same patterns were found, further evidence for a hypothesis of increasing biodiversity supporting increasing productivity and sustainability. Tilman also points out that conversely, 'these results demonstrate that the loss of species threatens ecosystem functioning and sustainability'.

Without biodiversity within ecosystems, ecosystem services may function in a limited capacity, or not at all. Without ecosystems services, agriculture needs more substitution inputs such as fertilizer, pesticides, irrigation, and other such human-mediated inputs, which are expensive and not likely sustainable for the long term (Tilman *et al* 2002).

The economic value of ecosystem services on farmland

In 1997, Costanza *et al.* calculated the ecosystem service (ES) provision per hectare of croplands worldwide to be US\$92/ha. Costanza accepts that this is an underestimate, because of limited data at the time of writing – cropland was one of the biomes for which already-undertaken valuation studies were not available. Even so, when this figure (\$92/ha) is compared with other totals for biomes represented in the table in Appendix 1, it remains a seemingly insignificant number – it is the largely unmodified biomes that appear to be the major providers of ES.

"Preservation of what we already have has a critical role to play in the conservation of diversity, but it is clear that by itself preservation is not an adequate strategy for conserving diversity" Wilson ed. (Jordan, 1988).

As it has been previously stated, loss of ES is a consequence of loss of biodiversity.

Martens *et al* (2003) stated that there are two main processes that result in biodiversity loss: a reduction in the size of natural areas and a change in ecosystem conditions. It is clearly apparent that modern agricultural practices affect both of these.

Recent research carried out by Sandhu *et al.* (2007) into the economic value of non-tradable species on farmland at Lincoln University supports Costanza's views that his resource-economics valuation of cropland ES was

conservative. Sandhu's research assigns average total values of the ES provided by conventional agricultural land at US\$231 billion.

Improving ecosystem services in agriculture

There is increasing pressure to improve ES worldwide as it is predicted that the world population will reach nine billion by 2040 (<http://www.census.gov>). Tilman *et al.* (2002) stresses "New incentives and policies for ensuring the sustainability of agriculture and ecosystem services will be crucial if the human populations are to meet the demands of improving yields without compromising environmental integrity or public health".

The challenge currently facing society is that of feeding the world's rapidly increasing population in a sustainable manner. How can this be achieved in a way that allows ecosystem services to improve and productivity levels to be maintained or increased? It is preferable that this is accomplished without a corresponding increase in the area of land under agricultural production if we wish to 'save land for nature'. Most of the best quality land is already used for agriculture, so any further expansion of this area would spill into marginal land already incapable of sustaining high yields and would degrade the value of this marginal land further (Tilman *et al.* 2002).

Modern conventional agriculture relies on high levels of inputs including sizeable quantities of synthetic pesticides and fertilisers and is therefore dependent on fossil fuels to provide these and power farm machinery necessary for large scale production. The sustainability of the levels of synthetic inputs currently required by conventional agriculture is doubtful in the current economic/oil resource use 'climate'. Fertiliser prices have increased rapidly of late in New Zealand in line with surging fuel prices. For example, one tonne of urea from Ravensdown, the largest fertiliser supplier in New Zealand cost \$286 in February 2000 (Lincoln University Financial Budget Manual, 2000), \$699 in April 2008 (Lincoln University Financial Budget Manual, 2008) and \$929/tonne in August 2008 (<http://www.ravensdown.co.nz>). Subsequently, conventional systems have correspondingly high production outputs.

In comparison, organic farming systems avoid the use of any synthetic pesticide or fertiliser inputs and instead focus on the use of a small number of natural inputs (green and animal manures, naturally occurring mineral fertilisers and biological control of plant pests and diseases), allowing the system to enhance and retain natural soil fertility, biodiversity and ES. Consequently, it is interesting to note the average total value of ES provided by land under organic agriculture: US\$431 billion (Sandhu *et al.* 2007). When this figure is compared with that calculated for conventional agriculture (US\$231 billion), it is apparent that the high yields achieved through conventional farming practices come at a cost – suppression of the ability of farmland to provide valuable ES.

Table 2. Ranges of inputs and outputs for conventional and organic arable cropping systems in New Zealand (Sandhu *et al.* 2007).

Inputs (ha⁻¹ yr⁻¹)	Conventional agriculture	Organic agriculture
Energy (GJ ha ⁻¹ yr ⁻¹)	5-9.8 ²⁵	3.3-7.8 ²⁵
Industrial N fertilizer (kg)	30-80 ²⁴	-
Insecticides (kg)	0.9-1.2 ²⁴	-
Fungicides (kg)	4.3-5.5 ²⁴	-
Herbicides (kg)	0.2-0.8 ²⁴	-
Irrigation (mm)	25-60 ²⁴	16-30 ²⁴
Outputs (ha⁻¹ yr⁻¹)		
Energy (GJ ha ⁻¹ yr ⁻¹)	58-109 ²⁵	48-79 ²⁵
Grain (t dry matter)	5-8.5 ²⁴	3.5-6 ²⁴

Table 3. Mean and range of economic value of ecosystem services and crop value under conventional and organic agriculture along with global estimates for arable area (Sandhu *et al.* 2007).

	Conventional agriculture	Organic agriculture
Biological control (\$ ha ⁻¹ yr ⁻¹)	0(0)	99 (66-207)
Nutrient mineralisation (\$ ha ⁻¹ yr ⁻¹)	144 (45-350)	173 (25-425)
ES Value (\$ ha ⁻¹ yr ⁻¹)	150 (48-355)	280 (92-570)
Crop value (\$ ha ⁻¹ yr ⁻¹)	812-2380	1176-3500
Global estimates (1.54 x 10 ⁹ ha)		
Total ES value (US \$ x 10 ⁹)	231 (74-547)	431 (142-878)

Strategies for implementing and improving ecosystem services

Organic agriculture, a production system often attracting ill-informed criticism of its productivity and scientific credibility, is currently experiencing a rapid period of development worldwide. *The World of Organic Agriculture – Statistics and Emerging Trends (2007)* states that there are currently 633,891 organically managed farms in 120 countries – this equates to 31 million hectares of agricultural land currently under organic management, which constitutes 0.7% of the area of agricultural land in the countries surveyed. This may seem an insignificant figure, but it continues to increase. For example in North America since the end of 2004 there has been an increase in land area under organic production of 500,000ha – an increase of almost 30% (Willer and Yuseffi 2007).

International trade in organic products was valued at US\$33 billion/year in 2005, and was expected to reach \$40 billion a year later. Europe is the largest market, spending \$17 billion, followed by the USA contributing over \$15 billion (Middleton 2008)

In 2007 New Zealand had 820 certified organic farms with 45,000 ha under organic production – equivalent to 0.3% of the total area under agricultural production (Willer and Yuseffi 2007). New Zealand's organic exports continue to increase – worth NZ\$71 million in 2002 and \$120 million in 2007. The number of licensed organic producers also increased from 335 in 1997 to 860 in 2007 (Grice *et al.* 2007).

National research conducted by the University of Otago in 2007 calculated the area under organic production in New Zealand to be significantly higher than Willer and Yuseffi's research at 68, 883 ha, a 455% increase since 1997. The NZ domestic trade in organics was calculated to be worth NZ\$210 million, a market share of 1.1%. This is relatively low when compared with that of

countries with a high organic consumption market such as Denmark (3% market share) (Grice *et al.* 2008)

There are many benefits for organic producers in New Zealand. Multi-national dairy corporation Fonterra pays an organic premium of \$1.05 per kilogram of milk solids and \$0.45/kg/ms while farms are in conversion to organic production. Growers of conventionally produced apples in New Zealand have had economic difficulties recently. In contrast, growers of organic apple growers have generally been able to keep a positive cash flow and their product attracts a 33% premium over conventional fruit. Producers of conventionally-farmed lamb have also faced economic difficulties recently while organic lamb returned a 100% premium over conventional in 2007 (Middleton *pers. comm*). Orchard-gate returns for kiwifruit are currently \$24,100/ha and \$34,662/ha for organic fruit (Organics Aotearoa New Zealand industry factsheet).

Gavin Middleton, the executive officer of OANZ endorsed the marketability, integrity and level of consumer confidence in organic products in a speech given to the Fonterra Organics Conference held in Matamata in June 2008, the week following the 2008 national Fieldays at Mystery Creek, Hamilton. *“Organic production is the only eco-verification system which is instantly recognised and retains its value internationally”*

In a press release on 11 June 2008 entitled *“Science key to unlocking potential of primary sector”*, the CEO of AgResearch, Dr Andrew West commented that New Zealand needs to move towards “high value add and high value capture” as it is obvious that our current production levels cannot feed the world. To many, organic production fits naturally in line with these ideals. Added value in this context not only means such concepts such as functional foods (also known as nutraceuticals, which are foods or food ingredients which may provide a health benefit beyond that expected from the nutrients it contains, for example having a cholesterol-lowering effect (Savage 2005) but must include science-based evidence of real sustainability in the production of the food, be it a vineyard, kiwifruit orchard or a sheep station. Ironically, this requirement is driven almost exclusively by overseas markets. In the European Union in contrast, concern for the loss of revered 1000-year-old landscapes and of the fauna and flora associated with them are major influences on agricultural policy. For example, the in the United Kingdom, the Ministry of Agriculture and Fisheries no longer exists but has been subsumed into the Department for Environment, Food and Rural Affairs (DEFRA).

Intensification

An ES increase should improve farm sustainability and productivity, with positive flow-on effects relating to the marketability of farm produce. However, as farming intensifies (e.g. higher inputs and yields/unit area) enhancing ES may have to be restricted to un-cropped farm areas. Most farms have areas of non-crop woody plants – usually in the form of intentionally planted shelter belts, but many have areas of remnant native vegetation. As the value of retaining and enhancing these areas is publicised, the level of understanding of the links between the ecological values and the

costs and benefits of native plant remnants will increase. Research carried out in New South Wales, Australia, used farm survey data and GIS to develop a model incorporating agricultural and biophysical attributes to explain pasture productivity. Results from this research indicated that the value of pasture output per farm may increase by having a proportion of land under woodland vegetation. The gross value of pasture output was at its highest level when the proportion of tree area across the farm was at 34% (Walpole 1999).

The role of biodiversity in relation to the stability and productivity of agricultural ecosystems must not be ignored. The idea that more diverse plant ecosystems are more stable was investigated by Charles Darwin in the *Origin of Species* and research carried out by Tilman *et al.* (1996) has shown that the productivity of grassland plots increases with increasing plant diversity, as does the utilisation of soil nitrogen – an important factor to consider when attempting to reduce nutrient leaching and oil-based inputs.

The Game and Wildlife Conservation Trust in the United Kingdom (<http://www.gct.org.uk>) suggests a number of easy-to-implement strategies for conserving and enhancing biodiversity on farmland. Buffer strips, which are uncultivated grassy areas can help reduce soil run-off and therefore can be part of a soil management program. They are also useful for protecting streams, ponds and ditches from run-off. Conservation headlands involve a reduction or complete avoidance of pesticide use in the 6m margin around crops (the headlands), which results in an increase in floral diversity and insect abundance, possibly enhancing biological control prospects. However, this is an un-directed approach to enhanced plant diversity as the plant species which appear in the headlands, as well as their density and their ES provision are largely unpredictable. Field corners, areas of cropping land which tend to be poorly utilised and unproductive (as they are awkward to work and the soil around them is prone to compaction by machinery) can be taken out of production and “cultivated” as areas of wildlife habitat.

Extensification

Extensification is another method in which the sustainability and productivity of agricultural production systems can be improved. This is achieved by implementing protocols for ES enhancement *within* the cropped area. Examples of such practices include the use of beetle banks (Landis *et al.* 2000, Thomas and Marshall 1999) in cereal crops, strips of floral resources such as buckwheat and native plant strips in vineyards. Also included in this approach can be strip harvesting in lucerne (alfalfa) (see Hossein *et al.* (2001).

Beetle banks

As the size of cropping fields increased over time with the mechanisation of agriculture, the distance from the centre of an arable crop or pastoral field to the field margin has increased. This makes it harder for beneficial insects such as non-flying predatory ground beetles which reside in hedgerows and long grass to disperse into the crop. Therefore when a pest insect outbreak

occurs, biological control is unable to contribute pest suppression to the fullest extent.

Beetle banks are a method of creating an overwintering habitat within fields for predators of pest insects such as aphids (Thomas and Marshall 1999). They consist of a minimum two metre wide ridge running across the centre of the field. The bank is usually created during autumn ploughing and a clear area of 25m can be left at either end to allow machinery to manoeuvre. The bank should be planted in a mixture of tussocky perennial grasses such as *Dactylis glomerata* (Cocksfoot), *Holcus lanatus* (Yorkshire fog) and *Phleum pratense* (Timothy) (www.fwag.org.uk). When beetle banks are incorporated into a field running parallel with the crop rows, enhancement of predatory insects (up to 1500 beetles/m²) can be achieved in only two years (Landis *et al.* 2000). Once established, the bank will require 'topping' every third year and spot spraying to remove any troublesome perennial weeds. It should not receive any fertiliser or pesticide sprays other than the selective herbicide use mentioned above.

Combined Food and Energy

In Denmark, an initiative combining aspects of intensification and extensification is being researched and put into practice at Copenhagen University. This is known as the CFE system (combined food and energy). It consists of strips of willow (*Salix* spp.) grown as short-rotation coppices (SRC) which separate fields used for crop production – a temperate agroforestry system which absorbs CO₂ from the atmosphere. When harvested, the wood produced is used for the production of biofuel in distributed local power stations and ES are provided by the wooded strips themselves as well as by the fields themselves (Kuemmel *et al.* 1998).

CFE exploits the positive benefits of biofuel strips while avoiding the monocultural husbandry of first generation biofuels and crops grown in distinctly separate cultivated areas. First generation biofuels (those made by fermentation or esterification from plants with high sugar, oil or starch contents such as sugar cane, maize and oil palm) have several disadvantages. Many of these plants have thresholds above which sufficient quantities cannot be produced for fuel without posing a threat to biodiversity and food supplies (UN Biofuels Report 2007). The benefits of CFE systems include energy neutrality, increased biodiversity (of both plants and animals), the provision of shelter, conservation of C and N, a new (non-food) revenue source for farmers, extensified agriculture and a more varied landscape (Kuemmel *et al.* 1998).

The biofuel produced by the forested strips should produce at least as much fossil energy as is consumed in the direct agricultural operations, including the energy used in harvesting and transporting the biofuel. This substitution of fossil fuel with biofuel energy neutralises the fossil CO₂ emissions from agricultural activities.

CFE increases biodiversity through the conscious addition of a number of plant species to the system (combinations of willow and other species such as

hazel (*Corylus* spp.) are common). A diverse range of plants in any agricultural system helps increase the provision of habitat and food sources for beneficial insects, enhancing biological control. This 'biodiversity effect' could therefore substitute for some chemical pest control. Plant diversity provides some or all elements of the needs of natural enemies of plant pests, enhances biocontrol and therefore could substitute for some chemical pest control that would otherwise be applied (although the Danish CFE system does not use mineral fertilisers or synthetic pesticides - therefore, the reduction in mineral fertiliser use in particular diminishes the system's overall indirect energy demand) (Kuemmel *et al.* 1998).

The woodland area created by the biofuel strips (although not permanent) would in time create a wildlife refuge, (breeding/feeding habitat) that could in turn be used by birdwatchers/hunters/the general public. The landscape beautification aspect also ties in here, as CFE systems create a more varied landscape when compared with large-scale monocultures.

These biofuel strips also act as shelterbelts, not only useful for protecting grazing stock but also useful in some instances for helping to reduce windborne soil erosion. The "shelterbelt effect" helps reduce windspeed, reducing the rate of evapotranspiration, resulting in less water loss from crops – thus reducing the risk of a moisture deficit.

Extensification is two-fold with CFE systems – a) environmentally, this form of biofuel production is not energy intensive, leaving part of the land undisturbed (for a longer period than in annual fallow schemes) and b) in regards to management/workload over the seasons – the hedges require minimal inputs for most of the year and harvesting etc takes place during off-peak periods (Kuemmel *et al.* 1998). Carbon is amassed in the below-ground parts of the willow 'hedges'. The CO₂ released when the biofuel is burned is recycled retrospectively during the lifetime of the biofuel hedge, through the process of photosynthesis. The biofuel energy substitutes for fossil energy, resulting in a net reduction of CO₂ emissions. Substituting CFE-produced wood for coal as an energy source reduces CO₂ emissions by 9.6 kg per hectare per year, assuming that the system produces 10 oven-dry tonnes of wood per hectare each year (Kuemmel *et al.* 1998).

The CFE system, in the form described above at Copenhagen University is an experimental scheme, however, the financial, environmental and social benefits of the CFE system result in a win-win-win approach to several of the current problems which agriculture and society face.

‘Greening Waipara’

Often the best ways of generating interest and promoting uptake of a new method or technology is to create a practical working example of the model system at hand – incorporating the ‘learning by doing’ approach – experiential education or ‘social learning’ (Cullen *et al.* 2008; Warner 2007).

The Greening Waipara project, located in the Waipara Valley, North Canterbury, New Zealand is a prime example of the promotion of a sustainable, extensified approach to managing an area of productive land which could otherwise have become a bleak monocultural landscape.

By planting New Zealand endemic plant species and specifically selected introduced annual plants such as *Phacelia tanacetifolia* and buckwheat (*Fagopyrum esculentum*) in and around vineyards and pastoral farms, the project aims to increase the levels of biodiversity in these productive agricultural ecosystems, with a net result of significantly increasing the variety, quantity and quality of ES provided on farmland. Research is being carried out into the specific ES-related benefits which NZ endemic plant species are capable of providing. Of key interest are two characteristics with the potential to decrease vineyard pesticide inputs: the sugar ratios contained in the nectar of native plants and their contribution towards enhancing the longevity and fecundity of beneficial insects (Vattala *et al.* 2006) and the ability of native groundcover plants to suppress weeds in the under-vine area. Mulching the non-native plants after their nectar has delivered biological control enhancement may accelerate degradation of vine prunings, interrupting the life cycle of grey mould (*Botrytis cinerea*). Recent research has shown that mulching the under-vine area with plant material reduces grape infection rates to such an extent that fungicides are no longer needed (Jacometti *et al.* 2007).

Educational initiatives stemming from Greening Waipara operate at many levels in the Waipara-North Canterbury community, as well as further afield in the greater Canterbury region as well as in a national context. The project commenced in 2005 with native plantings on four vineyards in the valley. In August 2008 the number of properties involved stood at 46, including plantings on pastoral farms, a variety of horticultural operations (including but not limited to vineyards), the local primary school and prominent community sites such as the local domain, railway stations and road frontages on State Highway One – local community groups and families have a strong involvement in Greening Waipara plantings. Three participating vineyards have opened ‘biodiversity trails’, a world first for vineyards and a further step in educating children and families who visit Waipara vineyards about the cultural and ecological values of native plants and their contribution to the provision of ES. The project has a strong media profile and continues to attract national and international attention. More information about the project can be found at <http://www.bioprotection.org.nz> and <http://ecovalue.uvm.edu/newzealand>

In early winter 2007, several researchers involved with Greening Waipara toured the main winegrowing regions of New Zealand at the invitation of Sustainable Winegrowing New Zealand and presented a series of interactive

workshops. These were well received by the people of paramount importance when in the process of implementing and expanding sustainable management programs – the winegrowers themselves.

The benefits to growers joining a scheme such as Greening Waipara are many – increased sustainability and profitability due to increases in ES provision and the related decrease in pesticide use and increased marketability due to product differentiation. Greening Waipara-specific labels or captions are being included on wine labels. The project also helps the relatively new Waipara Valley wine region distinguish itself from the other more established New Zealand wine regions by projecting a dynamic, sustainable image from a unique vantage point; overseas marketing opportunities are likely to be enhanced as a result.

Barriers to adoption

The adoption of any new technologies or concepts in a farming system requires individual farmers to change their practices (Cullen *et al.* 2008). In New Zealand, farms are often handed down from generation to generation and traditional mindsets can be hard to change, especially when there is pressure to “do things exactly the way you mother or father did” – older landholders are less likely to adopt innovations that have long lags before payoff (Cullen *et al.* 2008). A study conducted in regards to attitudes towards conservation biological control in Waipara, found that female viticulturalists were twice as likely as were males to advocate biological control of pests (Shadbolt, unpublished). Change always involves an element of risk and this is often feared, especially when economic livelihoods are at stake.

Education plays a key role in the adoption of innovation, allowing landowners to develop awareness and understanding of the new practice or technology before making a decision regarding its possible value to them (Cullen *et al.* 2008). The Greening Waipara project presents a working example of this education process. New properties opting to join the project have had the opportunity to see the benefits of adoption happening “in the field” on neighbouring properties before making the decision to join themselves. The Waipara work is part of a research project entitled *Biodiversity, ecosystem services and sustainable agriculture* funded by the New Zealand Foundation for Research Science and Technology (FRST; LINX 0303).

Member countries of the European Union have benefitted from subsidies for low-input and sustainable farming practices for many years and have been in place in other countries for a considerable length of time as well – for example in Switzerland since 1993 Gurr *et al.* ed. (Pfiffner and Wyss, 2004). These subsidies include payments in lieu of farmers “setting aside” areas of their farmland, to be taken out of cultivation and managed sustainably.

Farm ‘subsidies’ are virtually non-existent in New Zealand (representing 2% of the value of output in 1999, which was spent mainly on research and development). In 1984 however, 40% of the average gross income of a NZ sheep and beef farmer was from government subsidies. Later in the year, the

fourth Labour government abolished all agricultural subsidies and insisted that primary industries succeed or fail on their export and local market earnings.

The general opinion is that the removal of these subsidies has increased levels of innovation and self-esteem amongst farmers, who no longer depend on the state. It has also increased the information flows between farmers and the market and ensured long-term viability by continuously responding to change – subsidies had the effect of progressively removing farms from reality. On-farm productivity gains have increased by an annual average of 5.9%, compared with 1% growth prior to the removal of subsidies (www.agritech.org.nz)¹ However, it is likely that environmental damage caused by these more intensive practices has increased.

As it seems unlikely that farming subsidies will be re-introduced on a large scale in New Zealand, any financial benefits offered to farmers adopting sustainable management protocols could possibly be offered in the form of tax relief.

One very positive benefit of sustainable systems is having a differentiated product (in comparison with conventionally produced alternatives) that is usually viewed very favourably in the marketplace. In recent in-publication surveys of wine buyers in Christchurch, New Zealand supermarkets, it was found that over 70% were prepared to pay more for wine produced by environmentally sustainable methods (Figure 1).

Sustainable Wine & Price

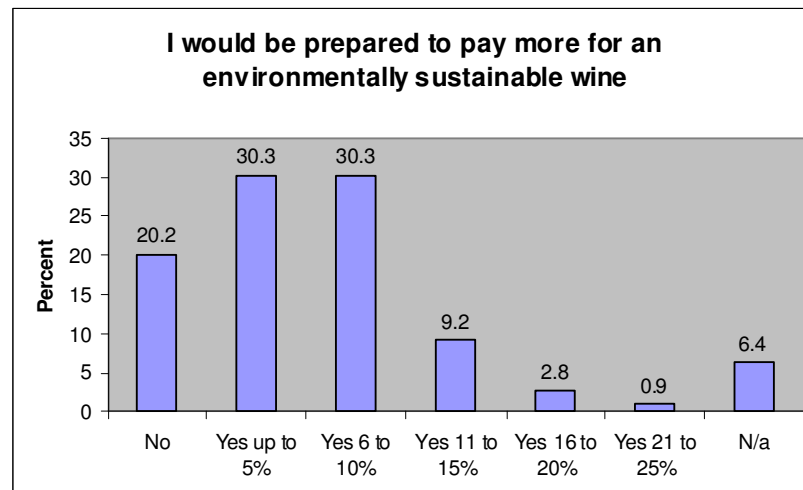


Figure 1. Wine buyers' attitudes towards the price of environmentally sustainable wine.

References

- Burt, E.S. (Ed.) (2000)** *Financial Budget Manual*. Farm Management Group, Applied Management and Computing Division, Lincoln University, Canterbury, New Zealand.
- Chaston, T. (Ed.) (2008)** *Financial Budget Manual*. Agriculture and Life Sciences Division, Lincoln University, Canterbury, New Zealand.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M. (1997)** The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.
- Costanza, R. (2008)** Ecosystem services: Multiple classification systems are needed. *Biological Conservation* 141: 350-352.
- Crutzen, P. (2002)** Geology of mankind. *Nature* 415: 23.
- Cullen, R., Warner, K.D., Jonsson, M., and Wratten, S.D. (2008)** Economics and adoption of conservation biological control. *Biological Control* 45: 272-280.
- Daily, G., Matson, P. and Vitousek, P. (1997)** Ecosystem services supplied by soil. In: G.C. Daily (Ed.) *Nature's Services: Societal Dependence on Natural Ecosystems*, Island Press, Washington DC 113–132.
- Grice, J., Cooper, M., Campbell, H., and Manhire, J. (2007)** The state of the organic sector in New Zealand, 2007. *Centre for the study of Agriculture, Food and Environment, University of Otago*.
- Gurr, G., Wratten, S. and Altieri, M. (Eds.) (2004)** *Ecological Engineering for Pest Management: Advances in Habitat Manipulation for Arthropods*. CSIRO Publishing, Victoria, Australia.
- Hossein, Z., Gurr, G.M., and Wratten, S.D. (2001)** Habitat manipulation in lucerne (*Medicago sativa* L.): strip harvesting to enhance biological control of insect pests. *International Journal of Pest Management* 47(2): 81-88.
- Jacometti, M., Wratten, S.D., and Walter, M. (2007)** Enhancing ecosystem services in vineyards: using cover crops to decrease botrytis bunch rot severity. *International Journal of Agricultural Sustainability* 5(4): 305-314.
- Jordan, W.R. (1988)** Ecological Restoration: Reflections on a half-century of experience at the University of Wisconsin-Madison arboretum. In: E.O. Wilson (Ed.), *Biodiversity* (pp. 311-316). National Academy Press, Washington D.C.

Kuemmel, B., Langer, V., Magid, J., De Neergaard, A., and Porter, J.R. (1998) Energetic, economic and ecological balances of a combined food and energy system. *Biomass and Bioenergy* 15 (4/5): 407-416.

Landis, D.A., Wratten, S.D., and Gurr, G.M. (2000) Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology* 45:175-201.

Martens, P., Rotman, J., and de Groot, D. (2003) Biodiversity: luxury or necessity? *Global Environmental Change* 13:75-81.

MacLeod, C. and Moller, H. (2006) Intensification and diversification of New Zealand agriculture since 1960: An evaluation of current indicators of land use change. *Agriculture, Ecosystems and Environment* 115: 201-218.

Manktelow, D., Stevens, P., Walker, J., Gurnsey, S., Park, N., Zabkiewicz, J., Teulon, D. and Rahman, A. (2005) Trends in pesticide use in New Zealand, 2004 pp. 74. Ministry for the Environment, Wellington, New Zealand.

Organics Aotearoa New Zealand. Kiwifruit producers: Future-proofing New Zealand kiwifruit.

Paula, A.H. and Geraldies, M.C. (2003) Holocene Pb isotope chronological standard curve: A review of the record of the anthropogenic activity in the last 6,000 years. *Short Papers—IV South American Symposium on Isotope Geology*. pp465–468.

Pfiffner, , L., and Wyss, E. (2004) Use of sown wildflower strips to enhance natural enemies of agricultural pests. In: Gurr, G.M., Wratten, S.D., and Altieri, M.A. (2004) *Ecological Engineering for Pest Management* (pp. 165-186). CSIRO Publishing, Victoria, Australia.

Rhodes, H., Closs, G. and Townsend, C. (2007) Stream ecosystem health outcomes of providing information to farmers and adoption of best management practices. *Journal of Applied Ecology* 44: 1106-1115.

Sandhu, H.S., Wratten, S.D., and Cullen, R. (2007) Field evaluation of ecosystem services in arable land. *Agriculture, Ecosystems and Environment* 5: 39-50.

Savage, G. (2005) Functional foods – a curious trend.
<http://www.lincoln.ac.nz/story2043.html> (5th August 2008).

Smith, S. (2007) Chairman of New Zealand Wine Growers, In: *New Zealand Wine Grower*.

Thomas, C.F.G., and Marshall, E.J.P. (1999) Arthropod abundance and diversity in differently vegetated margins of arable fields. *Agriculture, Ecosystems and Environment* 72: 131-144.

Tilman, D., Wedin, D., and Knops, J. (1996) Productivity and sustainability influenced by diversity in grassland ecosystems. *Nature* 379: 718-720.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D., Schlesinger, W., Simberloff, D. and Swackhamer, D. (2001) Forecasting agriculturally driven global environmental change, *Science* 292: 281–284.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., and Polasky, S. (2002) Agricultural sustainability and intensive production practices. *Nature* 418: 671-677.

United Nations (2007) *Sustainable Bioenergy: A Framework for Decision Makers*. <http://esa.un.org/un-energy/pdf/susdev.Biofuels.FAO.pdf> (5th August 2008).

Vattala, H.D., Wratten, S.D., Phillips, C.B. and Wackers, F.L. (2006) The influence of flower morphology and nectar quality on the longevity of a parasitoid biological control agent. *Biological Control* 39: 179-185.

Vogeler, I., Green, S., Greven, M., Robinson, B., van den Dijssel, C. and Clothier, B. (2005) Environmental Risk Assessment of CCA Leaching from Treated Vineyard Posts. Auckland, N.Z.: The Horticulture and Food Research Institute of New Zealand.

Walpole, S.C. (1999) Assessment of the economic and ecological impacts of remnant vegetation on pasture productivity. *Pacific Conservation Biology* 5: 28-35.

Warner, K.D. (2007) *Agroecology in action: Extending Alternative Agriculture Through Social Networks*. MIT Press, Massachusetts, United States of America.

Willer, H. and Yuseffi, M. (Eds.) (2007) *The World of Organic Agriculture: Statistics and Emerging Trends 2007*. International Federation of Organic Agricultural Movements, Bonn, Germany.

Zalasiewicz, J., Williams, M., Smith, A., Barry, T.L., Coe, A.L., Bown, P.R., Brenchley, P., Cantrill, D., Gale, A., Gibbard, P., Gregory, F.J., Hounslow, M.W., Kerr, A.C., Pearson, P., Knox, R., Powell, J., Waters, C., Marshall, J., Oates, M., Rawson, P. and Stone, P. (2008) Are we now living in the Anthropocene? *GSA Today* 18 (2): 4–7.

¹ Subsidy-free and profitable agriculture - adapted from *Life After Subsidies: The New Zealand Farming Experience 15 years later* (1999) Federated Farmers of New Zealand. <http://www.agritech.org.nz/subsidy.shtml> (5 August 2008).