CHAPTER 1

INTRODUCTION

"…those to whom the faculty of reason is predominant, and who most skillfully dispose their thoughts with a view to render them clear and intelligible, are always the best able to persuade others of the truth of what they lay down"

Descartes

1.1 Introduction

There is still a fundamental lack of confidence in the outcomes of attempts to value the environment. Costanza *et al's.,* (1997a) seminal paper published in *Nature* pulled together many social studies of diverse ecosystems to arrive at a gross value for the earth's ecosystem goods and services at US$33 trillion, with some individual ecosystems, for example wetlands, being worth in excess of $14000 ha^{-1} yr^{-1}. Yet despite this notable attempt, ecosystems are still being degraded from the want of a simple and practical method to assign values to individual ecosystem goods and services. Costanza *et al.,* (1997b) also claim that there is now 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. Good allocation is efficient and reflects choice amidst scarcity (microeconomic theory), which must be weighted by individual ability to pay (Frank 1991; Daly and Townsend 1993). Added to this are the problems of removing the odium attached to the idea of putting a money value on everything, distributional effects, and translating and communicating the need for a market mechanism to conserve these formerly 'free' goods and services.

Methods used to date to value the environment have been primarily to do with societies' 'willingness to pay' to avoid a nuisance, eg. pollution, or 'willingness to accept' ie. compensation, for a negative external effect (Pearce 1971; 1983; Schofield 1987). The most widely used application of this type of expressed preference is known as the contingency valuation method, as it is contingent on the hypothetical market described to respondents (Mitchell and Carson 1989; Johansson 1993; Hanley and Spash 1993; Bateman and Turner 1995; Judez *et al.,* 2000). Apart from the very time-consuming nature of expressed preference surveys, many biases exist with regard to the description and perceived feasibility of the hypothetical market, and the vagaries of the bidding process (see Mitchell and Carson 1989). Other than expressed preferences, revealed preferences are often used to evaluate specific externalities, such as aircraft noise, by a comparison of house prices (with and without), which is known as 'hedonic pricing'. This, and the ‘travel cost method’, which uses the cost of accessing a conservation area as a surrogate for value, only ascribes value to 'use', and ignores 'non-use' value. Revealed preference methods also only ascribe value to a particular attribute of the environment, eg. recreation (Hanley and Spash 1993; Johansson 1993). However, a revealed preference or surrogate market overlooked so far in empirical studies is the broader property market. For use as a surrogate, the property market is notable and validated by the pivotal role it plays in national administration, eg. taxation, and widespread acceptance by the commercial world, individuals and the judiciary. Individual landholdings in a region are valued by state and/or federal agencies, and the gross valuations 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 in a wider geographical region.

The founder of political ‘arithmetic’ in the 17th century, Sir William Petty, ascribed a close link between the theory of valuation and general economics, based on his observations and interpretation of phenomena in the material world (Murray 1954). However, this link was broken about the time of Adam Smith (1723-1790) by the disassociation of economic theory from empirical verification. Economics then fell into the realm of pure theory, with later works dealing with value relying on the marginal utility approach and indifference curves developed by Hicks (Murray 1954). The two disciplines differed principally in that one dealt with the abstract theory of value based on psychological preferences and subjective approaches without empirical verification, while the other, with actual market measurement and standards. Murray (1954:82) asserts that this involved:

"…imputing prices to goods and services which exhibit individual characteristics",

some of which may have been,

"…intangible, and related to factors such as risk and uncertainty or potential earning capacity".

Although apparently pre-empted by ancient Greek and Roman appraisal practice, Petty was 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. More recently, and analogous to the concept of *'usus fructus per annum'* was the rule laid down by Harold Hotelling (1895 - 1973). Hotelling put forward the proposition that if a natural resource did not generate a benefit stream at least equivalent to the cost of money, it would be degraded (Hotelling 1931; Costanza *et al.,* 1997b; Hackett 2001). Hartwick (1977) proposed a similar rule. The 'Hartwick rule' required that to achieve the status of full intergenerational equity, each generation must reinvest the economic rent (in situ value) of an exhaustible resource. The theory of valuation thus stands in the forefront of the social sciences, being a branch of applied economics principally to do with all of the ramifications of land utilisation and commerce, and employing the scientific method where hypotheses are tested by both empirical means and convergent validity (Murray 1936).

In this thesis, a new method to value the environment will be described. Relying on real property valuation theory and practice, and the property market as a surrogate market, the total value (TV) of the Wet Tropics of Queensland World Heritage Area in Australia is determined. A multiple criteria analysis combined with a Delphi inquiry is then used to assign shadow prices to the individual ecosystem goods and services and groups of goods and services provided by the World Heritage Area.

1.2 Need for the study

Ecosystems are being degraded and destroyed worldwide 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 (Raven 1988; Wilson 1988a). For the first time in geological time, the present threat includes a decline in plant diversity (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). Human existence is intimately entwined with wild genetic resources (Lovejoy 1984). Wholesale eradication of populations and species of organisms has a critical and fundamental impact on the provision of ecosystem goods and services that are essential as planetary life support systems, and not only for humans. Insects and other animals play a major role in pollination and every species has an ecological niche outside of which it cannot survive. All living biota exchange gases with their environment and are directly or indirectly responsible for the atmospheric composition of the planet (Ehrlich 1988; Beattie and Ehrlich 2001). Without the photosynthetic plants and other organisms that only started to proliferate since the Carboniferous period, converting carbon dioxide to food and oxygen, the planet would be unlivable (Raven *et al.*, 1992). The direct and indirect partitioning at the present time of over 40% of the net primary production of ecosystems by humans (Costanza *et al.,*1997b; Beattie and Ehrlich 2001) may be just the early indicator of a catastrophic misappropriation of nature’s beneficence.

It is only in recent years that the broader population has started to become aware of the role that ecosystems and biodiversity play in planetary life support, although the environmental movement can be traced back 40 years to the publication of Rachel Carson’s ‘Silent Spring’ in 1962 (Goodstein 1999). The extraordinary variety of life on earth had been imagined through the work of luminaries such as Terry Erwin (1988) and E. O. 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 humans really are not in control of sufficient knowledge to make a difference (Beattie and Ehrlich 2001). The genetic diversity within species is declining rapidly and it is largely irreplaceable. Ecologists believe that many genetically diverse populations are necessary to ensure persistence of a species, as genetic variation in disjunct populations increases the potential for evolving in response to long-term environmental change (Ehrlich 1988). Genetic diversity is arguably the most valuable resource to humans as a living storehouse or 'pharmacological bounty of wild species' (Wilson 2002). Millions of species have evolved over geological time and are available for humans to consult to assemble their own pharmacopoeia to ward off disease (Beattie and Ehrlich 2001; Wilson 2002). *"Thus, antibiotics, fungicides, antimalarial drugs, anesthetics, analgesics, blood thinners, blood-clotting agents, agents that prevent clotting, cardiac stimulants and regulators, immunosuppressive agents, hormone mimics, hormone inhibitors, anticancer drugs, fever suppressants, inflammation controls, contraceptives, diuretics and antidiuretics, antidepressants, muscle relaxants, rubefacients, anticongestants, sedatives and abortifacients are now at our disposal, compliments of wild biodiversity"* (Wilson 2002:1).

The main descriptive terms in ecology were coined by:

- Frederic Clements, who coined the terms "succession of plants" and "climax community" in the 1890s;
- J. Arthur Thompson referred to the "web of life" in 1914;
- Charles Elton constructed the "food chain" in 1927, and introduced the concept of "niche";
- Clements and Victor Sheppard together, in the 1930s, coined the terms "biotic community" and "biome" (Nash 1990:56-58).

Edward G. Tansley took a more metaphysical approach in 1935 by reducing nature to chemicals and energy flowing through living things according to the laws of physics (Nash 1990). Later Alfred North Whitehead confirmed the connectivity of all things in nature, whether living or not, by describing the flux of electro-magnetic particles that made up all matter (Nash 1990). Environmental ethics is defined as "a systematic account of the moral relations between human beings and their natural environment" (Des Jardins 1997:13). Ethics assumes that moral norms can and do govern behaviour.

The responsibility to protect the environment is indirect. Ethics being a human construct implies that only humans have moral values. This anthropocentric view also suggests that humans have responsibilities regarding the environment, but not to the environment (Passmore 1974; Sylvan and Bennett 1994; Des Jardins 1997). The western philosophical tradition of anthropocentrism could be held largely responsible for the world's present predicament (Des Jardins 1997). On the other hand, a non-anthropocentric view argues that plants and animals, rocks and minerals, and even geomorphological features have moral standing. Biocentrism places all living things on an equal footing, while holistic ethics (or deep ecology) accords rights to collections rather than individuals, in other words, whole ecosystems including non-living natural features (Leopold 1949; Nash 1990; Attfield 1991; Sylvan and Bennett 1994; Des Jardins 1997).

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). Wilson (2002) argued that it was not possible to guess the full future value of any kind of animal, plant or microorganism owing to the unimaginable spectrum of its potential to satisfy human needs. Yet value we must as it is the presumption that these goods and services are 'free' that is leading to their destruction. Many ecosystem goods and services fall under the definition of 'critical natural capital', as they are essential to human life and cannot be replaced or substituted by human-made capital. Under these conditions Winpenny (1991) argued that they are 'priceless'. Other natural capital should be valued in order that the costs of activities that may deplete them or destroy them can be calculated, for example to invoke the 'polluter pays' principle, it must be determined 'how much?' (Winpenny 1991). Similarly to invoke a carbon tax to offset the damage of excess greenhouse gas emissions, or to raise a carbon credit to reward minimisation mechanisms or carbon sink activities, a price must be determined for carbon (Curtis 2001). However, by placing a value on one ecosystem service or good, and not on another, the latter tends to be devalued or deemed to be free. This leads to exploitation, over-consumption, and depletion. 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".

The purpose of this study is to place a value on all of the ecosystem services and functional groups of ecosystem services in order that whatever the impact of a current or proposed human activity, it can be compensated. Ideally some actions would not proceed on the strength of the costs to society outweighing the benefits. However, others with minimal impact, say on one or more specific ecosystem goods or services, can be offset by provision of compensatory services elsewhere, or by technology.

1.3 Description of ecosystem goods and services: the attributes

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.

Ecosystem goods and services include:

- Regeneration services: air; water; soil fertility, seed and pollen dispersal.
- Stabilisation services: climate; hydrological cycle; ecosystem resilience; pest/disease control; assimilation of waste; attenuation; a living storehouse.
- Production of goods: food; fibre; timber; medicine; genetic resources.
- Life fulfilling services: aesthetics; cultural; spiritual.

These ecosystem goods and services 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).

Wilson (2002:1) defined ecosystem services as:

"…the flow of materials, energy and information from the biosphere that support human existence. They include the regulation of the atmosphere and climate, the purification and retention of fresh water, the formation and enrichment of the soil, nutrient cycling, the detoxification and assimilation of waste, the pollination of crops and the production of lumber, fodder and biomass fuel".

Some questions, which help define ecosystem services, may include:

- Who owns them?
- Who benefits from them?
- What ecosystems provide which service?
- How can the level of disturbance (anthropogenic or otherwise) be correlated with the level of provision of ecosystem services?

Cork *et al*., (2001) posed a longer list of questions to do with:

- temporal and spatial beneficiaries;
- human impact on supply;
- current level of damage to ecosystem services and what is required to repair them;
- where the problems are geographically;
- the role of biodiversity in the provision of services, and
- the possibility/probability of technological substitutes now and in the future.

The general role that individual ecosystem attributes play in ecosystem function and hence planetary life support, and the primary threats to them are shown in Table 1.1, although the real complexity or inter-relatedness of all of the attributes, if known, would be impossible to tabulate. In a sense they operate on several strata, the atmosphere, the land/ocean/atmosphere interface, the biosphere, the biosphere/regolith interface, and within the regolith, for eg. minerals (Figure 1.1).

Table 1.1 Role, function, interdependencies, threats, ownership and beneficiaries of ecosystem goods and services (Source: see note below).

Attribute	Role	Function	Interdependencies	Main threats	Who owns it	Who benefits
Gas regulation	Maintenance	Balance	All biota. Ocean/atmosphere interface. Geological degassing.	Deforestation. Loss of biodiversity.	Public good	All
Climate regulation	Maintenance	Stability	Human activities. Planetary cycles	Deforestation. Greenhouse gas emissions	Public good	All
Disturbance regulation	Stability	Resilience	Human activities. Climate	Population growth. Climate change	Public good	All
Water regulation	Control	Reliability	Climate. Vegetation cover. Topography	Deforestation. Misappropriation	Public good. Private property	All. Ratepayers
Erosion control and soil retention	Control	Preservation	Human activities. Vegetation cover. Topography	Deforestation. Desertification	Public good. Private property	All. Property owners
Biological control	Control	Stability	Habitat. Refugia	Habitat destruction. Climate change	Public good	All
Refugia	Maintenance	Preservation	Human activities. Vegetation cover	Population growth. Climate change	Public good. Private property	All
Soil formation	Stasis	Stasis	Parent material. Climate. Relief. Time. Organisms	Deforestation. Erosion. Urbanisation	Public good	All
Nutrient cycling and storage	Retention	Availability	Vegetation cover. Climate. Organisms	Deforestation. Urbanisation	Public good	All
Assimilation of waste	Attenuation	Sink	Soil cation exchange capacity. Ocean currents	Population growth. Urbanisation	Public good	All
Purification	Stability	Purification	Water, soil, biological control	Population growth. Urbanisation. Agro-practices	Public good	All
Pollination	Security	Regeneration	Vegetation	Deforestation. Disturbance. Pests. Exotics	Public good	All
Biodiversity	Security	Preservation	All	Every	Public good	All
Water supply	Control	Reliability	Catchments. Regulation.	Deforestation. Climate change	Public good. Private property	All

Table 1.1 continued. Role, function, interdependencies, threats, ownership and beneficiaries of ecosystem goods and services (Source: see note below).

Attribute	Role	Function	Interdependencies	Main threats	Who owns it	Who benefits
Food production	Sustenance	Availability	Vegetation. Water supply. Climate	Disturbance. Pests. Over harvesting	Public good. Private property	All. Property owner
Raw materials	Availability	Materials	Vegetation. Climate	Disturbance. Pests. Over harvesting	Public good. Private property	All. Property owner
Genetic resources	Security	Option	Vegetation. Climate. Human activities	Deforestation, climate change	Public good	All
Recreation opportunities	Leisure	Pleasure	Human activities. Climate	Alteration. Development	Public good	All
Aesthetics, cultural and spiritual	Life fulfilment	Life fulfilment	Human activities. Naturalness	Alteration. Development	Public good	All
Other non-use values	Security	Bequest	All	Over-consumption	Public good	All

Note: The above table was derived from a process of psycho-cybernetics, where in the first year of research, goals were set and the author's sub-conscious mind was allowed free reign in a variety of conceptual areas. Accordingly no particular source can be ascribed to any of the above categorisations, although some may have been as a result of a review of the literature, electronic sources, personal communications, conferences and workshops, all *without* this table in mind. The table was cognitatively put together when writing this chapter without reference to any notes or literature, and the descriptions allocated under the categories are purely the view of the author.

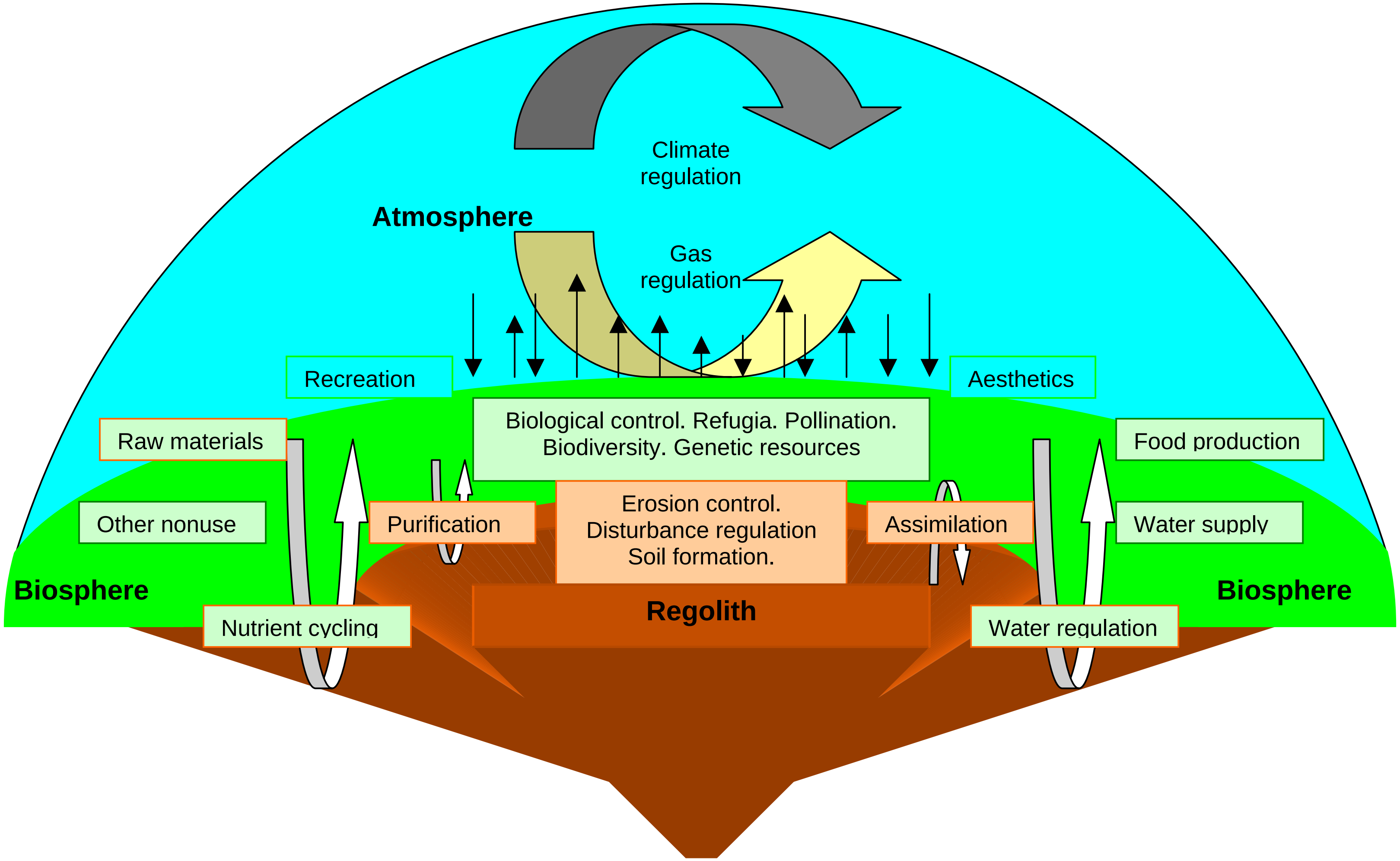

Figure 1.1 Atmosphere; atmosphere land/water interface; biosphere; biosphere/regolith interface; regolith: stratification of ecosystem services

1.4 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, 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% (Figure 1.2). The Wet Tropics Bioregion comprises tropical wet coastal ranges and plains, rainforests and forests. The dominant condition is described as 'modified ecosystems', ie. 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'. The Wet Tropics Bioregion is a priority area for funding under the National Reserves System Cooperative Program (Environment Australia 2001), however, it has the highest levels of biological diversity of any region in Australia (WTMA 2001). Australia is included in the 12 'mega-diverse' countries of the world, with collectively 75% of the total global biodiversity (EPA 1999).

A particular combination of geology, landforms and soils, together with food chains and nutrient cycles have been found to be associated with a distinctive vegetation community within the bioregion, and these have been used to establish the Regional Ecosystem (RE) scientific basis of classification (WTMA 2001). Legends for the REs along with their description and original source (reference) are included in Appendix A. Statistically, the Wet Tropics Bioregion has the third smallest area of the 13 Queensland bioregions and the fourth largest number of REs, however it has the second largest number (and %) of endangered ecosystems. The bioregion scores better with 'of concern' ecosystems, ranking seventh lowest in number and eleventh lowest as a percent of REs (WTMA 2001). At the species level, the Wet Tropics Bioregion (0.26% of the land area of Australia) hosts a large proportion of the country's biodiversity (30%), with over 3000 known species of vascular plants, 700 of which are restricted to the area. The Wet Tropics Bioregion also has at least 32% of the terrestrial vertebrate fauna. Invertebrates include 58% of all described species of butterflies in Australia, 42% of all dung beetles, 42% of all barkbugs, and 50% of wetas or giant king crickets (WTMA 2001).

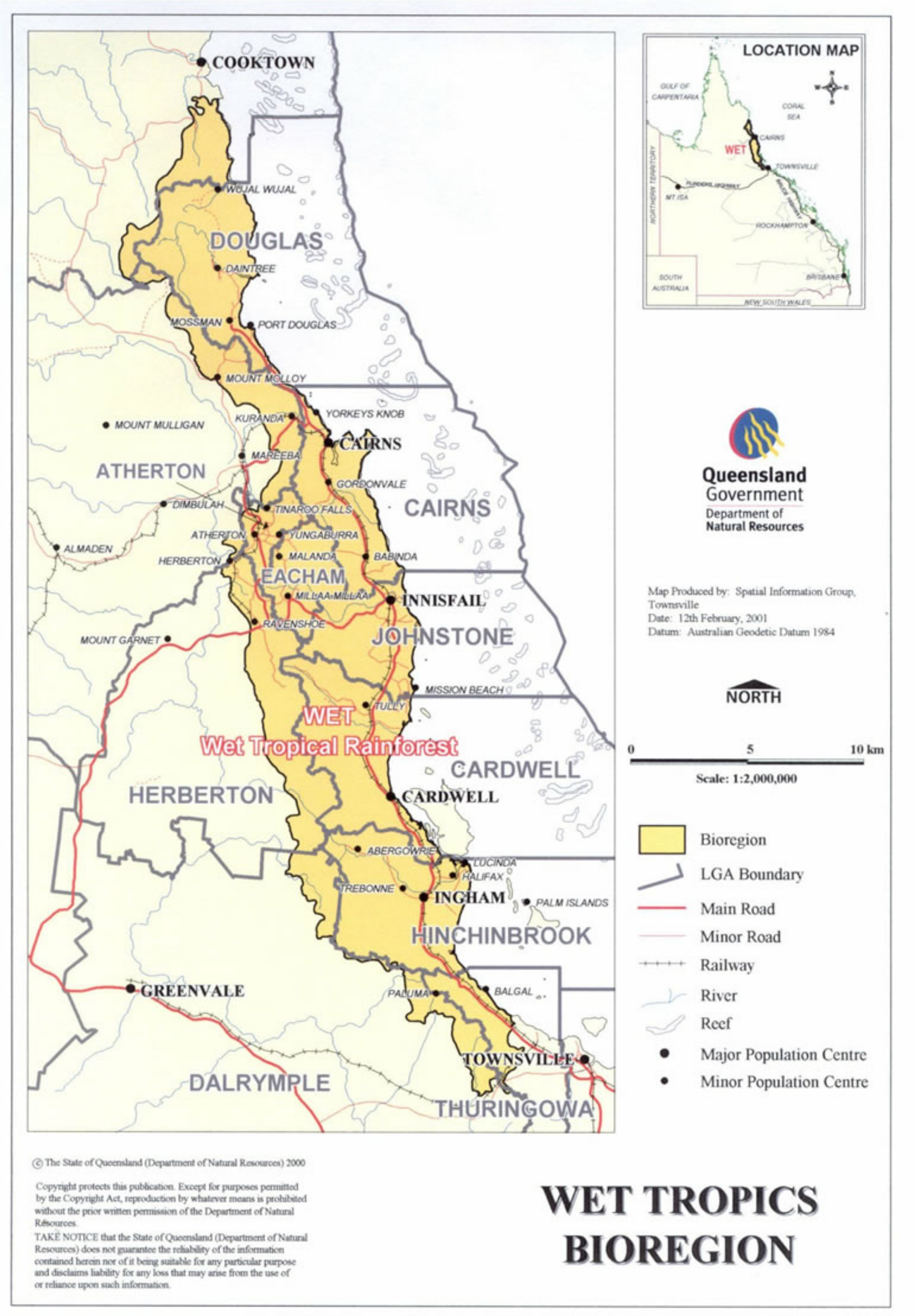

Figure 1.2 The Wet Tropics Bioregion showing local government boundaries (Source: Department of Natural Resources, Queensland 2001).

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:

1. An outstanding example representing major stages of the earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features.
2. An outstanding example representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.
3. Contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance.
4. Contain the most important and significant natural habitats for *in situ* conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation (WTMA 1995).

The WTWHA comprises some 8,944 km^2 and is totally contained within the Wet Tropics Bioregion (Figure 1.3). The WTWHA consists of a variety of tenures (Table 1.2).

Table 1.2. Areal extent of the various land tenures in the Wet Tropics of Queensland 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 & energy	6	24	0.003
Leasehold: DPI & EPA	43	3,093	0.35
Freehold & similar	204	17,341	2
Roads, Esplanades, Railways		5,696	0.6
Rivers		3,308	0.4
Total	**727**	**894,420**	**100**

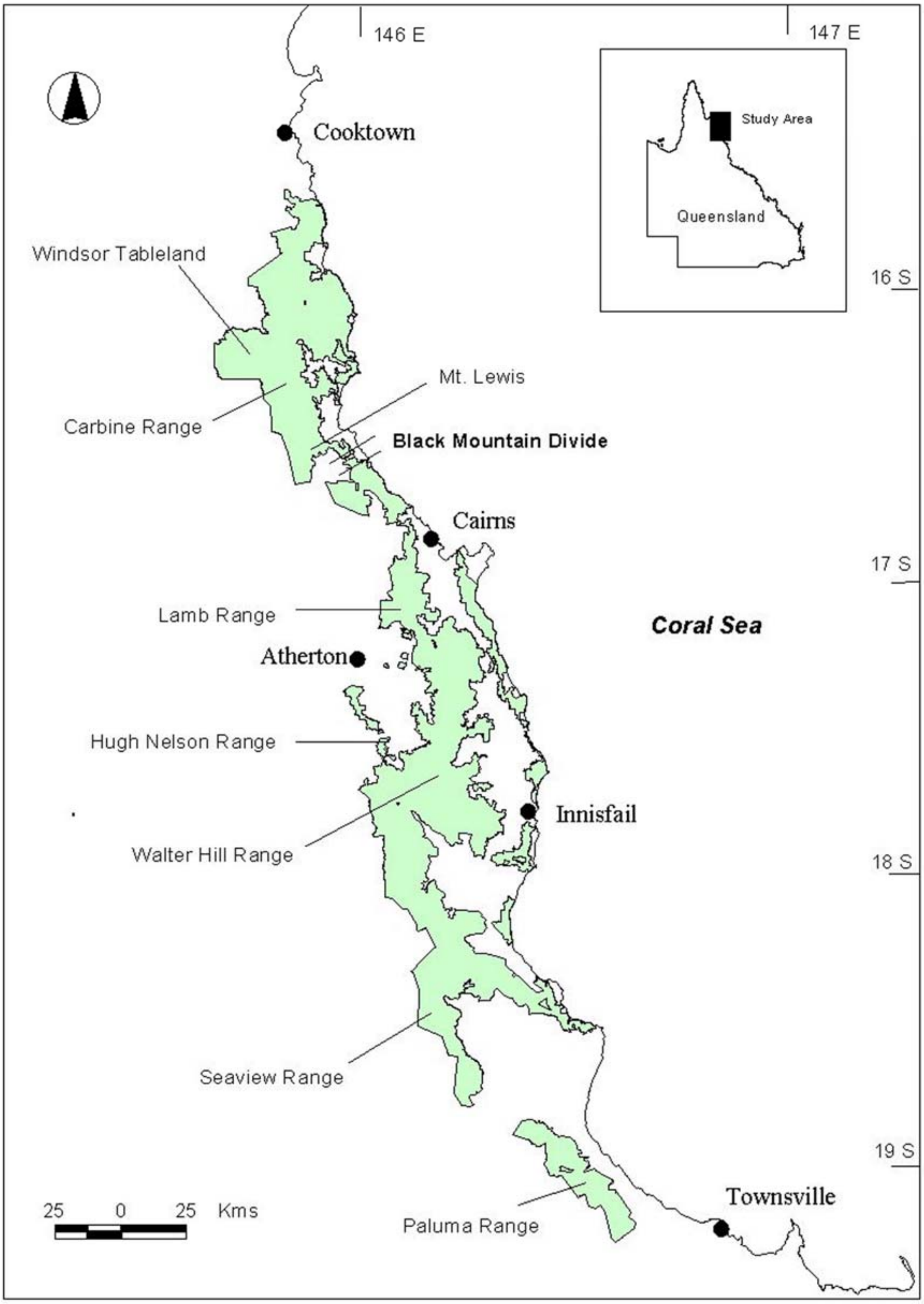

Figure 1.3 The Wet Tropics World Heritage Area (Source: Rainforest CRC-Wilson 2002).

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

The parameters developed for the zones, A, B, C and D, are summarised below (WTMA 2002):

Zone A.

- High degree of ecological integrity (includes a minimum 150 hectares of undisturbed habitat ie nothing obvious for the last 40 years);
- Remote from disturbances (at least 500m from all roads, powerlines, pipelines, transmission towers, mines etc., and at least 700m from any clearing;
- Natural physical and aesthetic condition.

Zone B.

- High degree of ecological integrity and natural state (up to 150 ha of undisturbed habitat, some obvious disturbance in the last 40 yrs);
- Not necessarily remote from disturbance (within 500m from roads etc., less than 700m from clearings);
- Not overlap with zones A, C and D;
- Could be restored to qualify for inclusion in Zone A.

Zone C.

- Contains disturbances associated with existing community infrastructure, including visitor facilities, otherwise mostly in a natural state and managed to minimise any adverse impact from these activities. Includes clearings, roads, powerlines, orchards, plantations, airstrips, army camps and so forth.

Zone D.

- Contains well-developed visitor infrastructure, obvious management presence, however land is in mostly a natural state. Intended for more intensive organised visitor activities, however managed to minimise the adverse impact of any activities or facilities.

With the introduction of the *Wet Tropics Management Plan 1998* clearing even on private land without a permit is now prohibited. Existing linear clearings associated with roads and powerlines comprise some 2,406 hectares or less than 0.3%, and those associated with dams and impoundments: 2,129 hectares, or just over 2%. Only 101 hectares (0.01%) of clearing has taken place since listing, 85 hectares on private land and 16 hectares for community infrastructure (WTMA 2002).

The Wet Tropics Bioregion experiences a hot humid tropical seasonal monsoonal climate, with high but variable annual rainfall ranging from 2000-4000mm (Turton *et al.,* 1999). The WTWHA contains the wettest rainforest in Australia, with the coastal Daintree area between the Daintree and Bloomfield Rivers being the second wettest (and therefore cloudiest) after the wet tropical coast (Babinda-Tully) to the south of Cairns. Rainfall and hence cloudiness is closely related to local relief and alignment of the coast with respect to the prevailing south-easterly trade winds (Turton *et al.,* 1999; Curtis and Turton 2002). Results of a recent study to indicate year round solar energy potential for the Daintree lowlands in the northern section of the bioregion also indicated marked intra-seasonal and inter-annual variability (Curtis and Turton 2002).

1.5 Aims, Expected Outcomes and Arrangement of the Thesis

The primary aim of the project is to develop a new or modified approach to the economic conundrum of valuing non-market (unpriced) goods, typically environmental goods and services. It is important to emphasise here that this primary aim proved to be extremely challenging, as there is yet no consensus as to the preferred method to value the environment. The thesis challenges many established paradigms in economics, yet conforms to the theory of valuation. The methodology uses established procedures in systems analysis and social research and applies them to a problem in a way that has not been done before. In these ways, the thesis is both multidisciplinary and interdisciplinary, and it will no doubt raise the hackles of many whose paradigms are challenged, but that is the nature of science. There are four original contributions to knowledge in this thesis, namely:

1. The use of the property market in a bioregion to establish median unimproved values and acceptance of the provision of ecosystem services as being the 'highest and best use' of land (the *Usus Fructus per annum*) in that context. Any use of land has an opportunity cost, that being the other uses to which the land could be put (McNeeley 1988; Frank 1991). The opportunity cost of converting land in its natural state to another use is the loss or reduction in ecosystem goods and services provided by that land which are essential to planetary life support;
2. The combination of a multiple criteria analysis and a Delphi Inquiry to gain consensus as to the relative non-pecuniary weightings of individual ecosystem goods and services;
3. The development of a conceptual model to determine the level of provision of ecosystem services using species richness, vegetation cover, and either the level of protection or land use characteristic;
4. The development of a valuation table to assess the natural production function of land in dollar terms.

Proposed outcomes of the research were as follows:

- Improved understanding of the costs and benefits of ecological systems in the provision of a range of services, along with recognition of the need for sound environmental practice appropriate to enhance services and minimise disservices.
- An appraisal technique developed to establish an opening price for ecosystem services in a future trading market.
- Acceptance of these techniques by mainstream practitioners, producers, consumers and financiers.

1.5.1 Thesis Outline

The thesis expounded herein is that the use of the broader property market as a surrogate market for the capital value of public (unrateable) land is justifiable as being indicative of society's preferences as a whole for the pecuniary measure attributable to this land whatever its conservation status or level of protection. The production function of land (the *Usus Fructus*) includes whatever ecosystem services are functioning at the time of the valuation, and are measured as a flow of benefits (per annum), by the application of a market capitalisation rate. Expert opinion of the non-pecuniary preferences of informed individual humans as to the relative weightings of individual ecosystem goods and services are preferable to random social preference surveys of uninformed individuals, provided anonymity is maintained. Sensitivity is better expressed by stating a range of values based upon the extent to which ecosystem services are provided, rather than the cost of money, which determines the value of a flow of benefits.

The thesis is enunciated in the following way:

After this introduction, the thesis is divided into three sections. **Section 1** is devoted to a comprehensive and critical review of the relevant literature, and comprises 5 chapters including a summary:

Chapter 2 examines the foundations of environmental valuation, the need for which was first recognised in the systematic analytical procedure known as Cost Benefit Analysis.

Chapter 3 presents a review of the literature surrounding the emergence of environmental economics, ecological economics, and the principles of environmentally or ecologically sustainable development (ESD).

Chapter 4 will focus on the historical precepts and theory and practice of valuation (*United States*~appraisal).

Chapter 5 examines the development of the ecosystem approach to environmental issues as the lowest common denominator. And finally,

Chapter 6 presents a summary of the literature review.

Section 2 is devoted to the experimental and research component of the thesis and comprises six chapters, commencing with the methodology:

Chapter 7 begins with the theory behind derivation of the median capital value of public land from the current rateable value of land in a bioregion, and the flow of benefits (the *usus fructus per annum*). The multiple criteria analysis is described, including justification for inclusion of the twenty ecosystem attributes, and the criteria for the three models: ‘anthopocentric’, ‘utilitarian’ and 'balanced sensitivity'. The methodology surrounding the 'Delphi' philosophical inquiry is presented and details of the four rounds given, along with a description of the purpose-designed web-site that hosted the inquiry. Finally the conceptual model devised to estimate the level to which ecosystem services are functioning on a landscape scale is presented, along with arguments for this approach.

Chapter 8 presents the results of the philosophical inquiry (Delphi). Results from the questionnaires in rounds 1, 2 and 3 are summarised along with presentation of any valuable insights from the panellists.

Chapter 9 presents the results of the multiple criteria analysis. Results from the panellists' non-pecuniary weightings of the ecosystem attributes for each of the three models is given along with statistical significance of the combined and interdisciplinary responses.

Chapter 10 describes the results of the conceptual modelling and valuation tables, which are included in the appendices. The upper and lower limits of provision of ecosystem services in the individual tenure categories within the WTWHA are derived from the conceptual models.

Chapter 11 sets out the values derived for the individual attributes and the tenure categories in the WTWHA. The current median capital value of the public land is calculated from the records of the Local Governments in the bioregion. The production function of this land, and other land where ecosystem services are functioning is derived by application of an appropriate capitalisation rate. Finally the current (30/6/02) annual values for aggregate ecosystem services in each tenure category in the WTWHA are given along with a total for all categories. Annual values are also presented for each group of attributes, and for each of the twenty attributes.

Chapter 12 summarises the results.

Section 3 comprises two chapters, discussion and conclusion:

Chapter 13 presents a synthesis of the thesis and discusses deficiencies in economic valuation procedures and difficulties in transferability, the advantages of the empirical method including its already pivotal role in national administration and convergent validity, what the values mean and what the future holds, and finally, implications for widespread application and acceptance of the method.

Chapter 14 sets out the main findings and conclusions along with some limitations of the research, recommendations and avenues for future research.

The conclusion is followed by a reference list, acknowledgements and the appendices, which includes the web page published on the internet for each round of the Delphi Inquiry; unedited responses of the panellists to the questionnaires by way of feedback, and the conceptual models and valuation tables.