From Poachers to Gamekeepers: Perceptions of Farmers Towards Ecosystem Services on Arable Farmland

Harpinder S. Sandhu[1], Stephen D. Wratten[1] and Ross Cullen[2]

[1] National Centre for Advanced Bio-Protection Technologies, PO Box 84, Lincoln University, Canterbury, New Zealand;

[2] Commerce Division, PO Box 84, Lincoln University, Canterbury, New Zealand

Main contact author: Harpinder S. Sandhu

Bio-Protection and Ecology Division

PO Box 84, Lincoln University

Lincoln, New Zealand 7647.

Tel.: +64 3 325 3838 extn. 8386

Fax: + 64 3 325 3864

E-mail: sandhuh@lincoln.ac.nz

Abstract

Management of ecosystem services (ES) is vital to maintain and improve the productivity of agricultural systems in order to meet the food demands of a growing human population. However, some land management practices can severely reduce the ecological and financial contribution of some of these services to agriculture, which in the longer term can offset the ability of farming to produce large amounts of food and fibre. Therefore, to improve the understanding and enhancement of these services, it is crucial to know the opinions of farmers who manage ES on their land. Being in close contact with the land provides them with an opportunity to understand its natural processes and functions as well as to act as its stewards. This paper describes ES associated with arable farming in Canterbury, New Zealand and analyses the results of a survey of farmers' perceptions of these services. There was no difference between the measured perceptions of these services by organic and conventional farmers except in the case of biological control. However, organic farmers gave a higher score to 16 individual services compared with conventional farmers. Also, for organic farmers, the importance of some of these services increased significantly with the number of years the farmers had been operating under an organic regime.

Keywords: arable farmland, ecosystem services, farmers' perceptions, New Zealand, organic farming.

Introduction

Agriculture is the major cause of land use change (Goldewijk & Ramankutty, 2004; UNEP, 2005; Vitousek *et al.*, 1997), leading to environmental destruction and associated loss of ecosystem services (ES) (Heywood, 1995; Krebs *et al.*, 1999; Tilman *et al.*, 2001). Therefore, a growing human population and associated increasing food demands make the challenge to maintain and enhance ES in agriculture greater than in other ecosystems (UN, 1992; Pinstrup-Andersen, 1998).

Agricultural activities before the twentieth century were dependent mainly on crop rotation and the reduction of pests and diseases through diverse agro-ecosystems (Ernle, 1961). Farmers were able to meet the food requirements of human populations without being highly dependent on external chemical inputs. They had an instinctive, if not scientific understanding of nature and its services (Pretty, 2002). In New Zealand, Maori (and other 'first people' cultures elsewhere) often have a profound understanding of inter-generational sustainability issues. This is expressed among the largely oral Maori culture as *kaitiakitanga*.

However, since the onset of the industrial revolution, and especially more recently, farmers are becoming very susceptible to pressures imposed by expanding international food markets (Aksoy & Beghin, 2005). These markets demand higher production and year-round availability of many products. This has led to massive expansion and intensification of agriculture (Tilman *et al.*, 2002), which is heavily dependent on fossil fuels, chemical fertilizers and pesticides. This 'substitution agriculture' has resulted in the loss of valuable ES (Daily, 1997; Reid *et al.*, 2005) as well as leading to other detrimental effects (National Academy of Sciences, 2001; Tilman, 1998; Tilman & Lehman, 2001) and high 'external costs' (Pretty, 2005; Pretty *et al.*, 2000; Pretty *et al.*, 2001; Tait *et al.*, 2006; Tegtmeier & Duffy, 2004). These 'external costs' of chemical-dependent, intensive agricultural practices include severe damage to soil fertility, water, biodiversity and human health.

This has led to world-wide concerns about the environmental consequences of modern agriculture (Reid *et al.*, 2005). There is also the additional concern that as the world approaches 'peak oil', agriculture may no longer be able to depend so heavily on oil-derived ‘substitution’ inputs (Pimentel & Giampietro, 1994). Such a grave situation does not detract from the responsibility of agriculture to meet the food demands of a growing population but it does question its ability to increase yields without further ecosystem damage (Escudero, 1998; Pimentel & Wilson, 2004; Tilman, 1999).

The key challenge is to meet the food demands of a growing population and yet maintain and enhance the productivity of agricultural systems (UN, 1992). There is therefore currently an increasing interest in the services provided by nature. As the economic value of the direct and indirect benefits of ES are substantial (Costanza *et al.*, 1997; Daily *et al.*, 1997b; Sandhu *et al.*, 2005), there is growing awareness of the utilisation of these services for the long-term sustainability of agro-ecosystems and their ability to provide increased production while maintaining ES (Gurr *et al.*, 2004: Pretty & Hine, 2001; Tilman *et al.*, 2006).

Background to the current work

Agriculture is both a consumer and a producer of ES (Heal & Small, 2002; Sandhu *et al.*, 2005; Takatsuka *et al.*, 2005a). A number of ES are utilised to produce others such as food, which is supported by the maintenance of soil fertility, plant protection, water regulation and many other services (Daily *et al.*, 1997b). Food and fibre production are valued in commercial markets and the foremost objective of modern agriculture is to maximise commercial gains. However, doing so usually results in the decline of other valuable ES. However, the concept of using ES to enhance farm sustainability is growing worldwide (Gurr *et al.*, 2004; Kremen, 2005; Matson *et al.*, 1997; Robertson & Swinton, 2005). Researchers and practitioners aspire to strike a balance between production and consumption of ES in agriculture for long-term farm sustainability (Bjorklund *et al.*, 1999; Firbank, 2005).

Sustainable agriculture involves the use of agricultural technologies and practices that maximise the productivity of the land after considering all the costs and benefits (Altieri, 1995; Thrupp, 1996; Pretty, 1995; Pretty & Hine, 2001; Tilman *et al.*, 2002). Organic agriculture is considered to be one of the production systems that aim to achieve sustainability (Lampkin & Measures, 2001; Mäder *et al.*, 2002; Reganold *et al.*, 1990). The estimated magnitude of ES is very high in organic agriculture compared with high-input substitution agriculture (Takatsuka *et al.*, 2005a). It is well established that organic farming delivers more environmental benefits compared with conventional practices (Mäder *et al.*, 2002; Pacini *et al.*, 2003; Pimentel *et al.*, 2005; Swift *et al.*, 2004). The provision of ES is higher in organic than in conventional farms (Sandhu *et al.*, 2005). Organic farmers are more dependent on ES because most chemical inputs are prohibited.

They are also more concerned about the environment than are those who farm conventionally (Egri, 1999; Fairweather & Campbell, 2003). However, information on the importance of ES on farmland and the perceptions of farmers who manage ES (Edling, 2003) is limited. Farmers have deep ties to the land as they earn their livelihood from it and this can provide them with an opportunity to have an appreciation of natural processes and functions as well as to act as stewards of their land (McCann, 1997). Also, by understanding the perceptions of arable farmers, new eco-technologies based on the novel application of sound ecological knowledge can be targeted to design efficient farming systems by involving the 'end-user' at the conceptual stage, not through 'end-of-project' attempts to sell research results to hitherto previously un-involved farmers (Chambers, 1990; Pretty, 1995; Warner, 2006). The research in this paper aims to explore the extent of appreciation of on-farm ES by farmers in relation to within- and off- farm benefits. It surveyed organic and conventional farmers in Canterbury, New Zealand in 2005.

Aim of the Study

Agriculture contributes 16% of the annual Gross Domestic Product (GDP) in New Zealand (Statistics New Zealand, 2003). About half of the New Zealand land area is under pastoral or arable agricultural production. Arable landscapes are intensively 'engineered' systems, designed to maximize the delivery of socially valued goods and services (Cullen *et al.*, 2004; Cullen *et al.*, 2006; Sandhu *et al*., 2005). As is the case worldwide, some New Zealand arable farming practices can reduce the ability of the ecosystem to provide goods and services while others may enhance the latter (Sandhu *et al.*, 2005; Takatsuka *et al.*, 2005a).

The focus of this study is on one sector of an engineered ecosystem (arable farming) and since the province of Canterbury is the major arable area in New Zealand, this work addresses the perceptions of arable farmers in that province towards ES in both conventional and organic systems. A conceptual model depicting the perceptions of farmers of ES is outlined in Fig. 1.

Ecosystem Services in Agriculture

ES associated with farming are classified into four groups, as explained by Reid *et al.* (2005). Based on the ES literature and discussion with experts, several ES have been identified in agriculture (Cullen *et al.*, 2004; Reid *et al.*, 2005; Takatsuka *et al.*, 2005b). These are summarised in Table 1. Although these types of ES have been defined and explained in the economics literature, they are dealt with here, specifically for a biological/agricultural readership. Each of the ES is defined below with special reference to Canterbury, New Zealand arable land.

(1) Supporting services

These are the services that are required to support the production of other ecosystem goods and services. In this case they support food goods. Suppression of these services can lead to their substitution with external inputs. Key supporting ES associated with arable farming are described below.

(1a) Pollination

The transfer of pollen grains from anthers to stigmas is pollination (Free, 1970). Of the 1330 crop species, two thirds require animal pollinators (Roubik, 1995). Of the 100 crop species that provide 90 percent of human food supplies, 71 are bee pollinated (Prescott-Allen & Prescott-Allen, 1990). The dependence of important food crops on pollination makes this service crucial in agriculture. Earlier work provides information about the value of pollination services (Gordon & Davis, 2003; Kremen *et al.*, 2002; Matheson, 1987; Pimentel *et al.*, 1997; Ricketts, 2004; Ricketts *et al.*, 2004). Extensive use of insecticides in agriculture is leading to a decline of this ES (Nabhan & Buchmann, 1997, 1998) which is worth US $200 billion annually in cropland worldwide (Pimentel *et al.*, 1997). The value to New Zealand is estimated to be in the range of US $1.4-2 billion annually (Matheson, 1987; Matheson & Schrader, 1987). New Zealand arable land produces high-value seed crops including clovers that fix atmospheric nitrogen and require bees for pollination. The grain and seed industry in New Zealand is worth US $300 million annually (www.maf.govt.nz/mafnet/rural-nz/overview/nzoverview012.htm). To provide increased pollination services for this industry, farmers rent honey-bee hives every year, adding to the costs of production. Any major reduction in populations of pollinators will lead to severe losses to the seed industry. This ES therefore plays a vital role in the economy of Canterbury, New Zealand.

(1b) Biological control

Biological control of pests, diseases and weeds is crucial to the production of crops. Ninety-nine per cent of the populations of agricultural pests and diseases are controlled by their natural enemies - predators, parasites, and pathogens (de Bach, 1974). The provisions of this ES are higher in organic compared with conventional agriculture (Sandhu *et al.*, 2005). Intensification of agriculture, with associated habitat destruction, has led to a severe reduction of this ES, which is worth US$ 100 billion annually in cropland worldwide (Pimentel *et al.*, 1997). Severe detrimental effects (such as damage to human health) from increasing pesticide applications in agriculture are also well documented (Pretty, 2005). High environmental and economic costs of pesticide use worldwide are also evident (Pimentel *et al.*, 1992; Pretty, 2005). It is estimated that 2.5 million tonnes (active ingredients) of pesticides are used worldwide in crop production (Pimentel *et al.*, 1992). In New Zealand, 3200 tonnes (active ingredients) of pesticides that includes fungicides and herbicides are applied yearly to soils (Holland & Rahman, 1999). There has recently been an increase of 27% in pesticides use over a period of four years in New Zealand (Manktelow *et al.*, 2005). Biological control, if properly utilised on farmland can result in annual savings worth billions of dollars and these services can be enhanced using 'ecological engineering' principles (Gurr *et al.*, 2004).

(1c) Services provided by the soil

Soil supports crops by providing shelter to seeds, aeration, plant support, nutrients, water, accumulation of carbon and fixing atmospheric nitrogen (Brady, 1990; Daily *et al.*, 1997b; de Groot *et al.*, 2002). Each of these services is vital for the growth of plants. For successful farming, healthy soils are a prerequisite. The economic value of the services provided by soil was estimated by Pimentel *et al.* (1997) to be $1.2 trillion per year worldwide. Carbon accumulation in soils was considered by Garcia-Torres *et al.* (2003) as an important alternative to offset the emissions of CO_2 in the atmosphere by industry and other human activities. Practices such as crop residue management, zero or minimum tillage or conservation agriculture can increase carbon accumulation in soils (Garcia-Torres *et al.*, 2003; Magdoff & Weil, 2004). Nutrient mineralisation in the soil provides minerals to plants. Soil fungi, bacteria and micro- and macro-fauna decompose organic matter to release these nutrients (Brady & Weil, 2004). This process can be enhanced by appropriate rotations of crops and by maintaining or increasing soil organic matter. Low-carbon, mineral and un-vegetated soils are more prone to erosion by wind and water. Also, improved activity of soil organisms in the soil by adding mulches or cover crops can decrease the incidence of plant diseases by accelerating the decomposition of overwintering life stages of plant diseases and improving plant vigour (Jacometti *et al.*, in press). Well-structured soils with ample cover protect against erosion. Annually, large quantities of nutrients are lost due to soil erosion by wind and water (McLaren & Cameron, 1996). Tall crops such as maize require well-structure soils to provide a good anchor for the roots to prevent lodging.

Soil formation is also an important ES provided by soil biota (Breemen & Buurman, 2002). Earthworms are the most important component of the soil biota in terms of this service and the maintenance of soil structure and fertility (Edwards, 2004; Lee, 1985; Stockdill, 1982). According to Pimentel *et al.* (1995), soil biota aid the formation of approximately 1 tonne $ha^{-1}yr^{-1}$ of topsoil. Earthworms also maintain soil nutrient levels by mixing the soil, providing nutrients in the plant root zone. Nitrogen fixation by growing legumes can provide all or some of the nitrogen required by the subsequent crop. In Canterbury, New Zealand, clovers are still used as a restorative phase in this way even though the use of urea has increased markedly over the last few decades (PCE, 2004).

(1d) Services provided by shelter belts and hedges

Shelterbelts on farmland benefit crops and farm animals by improving yields and quality (Kort, 1988; Sturrock, 1969). This is because of reduced wind speed, minimising soil erosion, improving microclimate and giving higher levels of soil moisture (Kort *et al.*, 1988). They also provide shelter and pollen/nectar resources to pollinators (Norton, 1988) and to natural enemies that perform biological control of pests and diseases (de Groot *et al*., 2002; Heal & Small, 2002; Landis *et al.*, 2000; Thomas *et al.*, 1991). In Canterbury, New Zealand, good shelter can increase crop yield up to 35 per cent (Sturrock, 1981).

(2) Provisioning goods and services

These include food and services for human consumption, ranging from raw materials and fuel wood to the conservation of species and genetic material (de Groot *et al.*, 2002, Reid *et al.*, 2005). These goods and services are produced in agricultural landscapes by consuming some of the supporting and regulating services.

(2a) Food

Modern agriculture is feeding over 6 billion people worldwide and it is estimated that with an increase in population to 9 billion by 2050, global food demand will double (Pimentel & Wilson, 2004). Agriculture has played a major role in shaping the environment as well as the economy of the world. Although natural ecosystems are sources of a considerable amount of wild foods, including fish, the needs of the growing population will be largely fulfilled by agriculture.

(2b) Raw materials

Agriculture also produces raw materials in the form of fibre, fuel wood, pharmaceuticals and industrial products (Daily *et al.*, 1997b). Arable farming in Canterbury, New Zealand produces straw, fuel wood, medicinal plants etc., as well as food and seeds.

(2c) Conservation of species and genetic resources

Agriculture can provide for the maintenance of genetic material and conservation of species of plants and animals on farmland. Many species have been improved by using genetic resources from their wild relatives by cross-breeding. Further, these resources can be obtained from cultivated plants and domesticated animals in the absence of wild relatives (de Groot *et al.*, 2002). Hedges and shelterbelts around arable fields are major refugia for plants and animal species which are rare, transient or absent on the cultivated parts of the farm (MacLeod *et al.*, 2004; Pollard *et al.*, 1974; Thomas *et al.*, 1991, 1992).

(3) Regulating services

Ecosystems regulate essential ecological processes and life-support systems through bio-geochemical cycles and other biospheric processes (Costanza *et al.*, 1997; Daily, 1997). Hydrological flow in the plant-soil-atmosphere plays a critical role in arable farming. The hydrological cycle renews the earth's supply of water by distilling and distributing it (Gordon *et al.*, 2005). The earth's atmosphere contains approximately 1.3×10^{13} m^3 of water (which is 0.001% of the water in oceans) and is the source of the rainwater that falls on earth (Pimentel *et al.*, 1997). This rainfall is collected in lakes, rivers and oceans or seeps into the ground and eventually evaporates or transpires to the air from the leaves of plants; the latter is known as evapotranspiration. One rainforest tree can return at least 10 million litres of water to the atmosphere in 100 years (Myers, 1996). In contrast with this, maize crops occupying roughly the same area as taken up by a rainforest tree (but for only part of the year) transfer 50 million litres in 100 years (Myers, 1996). This rate of use of ground water would greatly exceed inputs, whereas that of the tree would not.

(4) Cultural services

Cultural services contribute to the maintenance of human health and well-being by providing recreation, aesthetics and education (Costanza *et al.*, 1997; de Groot *et al.*, 2002; Reid *et al.*, 2005). Agriculture provides these services as some farmers conserve field-boundary vegetation or enhance landscapes by planting hedgerows, shelterbelts or native trees. Arable farms in Canterbury are characterised by highly managed shelterbelts. Although there is a very well-travelled 'scenic route' in Canterbury, New Zealand (State Highway 72) which features farmland which is considered to be attractive by motorists, most of this vegetation comprises non-native species such as *Cupressus macrocarpa* (Hartw. ex Gordon).

Some farms provide accommodation and recreational activities for family members as well as for national and international visitors. 'Farm stays' are very common in Canterbury, especially on organic farms. Participation of farms in research and education enhances this cultural service (Warner, 2006).

However, the perceptions of, and attitudes to the provision of ES in Canterbury, New Zealand arable farmland by farmers in that province have not been quantified. This knowledge is important in the development of statutory policies and voluntary practices to enhance functional diversity on arable land. This paper quantified Canterbury arable farmers' attitudes to the provision of ES by conventional and organic farming practices in that province.

Materials and Methods

Site description

The province of Canterbury is the major arable area of New Zealand, comprising 125,000 ha of arable land. Fifteen arable farmers were selected in September 2004 from throughout the Canterbury Plains, New Zealand and seven of these were practising organic agriculture while eight used conventional methods. Of the seven organic farms, three were certified by AgriQuality (www.agriquality.co.nz), New Zealand and four by BIO-GRO (www.bio-gro.co.nz), New Zealand. Both certifiers are accredited with IFOAM, the International Federation of Organic Agriculture Movements (www.ifoam.org).

A list of arable farmers in Canterbury was obtained from the Foundation for Arable Research (www.far.org.nz), Lincoln and OPENZ (Organic Products Exporters of New Zealand; www.organicsnewzealand.org.nz) provided the contacts for all organic farmers. The latter were contacted first by sending a letter, followed by a telephone call and a meeting to collect detailed information about the farming practices such as crop rotation and the crops grown, as well as soil type. After this, conventional arable farmers within 5 km of the selected organic farms were contacted. These were selected within this radius because they were growing similar crops on similar soil types.

Survey methodology

First, a Delphi panel of experts (Angus *et al.*, 2003; Brooks, 1979; Curtis, 2004) was used to place all the ES identified in this work into one of five categories in terms of whether the perceived benefits were attributable mainly to private or public entities. The panel comprised three ecologists and two resource economists.

The five categories allocated for ES were: (1) purely private, (2) mostly private, (3) in between the two, (4) mostly public and (5) purely public. Each of the identified ES was considered once as a good and then as a benefit. Goods are those articles that can be traded whereas benefits are those that promote or enhance human well-being but which are not usually traded (McTaggart *et al.*, 2003). Members of the panel were requested to provide one rating for each ES. In the first round, each member provided a rating for each ES. In the next round, the initial results were sent to the members such that they could reconsider and modify their initial estimations in the light of the first round estimations. The final results were presented after the panel came to a consensus over the allocation of ES into different categories.

Next, data were collected by face-to-face surveys of each selected farmer. A survey questionnaire was prepared, covering the demographic details of farms, farm management practices and perceptions of ES. Each farmer was asked to rank the importance of the listed ES (Abeyasekera *et al.*, 2001). The rankings were on a score of 1-5, one being least important, 3 being moderately important and five being highly important for their farming. Fisher's exact test was used to compare the perceptions of individual ES by organic and conventional farmers.

Results

The Delphi exercise resulted in categorizing the identified ES as different categories of goods and benefits (Table 2). When all the ES were considered as goods, 14 were identified as private, two in between (soil erosion control and aesthetics) and three as public goods (conservation of species, maintenance of genetic resources and science/education). For benefits, 11 were identified to be purely private, five in between (pollination, soil erosion control, nitrogen fixation, hydrological flow and aesthetics) and three purely public (conservation of species, maintenance of genetic resources and science/education).

The mean values for perceptions of the importance of ES to organic and conventional farmers obtained by the scoring exercise are presented in Table 2. It is noteworthy that two ES (pollination and soil fertility) were ranked as most important by organic as well as conventional farmers (Figures 2 & 3). Conventional farmers rated 11 ES at a score of 3 or more. This includes seven supporting, three provisioning, one regulating and none of the cultural services. Eight ES were given scores lower than 3 by these conventional farmers. In contrast, organic farmers rated 16 ES at 3 or more; these included nine supporting, four provisioning, one regulating and two cultural services. Only three ES were ranked below 3.

Organic farmers considered most of the supporting services (which provide private goods and benefits) as highly valuable for their farming systems and also ranked the cultural services (which provide public goods and benefits) higher than some of the provisioning and regulating services (Fig. 2). However, conventional farmers rated only the provisioning services, such as food production (which have high economic value) as highly important (Fig. 3). The responses of conventional farmers indicated that they also considered some of the supporting services to be important, as demonstrated by mean values of 3 or more for these ES (Table 2).

Organic and conventional farmers did not differ significantly for their perceptions of ES except for biological control ($p<0.05$). When the responses of organic farmers were analysed in relation to the number of years their land had been certified organic, there was a significant ($y = 0.0673x + 3.1224$; $R^2 = 0.61$; $p<0.05$) relationship with time for supporting services. However, in terms of their perception of provisioning, cultural and regulating services there was no significant change with time.

Organic farmers depend on nature's services for production, therefore there is increasing importance of these ES, particularly supporting services. Farmers can achieve desired outcomes only by utilising these nature's services in the absence of most external chemical inputs.

Discussion

Ecosystem services in agriculture

In Canterbury, New Zealand, arable farms comprise highly modified landscapes designed to generate revenue for farmers. Farmers use chemical as well as natural inputs to produce food and fibre. The latter are the ES that have been identified and classified here. Intensive agriculture largely replaces these ES with chemical inputs, resulting in a decrease in their value and importance on farmland (Sandhu *et al.*, 2005). This 'substitution agriculture' has also to a large extent replaced these ES worldwide in the 20th century. Severe environmental destruction, increasing fuel prices and the external costs of modern agriculture have resulted in increased interest among researchers and farmers in using ES for the production of food and fibre (Costanza *et al.*, 1997; Cullen *et al.*, 2004; Daily, 1997; Gurr *et al.*, 2004; Robertson & Swinton, 2005; Tilman, 1999; Tilman *et al.*, 2006).

Increasing concerns about intensive agriculture and its detrimental effects have led to the development of sustainable agricultural practices such as organic farming (Anon., 1994). At present, this is practised on 31 million ha worldwide with a global market of US $26.8 billion, which is increasing at 20% per year (Willer & Yussefi, 2006).

Previous studies have classified and described various ES at a regional or global level (Costanza *et al.*, 1997; Daily, 1997; de Groot *et al.*, 2002; Wilson *et al.*, 2004; Takatsuka *et al.*, 2005a). However, this study focuses on one sector of an 'engineered ecosystem' (arable farming) and addresses both conventional and organic systems in Canterbury, New Zealand. ES operating on arable farmland have been classified as goods as well as benefits using the Delphi technique (Brooks, 1979) in this study. These ES have been described individually as private or public goods and benefits. Individual farmers derive more immediate advantages from these ES compared with the benefits to the general public (Daily *et al*., 1997a; Heal and Small, 2002). However, the public also derives aesthetic and other advantages from these ES which are maintained and enhanced on farmland (Anon., 2001; Takatsuka *et al.*, 2005a). Further research is required to study the net private and public benefits of ES on farmland. Better understanding of the importance of ES by farmers and the public is required to enable the inclusion of this natural, social and cultural capital into assessments of gross national product (GNP) (Williams, 2004).

Perceptions of ES by farmers

To ensure the sustainability of agriculture and to minimize associated detrimental effects, it is imperative to evaluate and enhance ES on farmland (Tilman *et al.*, 2002). In the present work, although a larger sample size would be required for a full understanding of the importance of ES on New Zealand farmland, that used here is not atypical of studies using this type of scoring exercise (Abeyasekera *et al*., 2001; Silvano *et al.*, 2005). The literature provides information on farmers' perceptions of single ES (Johns, 1999; Leenders *et al.*, 2005; Silvano *et al.*, 2005; Quansah *et al.*, 2004) or on farmers' general environmental awareness (Fairweather & Campbell, 2002; McCann, 1997). To date, no study has evaluated the perceptions of farmers towards ES in arable farming.

Intensive agriculture in the past has made some unprecedented changes to agroecosystems, resulting in declines in ES (Reid *et al.*, 2005). As farmers became more dependent on ‘substitution’ agriculture in the last 50 years, they ignored the importance of ES. However, this study confirmed that there is moderate to high awareness of the importance of these services among two groups of arable farmers, irrespective of whether they intended to utilize these services or not.

Perceptions of ES by conventional farmers

Although conventional farmers in this study depend heavily on external chemical inputs they also rated certain key ES as very important for their farming. The top five were pollination, soil fertility, food production, soil erosion control and hydrological flow. A better understanding of the detrimental effects of current conventional farming practices has made these farmers more aware of the role of ES on their farmland (Fairweather, 1999; Storstad & Bjørkhaug, 2002). While intensive agricultural practices are associated with a decline in pollination and soil fertility (Daily *et al*., 1997a; Kremen *et al.*, 2004; Nabhan & Buchmann, 1997), these were the top two services identified by conventional farmers to be highly important. It could be inferred that the recognition of the importance of ES by conventional farmers provides an opportunity for researchers and policy makers to offer alternative tools, techniques and incentives to incorporate new thinking into practice (Silvano *et al.*, 2005). There is a need for practical advice on how to capture ES in agriculture; defining the SPU (Service Providing Unit; Luck *et al.*, 2003) is a key step in this process. An SPU is a characterization of which species provide(s) the service, how many individuals are needed and how to deploy this provider of ES in the agricultural landscape. A good example in which this has been done is “beetle banks’ (Sotherton, 1995; Thomas, 2000); the plant type, where and when to use it and its benefits (for pest biological control in this case) have all been quantified and the practice has been widely adopted (Bowie *et al.*, 2003; Collins *et al.*, 1997; MacLeod *et al.*, 2004). More examples of this type will help to ameliorate some of the profound negative effects of ‘substitution’ farming. Higher food production per unit area per unit time is the goal of arable farmers to maximise their profits. This is very important but surprisingly its score for conventional farmers was below the scores for pollination and soil fertility. This suggests that an awareness of long-term sustainability may sometimes over-ride short-term profit motives (Andreoli & Tellarini, 2000; Freyenberger *et al*., 2001) and that the associated need for clearly-defined SPU, is high.

Perceptions of ES by organic farmers

Organic farmers are more dependent then are conventional ones on nature's services to support production of food and fibre. Not surprisingly, they ranked key (soil fertility, pollination) ES as most important. Organic farmers utilize appropriate crop rotations and practise sustainable land management to grow food (Lampkin & Measures, 2001). It became clear in this study that this category of farmers adopts those practices that maintain and enhance ES on farmland. There is strong motivation amongst this group to regard ES other than as a provider of premium profits for their produce (Fairweather, 1999). Recognition of some of the ES as highly important provides opportunities to researchers to target the improvement of these services in future (Gurr *et al*., 2004; Swift *et al*., 2004).

This study described various ES as goods and benefits and showed the importance of ES by organic and conventional arable farmers. Two hypotheses put forward in Fig. 1 were rejected: these were that the importance of public goods and benefits is low for conventional practitioners and that the importance of private goods and benefits is low for organic practitioners. Results suggests that conventional farmers also consider ES as important in farming but unlike organic farmers do not utilize these services as much because there are no direct incentives for them in the markets (Kumar, 2005). However, organic farmers have limited choices on the use of external inputs and obtain premium prices for their produce, so they are increasingly using these services in farming (Kasperczyk & Knickel, 2006; Sandhu *et al*., 2005). The awareness of consumers towards environmental change and factory farming-techniques driven by supermarkets (Lyon *et al*., 2003) are putting more pressures on these markets to provide environmentally safe food (e.g., www.waiparawine.co.nz). Conventional food producers which export their produce need to respond to the increased global trade which may nevertheless include non-tariff trade barriers (Anderson & Josling, 2005) and increasingly need to provide pesticide free food (Cranfield & Magnusson, 2003) to distant sophisticated markets.

Information on the vital role played by ES on farmland can be used by researchers and policy makers to increase ecological and economic wealth in a sustainable way. This can 'future-proof' agriculture in an increasingly uncertain food-production environment (Kristiansen *et al.*, 2006). Further research is required to study those ES which are of more interest to different group of farmers, based on their land management practices. Increased use of ES on farmland is possible only if the farmers are given ownership of them, share the benefits of maintaining them on their farmlands and are involved in decisions to safeguard them at regional and national level (Pretty, 2002, Vos, 2000; Warner, 2006).

It is concluded that 'poachers' can indeed turn into 'gamekeepers' as farmers' attitudes change as conventional producers shift to organic farming and as conventional growers become increasingly aware of environmentally-based market pressures.. Also, organic farmers increasingly appreciate the importance of ES for sustainable food and fibre production, minimising the social and environmental risks associated with the 'poaching' of resources in high-input, fossil-fuel-based agriculture.

Acknowledgements

The authors acknowledge the contribution of participating farmers as well as Dr Roddy Hale, Dr Yuki Takatsuka. Funding came from the Foundation for Research, Science and Technology (FRST) (project LINX0303). Thanks also to a Lincoln University Doctoral Scholarship, the Organic Products Exporters of New Zealand (OPENZ) and the Foundation for Arable Research (FAR), especially Mr Nick Pyke.

References

Abeyasekera, S., Ritchie, J.M. and Lawson-McDowall, J. (2001) Combining ranks and scores to determine farmer's preferences for bean varieties in southern Malawi. *Experimental Agriculture* 38, 97-109.

Aksoy, M.A. and Beghin, J.C. (2005) *Global Agricultural Trade and Developing Countries*. World Bank, Washington DC.

Altieri, M. (1995) *Agroecology: The Science of Sustainable Agriculture.* Westview Press, Colorado.

Anderson, K. and Josling, T. (2005) *The WTO and Agriculture*. Edward Elgar Publishing Ltd., UK.

Andreoli, M. and Tellarini, V. (2000) Farm sustainability evaluation: methodology and practice. *Agriculture, Ecosystems and Environment* 77, 43-52.

Angus, A., Hodge, I., McNally, S. and Sutton, M. (2003) The setting of standards for agricultural nitrogen emissions: a case of the Delphi technique. *Journal of Environmental Management* 69, 323-337.

Anonymous (1994) *Certified BIO-GRO Organic Production Standards*. Biological Producers and Consumers Council (Inc.), Auckland, New Zealand.

Anonymous (2001) *Private Lands, Public Benefits: Principles for Advancing Working Lands Conservation.* National Governors Association/ Center for Best Practices, Washington. On WWW at www.nga.org

Bjorklund, J., Limburg, K.E. and Rydberg, T. (1999) Impact of production intensity on the ability of the agricultural landscape to generate ecosystem services: an example from Sweden. *Ecological Economics* 29, 269-291.

Bowie, M., Wratten, S. and Tylianakis, J. (2003) An introduction to entomological research on Kowhai Farm - The Heinz Wattie’s organic farm at Lincoln University. *Weta* 25, 18-23.

Brady, N.C. (1990) *The Nature and Properties of Soils*. Macmillan Publishing Company, New York.

Brady, N.C. and Weil, R.R. (2004) *Elements of the Nature and Properties of Soils*. Prentice Hall, New Jersey.

Breemen, N.V. and Buurman, P. (2002) *Soil Formation*. Kluwer Academic Publishers, Dordrecht.

Brooks, K.W. (1979) Delphi technique: expanding applications. *North Central Association Quarterly* 54, 377-385.

Chambers, R. (1990) Farmer-first: a practical paradigm for the third agriculture. In: Altieri, M.A. and Hecht, S.B. (eds) *Agroecology and Small Farm Development* (pp. 237-244). CRC Press, Florida.

Collins, K.L., Wilcox, A., Chaney, K., Boatman, N.D. and Holland, J.M. (1997) The influence of beetle banks on aphid population predation in winter wheat. *Aspects of Applied Biology* 50, 341-346.

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.

Cranfield J.A.L. and Magnusson, E. (2003) Canadian consumer’s willingness-to-pay for pesticide free food products: an ordered probit analysist. *International Food and Agribusiness Management Review* 6, 13-30.

Cullen, R., Takatsuka, Y., Wilson, M. and Wratten, S. (2004) Ecosystem services on New Zealand arable farms. Agribusiness and Economics Research Unit, Lincoln University, Discussion Paper 151, 84–91.

Cullen, R., Wilson, M., Wratten, S., Takatsuka, Y. Sandhu, H. and Tait, P. (2006) Accounting for ecosystem services associated with agricultural production in New Zealand. *Ecological Economics* (in press).

Curtis, I. (2004) Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and a Delphi panel to assign weights to the attributes. *Ecological Economics* 50, 29-44.

Daily, G.C. (1997) Introduction: what are ecosystem services? In: Daily, G.C. (ed.) *Nature's Services: Societal Dependence on Natural Ecosystems* (pp. 1-10). Island Press, Washington DC.

Daily, G.C., Matson, P. and Vitousek, P. (1997a) Ecosystem services supplied by soil. In G.C. Daily (ed.) *Nature's Services: Societal Dependence on Natural Ecosystems* (pp. 113-132). Island Press, Washington DC.

Daily, G.C., Alexander, S., Ehrlich, P.R., Goulder, L., Lubchenco, J., Matson, P.A., Mooney, H.A., Postel, S., Schneider, S.H., Tilman, D. and Woodwell, G.M. (1997b) Ecosystem services: benefits supplied to human societies by natural ecosystems. *Issues in Ecology* 2, pp. 18.

de Bach, P. (1974) *Biological Control by Natural Enemies*. Cambridge University Press, London.

de Groot, R.S., Wilson, M. and Boumans, R.M. J. (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* 41, 393-408.

Edling, P. (2003) A farmer's view of ecosystem services. In: Proceedings of the International conference on ecosystem services in European agriculture – theory and practice, Falkenberg, Sweden.

Edwards, C.A. (2004) The importance of earthworms as key representatives of the soil fauna. In: Edwards, C.A. (ed.), *Earthworm Ecology* (pp. 3-11). CRC Press, Florida.

Egri, C.P. (1999) Attitudes, background and information preferences for Canadian organic farmers: implementation for organic farming advocacy and extension. *Journal of Sustainable Agriculture* 13, 45-72.

Ernle, L. (1961) *English Farming, Past and Present*. Heinemann, London.

Escudero, G. (1998) The vision and mission of agriculture in the year 2020: towards a focus that values agriculture and the rural environment *Agricultura, medio ambiente y pobreza rural en America Latina* 21-54.

Fairweather, J.R. (1999) Understanding how farmers choose between organic and conventional production: results from New Zealand and policy implications. *Agriculture and Human Values* 16, 51-63.

Fairweather, J.R. and Campbell, H.R. (2003) Environmental beliefs and farm practices of New Zealand farmers; contrasting pathways to sustainability. *Agriculture and Human Values* 20, 287-300.

Firbank, L.G. (2005) Striking a new balance between agricultural production and biodiversity. *Annals of Applied Biology* 146, 163-175.

Free, J.B. (1970) *Insect Pollination of Crops*. Academic Press, London.

Freyenberger, S., Levins, R., Norman, D. and Rumsey, D. (2001) Beyond profitability: using economic indicators to measure farm sustainability. *American Journal of Alternative Agriculture* 16, 31-34.

Garcia-Torres, L., Benites, J., Martinez-Vilela, A. and Holgado-Cabera, A. (eds) (2003) *Conservation Agriculture*. Kluwer Academic Publishers, Dordrecht.

Goldewijk, K.K. and Ramankutty, N. (2004) Land cover change over the last three centuries due to human activities: the availability of new global data sets. *GeoJournal* 61, 335-344.

Gordon, J. and Davis, L. (2003) *Valuing Honeybee Pollination*. Rural Industries Research and Development Corporation, Canberra.

Gordon, L.J., Steffen, W., Jonsson, B.F., Folke, C., Falkenmark, M. and Johannessen, A. (2005) Human modification of global water vapour flows from the land surface. *Proceedings of the National Academy of Sciences USA* 102, 7612-7617.

Gurr, G. M., Wratten, S. D. and Altieri, M. A. (eds) (2004) *Ecological Engineering for Pest Management: Advances in Habitat Manipulation for Arthropods*. CSIRO, Victoria.

Heal, G.M. and Small, A.A. (2002) Agriculture and ecosystem services. In: Gardner, B.L. and Rausser, G.C. (eds) *Handbook of Agricultural Economics Vol. 2a* (pp. 1341-1369). Elsevier, Amsterdam.

Heywood, V.H. (ed.) (1995) *United Nations Environment Program, Global Biodiversity Assessment*. Cambridge University Press, Cambridge.

Holland, P. and Rahman, A. (1999) Review of trends in agricultural pesticide use in New Zealand. *MAF Policy Technical Paper* pp. 54. On WWW at http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/resource-management/pesticide-use-trends/PesticideTrends.PDF

Jacometti, M.A., Wratten, S.D., Walter, M. and Jaspers, M.V. (2006) Enhancing ecosystem services in vineyards: understorey management to reduce *Botrytis cinerea* primary inoculum. *Biological Control* (in press).

Johns, N.D. (1999) Conservation in Brazil's chocolate forest: the unlikely persistence of traditional cocoa agroecosystems. *Environmental Management* 23, 31-47.

Kasperczyk, N. and Knickel, K. (2006) Environmental impacts of organic farming. In: Kristiansen, P., Taji, A. and Reganold, J. (eds) *Organic Agriculture: A Global Perspective* (pp. 259-294). CSIRO Publishing, Australia.

Kort, J. (1988) Benefits of windbreaks to field and forage crops. *Agriculture, Ecosystems and Environment* 22/23, 165-190.

Kort, J. Collins, M. and Ditsch, D. (1988) A review of soil erosion potential associated with biomass crops. *Biomass and Bioenergy* 14, 351-359.

Krebs, J.R., Wilson, J.D., Bradbury, R.B. and Siriwardena, G.M. (1999) The second silent spring? *Nature* 400, 611-612.

Kremen, C. (2005) Managing ecosystem services: what do we need to know about their ecology? *Ecology Letters* 8, 469–479.

Kremen, C., Williams, N.M., Bugg, R.L., Fay, J.P. and Thorp, R.W. (2004) The area requirements of an ecosystem service: crop pollination by native bee communities in California. *Ecology Letters* 7, 1109-1119.

Kremen, C., Williams, N.M. and Thorp, R.W. (2002) Crop pollination from native bees at risk from agricultural intensification. *Proceedings of the National Academy of Sciences USA* 99, 16812-16816.

Kristiansen, P., Taji, A. and Reganold, J. (2006) Organic agriculture: opportunities and challenges. In: Kristiansen, P., Taji, A. and Reganold, J. (eds) *Organic Agriculture: A Global Perspective* (pp. 421-441). CSIRO Publishing, Australia.

Kumar, P. (2005) Market for ecosystem services. International Institute for Sustainable Development, Canada.

Lampkin, N. and Measures, M. (2001) *Organic Farm Management Handbook: Organic Farming Research Unit*. Aberystwyth: Institute of Rural Studies, University of Wales

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.

Lee, K. E. (1985) *Earthworms: their Ecology and Relationships with Soils and Land Use*. Academic Press, Sydney.

Leenders, J.K., Visser, S.M. and Stroosnijder, L. (2005) Farmers' perceptions of the role of scattered vegetation in wind erosion control on arable land in Burkina Faso. *Land Degradation and Development* 16, 327-337.

Luck, G.W., Daily, G.C. and Ehrlich, P.R. (2003) Population diversity and ecosystem services. *Trends in Ecology and Evolution* 18, 331–336.

Lyon, P., Colquhoun, A. and Janhonen-Abruquah, H. (2003) Consumer confidence and UK food retailing: why does local food matter? *Food, Agriculture and Environment*.1, 12-21

MacLeod, A., Wratten, S.D., Sotherton, N.W. and Thomas, M.B. (2004) 'Beetle banks' as refuges for beneficial arthropods in farmland: long-term changes in predator communities and habitat. *Agricultural and Forest Entomology* 6, 147-154.

Manktelow, D., Stevens, P., Walker, J., Gurnsey, S., Park, N., Zabkiewicz, J., Teulon, D. and Rahman, A. (2005) *Trends in pesticides use in New Zealand: 2004*. Ministry for the Environment, New Zealand. On WWW at http://www.hortresearch.co.nz/files/science/ifp/nz-pesticide-trends.pdf

McCann, E. (1997) Environmental awareness, economic orientation, and farming practices: a comparison of organic and conventional farmers. *Environmental Management* 21, 747-758.

McTaggart, D., Findlay, C. and Parkin, M. (2003) *Economics*. Pearson Education, Australia.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P., and Niggli, U. (2002) Soil fertility and biodiversity in organic farming. *Science* 296, 1694-1697.

Magdoff, F. and Weil, R.R. (eds) (2004) *Soil Organic Matter in Sustainable Agriculture*. CRC press, Florida.

Matheson, A. (1987) The value of honey bees to New Zealand. *The New Zealand Beekeeper* 194, 29.

Matheson, A. and Schrader, M. (1987) *The value of honey bees to New Zealand's primary production*. New Zealand: Ministry of Agriculture and Fisheries.

Matson, P.A., Parton, W.J., Power, A.G. and Swift, M.J. (1997) Agricultural intensification and ecosystem properties. *Science* 277, 504–509.

McCann, E. (1997) Environmental awareness, economic orientation, and farming practices: a comparison of organic and conventional farmers. *Environmental Management* 21, 747-758.

McLaren, R.G. and Cameron, K.C. (1996) *Soil Science.* Oxford University Press, Auckland.

Myers, N. (1996) Environmental services of biodiversity. *Proceedings of the National Academy of Sciences USA* 93, 2764–2769.

Nabhan, G.P. and Buchmann, S.L. (1997) Services provided by pollinators. In G. C. Daily (ed.) *Nature's Services*: *Societal Dependence on Natural Ecosystems* (pp. 133-150). Island Press, Washington.

Nabhan, G.P. and Buchmann, S.L. (1998) *Forgotten Pollinators*. Island Press, Washington.

National Academy of Sciences (2001) *Growing Populations, Changing Landscapes: Studies from India, China, and the United States*. National Academy Press, Washington, DC.

Norton, R.L. (1988) Windbreaks: benefits to orchard and vineyard crops. *Agriculture, Ecosystems and Environment* 22/23, 205-213.

Pacini, C., Wossink, A., Giesen, G., Vazzana, C. and Huirne, R. (2003) Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems and Environment* 95, 273-288.

PCE (2004) Growing for good: intensive farming, sustainability and New Zealand's environment. Parliamentary Commissioner for the Environment, Wellington, New Zealand. On WWW at http:// www.pce.govt.nz /reports / allreports/1_877274_45_3.pdf

Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A. and D'Amore, M. (1992) Environmental and economic costs of pesticide use. *BioScience* 42, 750–760.

Pimentel, D. and Giampietro, M. (1994). *Food, Land, Population and the U.S. Economy*. Carrying Capacity Network, Washington, DC.

Pimentel, D. and Wilson, A. (2004) World population, agriculture and malnutrition. *World Watch* 17, 22-25.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R. and Blair, R. (1995) Environmental and economic costs of soil erosion and conservation benefits. *Science* 267, 1117–1125.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D. and Seidael, R. (2005) Environmental, energetic, and economic comparisons of organic and conventional farming systems. *BioScience* 55, 573-582.

Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, Q., Saltman, T. and Cliff, B. (1997) Economic and environmental benefits of biodiversity. *BioScience* 47, 747–758.

Pinstrup-Andersen, P. (1998) A global vision of agriculture, food and the environment *Agricultura, medio ambiente y pobreza rural en America Latina* 3-20.

Pollard, E., Hooper, M. and Moore, N. (1974) *Hedges*. Collins New Naturalist Series, London.

Prescott-Allen, R. and Prescott-Allen, C. (1990) How many plants feed the world? *Conservation Biology* 4, 365-374.

Pretty, J. (2002) *Agri-Culture: Reconnecting People, Land and Nature*. Earthscan, London.

Pretty, J. N. (2005) *The Pesticide Detox: Towards a More Sustainable Agriculture*. Earthscan, London.

Pretty, J.N., Brett, C., Gee, D., Hine, R.E., Mason, C.F., Morison, J.I.L., Raven, H., Raymant, M.D. and van der Bijl, G. (2000) An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65, 113-136.

Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C., Morison, J., Rayment, M., van der Bijl, G. and Dobbs, T. (2001) Policy challenges and priorities for internalizing the externalities of modern agriculture. *Journal of Environmental Planning and Management* 44, 263 – 283.

Pretty, J. and Hine, R. (2001) *Reducing Food Poverty with Sustainable Agriculture: a Summary of New Evidence*. Final Report from the "SAFE-World" (The Potential of Sustainable Agriculture to Feed the World) Research Project, University of Essex Commissioned by UK Department for International Development. On WWW at http://www2.essex.ac.uk/ces/ResearchProgrammes/CESOccasionalPapers/SAFErepSUBHEADS.htm

Pretty, J. N. (1995) *Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance.* Earthscan Publications, London.

Quansah, C., Drechsel, P., Yirenkyi, B.B. and Asante-Mensah, S. (2004) Farmer's perceptions and management of soil organic matter – a case study from West Africa. *Nutrient Cycling in Agroecosystems* 61, 205-213.

Reganold, J.P., Papendick, R.I., and Parr, J.F. (1990) Sustainable agriculture. *Scientific American* 262, 112-120.

Reid, W.V., Mooney, H.A., Cropper, A., Capistrano, D., Carpenter, S.R., Chopra, K., Dasgupta, P., Dietz, T., Duraiappah, A.K., Hassan, R., Kasperson, R., Leemans, R., May, R.M., McMichael, A.J., Pingali, P., Samper, C., Scholes, R., Watson, R.T., Zakri, A.H., Shidong, Z., Ash, N.J., Bennett, E., Kumar, P., Lee, M.J., Raudsepp-Hearne, C., Simons, H., Thonell, J. and Zurek, N.B. (2005) *Millennium Ecosystem Assessment Synthesis report*. Island Press, Washington DC.

Ricketts, T.H. (2004) Tropical forest fragments enhance pollinator activity in nearby coffee crops. *Conservation Biology* 18, 1262-1271.

Ricketts, T.H., Daily, G.C., Ehrlich, P.R. and Michener, C.D. (2004) Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences USA* 101, 12579-12582.

Robertson, G.P. and Swinton, S.M. (2005) Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. *Frontiers in Ecology and Environmrent* 3, 38–46.

Roubik, D.W. (1995) *Pollination of Cultivated Plants in the Tropics*. FAO, Rome.

Sandhu, H.S., Wratten, S.D. and Cullen, R. (2005) Evaluating ecosystem services on farmland: a novel, experimental, 'bottom-up' approach. In: Proceedings of the 15th International Federation of Organic Agriculture Movements (IFOAM) Organic World Congress, Adelaide, Australia.

Silvano, R.A.M., Udvardy, S., Ceroni, M. and Farley, J. (2005) An ecological integrity assessment of a Brazilian Atlantic Forest watershed based on surveys of stream health and local farmers' perceptions: implications for management. *Ecological Economics* 53, 369-385.

Sotherton, N.W. (1995) Beetle banks-helping nature to control pests. *Pesticide Outlook* 6, 13-17.

Statistics New Zealand (2003) *Agricultural Production Statistics*. Statistics New Zealand, Wellington.

Stockdill, S.M.J. (1982) Effects of introduced earthworms on the productivity of New Zealand pastures. *Pedobiologia* 24, 29–35.

Storstad, O. and Bjørkhaug, H. (2003) Foundations of production and consumption of organic food in Norway: common attitudes among farmers and consumers? *Agriculture and Human Values* 20, 151-163.

Sturrock, J.W. (1969) Aerodynamic studies of shelterbelts in New Zealand-1. Low to medium height shelterbelts in mid-Canterbury. *New Zealand Journal of Science* 12, 754-756.

Sturrock, J.W. (1981) Shelter boosts crop yield by 35 per cent: also prevents lodging. *New Zealand Journal of Agriculture* 143, 18-19.

Swift, M.J., Izac, A.M.N. and van Noordwijk, M. (2004) Biodiversity and ecosystem services in agricultural landscapes – are we asking the right questions? *Agriculture, Ecosystems and Environment* 104, 113-134.

Tait, P. and Cullen, R. (2006) Some external costs of Dairy farming in Canterbury. In: Proceedings of the 50th Australian Agricultural and Resource Economics Society (AARES) Annual Conference, Manly, Australia.

Takatsuka, Y., Cullen, R., Wilson, M. and Wratten, S. (2005a) Using choice modelling to value ecosystem services on arable land. In: proceedings of the 49th Australian Agricultural and Resource Economics Society (AARES) Annual Conference, Coffs Harbour, Australia.

Takatsuka, Y., Cullen, R., Wilson, M. and Wratten, S. (2005b) Values of ecosystem services on arable land and the role of organic farming. In: Proceedings of the New Zealand Agricultural and Resource Economics Society (NZARES) 11th annual conference, Nelson, New Zealand.

Tegtmeier, E.M. and Duffy, M.D. (2004) External costs of agricultural production in the United States. *International Journal of Agricultural Sustainability* 2, 1-20.

Thomas, S. (2000) Progress on beetle banks in UK arable farming. *Pesticide Outlook* 11, 51-53.

Thomas M.B., Wratten, S.D. and Sotherton, N.W. (1991) Creation of 'island' habitats in farmland to manipulate populations of beneficial arthropods: predator densities and emigration. *Journal of Applied Ecology* 28, 906-917.

Thomas M.B., Wratten, S.D. and Sotherton, N.W. (1992) Creation of 'island' habitats in farmland to manipulate populations of beneficial arthropods: predator densities and species composition. *Journal of Applied Ecology* 29, 524-531.

Thrupp, L A. (1996) *Partnerships for Sustainable Agriculture.* World Resources Institute, Washington DC.

Tilman, D. (1998) The greening of the green revolution. *Nature* 396, 211-212.

Tilman, D. (1999) Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences USA* 96, 5995-6000.

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

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

Tilman, D. and Lehman, C. (2001) Human-caused environmental change: impacts on plant diversity and evolution. *Proceedings of the National Academy of Sciences* 98, 5433-5440.

Tilman, D., Reich, P.B. and Knops, J.M.H. (2006) Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature* 441, 629-632.

UN (1992) *Promoting sustainable agriculture and rural development. United Nations Conference on Environment & Development.* Rio de Janerio, Brazil, 3 to 14 June. Agenda 21, 14.1-14.104. On WWW at http://www.un.org/esa/sustdev/agenda21.htm

UNEP (2005) *One Planet, Many People: Atlas of Our Changing Environment.* UN, New York.

Vitousek, P.M., Mooney, H.A., Lubchenco, J. and Melillo, J.M. (1997) Human domination of earth's ecosystems. *Science* 277, 494-499.

Vos, T. (2000) Visions of the middle landscape: organic farming and the politics of nature. *Agriculture and Human Values* 17, 245-256.

Warner, K.D. (2006) Extending agroecology: grower participation in partnerships is key to social learning. *Renewable Agriculture and Food Systems* 21, 84-94.

Williams, M. (2004) Sustainabile New Zealand-the way forward. *New Zealand Geographic* 70, 7-8.

Willer, H. and Yussefi, M. (eds) (2006) *The World of Organic Agriculture 2006: Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements (IFOAM), Bonn.

Table 1 Ecosystem services associated with arable farming (adapted from Cullen *et al.*, 2004 and Takatsuka *et al.*, 2005).

Provisioning services	***Regulating services***	**Cultural services**
Food	Hydrological flow	Aesthetic
Raw materials		Recreation
Fuel wood		Science and education
Conservation of species		
Maintenance of genetic resources		
	Supporting services	
Pollination	Mineralization of plant nutrients	Support to plants
Biological control	Soil fertility	Soil formation
Carbon accumulation	Soil erosion control	Nitrogen fixation
		Shelterbelts

Table 2 Perceived importance of ES by organic and conventional farmers on a scale of 1-5.

	Ecosystem services	Organic farmers' responses (mean)	Conventional farmers' responses (mean)
	Supporting services		
1	Pollination	**4.8**	**4.7**
2	Biological control	**3.7**	**2.6**
3	Carbon accumulation	**3.2**	**2.6**
4	Mineralization of plant nutrients	**3.7**	**3**
5	Soil fertility	**4.8**	**4.5**
6	Soil erosion control	**4**	**3.8**
7	Support to plants	**2.5**	**2.8**
8	Soil formation	**3.8**	**3.6**
9	Nitrogen fixation	**4**	**3.6**
10	Shelterbelts	**3**	**3.6**
	Provisioning services		
11	Food	**3.7**	**4.2**
12	Raw material	**3.2**	**2.7**
13	Fuel wood	**2.1**	**2.3**
14	Conservation of species	**3.5**	**3.3**
15	Maintenance of genetic resources	**4**	**3.5**
	Regulating services		
16	Hydrological flow	**3.7**	**3.7**
	Cultural services		
17	Aesthetic	**3.5**	**2.7**
18	Recreation	**2.5**	**2.1**
19	Science and education	**3**	**2.7**

Figure captions

Fig. 1 Conceptual model depicting perceptions of ecosystem services in organic and conventional agriculture.

Fig. 2 Ranking based on the perceptions of organic farmers regarding the importance of each ES.

Fig. 3 Ranking based on the perceptions of conventional farmers regarding the importance of each ES.