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Abstract

Researchers have estimated the total economic value of global ecosystem goods and services showing that a significant portion of humanity's economic well being is unaccounted for in conventional GNP accounting (Constanza et al., 1997). To demonstrate this point, authors have conventionally used highly aggregated landscape units for analysis (e.g., biomes), and average, not marginal values, of each ecosystem good or service are estimated for each unit using value transfer methodologies (Wilson et al., 2004). For example, Patterson and Cole (1999a, b) replicated the Constanza et al., (1997) approach by estimating economic values for Waikato and New Zealand ecosystem goods and services associated with standard land cover classes including horticulture, agriculture and cropping. As a result, Patterson and Cole (1999b) argue that only five ecosystem services associated with cropping have non-zero value.

One of the reasons for this low number of non-zero values assorted with arable lands is that the original economic studies used by Patterson and Cole, are heavily weighted towards natural and undisturbed ecosystems rather than disturbed systems like agricultural or urban landscapes. To address this issue, more recently researchers have noted that many landscapes are actively modified by humans who seek to realise economic gain and this topic is thus an important one because in the 21st century, many of our homes, workplaces and recreational spaces are embedded within, or adjacent to, landscape mosaics that are to a greater or lesser degree affected by the conscious efforts of people to harness goods and services provided by ecological systems (Palmer et al., 2004). An *engineered* or *designed* ecosystem is one that has been extensively modified by humans to explicitly provide a set of ecosystem goods and services including more fresh water, trees, and food products and fewer floods and pollutants. These modified landscapes provide a range of ecosystem goods and services, particularly food production as farmers seek to maximize commercial gain from land use. The current paper examines issues in valuation of ecosystem goods and services derived from land used for arable faming in New Zealand and proposes ways to provide more detailed estimates of the flow and value of the flow of ecosystem services provided.

Keywords: Ecosystem management; Arable farming; Engineered ecosystem

1. Introduction

Ecosystems have various functions that provide services to the economic system. Researchers have estimated the total economic value of ecosystem services (ES) provided in 16 biomes (Constanza et al., 1997). More recent studies using in some cases Landsat data have provided estimates of ES for 122 nations (Sutton and Costanza, 2002). Average, but not marginal values per hectare, of each ecosystem service are estimated in these studies and the mean values per hectare are applied irrespective of location. Patterson and Cole (1999a, b) have replicated the Constanza et al., (1997) methods and estimated values for Waikato and New Zealand ecosystem services. The land cover classes used in the Waikato and New Zealand studies include horticulture, agriculture and cropping land. Patterson and Cole (1999a, b) argue that for arable land only five ecosystem services have non-zero values. Recent studies have noted that many landscapes are modified by humans to realise economic gain from designed or engineered landscapes (Palmer et al., 2004). These modified landscapes provide a range of ecosystem services, and in arable farming, particularly food production is the most significant service as farmers seek to maximize commercial gain from land use. The current paper examines issues in estimating the level of ecosystem services provided by designed agricultural systems and placing an economic value on the ecosystem services delivered to New Zealand. We propose new ways to provide more detailed estimates of the flow and values of the flow of ecosystem services provided on arable land.

2. Literature Review

Issues in ecosystem valuation have been discussed by researchers for more than a decade (Bockstael et al., 1995; Bingham, et al., 1995). At the Ecosystem Valuation Forum held by the U.S. Environmental Protection Agency in 1991, an expert group of ecologists, economists, and other social scientists discussed the state of art of ecosystem valuation methods. Their discussions were focused on the understanding of ecosystem values, on the relationship between ecological functions and economic actions, and the development of a highly integrated valuation process (Bockstael et al., 1995; Bingham, et al., 1995). It was proposed to construct a model that included interrelationships between ecology and economics, employing a landscape perspective (Bockstael, et al., 1995). Costanza and others developed this model in a project to estimate ecosystem service values in Maryland, focusing on spatial and temporal distributions of the ecosystem services and functions of both the natural system and human related phenomena. Their model was based on the Patuxent Landscape Model (PLM) (Costanza et al., 1990; Fitz et al., 1995), which captured spatial simulation of complex ecological systems and partially resolved the effects of human intervention of land.

Costanza and fellow researchers extended the spatial analysis at a regional and then at a global level, as described in the well known article in Nature entitled “The Value of the World’s Ecosystem Services and Natural Capital” (Constanza et al., 1997). The authors divided the surface of the planet into 16 biomes and estimated economic values of 17 ecosystem services for each biome, using value transfer methods. This economic valuation methodology estimates values for non-marketed goods or services, based upon information from previous studies valuing similar goods or services. Costanza argued the purpose of the 1997 article was to stimulate discussion on issues related to ecosystem service valuation at the global level. That goal was achieved and the article had received 375 scientific journal cites by February 2002 (Constanza and Farber, 2002).

After publication of the Costanza et al., (1997) article, arguments arose about possible double counting and overestimation of the values of ES (Turner et al., 2003; Toman, 1998; Loomis, et al., 2000). Further Turner et al., (2003) and Toman (1998) pointed out that the study estimated total but not marginal values, suggesting that aggregate values, like GDP, gave no insights into the direction of current changes in ecosystem services, the relative importance of specific ecosystem services, or the urgency of protecting specific ecosystem services. They considered that ecosystem service valuation should be helpful to understanding the impact of changes in the level and importance of ecosystem services.

3. What are Ecosystem Functions and Services?

De Groot et al., (2002 p394) defined ecosystem functions as 'the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly.' Costanza et al., (1997) used the term, ecosystem services, to represent both ecosystem goods (such as food) and services (such as waste assimilation) for simplicity, mentioning that the services consisted of flows of materials, energy, and information from natural capital stocks to produce human welfare. The authors divided ecosystem services into 17 major categories, which they named: gas regulation, climate regulation, disturbance regulation, water regulation, water supply, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, pollination, biological control, habitat/refugia, food production, raw materials, genetic resources, recreation, and cultural. The definitions and examples of these ecosystem services are shown in Table 1. De Groot et al., (2002) expanded the list into 23 ecosystem services and categorised these services into four ecosystem functions, namely the regulation function, habitat function, production function, and information function. Table 2 shows both the Costanza et al. and the de Groot et al. lists of ecosystem services used in their analyses. The classification used by de Groot et al. was based on the one developed by Costanza et al., (1997), but provided more detailed information on ecosystem services. For example, de Groot added 'spiritual and historic information' as well as 'science and education', as they were likely to be ignored in earlier classifications. The values for those services should be included in future analyses as they can play important roles in human lives.

4. Values of Ecosystem Services at the Global and New Zealand Level

Costanza et al., (1997) estimated the average total global values of ecosystem services to be in the range US $16-54 trillion per year (1994 $), with an average of US $33 trillion which was equivalent to 1.8 times the global gross national product. It was assumed that all lands in the same biome provided equal value ecosystem service. Values of an ecosystem service were assumed to be uninfluenced by specific factors such as regional scarcity or quality variations.

Patterson and Cole (1999a, b) have replicated the Costanza et al methodologies and estimated total values of ecosystem services for New Zealand generally, and the Waikato region specifically. They divided New Zealand into 13 land cover groups and then estimated values of the 17 ecosystem services for each land cover. The 13 land cover groups include: Horticulture and cropping, Agriculture, Intermediate Agriculture-Forest, Forest-Scrub, Forest, Wetlands, Estuaries, Mangroves, Lakes, Rivers, and Marine. They estimated the total ecosystem values for New Zealand to be approximately 1994 NZ $39 billion (≈ US $24 billion). Although Patterson and Cole (1999b) estimated the total values of the ecosystem services, we have converted the total values into values per hectare for the land cover classes in order to compare them to the Costanza et al., (1997) study.

Table 3 provides a comparison of information gleaned from Costanza et al., (1997) and Patterson and Cole (1999b) including estimates of the value of ecosystem services per hectare for 13 land cover groups. The third row of Table 3 gives information on area for each land cover group in both the world and New Zealand. Comparing the percentage shares of each land cover, the high percentage of grassland in New Zealand should be noted. On the other hand, there is a relatively low percentage of horticulture and crop lands in New Zealand compared to the global level. All other numbers below the area information are per hectare values in 1994 US dollars. Not surprisingly as Patterson and Cole have adapted values from Costanza et al., (1997), most of values calculated for NZ ecosystem services are similar to the ones at the global level, except for horticulture and croplands, forest, and mangrove. In forests and mangroves, per hectare values of ES at the world level are higher than the ones in New Zealand. However, the per hectare value of ES on New Zealand horticulture and crop lands are approximately 35 times higher than the world level because of significantly higher values of food production ecosystem service.

5. Ecosystem Service Valuation in NZ Arable Lands

Our research project is focused on arable lands in New Zealand. Many ES valuation studies have focused on wetlands, forests, or coastal areas, but few have focused on arable lands. Studying the few and rapidly shrinking natural, undisturbed landscapes is important, but now is the time to focus on an ecology that includes humans as active participants in the creation of liveable landscapes. Arable lands play a significant role in the ecosystems but they have been modified by humans who seek to realise economic gain from designed or engineered landscapes. By focusing on arable lands, our research perspective actively incorporates human activities as integral components of the New Zealand landscape and focuses on conscious modifications of that landscape to deliver specified goods and services.

Patterson and Cole (1999b) identified only five non-zero valued ecosystem services in arable farming. One explanation for Patterson and Cole (1999b) low number of non-zero valued services in arable farming is that their estimations are based on ecosystem services provided by natural and undisturbed ecosystems, and understate the possibility of ecosystem services provided on disturbed systems such as agricultural or urban landscapes. To address this issue, more recently researchers have noted that many landscapes are deliberately modified, but still provide a significant range of ecosystem services (Palmer et al., 2004). Designed ecosystems span a range from slightly altered, to highly manipulated landscapes that have literally been created by humans from scratch. Many of our homes, workplaces and recreational spaces are embedded within, or adjacent to, landscape mosaics that are to a greater or lesser degree affected by the conscious efforts of people to harness goods and services provided by ecological systems. An *engineered* or *designed* ecosystem is one that has been extensively modified by humans to explicitly provide a set of ecosystem goods and services including more fresh water, fewer floods, more trees, more food products and fewer pollutants. These modified landscapes provide a range of ecosystem goods and services, particularly food production, as farmers seek to maximize commercial gain from land use. The goal of our study is to examine issues in valuation of ecosystem goods and services derived from land used for arable faming in New Zealand and to propose ways to provide more detailed estimates of the flow and value of the flow of ecosystem services provided.

5.1 Objectives

The objective of our long-term study is to provide new detailed estimates of ecosystem services for arable land in New Zealand. This will require the estimation of the rate of flow of each ecosystem service provided on arable land, review of value transfer methodologies, creation of a database of New Zealand ecosystem valuation studies, and the calculation of the annual value for each ecosystem service. The information collected for the database of New Zealand valuation studies will be linked to a geographic information system to allow spatial analysis of ecosystem services provided in chosen regions of New Zealand.

The research requires two key actions. Original research is required to collect information on the flow of ecosystem services provided on arable lands, as there is only fragmentary information available at present. First information gained from current investigations by ecologists researching the flow of ES on arable lands will supplement information obtained from research literature and from personal interviews. This will provide data on rates of ES flow for the regulation functions such as soil information, nutrient cycling, pollination, and biological control. Second the research project will implement as needed non-market valuation (NMV) surveys to provide new information or attempt to verify values of selected ES provided on arable land. These NMV studies will aim to provide estimates of 'marginal' values especially for the information functions such as recreation and culture.

5.2 What Ecosystem Services are provided on NZ arable land?

Before starting to analyze ecosystem service values, definitions of ecosystem services provided on arable lands need to be specified, particularly the 11 ecosystem services for the regulation function categorized by de Groot et al., (2002). The definitions of ES contained in Constanza et al., (1997) and de Groot et al., (2002) require clarification before they are applied to arable farming in New Zealand. Comments and advice were obtained from ecologists, scientists, and engineers to improve understanding not only of the definitions but also of specific procedures to estimate the flow of ecosystem services in New Zealand arable farming. Definitions and proposed procedures for measurement of the flow of 11 ecosystem services are described below.

5.2.1 Gas Regulation

According to Costanza et al., (1997) and de Groot et al., (2002), gas regulation refers to maintenance of chemical composition of the atmosphere and oceans by bio-geochemical processes influenced by many biotic and a-biotic components of natural ecosystems. For example, this regulation maintains the CO_2/O_2 balance, the ozone-layer (O_3), and SO_X levels in the atmosphere. De Groot et al., (2002) note that natural, social, and economic processes can be impacted positively or negatively by any alternations which influences these gas balances. Arable lands in New Zealand emit CO_2 and NO_2 to the atmosphere (Cooper, pers comm. 13.05.04) and arable land makes a negative contribution towards gas regulation.

5.2.2 Climate Regulation

The climate regulation function influences global temperature, precipitation and other biologically mediated climatic processes at global or local levels (Costanza et al., 1997; de Groot et al., 2002). Maintenance of favourable climate for human habitation and healthy crop cultivation are important examples of the benefits flowing from this function. As mentioned above, arable farming produces CO_2 and NO_2 contributing to climate change and global warming associated with increases in extreme weather including high intensity rainfall or droughts. Hence, arable farming tends to disturb climate regulation and makes a negative contribution to this ES.

5.2.3 Disturbance Regulation

This regulation function concerns the ability of ecosystems to reduce the effect of disruptive natural events including storms, floods and droughts. It contributes to increased safety of human life and reduced hazard to human constructions. Storm protection, flood control, and drought recovery controlled by ecosystems are the main services of this regulation. An example of disturbance regulation is coral reefs that buffer waves and protect adjacent coastlines from storm damage (Costanza et al., 1997; de Groot et al., 2002). Most arable farming in NZ does not contribute this service, and is judged to be contributing to more disturbances through emissions of CO_2 and NO_2, which will turn in lead to more extreme rainfall or drought.

5.2.4 Water Regulation and 5.2.5 Water supply

Water regulation and water supply were categorised as two separate ecosystem services by Costanza et al., (1997). The water regulation function maintains normal conditions of hydrological flows in a watershed at the earth's surface. Examples of this function include buffering of extreme discharge levels of rivers, regulation of channel flow, and provision of a medium for transportation. On the other hand, the water supply function refers to the filtering, retention and storage of water in watersheds. It focuses on the storage capacity for water rather than the flow of water.

Information on these functions was provided by Professor Malin Falkenmark, Stockholm International Water Institute. In her view, water service is provided by the atmosphere, not by land ecosystems (Falkenmark, pers comm. 25.05.04). In other words, the terrestrial land ecosystems are water consumptive rather than water provisioning. For instance, the land ecosystems literally consume two third of the continental precipitation, which is called green water flow (Falkenmark, pers comm. 25.05.04). The runoff production is contributed by the water discarded by the land ecosystem, which is called the blue water flow. She explains that arable land receives water from the atmosphere and either discards some of it as overland flow forming flood flow in the river and infiltrates the rest into the soil. In both cases, the waters return to the atmosphere (the green water flow). The surplus of the water percolates down to the groundwater which moves under the ground to lower terrain areas where it seeps back to the land surface and often joins the river flow as time stable flow or dry season flow (the blue season flow). The water regulation function she suggests is basically defined as the ground water recharge. If we use the definition for the water regulation as one of ecosystem services, we might observe positive or negative impacts on the services of arable lands. The meaning of the water supply is more complicated. Falkenmark notes that even some scientists specialized in water issues use the term of the "water supply" in different ways. One way is for (blue) water availability, and the other way is for the service of providing water for household, industry or other uses. Falkenmark comments that the term water supply used by Constanza et al., (1997) refers to runoff production in terms of flood flow and dry season flow.

In this study the meaning of the "water supply" is consistent with Constanza et al., (1997), as the purpose of the present study is to clarify the meanings of ecosystems and evaluate them.

Bryce Cooper of the National Institute of Water and Atmospheric Research (NIWA) (pers comm. 13.05.04) and Vince Bidwell at Lincoln Venture Ltd. (pers comm. 18.05.04), comment that New Zealand arable farming negatively impacts water regulation and water supply ecosystem services. They comment that arable farming reduces the capacity of land to store rainfall and release it slowly over time even though the consumption of water is relatively moderate when compared to pasture's consumption of water.

5.2.6 Soil Retention

According to de Groot et al. (2002), the soil retention function mainly depends on the structural aspects of ecosystems, especially the vegetation cover and the root system. This service comprises the influence of preventing compaction and erosion of bare soil by tree root's soil stabilization and foliage's interception of rainfall. Plants growing along shorelines and (submerged) vegetation in near-coastal areas contribute greatly to controlling erosion and facilitating sedimentation. The services provided by this function are very important to maintaining agricultural productivity and prevent damage due to soil erosion (both from landslides and dust bowls). The main services provided by the erosion control and the sediment retention function are the maintenance of agriculture productivity and prevention of damage due to soil erosion.

Dr Les Basher, Landcare Research Ltd. (Basher, pers comm., 13.05.04) suggests that typically rates of erosion under arable cropping would be higher than for other land uses. The ecosystem functions of erosion control and sediment retention are generally diminished on arable land compared to bare ground (Basher and Ross, 2002). Studies of wind erosion on the Canterbury Plains (McLaren and Cameron, 1990) shows that stability of soil aggregates are worse in long-term arable land, which may lead to higher risk of soil erosion. Our summary judgement is that frequent cultivation on New Zealand arable land may diminish the level of this ecosystem service.

5.2.7 Soil Formation

Soil formation comprises the influence of weathering of rock and accumulation of organic matter. Soil formation usually is a very slow process; natural soils are generated at a rate of only a few centimetres per century and after erosion, soil formation (or regeneration) from bedrock takes 100-400 years per cm topsoil (Pimentel and Wilson, 1997). The main services provided by the soil formation function are the maintenance of productivity and natural productive soils (Constanza et al., 1997; de Groot et al., 2002). According to Trevor Webb at Landcare Research Ltd. (Webb, pers comm. 05.13.04), arable farming mines the organic matter that is restored under pasture systems and restorative crops.

5.2.8 Nutrient Cycling

This function refers to the ability of plants and animals to utilize nitrogen (N), sulphur (S), and phosphorous (P). For example, soil and water gain nitrogen when it is absorbed from the atmosphere by the roots of plants with the assistance of nitrogen fixing bacteria and algae. When plants die or are consumed by animals, nitrogen is recycled back into the atmosphere. This function plays a role in storage and recycling of nutrients and maintains healthy and productive soils. (Costanza et al., 1997; de Groot et al., 2002). This natural cycle is disrupted when farmers use excess commercial fertilizers. Depending on the amount of fertilizer used, arable farming may affect nutrient cycling either positively or negatively.

5.2.9 Waste Treatment

Excess levels of certain compounds in water or air can lead to unhealthy living conditions for humans and other species. Ecosystems provide waste treatment functions by storing and recycling some amounts of inorganic human waste through dilution, assimilation, and chemical re-composition. For example, trees and vegetation help to improve air quality by filtering out particulates and toxic compounds from air, making it more breathable and healthy. Wastes in arable lands are mostly crop residues and any waste treatment provided occurs through chemical residue assimilation. Andrew Dakers of EcoEng Ltd (Dakers pers comm. 13.05.04) has commented that the mass of crop and chemical residues in arable lands needs to be measured in terms of organic matter and key nutrients, such as N, P, and S, in kg/ha/yr in order to estimate quantum of waste treatment occurring on arable land.

5.2.10 Pollination

Pollination refers to a role of reproduction for most plants by many wild pollinator agents, such as insects, birds, bats, and wind. The service provided by this function can be derived from the dependence of cultivation on natural pollination (de Groot et al., 2002). Nobhan and Buchmann (1997) suggest that the economic value of agricultural pollination services can be directly measured by comparing the yield (loss) of the crop in the absence of these pollinators with the yield in the presence of the pollinators in question. Also non-market values for pollination need to be estimated, such as social benefits which include aesthetic values. An alternative way to quantify the value of the ecosystem service of pollination is to estimate the replacement costs for pollinators. However, a question arises is there are any alternatives to existing pollinators? Professor John Hampton of New Zealand Seed Technology Institute, Lincoln University (pers comm. 27.05.04), suggests two possibilities for replacement exist: 1. Create self pollinators; the development is time-consuming, and they cannot be used for all species 2. Collect pollen manually by a machine and blow it onto female flowers. The replacements cost should include costs of manpower and equipment. In our study, we will attempt to estimate the replacement costs of pollinators for the main arable crops including wheat, barley, peas, maize, beans, clover seed, grass seeds, potato.

5.2.11 Biological Control

Biological control refers to prevention of outbreaks of pests and diseases by the natural ecosystem, not by human controls. According to Naylor and Ehrlich (1997), natural ecosystems control more than 95% of all the potential pests of crops and carriers of disease to human beings. The substitution of synthetic pesticides for natural pest controls can result in pest resurgence and secondary pest outbreaks that reduce that fundamental stability of agriculture systems. Therefore, values of biological control might be estimated by the replacement cost of natural biological control, which include market values of synthetic pesticides and associated costs to society. The costs to society should consist of two parts: health costs and loss from damaging wildlife. Each year many people have health problems due to toxic chemicals. The medical costs should be included in the cost to society. Also toxic and polluting chemicals impact some natural enemies, hedgerows and shelterbelts, increase monoculture, reduce crop diversity, reduce sanitation, and leave increased crop residues on the surface of the land. Costs of all these also are a part of the costs to the society. In addition, some countries subsidise the cost of agricultural chemicals. Naylor and Ehrlich (1997) estimated all of these market and non-market items to provide an estimate of US$54 billion per year for the value of natural biological control on the planet. A similar approach can be used to estimate the value of biological control on New Zealand arable land.

6. Positive and Negative Values of Ecosystem Services

After reviewing the various definitions of ecosystem functions and possible procedures for quantifying the flow of ecosystem services provided on New Zealand arable land, it is clear that both positive and negative values will be estimated for ES on arable land. These values might replace the blanks in Patterson and Cole (1999b) column for ES in horticulture and cropping. Table 4 shows that the prospective signs of ES on arable land. The values for ES of nutrient cycling, pollination, biological control, food production, recreation, and cultural are expected to be positive on arable land. On the other hand, arable land may diminish the ES from gas regulation and erosion control and hence have negative ES values. Water regulation, water supply, and soil formation may be either positive or negative to be valued on arable land. The recognition that ES in engineered system may have positive or negative values has not been noted in any studies we have surveyed. Recognition of the range of possible values of each of the ES on arable land helps us to understand the importance of each ecological function. That knowledge provides insights that can allow us to modify the ways we manage ecosystem services in *engineered* or *designed* ecosystems. One obvious line of research to pursue is to compare the output rate and value of each ES under alternative management systems such as conventional and organic arable farming.

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References

Basher, L.R. & C.W. Ross. (2002). Soil erosion under arable cropping in New Zealand. In Stephens, P., Callaghan, J., Austin, A. (compilers). Proceedings: Soil Quality and Sustainable Land Management Conference, Landcare Research, Palmerston North.

Bingham, Gail, Richard Bishop, Michael Brody, Daniel Bromley, Edwin (Toby) Clark, William Cooper, Robert Costanza, Thomas Hale, Gregory Hayden & Stephen Kellert. (1995). Issues in Ecosystem Valuation: Improving Information for Decision Making. Ecological Economics, 14: 73-90.

Bockstael, Nancy, R. Costanza, I. Strand, W. Boynton, K. Bell & L. Wainger. (1995). Ecological Economic Modelling and Valuation of Ecosystems. Ecological Economics, 14; 143-159.

Costanza, R. & S. Farber. (2002). Introduction to the special Issue on the Dynamics and Value or Ecosystem Services: Integrating Economics and Ecological Perspectives. Ecological Economics, 41 (3): 367-374.

Costanza, Robert, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburge, Shahid Neem, Robert O'Neil, Jose Parelo, Robert Raskin, Paul Sutton & Marjan van den Belt. (1997). The Value of the World's Ecosystem Services and Natural Capital. Nature, 387: 253-259.

Costanza, R., F. Sklar & M. White. (1990). Modelling Coastal Landscape Dynamics. BioScience, 40: 91-107.

de Groot, Rudolf, Matthew Wilson & Roelof Boumans. (2002). A Typology for the Classification, Desription and Valuation of Ecosystem Functions, Goods and Services. Ecological Economics, 4: 393-408.

Fitz, C., A. Voinov & R. Costanza. (1995). The Everglades Landscape Model. University of Maryland, Solomons, MD.

Loomis, John., Kent Paula, Liz Strange, Kurt Fausch & Alan, Covich. (2000). Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired River Basin: Results From a Contingent Valuation Survey. Ecological Economics, 33: 103-117.

Mclaren & Cameron. (1990). Soil Science. Oxford University, Auckland.

Naylor, Rosamond & Paul Ehrlich. (1997). Natural Pest Control Services and Agriculture. In Daily, G (ed.). Nature's Services: Societal Dependence on Natural Ecosystems. Island Press.

Nobhan, Gary & Stepehn Buchmann. (1997). Services Provided By Pollinators. In Daily, G (ed.). Nature's Services: Societal Dependence on Natural Ecosystems. Island Press.

Palmer, Margaret, E. Bernhardt, E. Chornesky, S. Collins, A. Dobson, C. Duke, B. Gold, R. Jacobson, S. Kingsland, R. Kranz, M. Mappin, M.L. Martinez, F. Micheli, J. Morse, M. Pace, M. Pascual, S. Palumbi, O.J. Reichman, A. Simons, A. Townsend & M. Turner. (2004). Ecology for a Crowded Planet. Science, 304: 1251-1252.

Patterson, Muray & Anthony Cole. (1999a). Estimation of the Value of Ecosystem Services in the Waikato Region. Environmental Waikato Regional Council. Hamilton.

Patterson, Muray & Anthony Cole. (1999b). Assessing the Value of New Zealand's Biodiversity. School of Resource and Environmental Planning. Massey University. Palmerston North.

Pimentel, D. & C. Wilson. (1997). Economic and Environmental Benefits of Biodiversity. BioScience, 47: 747-758.

Sutton, C. & R. Costanza. (2002). Global Estimates of Market and Non-market Values Derived From Nighttime Satellite Imagery Land Cover, and Ecosystem Service Valuation. Ecological Economics, 41 (3): 509-527.

Toman, Michael. (1998). Why Not to Calculate the Value of the World's Ecosystem Services and Natural Capital. Ecological Economics, 25: 57-60.

Turner, R. Kerry., Jouni Paavola, Philip Cooper, Stephen Farber, Valma Jessmy & Stavros Georgiou. (2003). Valuing Nature: Lessons Learned and Future Research Directions. Ecological Economics, 46: 493-510.

Wilson, Matthew A, Austin Troy, and Robert Costanza. (2004). The Economic Geography of Ecosystem Goods and Services: Revealing the Monetary Value of Landscapes through Transfer Methods and Geographic Information Systems. In Dietrich and Van Der Straaten (eds.) Cultural Landscapes and Land Use. Kluwer Academic Publishers.

Table 1. Definitions and Examples of Ecosystem Services

	Costanza et al. (1997)		
	Ecosystem Service	Definitions	Examples
1	Gas regulation	Regulation of atmospheric chemical composition	CO_2/O_2 balance, O_2 for UVB, SO_x levels
2	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels	Greenhouse gas regulation, DMS production affecting cloud formation
3	Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations	Storm protection, flood control, drought recovery
4	Water regulation	Regulation of hydrological flows	Irrigation, milling, transportation
5	Water supply	Storage and retention of water	watersheds, reservoirs, aquifers
6	Erosion control and sediment retention	Retention of soil within an ecosystem	wind, runoff, lakes, wetlands
7	Soil formation	Soil formation processes	accumulation of organic material, weathering of rock
8	Nutrient cycling	Storage , internal cycling, processing and acquisition of nutrients	Nitrogen fixation
9	Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds	Waste treatment, Pollution control detoxification
10	Pollination	Movement of floral gametes	reproduction of plant populations
11	Biological control	Trophic-dynamic regulations of population	reduction of herbivory by top predators, control of prey species
12	Refugia	Habitat for resident and transient production	Nurseries, habitat for migratory species, regional habitats for locally harvested species
13	Food production	That portion of gross primary production extractable as food	production of fish, crops, nuts, fruits
14	Raw material	That portion of gross primary production extractable as raw materies	production of lumber, fuel , or fodder
15	Genetic resources	Sources of unique biological materials and products	Medicine, products for materials science, resistance to plant pathogens and crop pests
16	Recreation	Providing opportunities for recreational activities	Eco-tourism, sport fishing, outdoor activities
17	Cultural	Providing opportunities for non-commercial uses	aesthetic, artistic, education, spiritual, and/or scientific values

Table 2. List of Ecosystem Services

Costanza et al. (1997)		de Groot et al. (2002)	
			Regulation function
1	Gas regulation	1	Gas regulation
2	Climate regulation	2	Climate regulation
3	Disturbance regulation	3	Disturbance regulation
4	Water regulation	4	Water regulation
5	Water Supply	5	Water Supply
6	Erosion control and sediment retention	6	Erosion Control
7	Soil formation	7	Soil formation
8	Nutrient cycling	8	Nutrient cycling
9	Waste treatment	9	Waste treatment
10	Pollination	10	Pollination
11	Biological control	11	Biological control
		12	Soil Retention
			Habitat function
12	Refugia	13	Refugia function
		14	Nursery function
			Production function
13	Food production	15	Food
14	Raw material	16	Raw material
15	Genetic resources	17	Genetic resources
		18	Medicinal resources
		19	Ornamental resources
			Information function
16	Recreation	20	Recreation
17	Cultural	21	Cultural and artistic information
		22	Spiritual historic information
		23	Science and education

Table 3. Summary of Average Value of Annual Ecosystem Services (1994 US$ per hectares)

Ecosystem Service	Hort & Crop		Grass/ rangelands		Forest		Wetlands		Estuarine		Mangroves		Lakes/ rivers		Total	
	World	NZ	World	NZ	World	NZ	World	NZ	World	NZ	World	NZ	World	NZ	World	NZ
Area (ha x 1000)	1400000	164	3898000	16878	4855000	8339	165000	166	180000	100	165000	19	200000	529	15323000	26195
%	9.1	0.6	25.4	64.4	31.7	31.8	1.1	0.6	1.2	0.4	1.1	0.1	1.3	2.0	100.0	100.0
1 Gas regulation			7	4			265	274								6
2 Climate regulation		7	0	91	141	91										33
3 Disturbance regulation					2		7240	7514	567	586	1839	1931				51
4 Water regulation		4	3	3	2		30	32					5445	5660		116
5 Water supply					3		7600	7888					2117	2200		94
6 Erosion control and soil retention		29	29	137	96	127										155
7 Soil formation			1	7	10	10										6
8 Nutrient cycling					361				21100	21899						84
9 Waste treatment			87	90	87	90	1659	1722		544	6696		665	690		114
10 Pollination	14	25	25													16
11 Biological control	24		23	17	2	4			78	77						16
12 Refugia			304				439	453	131	130	169	156				3
13 Food production	54	3222	256		43		47		521		466		41	18		103
14 Raw material			106	14	138	99	49		25		162					54
15 Genetic resources					16											
16 Recreation			2		66	37	491	506	381	391	658		230	238		22
17 Cultural				2	2	2	1761	1825	29	30						14
Total value per ha	92	3287	232	392	969	440	19580	20214	22832	23656	9990	2087	8498	8806	804	889

*(Reserve bank of New Zealand, http://www.rbnz.govt.nz/statistics/exandint/b1/download.html)
1994NZ$1.00 = 1994US$ 0.5917
"World" is referenced by Costanza et al (1997)
"NZ" is referenced by Patterson and Cole (1999b)

Table 4. Average Value of NZ Horticulture and Crop Lands Studied by Patterson and Cole (1999b) and the Prospective Signs

	Ecosystem Service	Patterson and Cole	Prospective Signs
1	Gas regulation		-
2	Climate regulation	12.20	
3	Disturbance regulation		
4	Water regulation	6.10	?
5	Water Supply		?
6	Erosion control and soil retention	48.78	-
7	Soil formation		?
8	Nutrient cycling		+
9	Waste treatment		
10	Pollination	42.68	+
11	Biological control		+
12	Refugia		
13	Food production	5445.12	+
14	Raw material		
15	Genetic resources		
16	Recreation		+
17	Cultural		+
	Total	5554.88	

+ : Positive contribution to a ecosystem service
- : Negative contribution to a ecosystem service
? : Either positive or negative contribution to a ecosystem service
Blank : Under research