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METHODS

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

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Abstract

A new approach to valuing ecosystem goods and services (EGS) is described which incorporates components of the economic theory of value, the theory of valuation (US ~ appraisal), a multi-model multiple criteria analysis (MCA) of ecosystem attributes, and a Delphi panel of experts to assign weights to the attributes. The total value of ecosystem goods and services in the various tenure categories in the Wet Tropics World Heritage Area (WTWHA) in Australia was found to be in the range AUD\$188 to \$211 million year^{-1}, or AUD\$210 to 236 ha^{-1} year^{-1} across tenures, as at 30 June 2002. Application of the weightings assigned by the Delphi panelists and assessment of the ecological integrity of the various tenure categories resulted in values being derived for individual ecosystem services in the World Heritage Area. Biodiversity and refugia were the two attributes ranked most highly at AUD\$18.6 to \$20.9 million year^{-1} and AUD\$16.6 to \$18.2 million year^{-1}, respectively.

Keywords: Valuing; Ecosystem services; Economics; Surrogate market; Shadow prices; Delphi; Multiple criteria analysis

1. Introduction

Ecosystems are being degraded and destroyed worldwide due to human activities at a rate unprecedented in human history (Daily, 1997; Ponting, 1998). Closed tropical rainforests only occupy 7% of the earth's land surface yet they contain more than half the world's biota. They will mostly disappear or be converted to secondary forests within the next century (Wilson, 1988a). Habitats are being clear-felled, paved over, flooded, ploughed under, rained on with acid, invaded by exotic organisms, overgrazed, and having their climate changed (Ehrlich, 1988). Destruction of forests also causes changes in the hydrological cycle leading to desertification, soil salinity, floods and erosion (Winpenny, 1991). Wholesale eradication of populations and species of organisms have a critical and fundamental impact on the provision of ecosystem goods and services that are essential as planetary life support

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systems, and not only for humans (Nunes and van den Bergh, 2001). The extraordinary variety of life on earth had been imagined through the work of luminaries such as Erwin (1988) and Wilson (1988b, 2002), however, the growth of the study of biological diversity as a field of scientific endeavour is revealing an even greater variety of life-forms and inter-connected evolutionary niches. Ignorance of these interactions and their connotations with respect to nature's services, such as the contribution of soil organisms to atmospheric composition, indicates that humans still lack basic understanding of the contributions made by the natural environment to planetary life support (Beattie and Erhlich, 2001). The genetic diversity within species is declining rapidly and it is largely irreplaceable. Protected areas or reserves may no longer be the solution to preserving genetic diversity, as climate change could cause forest migration and desertification and many existing natural populations of wild organisms will no longer be able to survive within their present ranges (Peters, 1988). An alternative would be for human modified areas to be made more environmentally hospitable and a balance maintained between wildlife habitat areas and areas designated for human habitation and food production (Winpenny, 1991). Scheffer et al. (2000: 451) argue that: "good ecosystem models, institutionalised ecosystem valuation, and innovative tax-setting schedules are essential to achieving a socially fair and sustainable use of ecosystems by societies". Ecosystem goods and services (EGS) can only support human life if a well-functioning and rich variety of systems are spread over most of the Earth's surface (Meffe and Carroll, 1997). Impairment of the ability of ecosystems to provide a sustained flow of beneficial services suggests the loss of a valuable resource (Howarth and Farber, 2002). Ecosystem services may be defined as the products of the role that ecological systems play in providing a sustainable environment for life support, such as clean air, clean water, food, habitat and recreational opportunities (Table 1). In this paper, a new method to value the environment will be described. Relying on valuation theory and the property market as a surrogate market, the total value of the Wet Tropics World Heritage Area (WTWHA) in Australia is determined. A multiple criteria analysis (MCA) combined with a Delphi Inquiry is then used to assign shadow prices to the individual EGS and groups of goods and services provided by the World Heritage Area.

Table 1
Ecosystem attributes used in the multi-model multiple criteria analysis (adapted and modified after Costanza et al., 1997a; Cork and Shelton, 2000)

Group	Type
Stabilisation services	Gas regulation (atmospheric composition)
	Climate regulation (temperature, rainfall)
	Disturbance regulation (ecosystem resilience)
	Water regulation (hydrological cycle)
	Erosion control and soil/sediment retention
	Biological control (populations, pest/disease control)
	Refugia (habitats for resident and transient populations)
Regeneration services	Soil formation
	Nutrient cycling and storage (including carbon sequestration)
	Assimilation of waste and attenuation, detoxification
	Purification (clean water, air)
	Pollination (movement of floral gametes)
	Biodiversity
Production of goods	Water supply (catchment)
	Food production (that sustainable portion of GPP)
	Raw materials (that sustainable portion of GPP, timber, fibre, etc.)
	Genetic resources (medicines, scientific and technological resources
Life fulfilling services	Recreation opportunities (nature-based tourism)
	Aesthetic, cultural and spiritual (existence values)
	Other non-use values (bequest and quasi option values)

2. Background

There is still a fundamental lack of confidence in the outcomes of attempts to value the environment. The seminal paper by Costanza et al. (1997a) published in *Nature* pulled together many social studies of diverse ecosystems to arrive at a gross value for the earth's EGS at US$33 trillion. Yet despite this notable attempt, ecosystems are still being degraded partly from the want of a simple and practical method to assign values to individual

EGS. Very few attempts have been made to broadly value all EGS in a bioregion or whole ecosystems due to the difficulty in valuing certain aspects of them (Cork and Shelton, 2000). While the approaches used in neoclassical and environmental economics have been the subject of aggressive controversy for decades, due to continual refinement they still have some merit and application when it comes to placing value on certain attributes of the environment, such as recreation (Harrison, 2002). However, Costanza et al. (1997b) claim that there is now, more than ever, powerful evidence of the need for an innovative approach to this type of analysis that will encompass both economics and ecology. This new approach should require that an economically efficient allocation of resources be devised that adequately protects the stock of natural capital, and at the same time recognises the inter-relatedness and inter-dependence of all physical and biophysical components of the earth's finite ecosystems. Hawken et al. (1999) describe this requirement as reconciling economic and ecological goals. Added to this are the problems of removing the odium attached to the idea of putting a monetary value on everything, distributional effects, and translating and communicating the need for a market mechanism to conserve these formerly 'free' goods and services. Howarth and Farber (2002) refer to efforts to place a monetary value on EGS as having 'multiple roles' in linking human and natural systems, however warn of the 'well-known' limitations of the current non-market valuation methods and further question the equity issues of such evaluations. A revealed preference or surrogate market overlooked so far in empirical studies of environmental valuation, with the exception of hedonic pricing techniques, is the broader property market. The property market is notable and validated by the pivotal role it plays in national administration, e.g. taxation, and widespread acceptance by the commercial world, individuals and the judiciary. People reveal their preferences to purchase property for a multitude of uses. These sales are then used by state and/or federal agencies to establish gross valuations that are used as the taxable base for local governments. This data can be relatively easily obtained, translated and then extended to determine the median unimproved property value (MUV) in a wider geographical region. The MUV is then applied to public or unrateable land, national parks, etc., in the same region to establish a capital value per hectare. The terms value and valuation theory are used in this paper to describe the pecuniary worth of EGS and the associated theory and practice to do with establishing values for real property. If economic valuation procedures such as contingent valuation methods are discussed they are described as such, as is also the case with intrinsic value (existence value). The operational definition of value in this paper is thus that which is normally expressed through a commercial market (Funtowitz and Ravetz, 1994).

2.1. Valuation theory and practice

The principles of land valuation predate modern economics and consist essentially of precedents in English Common Law. Now, in Australia it has been greatly elaborated and replaced by legislation, most of which was first enacted in the late 19th and early 20th century. By far the majority of this legislation is to do with taxing laws (Herps, 1942). Current methods of valuation have been derived largely from decisions given by eminent judges of the Supreme Court in various States, the High Court of Australia, and of the Privy Council (Herps, 1942; Hyams, 1986; Whipple, 1992). These authorities have ruled that the term value means value in the open market. The precedent followed by all Courts in Australia when dealing with the valuation of land is Spencer v The Commonwealth (Griffith, 1907: 5 CLR 418). Land (real property or real estate) has long since been regarded as different from personal property, in that under common law no person can have an absolute title to real property (Hyams, 1986). Theoretically, absolute ownership in Australia vests in the Crown, who may resume, provided proper compensation is paid, the land and the wealth upon it (Herps, 1942). Land that is divested from the Crown, either freehold or leasehold and subject to local government rates and taxes is described as alienated.

The utilisation of land in a way that benefits both the individual owner and society, remains one of the principal problems in the world today, particularly in developing nations where the poor often have little choice but to deplete or degrade natural resources to earn a living (Nations, 1988). Nations, states and the local authorities have, from time immemorial, possessed a beneficial interest in all privately owned lands as being the basis of taxation and for local rating purposes (Murray, 1954; 1969; Inglis, 1960). In Australia the basis of rating is the unimproved value (UV). In order to derive the UV the courts insist that the improvements on the subject land are to be ignored, however they also insist that communal effort, and the presence of Government utilities, such as transport, water, gas, electricity, and the proximity of a dense population are all to be considered (Lambert, 1932; Herps, 1942; Principia, 1958).

The three primary methods used to value real property are complementary, and lead to convergent validity (Motha, 1979; Reynolds, 1984). They are summation, capitalisation and the use of comparable sales evidence. Summation involves, as the name suggests, addition of the depreciated value of improvements to the UV, or in the case of trying to find UV from comparable sales of improved property, deduction of the value of improvements from the improved value. Capitalisation refers to the application of an interest rate or desired/expected yield to the capital value of the land or improved property to arrive at a rent, or the capitalisation of the rent or net earnings to arrive at a capital value (AIVLE, 1997). Consideration must be given to the capitalisation rate as reflecting the elements of risk, and the return of capital within the life of the investment. The capitalisation rate is never less than the rate of bank interest, or at least comparable with the yield from gilt-edged securities such as long-dated government bonds (Lambert, 1932). The Valuer General for Ireland and founder of 'Political Arithmetic' in the 17th Century, Sir William Petty, was first credited with the theory of capitalisation of the *usus fructus per annum* (*L. usus* ~ *use; fructus* ~ *fruit*) or production function of the land, with capitalisation rates varying with risk (Murray, 1954). The Oxford Dictionary (Simpson and Weiner, 1989: 361) defines usufruct as: (1) Law. "The right of temporary possession, use, or enjoyment of the advantages of property belonging to another, so far as may be had without causing damage or prejudice to this. Usufruct is the power of disposal of the use and fruits, saving the substance of the thing". The Oxford Dictionary also cites Marsh (1864: 35), 'Man in Nature', wherein it is stated: "Man has too long forgotten that the earth was given to him for usufruct alone, not for consumption" (Simpson and Weiner, 1989: 362). Petty believed that capitalisation of all of the profit and benefits produced by land held in the public domain was a logical economic step to take to determine capital value, or vice versa. The correct rate of capitalisation at any point in time can only be discovered by a study of the market (Ab Initio, 1949; Else-Mitchell, 1963).

Comparable sales provide the additional evidence upon which buyers, sellers, valuers and the courts rely on to establish a parity or consensus of opinion of value, which can be averaged to ascertain 'the capital sum which similar land might be expected to realise' (Lambert, 1932: 17). McNamara (1983) described the use of comparable sales data as a fundamental activity in valuation work. Land under public utilities continues to have a potential for other uses, and the economic cost to society of dedication to use for a public purpose is the opportunity cost foregone, as is the case for resources generally. 'The relative scarcity of resources is ranked in the market place by price' (Rowles et al., 1998: 261), and in the case of public land the relative scarcity has to be determined in an indirect way by use of a 'surrogate market' or 'shadow price'. Valuers have proposed a number of techniques, including comparable sales of adjoining land, rating values of adjoining land and average municipal rateable value. The latter two techniques are regarded as the most suitable to provide a shadow price, due to their ability to rank relative scarcity, and ease of application (Rowles et al., 1998).

Conceptually, market value can be regarded as the equivalent of the current worth of future anticipated benefits (Reynolds, 1984). Rich et al. (1934: 51 CLR 509) in the full High Court of Australia stated that: "...market value is not an absolute, but a relative term, expressing the relationship of value existing at the date of valuation between the land in question and other similar land, with land generally, and further, with all other avenues of investment in the economic system" The concept of 'highest and best use' automatically extends to the 'highest and best legal use', for example compliance with zoning laws and local authority regulations (Whipple, 1962; Spencer, 1984), and now federal and state environmental laws (Hemmings, 1996). Liability for environmental harm can arise from common law or from statute, and as a valuer has a duty to make all prudent enquiries and take into account all matters that affect value, laws that are designed to protect the environment can have a significant impact (Hemmings, 1996). Putting aside the legal determinants of 'highest and best use', Whipple (1962) suggests that if a development achieves maximum acceptability in the marketplace, then the land has been put to its 'highest and best use'. If it is valid to equate the concept of 'highest and best use' with maximum acceptability in the market place, it must satisfy human social and economic preferences, and these are manifest in the development and evolution of communities in time and space (Whipple, 1962). Radcliffe (1972: 525) stressed that establishing a market value is a prediction of an economic event, and suggested that "no such thing as 'true' or 'real' value for a property exists", leading to the practise of establishing a range of values (Boyd, 1990; Westwood, 1993).

One of the difficulties in environmental valuation is the decreasing tangibility from direct use, to say existence values, or use and non-use values. However, there does not appear to be much difference between the economist's concept of total economic value (TEV) and the concept of market value, as the latter is simply made up of varying degrees of use and non-use values (Lally, 1998; Sarpong-Oti, 1998). In some situations the market value concept would take precedence over the TEV concept, particularly when assessing natural resource values. The difficulties when trying to assess these values from the point of view of all members of society are formidable, however the United Nations (SNA93) recommended that for national balance sheet purposes, valuation of natural resources should be: "...on the basis of current observable market prices as this is the basis on which decisions by producers, consumers, investors and other economic agents are made" (p. xi cited in Sarpong-Oti, 1998). This recognition of the role of market value in valuing natural resources, was then sanctioned by the publication of 'Experimental Estimates of Values of Natural Resources Covering Forests, Land and Subsoil', by the Australian Bureau of Statistics in 1995, which stated: "...the values for both urban and rural lands were based on land values for rating and taxation purposes provided by state valuation agencies" (Sarpong-Oti, 1998: 339). Moreover, this application was transferred to land under public utilities, and by implication to public reserves by the introduction of Australian Accounting Standard AAS27 (Rowles et al., 1998). More recently, Australian Accounting Standard AASB1041 was introduced which specifically applied to non-current assets, with strict guidelines as to how the assets were to be valued (Reed, 2003). It would thus appear clear that there is not only wide acceptance and support for the empirical method of valuation, but that it is the preference of both national governments and supra-national agencies.

2.2. The wet tropics of Queensland world heritage area

The Wet Tropics World Heritage Area (WTWHA) comprises about 48% of the Wet Tropics Bioregion in Queensland, Australia, which is described in the Interim Biogeographic Regionalisation for Australia (IBRA), as having an area of 18,497 km^2 and a protected status of greater than 10%. The WTWHA comprises tropical wet coastal ranges and plains, rainforests and forests. The dominant condition is described as 'modified ecosystems', i.e. very little natural ecosystems remain, and/or natural ecosystems present, but co-existing with pastoral and timber industries. The dominant limiting factors and constraint codes in IBRA are 'cropping, urbanisation, tourism'. However, the Wet Tropics Bioregion has the highest levels of biological diversity of any region in Australia (WTMA, 2001), and Australia is included in the 12 'mega-diverse' countries of the world with collectively 75% of the total global biodiversity (EPA, 1999). The WTWHA was listed in 1988 as international recognition that the area is an outstanding example of the world's natural or cultural heritage, having satisfied all four of the natural heritage criteria. The WTWHA comprises some 8,944 km^2 and is totally contained within the Wet Tropics Bioregion (Fig. 1), and consists of a variety of tenures (Table 2). The Wet Tropics World Heritage Protection and Management Act 1993 provides for a management plan (The Wet Tropics Management Plan 1998) that divides the WTWHA into zones based on a 'distance from disturbance' model where various types of activities are either allowed or

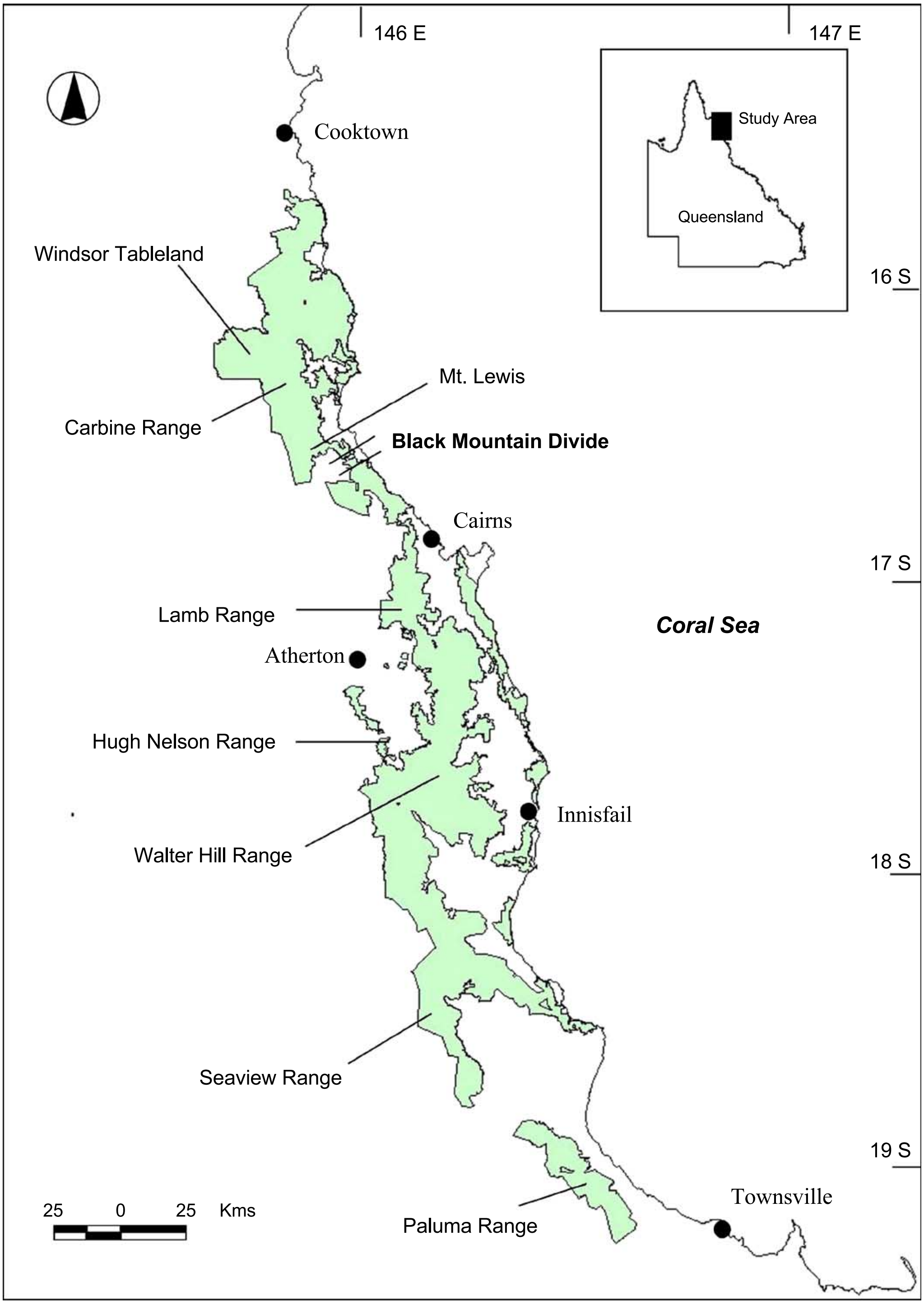


Fig. 1. The Wet Tropics World Heritage Area (source: Rainforest CRC and Wilson, 2002).

Table 2
Areal extent of the various land tenures in the Wet Tropics World Heritage Area (source: WTMA, 2001)

Tenure	Parcels	Area (ha)	% of WHA
National parks	21	285,744	32
State forests	32	347,300	39
Timber reserves	5	74,163	8
Various reserves and dams	64	10,207	1
Unallocated state land	203	60,515	7
Perpetual leases	11	132	0.01
Expiring leases	138	86,897	10
Leasehold: mines and energy	6	24	0.003
Leasehold: DPI and EPA	43	3,093	0.35
Freehold and similar	204	17,341	2
Roads, Esplanades, Railways		5,696	0.6
Rivers		3,308	0.4
Total	727	894,420	100

prohibited. The zones are based on ecological integrity, physical and social settings, past, present or future use, and management of these activities (WTMA, 2002).

3. Methodology

The methodology for this research project had four components:

1. Establishing a surrogate capital market, from which will be derived the shadow prices for EGS provided by public and other land in the Wet Tropics Bioregion of Queensland.
2. A systematic analysis, namely a multiple criteria analysis, using the 20 identified ecosystem attributes (Table 1). And three models with six different criteria for each model in order to establish the non-pecuniary weightings and sensitivities for the attributes.
3. A Delphi Inquiry, to establish expert opinion as to the need for the research, and the relative rankings and weightings of the attributes for each model.
4. Development of a valuation table to appraise the value of EGS provided by individual landholdings, and development of a conceptual model to appraise the value of ecosystem goods and services on a landscape scale.

The pluralistic approach taken in this research is supported by the literature in ecological economics, where ‘valuation, ecological assessment and equity analysis are properly viewed as complements, not substitutes’ (Howarth and Farber, 2002: 428).

3.1. The surrogate market

The surrogate market was the broader property market in the bioregion selected for study. Individuals in the community reveal their preferences to purchase property for a multitude of uses and the pecuniary measures of these preferences are used as comparable sales by state agencies charged with the responsibility of valuing property and determining UVs as a basis for levying rates and taxes. The collective values thus underpin the costs of administration and provision of infrastructure in the bioregion (Lambert, 1932; Herps, 1942; Murray, 1954; Blackwell, 1994). UVs are assessed on the principle of the highest and best legal use, yet assume that improvements do not and have never existed. Every use of land has an opportunity cost, that being the existing use or other uses to which the land could be put (the use foregone) (Edwards, 1987; McNeeley, 1988; Frank, 1991; O’Connor, 2000). Marginal opportunity cost can be expressed in terms of the annual net revenue foregone, in which case it would be capitalised, resulting in a land value in restricted and unrestricted use (McNeeley, 1988). This concept clearly links the natural production function of land with land valuation procedures. As EGS are the production function of land in its natural state (the Usus Fructus per annum), and as some if not all of them are essential for planetary life support (Weaver and Ke Chung, 1994), it could be argued that the provision of EGS are the ‘highest and best use’ of land. It was therefore reasonable to assume that the other (unrateable) land in each LGA was worth at least as much for the EGS it provides as the rateable land put to its ‘highest and best’ use. However, adoption of the median unimproved value (MUV) as a surrogate value implies that the value is for the ‘median’ use in the region and not the single ‘highest and best’ use. It is thus a conservative estimate, allowing that other uses of land can co-exist with the provision of EGS.

The local government areas (LGAs) that are contained wholly within or that administer parts of the Wet Tropics Bioregion were ascertained from public records and maps. These local governments were consulted as to the total rateable value of alienated land within their jurisdiction, and the total area of that land. A dollar value per hectare was calculated for each LGA and descriptive statistics were derived for the set of values. Owing to the variability in the data due to varying degrees of urbanisation, development, use, distance from services, and average parcel size, the data set was expected to have a high degree of positive skewness. The measure of central tendency most commonly accepted for this type of skewed data set is the 'median' (Zar, 1996; Hicks, 1999). The skewness attributable to a high degree of development (disturbance) is also indicative of smaller lot sizes, which are least conducive to the provision of a suite of ecosystem goods and services. Hence, the median unimproved value (MUV) is the measure that will provide the best approximation of all of the uses to which land is put in the bioregion on a *broadacre* basis and will take into account all of the various principles and factors that affect the value of land. The MUV (ha^{-1}) of the alienated (rateable) land in the bioregion was then used as a surrogate for the MUV (ha^{-1}) of the un-alienated (public or unrateable) land. This is consistent with valuation practice (use of comparable sales is a fundamental activity).

Sir William Petty, Valuer General for Ireland and one of the founders of the Royal Society in 1662, was well aware of the valuation theory to do with the differential element in rent when he enunciated it, although it was later attributed to Ricardo (Murray, 1954). However, Roll (1961) in his *History of Economic Thought* pointed out that it was Petty, and not Ricardo, who evolved the theory. Murray (1954:40) puts the theory succinctly: "...the value of land could be ascertained by the capitalisation of the 'Usus Fructus per annum', and added that it is "...a process which is known today as the productivity method of valuation" (Murray) 1954:40). Petty was also well aware that capitalisation rates varied with risk, stating in 1661 that lands in Ireland were worth 'but seven years purchase' (indicating a capitalisation rate of about 14.3%), without elaborating on the reason for the heightened risk (Murray, 1954:40). The theory is both applicable to derivation of land value from rent and to derivation of rent, or the "Usus Fructus per annum", by the use of comparable sales data for land. Earlier, Petty was uncertain as to how to determine the rate of return from land and came up with an ingenious solution. Petty determined that the rights to the usufruct of land of three generations of humans would be a reasonable estimate, and computed the value of land at 21 year's purchase of its annual rent, or in money-capital terms 4.76% (Roll, 1961).

An appropriate capitalisation rate was derived from a study of the market and applied to the median capital unimproved value (MUV) per hectare, producing a value for the flow of ecosystem benefits from land (the Usus Fructus per annum). Care was taken that the capitalisation rate chosen was low enough to satisfy 'Hotelling's rule' without being too low to ensure that the 'Hotelling rent' (also known as 'Ricardian rent' or 'scarcity rent') generated a flow of benefits of a value undiminished into the future (Hotelling, 1931; Hackett, 2001). The Usus Fructus per annum (UFpa) was thus represented by the equation:

$$\mathrm{UFpa}(\$/\mathrm{ha}) = \mathrm{MUV}(\$/\mathrm{ha}) \times \mathrm{cr}(\%) \quad (1)$$

where cr is the capitalisation rate.

As both alienated and un-alienated land provide EGS it was important to be able to estimate the extent to which the land contributed to the overall contribution. Depending on the level of disturbance, other human activities on the land can co-exist with the provision of EGS. Therefore on a landscape scale, total value of a whole ecosystem (TVw) is represented by the equation:

$$\mathrm{TVw} = \mathrm{UFpa} \times \mathrm{area}(\mathrm{ha}) \times \mathrm{esi}(\%) \quad (2)$$

where esi is the extent to which ecosystem services are intact.

In order to distinguish between the value of individual EGS that may or may not be present in a given situation, or that may be present but only to a limited extent, and to be able to account for them separately, weightings for the individual ecosystem attributes need to be derived. Then the total value or shadow price of an individual ecosystem attribute (TVi) is represented by the equation:

$$\text{TVi} = \text{UFpa} \times \text{area(ha)} \times \text{esi(\%)} \times \text{wt}. \quad (3)$$

where wt is the final weighting of the attribute, expressed as a decimal.

A diagrammatical representation of the methodology is shown in Fig. 2.

3.2. The systematic analysis

A three-model multiple criteria analysis (MCA) of ecosystem attributes was designed in conjunction with the Delphi Inquiry using a panel of experts to assign appropriate weightings and sensitivities to the attributes. Munda (1996) describes 'weak comparability' (strong conflictual consequences of actions) as the philosophical foundation of multicriteria analysis. However, MCA does have the ability to incorporate information about alternatives from a variety of sources, convert it to standard units of measure, weight the data according to magnitude and significance, test for sensitivity, and rank alternative options. Environmental, social and cultural trade-offs become more explicit and can be considered in the process (Blalock and Blalock, 1968; Rietveld, 1980; Dick, 1990; More et al., 1996; Hicks, 1999; KPMG, 2000; Rivett, 2000). MCA has broad application as a multi-attribute decision-making method (MADM), which was evaluated for this research project, along with the analytical hierarchical process (AHP), rank-order centroid method and the fuzzy method. The Department for Transport, Local Government and the Regions (DTLR, 2002) used MCA to appraise all transport projects, including proposals for all road schemes in the United Kingdom, and the National Audit Office in the UK did likewise to analyse the cost effectiveness of the Department of Trade's Overseas Trade Services export services (DTLR, 2002). Noh and Lee (2003) used criteria of time, area, irreversibility and scientific uncertainty to evaluate eight alternative impact categories, namely: abiotic resources depletion; global warming; ozone layer depletion; eutrophication; acidification; photochemical oxidant creation; ecotoxicity; and, human toxicity. Rivett (2000) used MCA to decide between four alternate options for the Kuranda Range Road upgrade in Far North Queensland. Using environmental sustainability, transport efficiency, social/amenity, and cost as criteria, weightings were applied through community and expert consultation for attributes including: important area for plants; ecological processes; construction issues; accommodate freight efficient vehicles; closures, delays; important areas for scenic amenity; noise environment; and, net present cost on a whole-of-project basis (Rivett, 2000). The general approach for MCA is as follows (some steps do not apply in this case, e.g. 2):

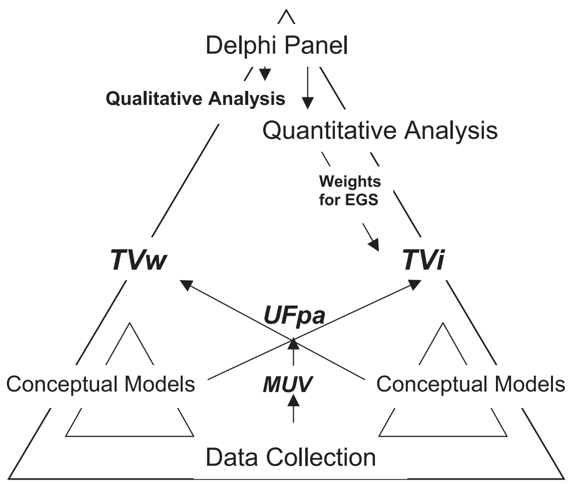


Fig.2. Diagrammatic representation of the derivation of the values. The multi-criteria analytical component of the Delphi only provides input to individual EGS (TVi). The conceptual models provide the level (%) of ecosystem integrity and control the capitalisation rate, which derives UFpa for both TVw and TVi.

1. Identify overall desired outcomes for the project;
2. Identify alternative solutions including the no-go option;
3. Identify and measure values that may be impacted upon by the options and convert these to evaluation criteria (present in the form of packages of criteria, attributes and elements);
4. Measure the impact of the project on these values or packages of attributes by way of technical studies or preference surveys;
5. Score and weight the impacts relative to a particular characteristic of the evaluation criteria, e.g. Area of native forest and relative significance of the species affected;

6. Standardise the scores (e.g. −5 to +5. with −5 being the worst, and 0, no change), the sign indicating the direction of the impact, and the integer the relative magnitude of the impact;
7. Determine overall scores for each option;
8. Undertake a sensitivity analysis including weightings of each package of criteria (a positive fraction adding up to one) to test robustness;
9. Iteration in order to refine alternatives; and,
10. Results (decision-making) (Rivett, 2000: 4–7).

These steps were followed as much as was consistent with the evaluation of individual EGS within an overall suite of EGS, rather than choosing between alternate policies or proposals, as is the main application of MCA. The MCA application in this study could thus be described as more closely resembling multi-attribute utility theory.

The models were in Microsoft Excel© format and each consisted of 20 ecosystem attributes (Table 1) with six criteria and suggested maximum weightings (Table 3), generating a matrix of 120 cells for each model (see e.g. Appendix A). The criteria for Model 1 were anthropocentric, economic and ecological. 'Essential' or 'desirable' for human life support were given the maximum weightings in this model, followed by the ecological criteria, and then economic. These criteria were cognitive, that is to say, inductive reasoning was used to determine appropriate choices after a study of the literature (see for example: Hawken, 1995; Meffe and Carroll, 1999). There were 20 ecosystem attributes, and in order to get a total of 100, or 100% of EGS, the nominal weight for each of them had to be 5. The panel was told that they could ascribe a lesser weight than that nominated to any attribute, but not a greater weight. Irrespective of what weight the panelist ascribed to an attribute, they were normalised to 5, and then 1, thus providing importance rankings. In the first model, 'Essential for human life', although an anthropocentric view is clearly more important than 'desirable for ecosystem health'. Criteria for Model 2 were economic, to do with intergenerational equity (bequest), and spiritual, aesthetic (existence value). These criteria are the main components of the economic approach to environmental valuation, hence the utilitarian model was reductionist rather than holistic in ranking criteria in terms of tangibility, i.e. use>non-use (see Nunes and van den Bergh, 2001). Model 3 had criteria that were essentially to do with risk and uncertainty, which are important elements of systematic analysis. Risk is best dealt with by a sensitivity analysis, however uncertainty is somewhat more complex. In this model the criteria of 'threats' and 'precaution' were included to 'round off' the negative values or deleterious criteria in the model, which were then offset by the positive qualities of 'resistance' and 'resilience'. Hence the sensitivity model ranked the negative aspects in order of their prominence in ecology, clearly a threat is greater than a risk, and a risk greater than an uncertainty. This model had negative weights for the negative criteria, and equal positive weights for ecosystem resistance and resilience, however selection of maximum weights for all criteria would still

Table 3
Multiple criteria analysis (MCA) models 1, 2 and 3 with selected criteria and maximum weightings allocated (panelists could choose a lesser weight than that suggested but not a greater weight)

	Maximum weight
Model 1 criteria 'Anthropocentric'	
Essential to human life	6
Essential component of ecosystem health	4
Essential for maintenance of natural capital	2
Desirable but not essential for human well-being	5
Desirable but not essential for ecosystem health	3
Desirable but not essential for maintenance of natural capital	1
Model 2 criteria 'Utilitarian'	
Direct use value	6
Indirect use value	4
Option use value	2
Option non-use value	5
Bequest non-use value	3
Existence non-use value	1
Model 3 criteria 'Balanced Sensitivity'	
Threats	−4
Risk	−3
Uncertainty	−2
Precaution	−1
Ecosystem resistance	7.5
Ecosystem resilience	7.5

result in the nominal weight of +5. The selection of criteria for this model (3) could be argued to be the essential criteria for ecosystem sustainability (Appendix B).

The results for each model were subjected to statistical analysis using Kendall's Coefficient of Concordance (Blalock and Blalock, 1968; Hicks, 1999; Zar, 1996). The coefficient W permits the evaluation of the extent of concordance or agreement between three or more sets of data. It has the value 1.0 if the groups agree perfectly and 0.0 if they disagree maximally. A more common use of Kendall's W is to express the intensity of agreement among several rankings or as a measure of the agreement of rankings within blocks. To determine if a calculated sample W is significant, i.e. if it represents an association different from zero in concordance, the relationship between the Kendall Coefficient of Concordance (W) and the Friedman chi-square χ_r^2 is used:

$$\chi_r^2 = M(n-1)W.$$

where M = the number of variables, n = the size of the sample, and employing the table of critical values for χ_r^2 (Zar, 1996).

For the models, each panelists' set of total weightings for each of the 20 attributes in each model was statistically analysed for the coefficient of concordance with every other panelists' set of weightings (all disciplines), in addition to those of each discipline, 'all economists' and 'all natural scientists'. For Models 1 and 2, where all values were positive, the coefficient of variance of the mean values of all panelists' weightings was also calculated. On the proviso that there was significant concordance between the sets of weightings provided by the expert panel for the attribute/criteria in each model, the mean weighting of the panelists' weightings for each attribute in models one and two was then normalised to a total of 100 (20 attributes multiplied by a nominal weighting of +5). The mean results of Model 3 (sensitivity) were then ranked as continuous positive scores and normalised for each attribute to a decimal totalling one for all attributes. Finally the mean result for each attribute for Models 1 and 2 was multiplied by the normalised score for Model 3 to reflect sensitivity. The final result was carried forward to the valuation table as the 'final weight' for each attribute in the full suite of ecosystem services.

4. The Delphi Inquiry

The Delphi Technique was first used by the Rand Corporation in the USA in the early 1950s as a futures forecasting tool (Cunliffe, 2002), and has since then been extensively used by researchers, where it is, as described by Kaynak and Macauley (1984, p. 88): "a unique method of eliciting and refining group judgement based on the rationale that a group of experts is better than one expert when exact knowledge is not available". Miller (2001) used a Delphi survey to develop indicators for sustainable tourism, and Cunliffe (2002) used the technique to forecast risks in the tourism industry. A Kantian, or 'contributory' Delphi, attempts to design a structure that allows many 'informed' individuals in different disciplines or specialties to contribute information or judgements to a problem area that is much broader in scope than the knowledge that any one of the individuals possesses. It is therefore a form of utilisation of the collective human intelligence capability that includes attitudes and feelings, and is part of the process of human motivation and action (Linstone and Turoff, 1975; Helmer, 1975; Mitroff and Turoff, 1975; Scheele, 1975; Dick, 1990; Miller, 2001; Cunliffe, 2002). Some situations where Delphi is useful, features of Delphi and the phases of the Inquiry are shown in Table 4.

A group of about 50 'experts' were recruited on the basis of a 'stated' interest in the topic from the disciplines of neo-classical economics; environmental economics; ecological economics; geography; natural resource management; ecology, and environmental science. The panelists were asked to confirm the category under which they nominated, and there was a degree of overlapping disciplines, which explains the apparent discrepancy in N in later tables in the results section. The Delphi Inquiry was conducted over a 6-month period ending October 2002, using a purpose-designed web site, which required the panelist to log-in with user-name and password, and preserved individual anonymity. The Delphi comprised four rounds where the panelists were required to contribute, followed by feedback

Table 4
Situations where a Delphi Inquiry is useful, features and phases of Delphi

Where Delphi is useful	Features of Delphi	Four distinct phases
The problem does not lend itself to precise analytical techniques but can benefit from subjective judgements on a collective basis	Some feedback of individual contributions of information and knowledge	Exploration of the subject under discussion, each member of the panel contributes additional information pertinent to the issue
More individuals are needed than can effectively and cost-efficiently interact face to face.	Some assessment of the group judgement or view	Process of reaching an understanding as to how the group views the issue, including agreement or not and meaning of any relative terms (i.e. significance)
Refereeing and anonymity ensure minimal bias	Some opportunity for individuals to revise views	Address any disagreement, underlying reasons, evaluate them
Heterogeneity of the participants is preserved to avoid the bandwagon effect.	Some degree of anonymity for the individual responses	Final phase. All previous information analysed and feedback has taken place.

Source: Linstone and Turoff, 1975; Helmer, 1975; Mitroff and Turoff, 1975; Scheele, 1975; Dick, 1990; Miller, 2001; Cunliffe, 2002.

immediately after each round was closed, or included in the preamble to the next round. Two further rounds followed where there was no requirement to contribute. In addition to a series of both open-ended and closed-ended questions/statements to do with the topic, the panelists were presented with the three MCA models outlined previously. The introductory round one consisted of 41 questions; round 2, 9 questions and model 1; round 3, 10 questions and model 2; and round 4, no questions and model 3. The questions or statements generally came from the literature, and either required a true or false response or a text response.

The panelists' responses were again tested for the level of consensus by way of Kendall's Coefficient of Concordance (Kendall's W). For the questionnaires, the panelists were grouped into the seven nominated disciplinary categories and frequencies of 'true' responses for each set of questions for each panelist and for each disciplinary category were calculated and the level of agreement tested using Kendall's W. Each pair of disciplines' set of responses was also tested using the Wilcoxon Signed Ranks test to show the highest significance (by way of) extent of agreement, between the disciplines.

4.1. The conceptual model

Indicators for ecological integrity at the most obvious level are the naturalness of the environment, i.e. spatial and temporal distance from disturbance and the health of vegetation. At the less obvious level, indicators such as feeding guilds or functional groups of saproxylic insects may have relevance to understanding the relationship between ecosystem function and biodiversity (Grove, 2000). For example, the emerging pattern from studies is that in general logged forests support less species-rich assemblages, with fewer individuals overall, and also a different species composition compared to old growth forest. The purpose of this research is to develop a new or modified approach to valuing the environment that will have wide application and can be readily implemented when it is necessary to consider the value of intangibles in systematic analyses to do with development. The time-frame for this type of analysis, depending on the scale of development is usually measured in weeks to months. It would thus be counterproductive to suggest that the less obvious indicators of ecosystem integrity, such as saproxylic beetle assemblages be used. This type of study requires a dedicated researcher and assistants for an extended period of about 3–4 years. The development of the valuation table and conceptual models in this section are postulated on this assumption, and that of Lugo (1988), and the work of Holdridge (1967) and Holdridge et al. (1971) and Lugo's (1988) work with Brown. "Statistically significant relationships suggest that life zone conditions relate to characteristic numbers of tree species, biomass and rate of primary productivity, and capacity to resist and recover from disturbance" (Lugo, 1988:61). The theory of island biogeography poses similar conditions such as local extinction risk, rate of colonisation and species richness to habitat size and isolation (MacArthur and Wilson, 1967; Dreschler and Watzold, 2001). Focussing on general properties of ecosystems such as species richness, common scales that allow comparison between ecosystem integrity in different ecosystems do exist. MacArthur and Wilson (1967) related the species richness of an island or in a habitat patch to the area, in the function:

$$B = S = \alpha A^z$$

where the benefit (B) of an ecosystem is measured by the species richness (S), which is itself a function of area (A), with α some positive constant and the exponent of A in the range 0.15–0.35, subject to habitat type and taxonomy (MacArthur and Wilson, 1967; Dreschler and Watzold, 2001).

A valuation table was developed to determine the level to which EGS were intact, for use with both individual landholdings and landscapes. The former was based upon observation, historical records and empirical evidence from the proprietor or management agency; and the latter requiring a conceptual model based upon the literature as to what the defining parameters were. An example of a completed valuation table for one tenure category in the WTWHA (State Forests) is included as Appendix B. It should be noted that it is the valuer's responsibility to determine, using all means available, the appropriate and correct input to the columns within an acceptable margin. From observation and consultation the valuer determines if the individual ecosystem attribute is present or not present. If it is not present, whether the absence is temporary or permanent, and the type of disturbance, and if it is present, the degree (upper limit and lower limit %) to which it is intact or productive in the sense of provision of EGS (esi in Eqs. (2) and (3)). The conceptual model was developed using species richness, vegetation cover, and/or either the Level of Protection (LOP model: national park, conservation covenant, etc., Appendix C), or the Land Use Characteristic (LUC model: open forest, rangelands, etc., Appendix D), as measures of how productive or intact the ecosystem services are on a landscape scale (Holdridge, 1967; Holdridge et al., 1971; Lugo, 1988; Mooney, 1988; WTMA, 2001).

In this new conceptual model the apex represents 100% (of species richness and vegetation cover) and the basal apices, 0%. The level of protection decreases towards each basal apex, as the level of disturbance increases towards each basal apex. In order to reflect the economic concept of scarcity, capitalisation rates increased as the level of protection decreased and the level of disturbance increased from the centre of the base outwards to the basal apices. The defining parameters for both the individual model and the landscape model were:

1. The highest vegetation cover (closed canopy forest) and hence species richness is in tropical rainforest;

Table 5
Results of Kendall's W for Models 1, 2 and 3

Discipline	Model 1			Model 2			Model 3		
	W	N	Sig.	W	N	Sig.	W	N	Sig.
All disciplines	0.339	24	0.000	0.134	20	0.000	0.295	25	0.000
Neoclassical economists	0.589	4	0.001	0.289	5	0.094	0.262	5	0.165
Environmental economists	0.466	4	0.012	0.320	5	0.047	0.246	8	0.007
Ecological economists	0.246	8	0.007	0.147	9	0.156	0.479	8	0.000
All economists	0.331	16	0.000	0.175	19	0.000	0.331	16	0.000
Geographers and natural resource managers	0.315	8	0.002	0.464	8	0.000	0.338	7	0.001
Ecologists	0.289	11	0.000	0.129	8	0.420	0.333	11	0.000
Environmental scientists	0.392	10	0.000	0.230	9	0.004	0.355	11	0.000
All natural scientists	0.298	29	0.000	0.206	25	0.000	0.319	29	0.000

The coefficient W permits the evaluation of the extent of concordance or agreement between three or more sets of data. It has the value 1.0 if the groups agree perfectly and 0.0 if they disagree maximally. The apparent discrepancy in N values is due to discipline overlap.

Table 6
Results of Kendall's coefficient of concordance for the mean of each discipline's weightings for the attributes/criteria in each model

Discipline	Friedmans χ^2	Kendall's W	N	Significance
Model 1 Anthropocentric Perspective				
All disciplines	109.638	0.824	7	0.000
All economists	48.748	0.856	3	0.000
All scientists	66.365	0.873	4	0.000
Model 2 Utilitarian Perspective				
All disciplines	101.130	0.760	7	0.000
All economists	49.145	0.862	3	0.000
All scientists	60.017	0.790	4	0.000
Model 3 Balanced Sensitivity				
All disciplines	98.697	0.742	7	0.000
All economists	39.570	0.694	3	0.004
All scientists	66.581	0.876	4	0.000

2. As the canopy cover decreases so also does species richness. The following approximate relationships apply (in comparison to tropical rainforests):
   - moist tropical forest ~ species richness: 60–80%
   - dry tropical forest ~ species richness: 30–50%
   - temperate zone ~ species richness: 20–40%
   - Mediterranean zone ~ species richness: 40–60%;
3. The ratio of species richness to vegetation cover is generally 2:3, with the exception of Mediterranean zones, where it is generally 1:1;
4. The lowest level of provision of ecosystem services in the models on a landscape scale is 39%, which includes urban landscapes and deserts (Mooney, 1988).

The alternate conceptual model (LUC) should yield similar results to the LOP model, however allows wider application with choices of land use characteristic along the base of the triangle from the centre towards the basal apices, due to either human-induced or climate-induced modification (Appendix D).

5. Results and discussion

In the first three rounds of the Delphi the frequency of 'true' answers to the questionnaire were highly

Table 7
Final weights for the ecosystem attributes (goods and services)

Attribute	Model 1	Model 2	Mean 1 and 2	Model 3	Importance/ rank Model 3	Normalised rank	Weight	Final weight
Biodiversity	5.46	5.34	5.40	−2.62	9.14	0.092	0.497	0.099
Refugia	4.92	4.79	4.86	−2.30	8.82	0.089	0.431	0.086
Erosion control	5.02	4.91	4.97	−0.74	7.26	0.073	0.363	0.073
Genetic resources	4.75	5.26	5.01	−0.68	7.20	0.072	0.363	0.073
Gas regulation	6.22	5.79	6.01	0.82	5.70	0.057	0.345	0.069
Climate regulation	5.80	5.17	5.49	0.34	6.18	0.062	0.341	0.068
Biological control	4.89	4.81	4.85	0.04	6.48	0.065	0.316	0.063
Purification	5.44	5.36	5.40	1.20	5.32	0.054	0.289	0.058
Disturbance regulation	5.14	4.66	4.90	0.90	5.62	0.057	0.277	0.055
Aesthetics	3.71	4.85	4.28	0.20	6.32	0.064	0.272	0.054
Assimilation of waste	5.19	5.08	5.14	1.62	4.90	0.049	0.253	0.051
Water supply	5.68	5.53	5.61	2.70	3.82	0.038	0.216	0.043
Nutrient cycling	5.66	5.04	5.35	2.88	3.64	0.037	0.196	0.039
Pollination	5.02	4.44	4.73	2.78	3.74	0.038	0.178	0.036
Other non-use values	3.00	3.63	3.32	1.60	4.92	0.050	0.164	0.033
Raw materials	4.70	5.23	4.97	3.60	2.92	0.029	0.146	0.029
Recreation opportunities	3.49	4.96	4.23	3.60	2.92	0.029	0.124	0.025
Food production	5.29	5.06	5.18	4.18	2.34	0.024	0.122	0.024
Water regulation	5.75	5.32	5.54	5.52	1.00	0.010	0.056	0.011
Soil formation	4.87	4.78	4.83	5.44	1.08	0.011	0.052	0.010
	101	102.1	100.01		99.32	1.000	5.003	1.001

The nominal weighting of 5 for each ecosystem attribute adds up to 100 for all 20 attributes, or 100% of the full suite of services. Accordingly, the weightings ascribed by the panelists for each model were also normalised to a total of 100.

significant ($P < 0.000$. Kendall's $W = 0.814$; 0.747; 0.868).

More than 80% of respondents thought that there was a justifiable lack of confidence in past and current methods used to value the environment. Ninety four percent of the panelists agreed that human activities were beginning to affect ecological life support systems, and 91% answered true to statements to do with the merit of inclusion of ecosystem goods and services in the market system. The group was also in favour of market-based instruments and policy measures to address global inequities. Answers to the open-ended questions (text answers) showed very strong support for attempts to value the environment, yet recognised the difficulties inherent in using people's expressed preferences as a measure. The most important issues raised to do with placing a value on the environment were education, knowledge, information and understanding. Future trading markets in EGS were seen by most to be an aid to financing conservation provided they were set up properly, with a division of opinion as to whether global markets would capture them, and if that was a good thing. Testing each pair of sets of responses to the closed-ended questions using the Wilcoxon Signed Ranks test showed the highest significance (by way of) extent of agreement, between Natural Resource Managers and Ecologists ($P >$ 0.002); followed by Ecological Economists and Ecologists ($P > 0.033$); Neoclassical Economists and Ecological Economists ($P > 0.035$); Geographers and Ecologists ($P > 0.043$) and finally Environmental Economists and Ecological Economists ($P > .045$). The other 16 pairings were not significant. The 60 questions and the true/false and text responses from the panel are too extensive for inclusion in this paper and will be published separately.

For the three multiple criteria models, Kendall's W revealed a significant level of agreement between the panelists in all but a few cases where N was small (Table 5). However, the individual panelist's set of weightings for each attribute in the models was analysed for concordance with every other panelists' set of weightings, resulting in lower levels of concordance, although still significantly different to 'no agreement'. Taking the mean of the panelists' weightings for the attributes in each model, and comparing the level of agreement between disciplines, resulted in levels of concordance much closer to one. The effect of 'smoothing' the data by taking the mean reflects the group's collective weighting for the attribute, and not the individual's weighting, and the significance of the statistical comparison between disciplines of their mean weighting, reflects the group concordance, which was very high (Table 6).

Table 8
Relative rankings of the attributes for each of the models

Attribute	Model 1	Model 2	Mean Models 1 and 2	Model 3	Final importance rank
Stabilisation services					
Gas regulation	1	1	1	8	5
Climate regulation	2	8	4	7	6
Disturbance regulation	10	18	13	9	9
Water regulation (hydrological cycle)	3	5	3	20	19
Erosion control and soil retention	11	13	12	3	3
Biological control	14	15	15	5	7
Refugia	13	16	14	2	2
Regeneration services					
Soil formation	15	17	16	19	20
Nutrient cycling and storage	5	11	7	15	13
Assimilation of waste	9	9	9	12	11
Purification (clean air, water)	7	3	5	10	8
Pollination (movement of gametes)	12	19	17	14	14
Biodiversity	6	4	6	1	1
Production of goods					
Water supply (catchment)	4	2	2	13	12
Food production	8	10	8	18	18
Raw materials	17	7	11	16	16
Genetic resources	16	6	10	4	4
Life fulfilling services					
Recreation opportunities	19	12	19	17	17
Aesthetic, cultural and spiritual	18	14	18	6	10
Other non-use values (bequest, etc.)	20	20	20	11	15

In Model 1 the coefficient of variance was lowest for gas regulation, and highest for the three life-fulfilling attributes, recreation, aesthetics and other non-use values (bequest, existence, option). In model 2 the coefficient of variance was lowest for gas regulation and biodiversity, and highest for pollination, aesthetics and other non-use values. While in model 3, which had some negative values and the coefficient of variance statistic did not apply: the range was smallest for erosion control, biological control and biodiversity, and largest for climate regulation, recreation and other non-uses values. Clearly a higher degree of uncertainty existed with the panelists when it came to providing weightings, or ranking attributes, when they were most intangible such as the life-fulfilling services, although recreation is possibly the one EGS that has been most valued. One could conclude from these results, one or all of three things: In the absence of complete information it is not possible to make a rational judgement; that humans are more certain about the services that provide ‘real’ benefits, rather than those that provide ‘psychological’ benefits; and that there is still a lack of confidence in past methods used to value the environment, with recreation being the most valued attribute using neo-classical methods, yet the panelists showed a higher degree of uncertainty in weighting this attribute than most other attributes that have never been valued by any previous method. The final weighting for each attribute for each model, and final overall weight calculated in accordance with the methodology are given in Table 7.

The weights were expressed as final ranks for each attribute for each model and final overall rank in Table 8 for discussion purposes. Criteria for the first model were anthropocentric, biophysical and economic, however, the maximum weights were assigned to the anthropocentric criteria (Essential for human life, and desirable but not essential for human life). Ecosystem health was ranked second most important as being essential for planetary life support, and maintenance of natural capital, a surrogate for intergenerational equity. Model 1 results indicate that humans ascribe most value to a stable atmosphere and climate, clean air and water, the capacity of the environment to cycle and assimilate nutrients and pollutants, biodiversity and food production. Model 2 criteria consisted of direct and indirect use, non-use, option, bequest and existence values. In this model, while the results are similar in many ways, climate was seen to be less important, and raw materials and genetic resources more important, which is consistent with the utilitarian perspective. Model 3, which dealt with threats, risk, uncertainty, precaution and the resistance and resilience of ecosystems, provides a rather different perspective, with higher importance given to biodiversity, refugia, biological control, genetic resources, and erosion control and soil retention. These are clearly ecosystem attributes that are endangered in one way or another. Finally the result of the sensitivity analysis qualifies the results in terms of the non-pecuniary preference values ascribed by the panelists with the highest ranking given to attributes that are either endangered or essential for human life, or both. Interestingly an insight into human value preferences for the present as opposed to the future is also evidenced here, with attributes such as ‘soil formation’ shown as

Table 9
Capitalisation rates and conceptual models used to determine upper and lower limits of provision of ecosystem services

Tenure category	Capitalisation rate (%)	Conceptual models used (Appendix E)	Upper and lower limits (%)
National parks	6.50	LOP E1 and E2	99 and 92
State forests	7.00	LOP E2 and E3	92 and 84
Timber reserves	7.50	LOP E3 and E4, LUC E5 and E6	84 and 66
Various reserves and dams	7.50	LOP E4, LUC E5	79 and 66
Unallocated state land	7.75	LOP E7, LOP E4, LUC E5	72 and 56
Leasehold land	8.00	LOP E4 and E7	66 and 56
Freehold and similar	8.25	LOP E4 and E8, LUC E9	66 and 48
Roads, esplanades, railways	9.00	LOP E8 and E10, LUC E9 and E11	48 and 39
Rivers	7.50	LOP E3 and E8, LUC E9	84 and 48

Table 10
Total rateable value of land in the 11 LGAs represented in the Wet Tropics Bioregion as at 30th June 2002

Local government area	Total land area (ha)	Alienated land (ha)	Rateable value (AUD$)	Dollar value per hectare
Cook Shire		5,548,440	97,324,240	17.54
Mareeba Shire	5,388,476	4,194,377	384,843,420	91.75
Herberton Shire		993,449	92,386,550	93.00
Hinchinbrook Shire	247,207	179,101	464,679,440	2594.51
Eacham Shire	112,400	52,535	183,805,350	3498.72
Cardwell Shire	290,100	96,700	368,429,100	3810.02
Thuringowa		169,983	860,828,043	5064.20
Atherton Shire	62,182	52,358	293,278,890	5601.42
Johnstone Shire		75,214	476,226,650	6331.62
Douglas Shire	238,600	50,106	491,603,500	9811.27
Cairns City	168,750	74,790	3,840,000,000	51,343.76

least important. Clearly there is little humans can do to influence 'soil formation', which while obviously extremely important, is measured in thousands to tens of thousands of years. A counterpoint to this is that 'erosion control and soil/sediment retention' is ranked third in the order of importance. This attribute is manifest in the present time.

The conceptual models for level of protection (LOP) and land use classification (LUC) were used to derive the upper and lower limits of ecosystem service provision as per the methodology for the various land tenure categories in the WTWHA (Appendix E). The tenure categories in the WTWHA include a range of vegetation types and canopy cover, yet all were protected by virtue of inclusion in the protected area management framework. The tenure categories were best used as a measure of past disturbance, which were also reflected in the zoning system adopted by the Wet Tropics Management Authority (WTMA). WTMA identify community infrastructure as being the greatest deleterious impact by way of ecological fragmentation, yet while this is undoubtedly true, depending on the impact these sites can still contribute substantially to the overall level of EGS being generated in a landscape. The capitalisation rates for the tenure categories, the conceptual models used to derive the upper and lower limit of provision of EGS (Appendix E), and the upper and lower limits used in the valuation tables are given in Table 9.

The MUV in the Wet Tropics Bioregion as at June 30th 2002 was AUD$3810.02 ha^{-1} (Table 10). The bioregion is administered by 11 local governments, some of which are totally within the boundaries of the bioregion and others with only a small part of their administrative area within the bioregion. The total value of the rateable land in each LGA in the bioregion is given in Table 10 along with the area of that land. The outliers were the largest and least developed shires and the most developed, Cairns City. The median was represented by the coastal Shire of Cardwell. The per

Table 11
The Usus Fructus per annum or shadow price per hectare for the tenure categories adjusted for the decreasing level of protection and increasing disturbance (increasing capitalisation rate) and by the mean of the upper and lower limit of provision of services

Tenure category	Capitalisation rate	UFpa ha^{-1}	Lower limit %	Upper limit %	UFpa ha^{-1} × mean limits
National Parks	6.5	AUD$247.65	92	99	AUD$236.51
State Forests	7	AUD$266.70	84	92	AUD$234.70
Timber Reserves	7.5	AUD$285.75	66	84	AUD$214.31
Various reserves and dams	7.5	AUD$285.75	66	79	AUD$207.17
Unallocated state land	7.75	AUD$295.28	56	72	AUD$188.98
Leasehold land	8	AUD$304.80	56	66	AUD$185.93
Freehold and similar	8.25	AUD$314.33	48	66	AUD$182.31
Roads, esplanades railways	9	AUD$342.90	39	48	AUD$149.16
Rivers	7.5	AUD$285.75	48	84	AUD$188.60

Table 12
Annual values or shadow prices of the individual ecosystem goods and services (attributes) totaled for all the tenure categories in the WTWHA

Ecosystem good or service/ attribute	National Parks		State Forests		Timber Reserves		Var Res and dams		Unallocated land	
	Lower AUD$000/ year	Upper AUD$000/ year	Lower AUD$000/ year	Upper AUD$000/ year	Lower AUD$000/ year	Upper AUD$000/ year	Lower AUD$000/ year	Upper AUD$000/ year	Lower AUD$000/ year	Upper AUD$000/ year
Gas regulation	4492	4834	5369	5880	965	1228	133	159	690	888
Climate regulation	4427	4764	5291	5795	951	1210	131	157	680	875
Disturbance regulation	3581	3853	4279	4721	769	979	107	128	550	708
Water regulation	716	771	856	937	154	196	22	26	112	144
Erosion control	4753	5114	5680	6221	1021	1300	141	168	730	939
Biological control	4102	4414	4902	5369	881	1121	122	146	630	811
Refugia	5999	6025	6691	7329	1203	1531	166	198	861	1106
Soil formation	651	701	778	852	145	185	20	24	104	134
Nutrient cycling	2539	2732	3034	3323	545	694	75	90	390	502
Assimilation of waste	3321	3573	3968	4346	713	908	97	117	510	656
Purification	3776	4063	4513	4942	811	1032	111	133	580	746
Pollination	2344	2522	2801	3068	504	641	69	82	360	463
Biodiversity	6445	6936	7703	8436	1385	1762	191	228	991	1274
Water supply	2799	3012	3346	3664	601	765	83	100	430	553
Food production	1562	1681	1867	2045	336	427	47	56	240	309
Raw materials	1888	2032	2256	2471	406	516	56	67	290	373
Genetic resources	4753	5114	5680	6221	1021	1200	141	168	730	939
Recreation	1628	1751	1945	2130	350	445	48	57	250	322
Aesthetic,	3516	3783	4201	4636	755	961	105	125	540	965
Other non-use values	2148	2312	2568	2812	462	587	63	76	330	425
Totals	65,440	69,987	77,728	85,198	13,978	17,688	1928	2305	9998	13,132

This table should be read in conjunction with Tables 2 and 11, which provide the area (ha) of the tenure categories, the capitalisation rate, the UFpa, the upper and lower limits (%) and the UFpa adjusted for the level of provision of ecosystem services. The UFpa across tenures thus ranges from AUD$210 to AUD$236 per ha pa, and within tenures from AUD$247.65 to 342.90 per ha pa before adjustment (i.e. 100% provision), and AUD$149.16 to AUD$236.51 per ha pa after adjustment.

hectare value or shadow price for the full suite of ecosystem goods and services, or UFpa ha^{-1} (Eq. (1)), starts at AUD$247.65 $year^{-1}$ (AUD$3810.02 × 6.5%) for the National Parks, and increases for the tenure categories with increasing capitalisation rates to reflect scarcity as the level of protection decreases, disturbance increases and the level of provision of EGS decreases (Table 11). The level of provision of EGS (or the extent to which they are intact) was determined using the conceptual models. It should be noted, however, that higher capitalisation rates are offset by lower levels of provision of EGS, e.g. remnant vegetation is most at risk, but by definition, there is less of it. Finally, using the valuation tables and the complete methodology, the total value of ecosystem goods and services in the WTWHA (TVw in Eq. (2)) was determined to be in the range AUD$188 million to AUD$211 million $year^{-1}$ (Table 12). Values for individual attributes, if present, depend on the weight assigned and the level of provision (see for exam-

Leasehold		Freehold		Roads, rail, etc.		Rivers		Totals	
Lower AUD$000/year	Upper AUD$000/year	Lower AUD$000/year	Upper AUD$000/year	Lower AUD$000/year	Upper AUD$000/year	Lower AUD$000/year	Upper AUD$000/year	Lower AUD$000/year	Upper AUD$000/year
1062	1251	181	211	53	65	31	55	12,976	14,571
1046	1233	178	208	52	64	31	54	12,787	14,360
846	997	145	169	42	52	25	44	10,344	11,651
172	203	29	34	9	11	5	9	2075	2331
1123	1324	191	223	55	68	33	58	13,727	15,415
969	1142	165	193	48	59	29	50	11,848	13,305
1323	1560	225	263	66	81	39	68	16,573	18,161
160	189	27	32	8	10	5	8	1898	2135
600	707	103	120	30	37	18	31	7334	8236
785	925	132	154	39	47	23	40	9588	10,766
892	1052	151	176	44	54	26	46	10,904	12,244
554	653	93	109	27	33	16	28	6768	7599
1523	1795	259	302	75	93	45	78	18,617	20,904
662	780	113	132	33	41	20	34	8087	9081
369	435	64	74	19	23	11	19	4515	5069
446	526	76	89	22	27	13	23	5453	6124
1123	1324	191	223	55	68	33	58	13,727	15,315
385	453	65	76	19	23	11	20	4701	5277
831	979	142	166	41	51	25	43	10,156	11,709
508	598	86	100	25	31	15	26	6205	6967
15,379	18,126	2616	3054	762	938	454	792	188,283	211,220

ple the valuation table in Appendix B). Values for the individual attributes in the WTWHA (TVi in Eq. (3)) are also shown in Table 12.

The main issue in rationalising a range of values for EGS is maintaining them within an order of magnitude of the values for all other uses to which land is put and other avenues of investment in the economic system. This statement may seem controversial considering that according to Martinez-Alier et al. (1998) 'weak comparability' of values, is a 'characteristic feature of ecological economics'. However, the use of monetary measures also assumes commensurability of values according to Martinez-Alier et al. (1998). An order of magnitude as a measure of dispersion could hardly be termed strong comparability or commensurability either. Any investment in the economic system, including investment in nature conservation, relies on factors such as risk to determine an appropriate yield, and the variance in investment performance is generally to the order of only a fraction of one order of magnitude. Comparison of various studies, includ-

Table 13
Comparison of the subject (what) of a selection of studies of valuations of ecosystem services (sources: Castro, 1994; de Groot, 1994; Adger et al., 1995; Myers, 1988; Curtis, 2003; Driml, 2002; Duthy, 2002)

Researcher	Locality	What	Value ha^{-1} $year^{-1}$
Curtis, 2003	WTWHA Queensland Australia	Full suite of ecosystem services. Linked to unimproved property values and human population density	AUD$210–$236 across tenures, AUD$149–$342 within tenures
Driml, 1997 (updated 2002)	WTWHA Queensland Australia	Recreation	AUD$112–$224
Duthy, 2002	Whian Whian State Forest, NE NSW, Australia	Non-consumptive use and non-use values	AUD$214–$404
Davis et al., 1998	Gibraltar and Dorrigo National Parks, NE NSW, Australia	Recreation	AUD$264–$298
Adger et al., 1995	Mexico's forests	Limited suite of ecosystem services	US$80
de Groot, 1994	Panama's forests	Use and non-use values	US$500
Castro, 1994	Costa Rica 'wildlands'	Ecosystem services	US$102–$214
Pimentel et al., 1996	Several dozen forests	Sustainable use value	US$220

ing Castro's (1994) comprehensive work in Costa Rica, which is most similar to the WTWHA both in areal extent and ecosystem type, is given in Table 13.

The values for the WTWHA derived from the methodology and reflecting risk and uncertainty, level of protection and land use characteristic could be extrapolated for the whole of Australia (Table 14). Although some bioregions will have substantially higher UFpa or shadow prices due to scarcity factors and elevated real property values, and others such as in inland Australia will be much lower. Thus 140–150 billion Australian dollars per annum could be a reasonable ballpark figure for EGS for the whole of terrestrial Australia, which is the equivalent of about one quarter of the Australian

Table 14
Extrapolated values for the tenure categories for the whole of Australia using tenure categories and areas from Year Book Australia 2002 (ABS 2002)

Tenure category	%	km^{-2}	km^{-2} rate	Total value
Private Land	62.7	4,819,600	AUD$18,231.00	AUD$87,866,127,600.00
ATSI Land	14.3	1,094,800	AUD$18,898.00	AUD$20,689,530,400.00
Public land				
Nature Reserve	6.81	524,100	AUD$23,651.00	AUD$12,395,489,100.00
Aboriginal Freehold NP	0.14	10,800	AUD$23,651.00	AUD$255,430,800.00
Vacant Crown Land	12.49	960,700	AUD$18,980.00	AUD$18,234,086,000.00
Other Crown Land	1.06	80,600	AUD$14,916.00	AUD$1,202,229,600.00
Forestry Reserve	1.93	148,200	AUD$21,431.00	AUD$3,176,074,200.00
Water Reserve	0.14	11,000	AUD$20,717.00	AUD$227,887,000.00
Defence Land	0.25	18,600	AUD$18,593.00	AUD$345,829,800.00
Mining Reserve	0.07	5000	AUD$18,593.00	AUD$92,965,000.00
Mixed Category Land	0.12	8900	AUD$14,916.00	AUD$132,752,400.00
Total value	100.01			AUD$144,618,401,900.00

National land tenure details are the latest available from AUSLIG (1993).
Some changes have taken place since, particularly in the composition of public land tenures.

Gross Domestic Product for the year 2000–2001 (ABS, 2002). By comparison Costanza et al. (1997b) estimated about 12 trillion US dollars for the world's terrestrial ecosystems, or about two thirds of the then World's GDP. However, this study was widely criticised for a number of reasons, one being the magnitude of the figure (Cork and Shelton, 2000). Some of the values ascribed by different researchers that were extrapolated for Costanza's study for particular ecosystems were well out of the ballpark. For example: wetlands US$14,785 ha^{-1} year^{-1}, and Lakes/Rivers US$8,498 ha^{-1} year^{-1}, and even tropical forests, US$2,007 ha^{-1} year^{-1}. Closer to the mark were temperate forest US$307 ha^{-1} year^{-1} and grass/rangelands US$232 ha^{-1} year^{-1}.

The methods used to derive the values in this study are in accord with the principles of both the economic theory of value, which is based on price theory and human preferences (Frank, 1991) and the theory of valuation (which is based on actual interplays in market situations), the combination of which provides the empirical justification of the research. Irrespective of whether the values of the individual ecosystem attributes are adopted, a philosophical link between the value of land and its productive function (UFpa) as a supplier of planetary life support exists. However, what is less certain is whether this link supports the values derived by the very many and diverse contingency valuation (CVM) and travel cost (TCM) studies, or if it is the other way around. None of the CVM and TCM studies have any fixed reference point or longitudinal data set upon which to rely yet they generally produce results to the same order of magnitude as the UFpa in this study (Fig. 4). How is this? It could mean that the preferences that people reveal to purchase property for a multitude of purposes are subconsciously expressed when asked to bid for environmental protection of their investment. Yet they are not to know, or be able to compute the end result from their own simple bid. It could be that the bid levels are preordained to elicit a median or 'expected' response, which will result in a value to the order of the generally accepted magnitude. Some of the values of individual attributes of the environment revealed in this study can be compared with markets; for example, water, carbon (some trades have taken place), and they are again to the same order of magnitude. However, Driml's (2002) valuation of recreation in the WTWHA is an order of magnitude larger than the values for the pertinent life-fulfilling services (recreation and aesthetics) in this study, which totalled AUD$15 to AUD$17 million year^{-1} for the WTWHA as part of the whole suite of services worth between AUD$188 and AUD$211 million year^{-1}. Likewise the benefit transfer of recreation values derived for the Dorrigo and Gibraltar National Parks in northeastern NSW, Australia, to Whian Whian State Forest suggested by Duthy (2002), would have had the effect of doubling the total estimate for all of the other non-consumptive uses and non-uses in this forest. Clearly, this one use, recreation, is not worth more or as much as all of the others. The Delphi panel was emphatic in this regard. Recreation was ranked 19th in model one, 12th in model two, and 17th in model three, 17th overall. Aesthetics, cultural and spiritual values fared better, being ranked 18th in model one, 14th in model two and 6th in model three, 10th overall. The TCM uses travel cost to access a natural area as a surrogate for value.

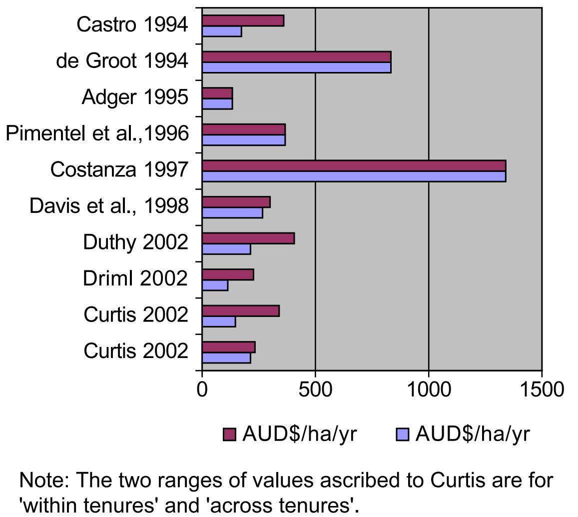


Fig. 3. Comparison of the values derived for various suites of ecosystem services by various researchers (source: Castro, 1994; de Groot, 1994; Adger et al., 1995; Costanza et al., 1997a; Myers, 1988; Curtis, 2003; Driml, 2002; Duthy, 2002).

However, this beggars the question: the value of what? The CVM describes a hypothetical market to respondents to elicit their response to a scenario that may impact on a natural area, but are they being asked to value a specific attribute of the environment that is being impacted or the whole basket of EGS? Psychologically it is difficult for respondents to separate out the, say, recreational value and nominate a bid level, when in fact they have absolutely no idea what other attributes there are, what attributes are valuable and what values apply to them. As a result, the imputed price derived from studies of this kind is not just for say, recreation, but everything the respondent consciously or subconsciously perceives as being part of the natural environment in question, and as such it must include non-use values and option values. The same logic can be applied to the TCM. If ‘weak comparability of values’ is a ‘foundation for ecological economics’ (Martinez-Alier et al., 1998), perhaps it is due to this esoteric notion by respondents of what is being valued. The economic values of the whole suite of EGS are constrained within measures that are consistent with all other uses to which land is put and other avenues of investment in the economic system. The values of individual EGS are constrained within this overall basket of goods and services on a landscape or bioregional scale; however, in some ecosystems certain goods and services may be worth more than others based on scarcity or limiting factors.

Transferability of the methodology expounded in this paper to other bioregions requires advice from the state agencies or LGs as to the rateable value (*UV*) of land in the LGAs, and the area of that land, as well as a landscape assessment for ecological integrity. A minimum level of development is required in a bioregion by way of infrastructure for the values to be comparable, and as the level of development increases so do the values for EGS, which reflects the economic concept of scarcity. Dobson et al. (2001:1019–1026) conducted research on ‘underlying patterns of species diversity, the distribution of threats to diversity (such as relative rates of habitat loss)’, human population density, and the value of land in different areas in five states in the USA. The relationship between human population densities and land values was exponential ($R = 0.99$; $P < 0.001$), and there were similar strong relationships between human population densities and numbers of endangered species as well as numbers of alien species. Dobson et al. (2001:1019) concluded that ‘protecting wilderness is valuable and relatively easy’, however, greater focus was required on areas that are of most value to humans. Scott et al. (2001:999) found that nature reserves are most often dedicated at higher elevations with less productive soils, while an analysis of the distribution of plants and animals showed that the greatest number of species was found at lower elevations. Patterns of land ownership also indicated that land at lower elevations was more productive, and had been ‘extensively converted to urban and agricultural uses’. The predominantly private ownership of land at lower elevations and coastal zones where human population densities were highest, land values were highest, and thus EGS more scarce, required that the private sector should be involved in innovative strategies to capture the full range of biodiversity. The population density of the Wet Tropics Bioregion in 2002 was 22 persons km^{-2} (WTMA, 2001). A highly significant relationship was found to exist between the population of the 11 shires in the bioregion and the mean unimproved value of the land in each shire ($R = 0.929$; $P < 0.000$). The comparability of the values for EGS between and within bioregions using the methodology expounded in this thesis is thus linked to human population density and the level of development.

6. Conclusion

The values only apply to a certain point in time as the components used to derive them are themselves variables. The MUV for each LGA will vary as to the temporal regularity of valuations and provision of this information to the LGAs for rating purposes. UFpa will vary as to the cost of money and investment in other comparable securities in the economic system. The measure of ecosystem integrity, esi, will vary as to condition of the subject land, level of protection and land use. The weights will only change if further studies are done which reflect other preferences for the relative importance of the attributes, or environmental conditions change such that certain attributes become more or less at threat. The area of the tenure categories may change as some land is elevated to a higher order tenure (State Forest to National Park), and other land subverted to a lower order tenure, such as for increased infrastructure in the region.

The methods chosen for this research were unashamedly positivist–rationalist, however, when seeking an outcome that would have practical application in the real world, no apology is necessary. The use of an existing database of property values was complemented by valuation theory to arrive at the pecuniary value of EGS. The Delphi panel ascribed non-pecuniary weights to the EGS, which were subject to systematic and statistical analysis. Ecological and land use parameters were used to determine the extent to which EGS were intact based on a model of 'distance from disturbance'. The result was a simple algorithm. The production function of land managed for conservation *is* ecosystem goods and services (author's emphasis). The method is readily transferable across LGA and bioregional borders, and the variation in UFpa can be used as a relative measure for impact mitigation across borders.

Appendix A. Multiple criteria/multiple attribute analysis of ecosystem goods and services

Model 3. 'Balanced' sensitivity paradigm/perspective

Sensitivity criteria	Max weight
Threats	− 4
Risk	− 3
Uncertainty	− 2
Precaution	− 1
Resistance	7.5
Resilience	7.5

Instructions: For each attribute consider the sensitivity criteria and either award the maximum weight for that criteria, or less if you think the threat, risk, etc., is less than the maximum, obviously some attributes are under more threat, etc., than others, e.g. biodiversity. Then decide what level of resistance and resilience each attribute has and award a weight accordingly, i.e. 7.5 or less. See the webpage for definitions. Examples below: Water Reg: low threat/risk, zero uncertainty, need for precaution, both high resistence and high resilience. Refugia: max threat/risk/etc, low resistence, moderate to high resilience.

Group	Type	Ecosystem sustainability					
		Threats	Risk	Uncertainty	Precaution	Resistence	Resilience
Stabilisation services	Gas regulation (atmospheric composition)						
	Climate regulation (temperature, rainfall)						
	Disturbance regulation (ecosystem resilience)						
	Water regulation (hydrological cycle)	− 1	− 1	0	− 1	6	7
	Erosion control and soil/sediment retention						
	Biological control (populations, pest/disease control)						
	Refugia (habitats for resident and transient populations)	− 4	− 3	− 2	− 1	2	5
Regeneration services	Soil formation						
	Nutrient cycling and storage (including carbon sequestration)						
	Assimilation of waste and attenuation, detoxification						
	Purification (clean water, air)						
	Pollination (movement of floral gametes)						
	Biodiversity						
Production of goods	Water supply (catchment)						
	Food production (that sustainable portion of GPP)						
	Raw materials (that sustainable portion of GPP, timber, fibre, etc.)						
	Genetic resources (medicines, scientific and technological resources						
Life fulfilling services	Recreation opportunities (nature-based tourism)						
	Aesthetic, cultural and spiritual (existence values)						
	Other non-use values (bequest, option and quasi option values)						

Appendix B. Tenure category: state forest conservation area within the wet tropics of Queensland world heritage area

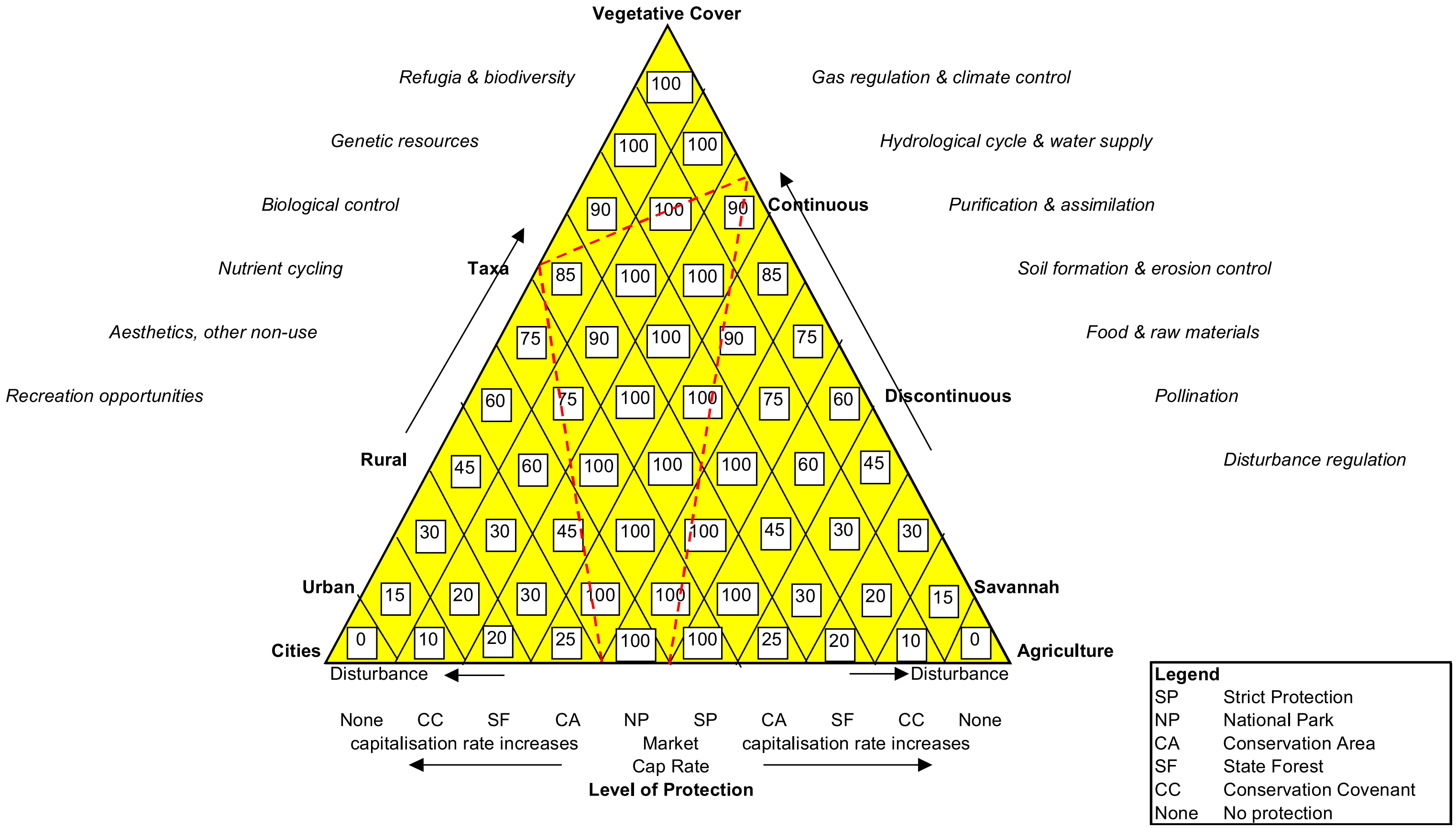
The median unimproved value of all rateable land in the 11 Local Govt areas represented in the Wet Tropics Bioregion: AUD$3,810.02 ha^{-1}.

Group and type of ecosystem service (attribute)	Not present		Type of disturbance	Present	Ufpa	% Intact		Weighting	Value per ha		TVi	
	Temporary	permanent			7%	Low	High		84% intact	92% intact	Lower range	Upper range
Stabilisation services												
Gas regulation (atmospheric composition)				Yes	$266.70	84	92	0.069	$15.46	$16.93	$5,368,567.96	$5,879,860.15
Climate regulation (temperature, rainfall)				Yes	$266.70	84	92	0.068	$15.23	$16.68	$5,290,762.63	$5,794,644.79
Disturbance regulation (ecosystem resilience)				Yes	$266.70	84	92	0.055	$12.32	$13.50	$4,279,293.31	$4,686,845.05
Water regulation (hydrological cycle)				Yes	$266.70	84	92	0.011	$2.46	$2.70	$855,858.66	$937,369.01
Erosion control and soil/ sediment retention				Yes	$266.70	84	92	0.073	$16.35	$17.91	$5,679,789.30	$6,220,721.61
Biological control (populations, pest/disease control)				Yes	$266.70	84	92	0.063	$14.11	$15.46	$4,901,735.97	$5,368,567.96
Refugia (habitats for resident and transient populations)				Yes	$266.70	84	92	0.086	$19.27	$21.10	$6,691,258.62	$7,328,521.35
Regeneration services												
Soil formation				Yes	$266.70	84	92	0.010	$2.24	$2.45	$778,053.33	$852,153.65
Nutrient cycling and storage				Yes	$266.70	84	92	0.039	$8.74	$9.57	$3,034,407.98	$3,323,399.22
Assimilation of waste and attenuation, detoxification				Yes	$266.70	84	92	0.051	$11.43	$12.51	$3,968,071.97	$4,345,983.59
Purification (clean water, air)				Yes	$266.70	84	92	0.058	$12.99	$14.23	$4,512,709.30	$4,942,491.14

Pollination (movement of floral gametes)	Yes	$266.70	84	92	0.036	$8.07	$8.83	$2,800,991.98	$3,067,753.12
Biodiversity	Yes	$266.70	84	92	0.099	$22.18	$24.29	$7,702,727.95	$8,436,321.09
Production of goods									
Water supply (catchment)	Yes	$266.70	84	92	0.043	$9.63	$10.55	$3,345,629.31	$3,664,260.67
Food production (that sustainable portion of GPP)	Yes	$266.70	84	92	0.024	$5.38	$5.89	$1,867,327.99	$2,045,168.75
Raw materials (that sustainable portion of GPP, timber, fibre, etc.)	Yes	$266.70	84	92	0.029	$6.50	$7.12	$2,256,354.65	$2,471,245.57
Genetic resources (medicines, scientific and technological resources	Yes	$266.70	84	92	0.073	$16.35	$17.91	$5,679,789.30	$6,220,721.61
Life fulfilling services									
Recreation opportunities (nature-based tourism)	Yes	$266.70	84	92	0.025	$5.60	$6.13	$1,945,133.32	$2,130,384.11
Aesthetic, cultural and spiritual (existence values)	Yes	$266.70	84	92	0.054	$12.10	$13.25	$4,201,487.97	$4,601,629.68
Other non-use values (bequest, option and quasi option values)	Yes	$266.70	84	92	0.033	$7.39	$8.10	$2,567,575.98	$2,812,107.03
					0.999	$223.81 84% intact	$245.12 92% intact	$77,727,527.49	$85,130,149.16
	TVw ($AUDpa)			Hectares (Ref WTMA GIS)	347,300	$77,727,527.49	$85,130,149.16		

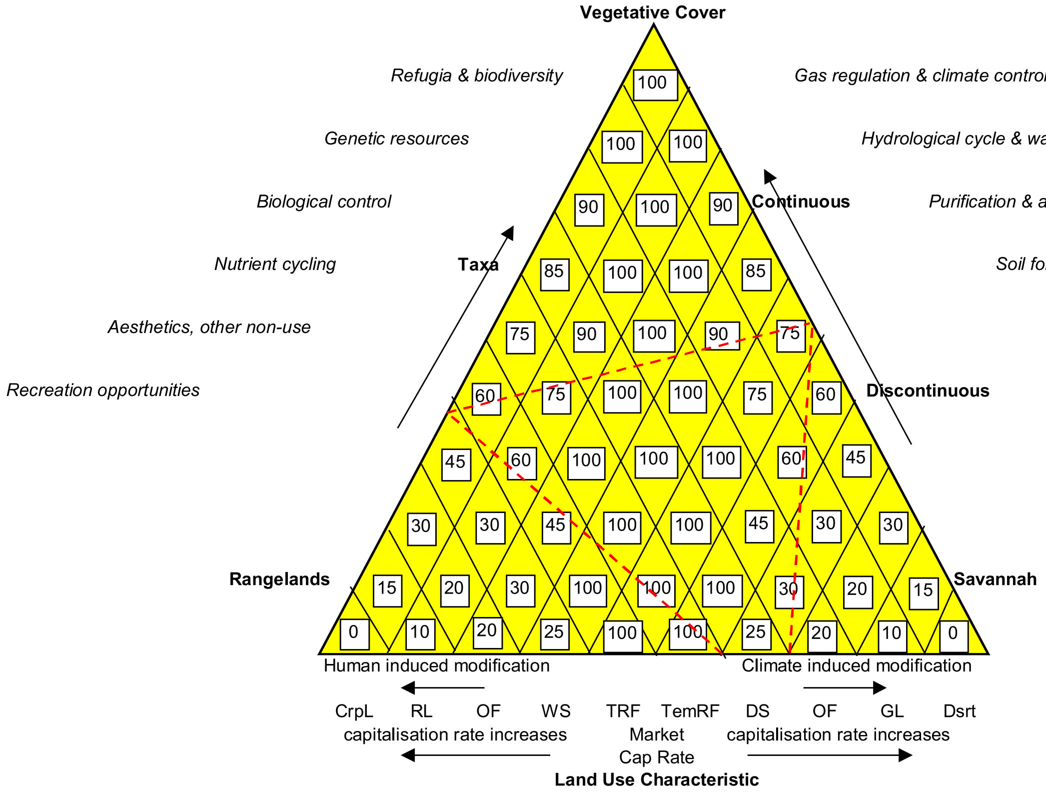
Appendix C. Triangulation model to assess extent of ecosystem services intact under a given level of protection or no protection

Scoring: Calculate the mean of the values within the diamonds included in the selection as well as those the dotted line passes through. This example, National Park: 92%.



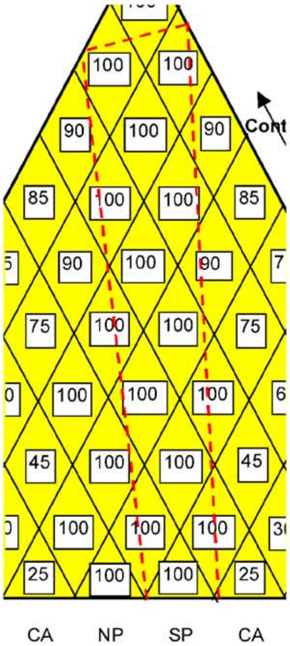
Appendix D. Triangulation model to assess extent of ecosystem services intact under a given land use characteristics

Scoring: Calculate the mean of the values within the diamonds included in the selection as well as those the dotted line passes through. This example, Dry Sclerophyll Forest: 76%.

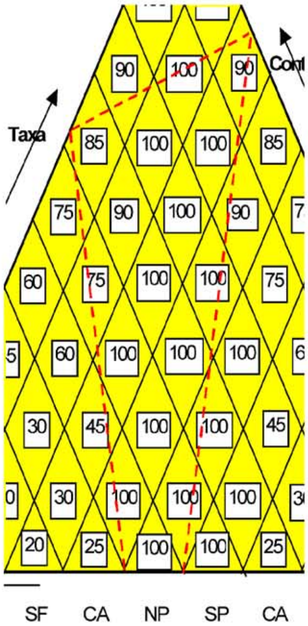


Legend			
TRF	Tropical Rainforest	RL	Rangelands
TemRF	Temperate Rainforest	Dsrt	Desert
WS	Wet Sclerophyll	CrpL	Croplands
DS	Dry Sclerophyll		
OF	Open Forest		
GL	Grasslands		

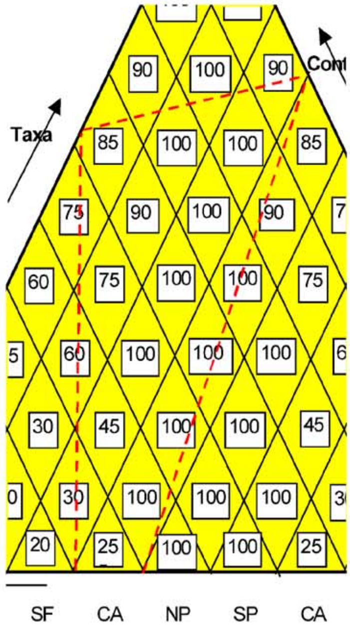
Appendix E. Models used to assess ecological integrity in the WTWHA tenure categories



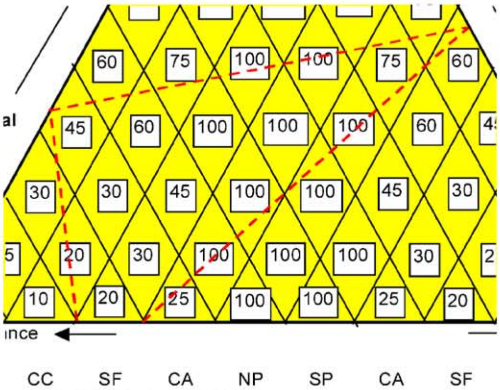
LOP E1 National Park (99%)



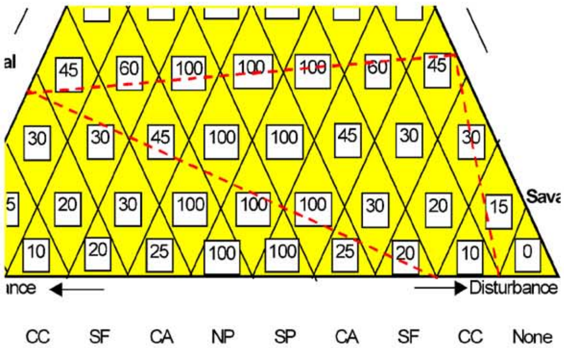
LOP E2 National Park (92%)



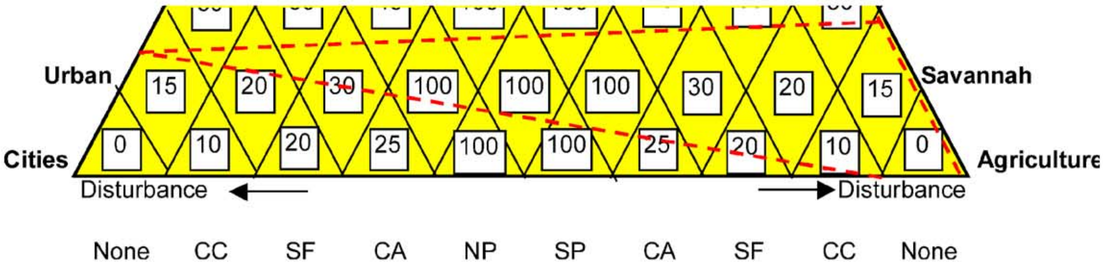
LOP E3 Conservation Area (84%)



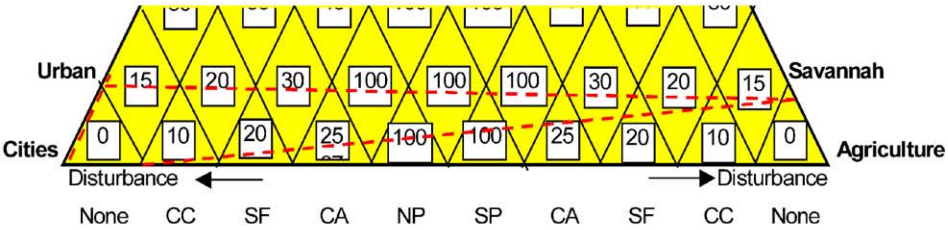
LOP E4 State Forest (66%)



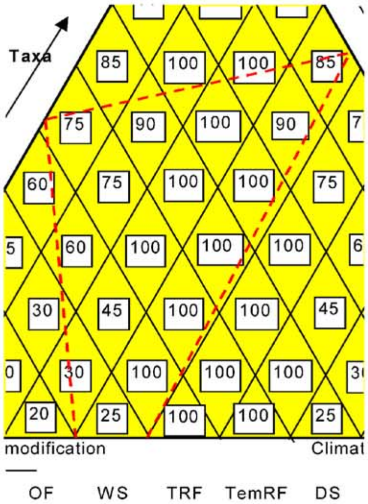
LOP Model E7 Conservation Covenant (56%)



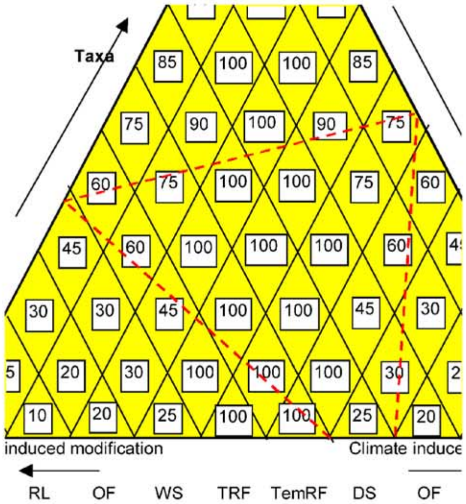
LOP Model E8 Savannah (48%)



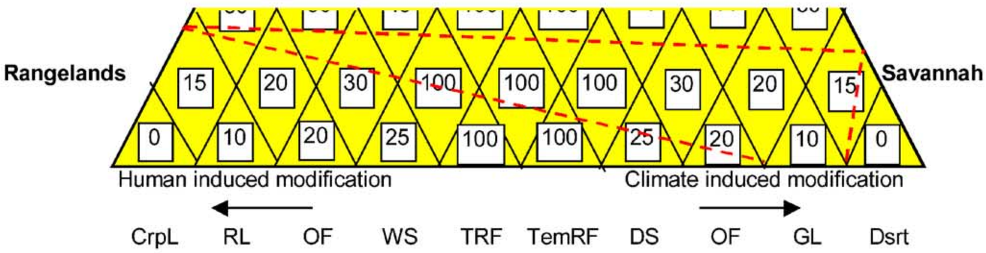
LOP Model E10 City/Urban (39%)



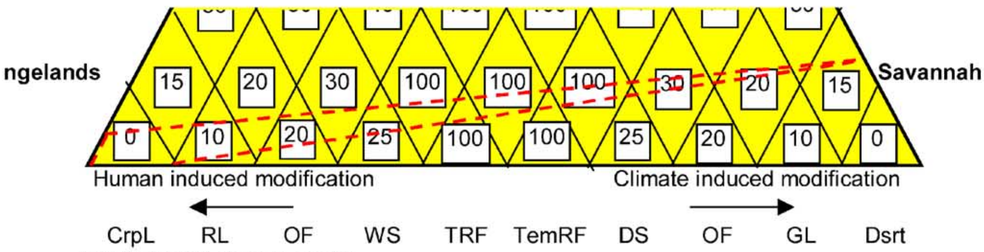
LUC Model E5 Wet Sclerophyll Forest(79%)



Luc E6 Model Dry Sclerophyll (76%)



LUC Model E9 Grasslands/Mediterranean(50%)



LUC Model E11 Croplands(43%)

Appendix E (*continued*).

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