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**A values-based wood-fuel landscape evaluation:  
building a fuzzy logic framework to integrate socio-  
cultural, ecological, and economic value**

**by  
Darrell Jon Smith BSc (Hons.)  
Lancaster University  
2014**

**This thesis is submitted in partial fulfilment of the requirements for the degree of  
Doctor of Philosophy. Submitted: October 2014, word count: 76 422.**

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## **Abstract**

**Title:** A values-based wood-fuel landscape evaluation: building a fuzzy logic framework to integrate socio-cultural, ecological, and economic value.  
**Author:** Darrell Jon Smith, BSc (Hons.)  
**Degree:** Doctor of Philosophy  
**Submitted:** October 2014  
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In meeting the UK Governments national and international renewable energies commitments and their role in UK energy security, decarbonisation of energy use, carbon sequestration and climate change mitigation, the recognition of a potential for considerable scaling up of UK woodland coverage is emphasised. Also, UK forestry has increasingly become realigned with the global sustainability agenda encompassing issues such as native woodlands, the decline of woodland biodiversity, the Government's quality of life indicators, and ideas of socio-cultural, ecological and economic landscape scale values. Accordingly, socio-cultural interaction with the natural world places structure and components into the landscape, the subsequent combinations of which are characterised by consequent ecological and economic conditions. As a consequence compositional, structural, spatial and temporal differences produce different value outcomes. This thesis explores these value outcomes illustrating the multi-dimensional nature of the relationships that society experience with their surrounding landscape, across a range of case study wood-fuel producing landscapes.

The case study landscapes describe traditional silvo-pastoral management, Natura 2000 forest, primarily managed around ideas of ecosystem goods and services, co-operatively and commercially owned sustainable forestry. Differences in value are observed between and within landscapes, value domains and value components. These differences reflect tensions that exist between sustainability and society's continued use of natural resources. Consequently value articulates the nature of relationships between and within multiple value components, characterised by competing socio-cultural, ecological, economic interests. Thus

value, as a concept, is built through an understanding of the connected, embedded nature of society's relationship with the natural world.

Using a novel fuzzy logic modelling based approach to valuation, the consequences of land-use choices and the associated changes across socio-cultural, ecological and economic value domains are made visible. Understanding the complex nature of these interrelated and interdependent relationships can inform the political and institutional decision making and policy setting process. In this manner knowledge of interaction, interdependence and the reality of trade-offs, consistent with systems describe by finitude, can support and facilitate deliberative discourse. Where the true nature of value is considered an emergent property expressed through an appreciation of the value components and the outcomes of their relationships. Thus value is fundamentally a comparative property and not the outcome of an accumulative argument.

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## **Glossary - definitions for the purpose of this study**

**Ecosystem** – a place where biotic and abiotic factors interact, where organisms interact with their environment (Elton, 1927; Tansley, 1935). Ecosystems exhibit temporal variability, spatial heterogeneity, hierarchical scaling and non-linear dynamic processes (Holling, 1973; De Leo & Levin, 1997; Levin, 1999), boundaries are fuzzy and permeable to the movement of both energy and organisms (Cadenasso et al., 2003; Post et al., 2007). The component parts are subject to selection processes and self organisation leads to endogenous pattern formation and emergent properties (Levin, 1998). The interaction between living elements and their environment is central to the concept of an ecosystem. Adoption of a systems perspective logically extends to including society as an integral component of ecosystems (O'Neill, 2001; Pickett et al., 2005).

**Evaluation** – the process by which the ‘value’ of a particular action or object is expressed (Farber et al., 2002).

**Landscape** – refers to an area defined by administrative boundaries. Although, it is recognised that, whilst this scale of observation represents local interactions, ecological, societal and economic boundaries may differ, will be permeable and are subject to external structural, functional and compositional (temporal, spatial and organisational) influences (Cadenasso et al., 2003; Pickett et al., 2005; Post et al., 2007). This approach is consistent with the hierarchical scale of interactions inherent within complex adaptive systems and acknowledges that the scale of any observation, by necessity, becomes defined by the observer (De Leo & Levin, 1997; O'Neill, 2001; Jax, 2005). This approach places the influence of society on landscape as a determinative element in the interactions between the societal, ecological and economic domains. In this relationship natural resources are managed to produce goods and services for the benefit of society.

**Learning-by-doing** – Haila (1999) describes a scenario where management systems are adaptive, reflexive and sensitive to local situations, and in which the historical experience of traditional resource use institutions direct future actions. This position reflects a respect for the capacity of nature to replenish the earth's life support systems, which is internalised in to all types of human activity (Haila, 1999). The ethical perspective is holistic; culture and nature occupy the same space. Nature is seen as a necessity for the existence of human culture, where all human activities are played out in the same biophysical processes as are the activities of other organisms (Haila, 1999).

**Natural resources** – refers to the natural components of ecosystem structure, their processes and interactions, the products of which provide a flow of goods and services, direct and indirect, to human societies (De Groot et al., 2003). These processes are the result of complex interactions between abiotic and biotic components of ecosystems (Elton, 1927; Tansley, 1935; De Groot et al., 2003), thus natural resources, ecosystem components, their processes and interactions provide the basis for ecosystem resilience, health and determine system integrity (De Groot et al., 2003). In the context of human use and natural resources, the provision of goods and services can be described as either renewable or non-renewable (Turner et al., 1994). The latter are relatively fixed in quantity, and their use means that there will be less available for use in the future (Turner et al., 1994).

**Post-normal science** – reflects an approach which encompasses the complexity and uncertainty of natural systems with the associated consequences of human interactions and values (Funtowicz & Ravetz, 1994). In contrast to '*....Kuhn's (1970) conception of normal science underpinned by positivist philosophy and a universal, objective and context-free knowledge..*', a post-normal science, as a general principle, accepts the irreducible plurality of perspectives, values and methods of understanding (Funtowicz & Ravetz, 2003). It is an interdisciplinary, context-sensitive science grounded in methodological pluralism and concepts of active stakeholder engagement. In the acceptance of '*different magnitudes of*

*scales (of time, space, and function), multiple balances (dynamics), multiple actors (interests) and multiple failures (systemic faults)*' (Frame & Brown, 2008), a post-normal perspective challenges the assumption that all values or evaluations can or should be reduced to a single, one-dimensional measure (Funtowicz & Ravetz 1994, 2003). Post normal science integrates complex, adaptive, reflexive social-ecological systems in a manner that brings together science, practice and politics for decision-making and policy setting (Funtowicz & Ravetz 1994, 2003; Frame & Brown, 2008).

**System** – a system for the purpose of this study is that of a ‘complex adaptive system’ (Levin, 1998) which at a basic level is made up of its components and their connective structure (Straton, 2006). Interactions occur over a hierarchy of spatio-temporal and organisational scales (O’Neill et al., 1989), where, at any given level of resolution, an element at one hierarchical level contains both interacting components in the level below and is itself a constituent of the level above (O’Neill et al., 1989; Levin, 1998). In this respect the scale of external observation is determined by the observer.

**Value** – the contribution of an action or object to user-specified goals, objectives or conditions (Costanza, 2000; Folke et al., 2002). Value describes both the characteristics of things, as well as the consequences of actions between things (Mendes, 2007).

**Value system** – the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions (Farber et al., 2002). Because ‘value systems’ frame how people assign rights and add ‘value’ to objects and actions, they also imply internal, subjective, user-specific goals, objectives or conditions (Farber et al., 2002).

**Woodland** – is used as a generic term throughout this thesis to refer to areas of tree cover in a spatial context. The use of the term does not relate to woodland in the technical sense that a professional forester, for example, might use.

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## **Chapter One**

### **Introduction**

#### **1.1 Summary**

This thesis is an interdisciplinary investigation which explores the use of a novel values-system based landscape evaluative technique. This approach provides information that facilitates and informs deliberative discourse supporting the sustainable landscape management decision making process. Society places structure and components in to landscape in the pursuit of physical and mental well-being. Differences in the components of landscape and the structures created lead to different value outcomes. These outcomes are described and used to express the multi-dimensional nature of the value relationship society holds with the surrounding landscape.

Taking the use of wood for fuel to illustrate the utilitarian relationship that society has, and continues to build, with the natural world, different approaches to landscape management with a wood-fuel component are assessed and evaluated. Analysis, at the landscape scale, allows for the relationships between socio-cultural, ecological, and economic value to develop a framework that respects the interaction between and within each value domain. In this manner the characteristics of complementarity, contrast and trade-off, inherent in systems described by finitude, become apparent. Such approaches are urgently needed if society is to address problems of the sustainable use of natural resources in a manner that fully considers future generations. The research rationale for this thesis is set out below followed by the research aims and objectives, and the research approach. The chapter concludes with a summary of the thesis structure.

#### **1.2 Research rationale**

Under the 2009 EU Renewables Directive (Directive 2009/28/EC) the UK Government has agreed to produce 15% of final energy consumption from renewable sources, by 2020. Within

this overall target, additional targets to be met through renewable sources include; 30% of electricity demand, 12% of total heat demand and 10% of total transport energy demand, by 2020 (HM Government, 2009). In relation to carbon dioxide emissions, the UK Government's long term goal is to see an 80% reduction, based on 1990 levels, by 2050 (Department for Energy and Climate Change, 2010). Understandably this has generated considerable interest in renewable energies and their role in UK energy security, decarbonisation of energy use, carbon sequestration and climate change mitigation. According to the International Energy Agency (2008), bio-energy will be essential in reducing the carbon intensity of energy production and decoupling energy use from carbon dioxide emissions.

The Independent Forestry Panel, established to advise the UK government on the future direction of forestry and woodland policy in England, whilst recognising a clear role for UK woodlands in climate change mitigation, places woodland resources in a landscape context (Department for the Environment and Rural Affairs, 2011). In doing so they give voice to the strong emotional connections people have with woodland, a continued role for public ownership and clear benefits for people, environment and economy (Department for the Environment and Rural Affairs, 2011). Wood-fuel has the potential to become an important component of the renewable fuel source mix (International Energy Agency, 2008). Biomass contributes the largest share towards renewable energies in the EU. As wood is the main EU source of biomass it can be seen as a vital source of renewable energy (Luker, 2011). Read et al. (2009) suggested that an increase in woodland planting of 200% could provide mitigation for 10% of the UK's predicted greenhouse gas emissions by the 2050's.

The UK Energy Research Centre (UKERC) recognise that the bio-energy component needed to provide 6% of UK energy needs could require an increase of 50% in current UK woodland cover (Skea et al., 2009). The Forestry Commission England (2007) set a target to bring an additional 2 million tonnes (Mt) of wood-fuel to the UK market, annually, by 2020. Moreover, they describe the utilisation of an extra 2 Mt of wood as saving 400,000 tonnes of

carbon, the equivalent to supplying 250,000 homes with energy, replacing 3.6 million barrels of crude oil (Forestry Commission England, 2007). In these scenarios the potential for a considerable scaling up of UK woodland coverage is emphasised. The current figure for UK woodland coverage of 12% of total land area is considerably lower than the European average of 37%.

Until relatively recently, the creation of new woodlands invariably involved the plantation approach taken by the Forestry Commission during the mid twentieth century (Rackham, 2010). Since the early 1990's, however, UK forestry has increasingly become realigned with the global sustainability agenda, encompassing issues such as native woodlands, the decline of woodland biodiversity, the Government's quality of life indicators, the ideas of socio-cultural and natural capital and landscape scale values (Rackham, 2010; Office for National Statistics, 2012). There is broad international consensus that strategies for biodiversity and resource conservation must be fully integrated into strategies for economic development and that these are essential elements of sustainable livelihoods at local scales (Elliott et al., 2002). There is also a wide body of evidence that points to the beneficial impact of woodlands on human physical, psychological and social well being (Rohde & Kindle, 1994; Tabbish & O'Brien, 2003; Roe & Elliott, 2004; O'Brien, 2005).

Increasingly, the complex nature of relationships between society, environment, and economy involved in the creation of a 'resilient' energy landscape has become recognised (Skea et al., 2009). This social-ecological connective framework, inherent in a wider 'resilient' ecosystems context, has begun to influence policy decision making and the landscape management process (Folke et al., 2002; Deutsch et al., 2003). The nature of this link between society and landscape, clearly illustrated by demonstrations against moves by the UK Government to sell publicly owned woodlands, has led to the creation of an independent advisory panel established to advise UK government on the future direction of forestry and woodland policy in England (DEFRA, 2011).

Within Europe examples of land use models exist that closely link woodland ecosystems with sustainable provision to community, which incorporate traditional knowledge, innovation and practice developed and adapted to the indigenous culture and environment (Elbakidze & Angelstam, 2007). These systems provide models for sustainable woodland management in real landscapes with a functional ecosystem approach, applying socio-cultural, ecological, and economic balance. Examples range from small scale usage of semi natural forest in areas like the Pindus Mountains, north-west Greece, where people still rely on woodland resources for products essential to their livelihoods, to heavily and intensively managed systems such as those in Austria (Jeanrenaud, 2001).

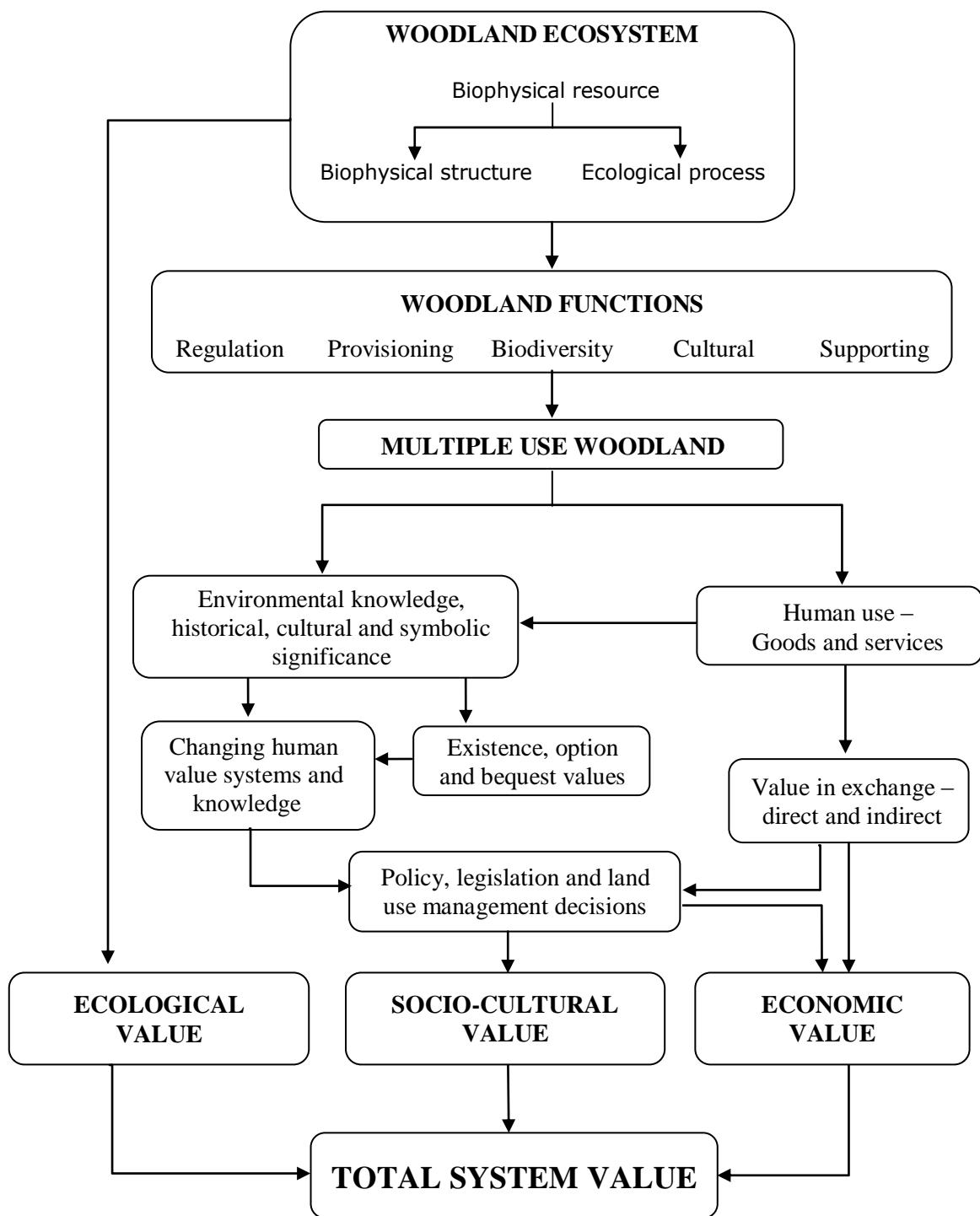
Decisions made about ecosystems and the management of natural resources, as a society, imply a valuation (Costanza et al., 1999) but, ‘value’ in society’s relationship with natural resources resides within three domains, socio-culture, the environment, and the economy (de Groot et al., 2002). Thus, the evaluation of ‘value’ is derived from the outcomes of interactions between and within components of each of these domains (Straton, 2006; de Groot et al., 2002; Turner et al., 2003; Kumar & Kumar, 2008).

Contemporary methods capture the relationship between society and natural resources through economic ‘demand’ led valuations (Turner et al., 1994). However, if our concept of ‘value’ is perceived solely in monetary terms, non-monetisation of any social or environmental component can result in its automatic exclusion from economic calculation, and therefore have no impact on the formation of a rational choice (Plottu & Plottu, 2007). Increasingly, ecological and economic thought understands that nature is vital to human well-being and survival for many social-ecological reasons (Costanza et al., 1997; Daily, 1997). Therefore, any restriction of ecosystem value to a single economic indicator is unrealistic.

This thesis aims to explore qualitative and quantitative mapping of socio-cultural, ecological, and economic ‘value’ in a manner designed to capture the relationships between society, land-

use and landscape. This will necessarily involve an interdisciplinary approach to the discourse around the planning of new woodland. The conceptual framework for this study is based on an approach which emphasises the connections between social and ecological system components (Folke, 2006). In this manner ‘value’ is generated through the normative and moral frameworks a community develops with the landscape that it creates and surrounds itself with (Farber et al., 2002). Here the concept of ‘living-in-place’ is utilised, where a sustainable sense of place builds upon local knowledge and the connections people have with their landscape (Borgstrom Hansson & Wackernagel, 1999).

The application of a systems based perspective seeks to incorporate the ecological components that contribute to economic value, which is itself determined by individual and community preference (Fig 1.1). Acceptance of society, ecological process, and economy as components of a complex adaptive [eco-] system underpins the idea that without societal and ecological ‘value’ there is no economic value (Straton, 2006). This research employs a reflexive perspective, where linking the dynamics of social, ecological and economic systems seeks to develop an understanding of landscape and long term sustainability (Elmqvist et al., 2003; Folke, 2006). In this context the evaluation of ecosystem ‘value’ represents a tool which can be used to help guide societal actions towards efficient and sustainable use of natural resources, based on the perceived benefits received (Winkler, 2006).



**Figure 1.1** A structure for the relationship of component elements and calculation of a 'Total System Value' for multi-functional woodland.

### **1.3 Research aims and objectives**

This thesis explores a values-based approach to landscape evaluation in a manner designed to provide information that supports a deliberative discourse and informs sustainable landscape management. Specific examples from Austria and Greece provide case studies for the assessment and evaluation of differing landscape management options towards the provision of wood for fuel. Both qualitative and quantitative data describe socio-cultural, ecological, and economic values in a manner that moves the decision making process around sustainable use of natural resources away from a purely accumulative monetary based argument. Sustainable land-use solutions, informed by value, should be communicated, in and supported by, language that conveys information which reflects the true nature of things based on the inherent relationships between society, land-use and landscape.

The desired outcome of this thesis is built upon three primary research aims, as set out below. These aims are supported by a series of specific objective steps which will inform and facilitate the evaluative process, enabling the overarching research question of this thesis to be addressed.

#### **1.3.1 Primary research aims and supporting objectives**

- 1) To describe a socio-cultural, ecological, and economic value for case study landscapes, in which land-use includes the provision of wood-fuel, exploring questions such as:
  - a) What is the socio-cultural value of the relationship between landscape, society and natural resources?
  - b) What is the ecological value of landscape that society creates in the pursuit of physical and mental well-being?
  - c) What is the value of the tangible, monetary revenue, society receives from real markets for goods and services produced?

2) To develop a model for the calculation of a total landscape value across a range of wood-fuel woodland landscapes, addressing issues such as:

- a) Can socio-cultural, ecological, and economic values be combined to create a total landscape value?
- b) How do the relationships between the socio-cultural, ecological, and economic value domains, for each landscape, influence each other?
- c) Does this modelling technique provide a tool for landscape assessment which allows comparison between study sites?

3) Apply the modelling technique developed to address the proposition of '*A values-based wood-fuel landscape evaluation: building a fuzzy logic framework to integrate socio-cultural, ecological, and economic values.*'

#### **1.4 Research approach**

This section explains the reasons for adoption of an interdisciplinary approach that promotes the use of multi-dimensional expressions of value in the sustainable land-use decision making process. Moving away from a commodification and monetisation of the goods and services derived from ecosystems challenges the contemporary neo-classical, economic world view informed through an explicitly utilitarian perspective. If we accept that ecosystems provide multiple benefits across multiple value domains, we must promote the use of value articulating institutions and methods to better reflect this value plurality (Martinez-Alier et al., 1998; Munda, 2004).

Schroeder (1996) suggests that to understand how people are related to environments we need to understand how people experience these environments. However, modern societies are becoming removed from the local landscape as ecosystem goods and services are increasingly supplied from distant ecosystems (Borgstrom Hansson & Wackernagel, 1999). In this scenario, signals that highlight the limits to human appropriation of ecosystem goods and

services are lost, and local lifestyles become less adapted to extant circumstances (Borgstrom Hansson & Wackernagel, 1999). However, traditional resource use institutions provide examples where learning-by-doing maintains ecosystem health (Haila, 1999). Observation at this community scale incorporates the dynamics of society's direct relationship with landscape and land use, which influence the self organisational properties and pattern formation of ecological systems in a manner that acknowledges a role for social-ecological processes (Haila, 1999).

In this thesis, interaction with the local ecosystem provides a familiar institutional context, within which respondents can feel comfortable enough to express importance in a manner that reflects their preferred behaviour (Borgstrom Hansson & Wackernagel, 1999; Meinard & Grill, 2011). This expression of value seeks to capture local distinctiveness and aims to incorporate the role of multiple stakeholder views (de Chazal et al., 2008). Society and the values it holds are an integral component of a wider social-ecological system; nature should not be viewed as external to the expression of socio-cultural values (Adger, 2000; Chiesura & De Groot, 2003; Folke, 2006).

Neoclassical economic valuation is constrained by the need to express value in purely monetary terms as a function of an exchange process (Gómez-Baggethun et al., 2010). This approach works to dis-embed cultural identity, belief systems, attitudes and intentions of society from any relationship with the natural world (Borgstrom Hansson & Wackernagel, 1999). The evaluation of sustainable landscape management needs to consider a broader set of goals that includes ecological sustainability and a societal perspective, alongside a monetary based economic valuation (Costanza, 2000; Stratton, 2006; Spangenberg & Settele, 2010).

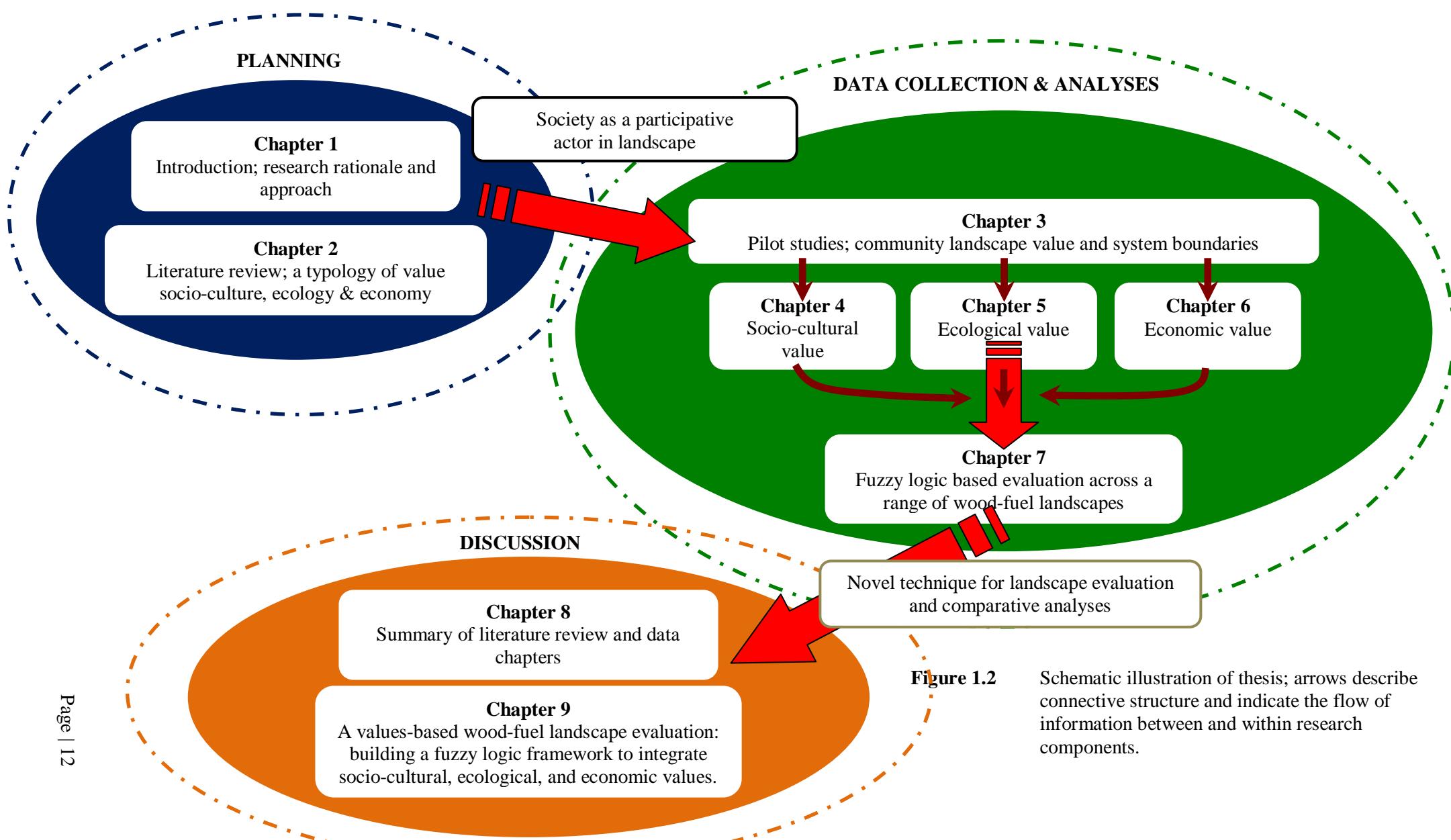
As new techniques are developed, monetary valuation will become just one component to consider in the calculation of an overall ecosystem value (Chiesura & De Groot, 2003). Increasingly a post-normal science approach is being taken to study the interrelated

connections of natural, complex adaptive systems (Funtowicz & Ravetz, 2003); where structure and components interact at different scales and levels (O'Neill et al., 1989; Levin, 1998; Noss, 1990), and what we know about nature becomes shaped by society's interaction with it (Boulding, 1966; Meadows et al., 1972; Arrow et al., 1995; Costanza et al., 1997; Daily, 1997; Costanza et al., 2007). By necessity, such complex systems can not be evaluated, analysed and understood from one single point of view (Funtowicz & Ravetz, 2003).

Acknowledgement of the interconnected nature of social and ecological systems (Folke, 2006) and the development of a pluralistic approach to value (de Groot et al., 2002; Turner et al., 2003; Stratton, 2006; Kumar & Kumar, 2008) encourages thoughts of variability and thus resilience leading to sustainability. Here, the relationships between ecological dynamics, management practices and institutional arrangements express the inherent adaptive capacity of social-ecological systems (de Chazal et al., 2008). Expansion of evaluation techniques that accommodate different values and interests can provide models for sustainable management in real landscapes with a functional ecosystem approach, seeking to apply intra and inter generational socio-cultural, ecological and economic equity. Approached from an ethical perspective the monetisation of natural resources masks the importance of equity related to the unequal distribution of costs and benefits (Jax et al., 2013), which promotes an uneven accumulation of wealth and extends the reach of global capitalism (Matulis, 2014). Thus continued commoditisation of nature may change ones judgment from doing what is considered the ethical obligation or communal requirement to a purely economic self-interest (Gómez-Bagethun et al., 2010; Spangenberg & Settele, 2010).

This thesis employs both quantitative and qualitative data collection, from the three 'value' research streams, to enable a calculation of landscape value for each study site (Fig 1.2). Questionnaires and interview techniques are used to calculate socio-cultural value, an ecological value will be determined from the relationship between landscape structure and faunal biodiversity within each study area, and an economic value will be calculated from

direct-use, marketed goods and services produced within each study area. Analyses of the relationships between and within each ‘value’ domain will allow the main aim of this thesis to be addressed, to build a fuzzy logic framework that integrates socio-cultural, ecological, and economic values.



## **1.5 Thesis structure**

Chapter 1 has introduced the research rationale, approach, aims and objectives of this thesis. Chapter 2 expands on the research rationale through a wider review of society's relationship with the natural world, characterised by a linear, temporal and comparable view of the prevailing paradigms experienced over time, across socio-cultural, ecological and economic value domains. In chapter 3 society's relationship with natural resources, expressed through the lens of the surrounding landscape, is explored. Here, the contemporary, neo-classical, economic world view of society's expression of value for natural resources, as predominantly communicated by value in exchange, is challenged. Also, the context of system boundaries for this research, from an observational perspective, is explored.

Chapters 4, 5 and 6 address objective 1, to describe indicators of socio-cultural, ecological, and economic value for the four case study wood-fuel woodland landscapes. Chapter 4 uses qualitative methods to establish a socio-cultural value, whilst chapters 5 and 6 use quantitative methods to describe ecological and economic values. Using a novel fuzzy logic based model, chapter 7 investigates objective 2 and calculates a total landscape value for each of the wood-fuel woodland landscapes. Chapter 8 provides a summary of the literature review, each of the subsequent data chapters and makes recommendations for further research. The final chapter of this thesis, chapter 9, reviews analyses and findings in relation to objectives 1 and 2, and concludes by proposing an answer to the primary research proposition, objective 3, 'A values-based wood-fuel landscape evaluation: building a fuzzy logic framework to integrate socio-cultural, ecological, and economic values'

## **Chapter Two<sup>1</sup>**

### **A typology of value; socio-cultural, economic and ecological**

#### **2.1 Summary**

This review of the literature engages with current debates on value and the increasing use of expressions of value in shaping society's decision-making relationship with the sustainable use of natural resources. Over recent decades society's relationship with natural resources has become characterised by a consumption and growth ethic, based on the benefits society receives from ecosystems, described as goods and services, and their consequent value (Gómez-Bagethun & Ruiz-Pérez, 2011; de Groot et al., 2012). More specifically economic valuation techniques are now used to communicate the monetary worth of the ecosystem goods and services society receives, for example see Costanza et al. (1997), van Beukering et al. (2003), Jobstvogt et al. (2014), and Morri et al. (2014).

Whilst these approaches, built upon the work of Boulding (1966) and Daly (1977), bring together ideas contained in ecology and economy, described by a common monetary metric, they fail to encompass all dimensions of value. In the portrayal of natural resource value through an essentially economic worldview, much of the nature of human behavioural interaction as participants within ecosystems described by changing structure, components and functions are lost. The main outcome of this thesis lies in the consideration of a broader set of perspectives and evaluation techniques, which are required to fully characterise an integrated, interdisciplinary approach to the interconnection of nature and society in sustainable social-ecological systems.

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<sup>1</sup> Sections from this chapter have been brought together for publication. The paper is currently in review: Smith, D., Convery, I., Ramsey, A. & Kouloumpis, V. (in review) 'Changing social perceptions of the natural world' in, *Shifting Interpretations of Natural Heritage* (eds I. Convery and P. Davis), Boydell & Brewer Ltd., Woodbridge, Suffolk

## **2.2 Introduction**

The components of value are presented in this literature review as a three stage narrative built around the historical context of our socio-cultural, economic and ecological relationships with the natural world. Ideas of an increasing distance and detachment become replaced by a growing realisation of the connected and embedded nature of society's relationship with the world in which they live. These ideas document the rise of a consumer society with a materialistic, utilitarian approach to nature and the resources it provides, and how an understanding of the consequences of this relationship is now shaping natural resource evaluation.

Through a conceptual organisation, which takes a linear, temporal and comparable view of the prevailing paradigms experienced over time, the nature of these relationships is explored. This series of events is created to move the process of understanding from a period of pre-normal science to a perspective characterised by a post-normal science (Funtowicz & Ravetz, 1994; Funtowicz & Ravetz, 2003). A perspective that re-embeds society within a natural world, a position of knowing the world and being in the world which seeks to address the dualistic thinking of nature and culture (Haila, 1999).

This approach sees humankind's relationship with the natural world move from an Aristotelian teleological position of the medieval ages, where religious thought viewed society as external to a non-human natural world (Hamilton, 2002; Heller, 2011), to the placing of a secular society firmly within a social-ecological system (Pickett et al., 2005). Here society occupies a position within the natural world, a component of a complex adaptive system (Levin, 1998; Pickett et al., 2005), where shared relationships are now described through a post-normal science (Funtowicz & Ravetz, 2003).

Consequently society reconciles the dualistic thought processes that once placed society in the role of ‘observers’ and, as such, outside the natural world (Hamilton, 2002). Now society can see landscape as the result of interaction between human intervention and natural processes operating at a range of spatial and temporal scales. A non-anthropogenic concept of natural history obscures this interconnection, described at a basic level both food and population are inextricably linked to nature.

Whilst, due to the structure of this thesis, the approach taken is one of discrete steps, the path of historical change does not exist as a series of themed events conveniently grouped in time and space. In the model presented here boundaries are discrete and simplistic but, with thoughts of the natural world in mind, boundaries between paradigms should be seen as fuzzy, permeable and containing overlap, akin to the idea of a socio-[eco]tone.

Section 2.3 describes the conversion of natural resources as natural capital in a theistic society to human capital in a consumer society. Section 2.4 introduces the development of a holistic world view where the social-ecological world relationship is just one of a multitude of interconnected relationships. Section 2.5 brings together humankind as a society of consumers within this holistic world view. Initially the use of economic valuation tools communicates the consequences of continued unlimited consumption, making this relationship visible to aid decision making for a sustainable future (Turner et al., 1994; Costanza et al., 1997; Balmford et al., 2002). This narrative ends as concerns are raised regarding the suitability of a continued use of monetary-based value, concerns in which the guiding aims of this thesis are grounded.

Society’s relationship with nature is complex, described by multiple scales, connections and components. Translation of data to a familiar single metric for ease of use and communication, as seen in the use of monetary language and valuation techniques, obscures the nature of relationships between and within the components of value (McShane et al., 2011; Martín-López et al., 2014). The position taken in this thesis recognises that the

expressions of value used to inform the institutional and political decision making process must reveal the true multi-dimensional nature of the value-society-natural resources relationships.

### **2.3 Socio-cultural value: the relationship between nature and society**

Socio-cultural value is presented here to examine the cultural landscape of the interconnected relationship between nature and society. Culture, in this context, can be thought of as elements created by humankind, such as society, religion, state, technology, art, poetry, and philosophy (Johann, 2007). The use of the term nature is in its broadest experienced ‘sense’ of the perceived world, where ‘sense’ can be seen as a meeting point between the physical world and human life (Whitehead, 1920; Toadvine, 2003; Toadvine, 2004).

#### **2.3.1 Reason replaces revelation**

The medieval philosophy of nature, pre 1600, was characterised by Aristotelian principals, an empirical view of the world governed by an explanation of ‘*substance and essence*’ based on observation and experience, ultimately all under the governance of God (Clarke & Wilson, 2011). Medieval society’s relationship with the natural world should also be understood through explanations based on the economic institutions of the time as well as socio-cultural belief and values. Albeit that during this period, as typified by the writings of Aquinas, Bacon, Buridan, Grosseteste and others, theology was seen as the pinnacle of understanding, described as ‘the highest science’ (Killeen & Forshaw, 2007).

An understanding of science and of natural philosophy not only relied upon biblical revelation but, also, provided assistance in interpretation of the divine word (Killeen & Forshaw, 2007). Society formed communities in which spiritual and material phenomena were not clearly differentiated (Hamilton, 2002). Since God had made nature, nature also must reveal the divine mentality; consequentially the religious study of nature sought a better understanding of God (White Jr, 1967). Intellectual, theological and natural philosophical thought of the age

all proceeded from the point of view that.... '*Nevertheless God is the cause of this world'*..... '*the motion of the heavens, and other effects, depend upon God as their First Cause*' (Padgett, 2003:217). Every major scientist from the 13<sup>th</sup> century up to and including Newton operated from a position that placed God as the source of the laws of nature, his power was absolute and he was able to alter the laws of nature at will (White Jr, 1967; Padgett, 2003).

The work of a divine creator, in a world contrived for the continued benefit of man, demonstrates God's economy. Francis Bacon (1561-1626), Lord Chancellor of England, is said to have proclaimed that '*the world is made for man, not man for the world*' (Worster, 1994: 30). The non-human natural world was denied a soul or innate spirit which, when combined with the idea of a world created for man to shape, separated man from nature (Worster, 1994). Orthodox Christian thought placed man at the apex of creation, in the position of trustee or steward, with a detached, external view of the natural world (Derr, 1975).

However, this perception of a detached relationship with a natural world must also be considered in association with the fact that the population of sixteenth century England was essentially rural (Lowry, 2004). Notwithstanding this idea of a non-human natural world, knowledge of the natural world, by communities, existed through what can be seen as a 'stewardship' approach to the landscape that guaranteed the survival of those communities into the future (Marangudakis, 2008). Medieval man was seen to balance the use of natural resources, multiple-use management of forests suggest communities controlled the provision of both short and long term benefits (Wilson, 2004). Seventy to ninety percent of the population lived on the land, with approximately ninety-four percent of the population working in agriculture (Lowry, 2004). Land ownership was characterised by a feudal society, vassals held land from lords in exchange for military service: Europe was a vast community consisting not of 'nations' but 'territories' which were loosely connected by the cultural and ideological ties of Christianity (Chengdan, 2010).

However, out of the late medieval period begins the gradual rise of a secular attitude where nature can be studied for its own sake and the knowledge gained used to control it (Derr, 1975). Feudalism made way for a centralised power of the state in the shape of an absolute monarchy (Goldstone, 1998). Economically, a move to an absolute monarchy sought to promote a unified market and a state directed policy of mercantilism; commerce was in the interest of the state (Goldstone, 1998).

The character of this post medieval period can best be described by a fundamental change to the way in which the new knowledge of the universe and its workings influenced our relationship with the world in which we lived. Tawney (1923: 461) articulates this development as ..... '*a change in the character of religious thought which gave secular political economy an opportunity to develop*'. '*Reason replaces revelation*', political and social systems begin to exist outside the church and religious doctrine (Tawney, 1923). The connection to a natural world through subsistence with wealth held in land tenure begins to be replaced with a usury approach to the natural world for the accumulation of money as wealth (Bryer, 2006).

The reformation destabilised the unity of the European Christian church and challenged long held religious belief and biblical explanation (Argemí, 2002; Clarke & Wilson, 2011). From a feudal approach to community where the natural world was created by God to sustain man, social change, through agrarian capitalism, created an environment in which individuals manage the natural world to accumulate monetary wealth (Shaw-Taylor, 2012). Revelation, Godly miracles and intervention, accepted as final cause and explanation of natural phenomena is replaced by an image of God as the creator of physical laws responsible for the production of all observed phenomena (Mayr, 1982).

Argemi (2002) argues that the social and economic theory of agrarian capitalism underpins this burgeoning classical political economy, '*derived from what Marx called primitive accumulation*', an accumulation that included social, technical and scientific transformation. The establishment of nation states, the development of an agrarian capitalism and scientific advancement fed an industrial revolution, which combined to form a new political and social structure (Argemí, 2002; Clarke & Wilson, 2011). The enclosures movement and engrossment, the growth of larger farms through the absorption of smaller ones, between the fourteenth and eighteenth centuries substantially changed the demographic and economic fabric of England's agrarian landscape (Allen, 1998; Allen, 2011; Shaw-Taylor, 2012). The social framework changed from one of an English traditional peasantry to an agrarian capitalism (Allen, 1998; Argemí, 2002).

In the former, social and economic worlds remained together, where, not only the current generation of the household but generations to come shared productive resources, ownership was not individualised (Macfarlane, 1978). In the latter the majority of land was owned by large private estate owners, rented to large-scale tenant capitalist farmers, and worked by landless waged agricultural labourers (Bryer, 2006; Shaw-Taylor, 2012). In a review of the decline in the family farm, Shaw-Taylor (2012) describes agrarian capitalism as dominant in southern and eastern England by 1700, further adding, that the rise of the capitalist farmer corresponds to a geographic spread in commercialisation and the consumer class.

What fuelled the rise of a consumer society? Initially a change in British agriculture, between 1500 and 1850 the percentage of the national population employed in agriculture fell dramatically from around eighty percent to twenty-five percent (Bryer, 2006). However, despite this proportional reduction in workforce numbers, English agriculture was characterised both by higher yields per acre and higher output per worker as a result of the introduction of a more technological approach to land management (Allen, 1999; Wrigley, 2006; Brunt, 2007; Wrigley, 2007). The widespread reduction in agricultural employment

opportunities led to increasing social displacement and a rising urban population (Wrigley, 2007). The modernisation of agricultural practice and increases in productivity fed growing urban populations, which in turn provided a growing workforce for continued expansion of industrial activity (Wrigley, 2006). These growing urban populations also provided a large emerging consumer society for the products of industry, agriculture and global trade (Berg, 2004).

The inherent worth of natural capital begins to be replaced by thoughts of human capital. From the beginnings of wholesale agrarian change, which fashioned productive agriculture, the emergence of agricultural economic thought also became largely influential on classical political economy (Bryer, 2000a). Where once capital was seen as a component *of* the world, its value measured by the productive powers of the land, now it was thought to be a component *in* the world, its value measured as the rate of return on capital employed in production (Bryer, 2000b; Wrigley, 2006; Allen, 2011).

Social change led to a new political economy, technological and scientific change led to thoughts of a new natural economy. Worster (1994) suggests that the incorporation of western science with the traditional Christian view of nature contributed to society's perception of nature as a '*mechanical contrivance*' ..... '*devised .....and made to obey strict sets of rules*'. Furthered by the work of Bacon, Descartes and others the natural world is explained by mechanical laws of causation, the spiritual and material worlds were separated (Clarke & Wilson, 2011). Science explains the nature of things, whereas, theology is concerned with the nature of man (Grobet, 2010).

Whilst the followers of Linnaeus could not accept the mechanised world of the Cartesians, they were very at home with the hand of God being utilitarian (Müller-Wille, 2003; Müller-Wille, 2007). This idea dovetailed with those of the new agricultural reformers and industrialists, where nature was seen as simply a warehouse of raw materials for the progress

of humankind (Müller-Wille, 2003). The rise of the individual, urbanisation, global trade, the capitalist, the consumer, and technological advancement changes the relationship that community once held with the natural world (Allen, 2011).

### **2.3.2 Reflection and romanticism**

Where the Linnaean theologians and the mechanistic Cartesians saw separation in the spiritual and material worlds others, such as Hegel and Goethe, began to express a view for an internal '*life force*' or '*plastic nature*' that was an extension of the material (Kelley, 2009). These ideas echoed those of Leibnitz and his view of nature as being composed of two equipotent elements, one corresponding to an efficient causal order in the world, and the other to a teleological order (McDonough, 2008).

Whereas earlier, as Spinoza had described these ideas, this causal force, the creative process, was thought to be Godly in origin, now, thoughts turn towards an internal process as being responsible for the natural world. Schelling, who believed the inherent teleology in nature was an unconscious purposive product behind all entities, saw everything in nature as connected and alive and as such providing of a way for the human mind to know nature (Lindsay, 1910; Sage, 2009). Schelling further spoke of nature as being self-productive and as such an active force, something more than the sum of its parts, an organic whole; '*natura naturans*', the productive, creative force of process, and '*natura naturata*', those created elements of components and structure (Guilherme, 2010). In this vision we see that there can be no components and structure without process, and no process without components and structure. Schelling believed that in order for human experience and interaction with the natural world to be both objective and subjective humankind must therefore be thought of as a constituent of the components and structure of the natural world (Guilherme, 2010).

This belief in an inherent quality, an inner spirit, in the natural world became the basis of opposition to come towards a mechanistic materialism, utilitarianism and imperialistic ethic of

the industrial revolution towards the natural world, especially from the Romantics (Gobster, 1999; Gobster et al., 2007). Whilst being well versed in the scientific advances of the age, the guiding tenant for the Romantic movement is best understood by the ideas of beauty, love and inspiration of the natural world found in the literature and art of the time (Sage, 2009). The vision of a vital, idyllic natural world was seen as the antithesis of the rising urban, industrial image that threatened environmental catastrophe by writers such as Blake, whose images and words describe the '*fall*' from grace and redemption that follows (Eaves, 2003; Hutchings, 2007).

However, the romantic view of the beauty of nature still persisted in placing humankind in the role of observer and therefore on the outside. Whilst picturesque landscape art of the time celebrated nature's wild and sublime beauty, their idea of natural beauty was a highly selective one (Birmingham, 1989). Landscape portrayal was often stylised, composed through a process of formal principles designed to enhance ideas of a sublime naturalistic beauty of the nature they described (Gobster, 1994; Tolia-Kelly, 2007). Descriptive terms from the romantic period reveal social constructs that idealised nature. Words such as '*sublime*', '*picturesque*', and '*naturelandscape*' became common place to refer to landscapes, found in paintings of the time, which held the desired formal aesthetic qualities. The term landscape takes on artistic meaning, as a view observed from a specific perspective (Gobster, 1994).

The Romantic aesthetic experience of nature becomes associated with composed, static views to the extent that a device called the Claude Glass was used to create a landscape that possessed the correct framing, colour and perspective (Birmingham, 1989; Tolia-Kelly, 2007). This view of a natural world landscape turned aspects of form, structure and components towards expectations of the viewer. Nature as experienced in this respect did not engage with any true representation of its inherent properties but paradoxically became a carefully crafted scene design to please sensibilities of the age (Tolia-Kelly, 2007).

The relationship between viewer and the natural world, as portrayed in these landscapes, was not based in ideas of connection other than the process of composition. Despite this juxtaposition between ideology and execution John Ruskin praised the wild qualities reflected in the work of J.M.W. Turner, seeing them as representative of the ‘natural fact’ of wild nature (Tolia-Kelly, 2007). A scenic aesthetic became the dominant mode through which to experience landscape; a perceived aesthetic quality influences society’s evaluation of ecological quality. Landscape in this context can be thought of as a repository of cultural values and beliefs. Elements of this influence can still be seen today in our approach toward the expression of preference for particular landscape management (Chenoweth & Gobster, 1990; Gobster et al., 2007).

As the influence of a romantic landscape aesthetic had replaced a more classical approach to art and literature, biology began to replace physics as the culturally paradigmatic science (Mayr, 1982; Worster, 1994). Scientific advances through the work of Buffon, Lamarck, Cuvier, Hume and Lyell amongst others introduced new observations and insights which described phenomena that challenged understanding based on a natural theology. The concept of a created, passive natural world became overturned by the work and writings of Charles Darwin and Alfred Russel Wallace. In particular the publication of Darwin’s ‘On the Origin of Species’ (1859), in which he gave the first sustained and convincing argument demonstrating the evolution of organisms (Mayr, 1977; Ayala, 2010). Whilst organisms might exhibit design characteristics it was not a design imposed by God but the result of a natural selection process leading to the adaptation of organisms to their environments (Mayr, 1982). Ernst Haeckel, an ardent proponent of Darwin’s work, furthered the idea of a world consisting of connected parts with his concept of an ecology, in which he supported the combining of natural selection, the inheritance of acquired characteristics with the influence of the environment.

### **2.3.3 A commodity culture**

This challenge to the understanding of man's position with respect to the natural world and the resources it provides for humankind should be set against the back drop of huge social change brought about by a culture of liberalisation, globalisation and industrialisation as seen in a Victorian Britain. Campbell (1983) sees the roots of what he describes as the modern consumer ethic, as having its origin in the doctrines of self-expression and fulfilment that the Romantic movement of the late eighteenth century brought about. Victorian society saw key developments in transportation and communication technologies, in the dissemination of information, and organisational tools such as cataloguing, public libraries, and office bureaucracy (Hilton, 2004; Weller & Bawden, 2006). Alongside this were social advancements including improved literacy and education, a widening electoral franchise, increased disposable income, a more developed and independent popular press, liberal economics, free trade with the transition to mass markets with shopping for pleasure (Hilton, 2004).

An era of Victorian capitalist and territorial imperialism saw the emergence of a commodity culture, the rise of consumption and consumerism, where the increasing use of advertisements created a dominant capitalist consumer culture (Richards, 1990; Hilton, 2004). Consumption led by advertising came to represent the emergence, not only of a consumer economy, but of consumerism which began to shape the world and its influence remains today (Richards, 1990). Excess production, individual greed and acquisitiveness, as Adam Smith had proposed more than two hundred years before, is seen as a necessary prerequisite for economic stimulation (Hilton, 2004). Consumption now becomes the means by which government shape policies and interventions (Hilton, 2003). Thus the politics of consumerism instils ideas of increasing consumption as the platform for a strong economy, the cultural effects of this are to bring social life in to the world of commodities, which also engenders the rise of the individual and self empowerment (Maniates, 2001; Hilton, 2003). Society becomes populated by plural actors with multiple incommensurable end values (Beckerman & Pasek, 1997).

How does contemporary society make sensible choices regarding its relationship with the natural world given incommensurate needs and wants? As individuals we think of ourselves as consumers first and members of society, citizens, second (Malpass et al., 2007). As citizens we address public interest however, as consumers we become concerned only with our individual interests (Malpass et al., 2007). The dichotomy of society's long played out external relationship with a non-human natural world is now enacted through the roles of the 'global citizen' and the 'consumer' of natural resources.

The chapter so far has presented thoughts of social value, with respect to the natural world. This commentary has reviewed the changing perspectives of social value with a focus on ideas of our natural world and society's relationship with natural resources. Although choosing to begin within a medieval setting is an arbitrary decision, it does however highlight the long held belief, at this time, in an external influence being responsible for the creation and maintenance of all elements of our natural world. At this point in time religious thought views society as external to a non-human natural world; a position of theism is maintained. In contrast this review ends at a time of an increasingly secular and utilitarian society. A time in which each landscape can be viewed as an expression of the underlying social system which has left its impression on the surrounding countryside through a process of commodification.

This commentary continues with a review of scientific ecological thought. The intention is to continue the narrative taking up the theme of an ecological value within which a belief in balance, internal harmony and adaptation to external conditions exists. A world described, in a Spinozian sense, by connected components and structure, '*natura naturata*', and a productive, creative process, '*natura naturans*', a world where any increased development of one part will be at the expense of another.

## 2.4 Ecological value: taking a complex systems perspective

### 2.4.1 An ecosystem

The ecosystem concept has been the central theoretical and organisational principal used in ecological sciences for more than 75 years (Currie, 2011). At its simplest the ecosystem can be seen as the place where biotic and abiotic factors interact (Post et al., 2007). Arthur Clapham in the 1930's conceived the term ecosystem to describe the biological and physical components of a system considered together as a unit, and the term was first used in a paper by his colleague Arthur Tansley (Willis, 1997). Tansley (1935: 299) described the idea of an ecosystem, where organisms interact with their environment, as '*the whole system (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome*'. General acceptance of Tansley's concept, where the ecosystem is formed by the fundamental concept of interaction between organism and environment, has seen it become used as a basic unit for ecological study (Currie, 2011).

The interaction between living elements and their environment is central to this idea of ecosystem. Odum (1971) stated '*Any unit that includes all of the organisms (ie: the "community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e.: exchange of materials between living and nonliving parts) within the system is an ecosystem*'.

Contained within each definition the main identifying feature of the ecosystem is that of it being a system. One within which a hierarchy of organisational levels exist, where interactions occur from the level of the gene, through cell to individual, population, community, ecosystem, up to those of the biosphere (Odum, 1971). Thus, this system of interacting components can be presented as a hierarchy of elements, wherein, at any given level of resolution, an element at one level contains elements in the level below and is itself a constituent of the level above (O'Neill et al., 1989; Currie, 2011). The component interactions

and selection processes at lower hierarchy levels creates endogenous structure which forms patterns that emerge at higher levels (Levin, 1998).

Classical ecosystem models describe the maintenance of stable states, where a self-regulating closed system provides a natural balance, within which ecologists seek a comprehensive understanding of the interactions responsible for any given ecosystem (O'Neill, 2001).

Through a process of aggregation, where difference identifies biotic and abiotic elements that are more alike than others, the complex nature of an ecosystem becomes focused on a defined subset of a population within a specified spatial area, and permits study of the relative stability of this abstract structure and its function (Levin, 1998; O'Neill, 2001). Examples are forests, wetlands, lakes, savannah and coral reefs. Thus, distinct ecosystems are described as landscapes of relative homogeneity which contain unique assemblages of species' communities and physiognomic characteristics (Vreugdenhil et al., 2002).

Physical or structural criteria define tangible boundaries based on visible or measurable discontinuities or structural characteristics of the landscape (Post et al., 2007). Whilst descriptors for ecosystem classification vary, common elements exist between models based on comprehensive inventories and data aggregation exercises, these include components such as; typology of natural habitat units, floristic zones, physiognomic and ecological systems, human management intervention or geo-physical elements such as soil and water regime amongst others (Vreugdenhil et al., 2002). However, these systems contain and are shaped by many thousands of interacting elements that vary at both spatial and temporal scales, within each hierarchical level (O'Neill, 2001).

Ecosystems are continually changed by evolutionary and biogeochemical process, they exhibit variability, spatial heterogeneity, and non-linear dynamic process, some communities are affected by periodic localised non-stochastic disturbance, for example intertidal communities, while others may experience catastrophic stochastic episodes, such as floods or forest fires, or

are characterised by differing successional phases (Holling, 1973; De Leo & Levin, 1997). Ecosystems are thermodynamically open; they exchange matter and energy with their environment (Currie, 2011). Here, boundaries are fuzzy and permeable to the movement of both energy and organisms (Cadenasso et al., 2003; Post et al., 2007). An inherent property of these complex systems is the propensity for change, where critical thresholds exist, through which alternative stable states may be reached (Holling, 2001). Stochastic disturbance events are an integral component of ecosystems; species have co-evolved with and become adapted to specific disturbance regimes (Folke et al., 2004).

Where the fundamental features of an ecosystem are considered in detail, often observation of potential interactions between hierarchical elements can be reduced (Muller, 2005). However, a reductionist investigation of ecosystem components completely ignores any emergent properties that develop as a result of the hierarchical organisation; ecosystems are more than the sum of their parts (Odum, 1971; Jorgensen et al., 1992; Jeanrenaud, 2001). Global system properties emerge from interactions at the local scale (Green & Sadedin, 2005). Similarly studies based on individual populations fail to capture functional relationships both between and within biotic and abiotic components (Odum, 1971).

Modern ecosystem models describe complex hierarchical systems of self-organising, adaptive, dynamic networks where interacting components display non-equilibrium dynamics that lead to feedback loops and cross-scale interactions (Levin, 1998; Parrott, 2010). Herein, we see the nature and fabric of ecosystems described by plurality of concept, attribute and dimension, where complexity results from the '*multiplicity of interconnected relationships and levels*' (Pickett et al., 2005).

#### **2.4.2 Ecological process and society**

With the multiplicity of interconnected relationships and levels in mind ecosystem definitions should seek to encompass a range of attributes; composition, structure and function, over

differing dimensional scales; spatial, organisational and temporal, within each domain; social, economic and ecological. In trying to simplify the idea of ecosystem complexity, Levin (1998: 432) describes the main functional elements as simply; '*Sustained diversity and individuality of components, localised interactions among those components, and an autonomous process that selects from among those components, based on the results of local interactions, a subset for replication or enhancement*'.

Thus, ecosystem structure and function can be understood through the process of natural selection ensuring continual adaptation and the emergence of hierarchical organisation from local interactions which results in endogenous pattern formation (Levin, 1998). Competition for resource translates into a mechanism for coexistence, which, in the presence of environmental disturbance reinitiates the adaptive, successional cycle (Levin, 2000). Species survive globally due to the availability of new patches and their ability to find them before competitively superior species (Levin, 2000). Spatial connectivity maintains the interchange of material and information between patches, which, through direct physical connections, underpins ecosystem structure and function (Green & Sadedin, 2005).

Here, we see the dynamic and adaptive elements of an ecosystem viewed in a holistic framework, where ecosystems are defined by a multiplicity of connections and relationships. The evaluation of ecological status requires not one indicator, but a range of different measurements (De Leo & Levin, 1997) that incorporate the system attributes of composition, structure and function (Tansley, 1935; Odum, 1971) moderated by spatial-temporal organisation and boundaries (Pickett et al., 2005). Additionally, with thoughts of ecosystem goods and services in mind, not only described within an ecological context but also in socio-cultural and economic terms (Elmqvist et al., 2003; Folke, 2006).

The Convention on Biological Diversity (1992) refers to an ecosystem as '*a dynamic complex of plant, animal and micro-organism communities and their non-living environment*

*interacting as a functional unit*'. The description of ecosystems as 'functional' units identifies purpose and therefore implies a utilitarian characteristic, thus difference is expressed between ecological process and ecosystem functions in the provision of goods and services. This perception of an ecosystem carries a clear anthropogenic message that links ecological processes with the provision of goods and services for continued human well-being. Ecosystem functions are seen as intermediary systems that connect human well-being to the biophysical components of ecosystems through ecological processes (Turner et al., 1994; de Groot et al., 2010).

In reality, the concept of an ecosystem is a human construct which describes the natural world and we define ecosystems according to the focal point and scale of our interest (De Leo & Levin, 1997; O'Neill, 2001; Jax, 2005). Recently thoughts have focused on the continued capacity of ecosystems to supply the goods and services that benefit human well-being (Meadows et al., 1972; Daily, 1997;). Whilst the management of landscape can be solely focused on anthropogenic interests, the ecosystem concept remains centred on the fundamental interactions between its components and its properties as a system (Tansley, 1935; Odum, 1971). Thus this systems perspective must include humans as a component; we simultaneously influence and depend upon ecosystems (Costanza et al., 1997; Daily, 1997).

Societal influence has moved ecosystems outside of their pre-existing conditions as society continually seeks to adapt landscapes to increase their perceived value (O'Neill, 2001; Nassauer & Opdam, 2008). Classical ecosystem models have tended to exclude humans or treat them as external drivers of ecosystem change, more recently, research has moved to a '*humans-as-part-of*' the environment perspective, where linking the dynamics of social, economic and ecological sciences seeks to develop an understanding of landscape and long term sustainability (Elmqvist et al., 2003; Folke, 2006).

The complex nature of organisation, relationships, connectivity and multiple stable states within and between ecosystems makes any initial assessment and comparison of ecosystem status problematic. That is, evaluation of the spatial and temporal considerations with reference to the adaptive, successional ecosystem cycle (Holling, 1973). But, through the mass of environmental and biodiversity data collected, as a function of national and international monitoring schemes, changes over time can be described. These data consistently demonstrate a clear pattern, which can be summarised as follows; anthropogenic driven land use and landscape change, exploitation and the associated changes in biotic structure and composition of ecological communities, either from the loss of species or from the introduction of exotic species, have led to depleted ecosystems (Vitousek et al., 1997; Dullinger et al., 2013).

#### **2.4.3 Ecological systems and disturbance**

Ecosystems are constantly changing they are a constituent of a biosphere in which many things change continuously, at various spatial and temporal scales (Levin, 2000). Consequently, through the evolutionary diversification of species' niches and life histories, the maintenance of biological diversity is supported, where the multiplicity of connections and relationships in the physical environment creates many resources from few (Levin, 2000). Species diversity has functional consequences that influence ecosystem processes (Elmqvist et al., 2003; Cardinale et al., 2006; Tilman et al., 2006).

Following external disturbance this multitude of connections, both current and future possibilities, provide multiple potential cross scale ecosystem combinations of composition, structure and function (Scheffer et al., 2001). In this way the possibility for alternative stable states is observed (Holling, 1973; Scheffer et al., 2001; Scheffer & Carpenter, 2003). In response to disturbance the presence of multiple stable states and transitions among them has been described in a range of ecological systems (Gunderson, 2000; Walker & Meyers, 2004). For example shifts between alternative stable states occur in; shallow lakes where sudden loss

of transparency and vegetation is observed in response to human-induced eutrophication, savannahs that become encroached by bushes, and the loss of perennial vegetation in arid and semi-arid regions leading to desertification (Scheffer et al., 2001; Scheffer & Carpenter, 2003; Walker & Meyers, 2004).

Thus, ecosystem status can also be described in terms of the relationship between ecosystems and disturbance, its influence and the ability of ecosystems to respond and maintain function (Belaoussoff & Kevan, 1998). After Holling (1973), and others (Gunderson, 2000; Carpenter et al., 2001; Folke et al., 2004), ecosystems that tend to maintain their general structure, levels of function, and delivery of services when disturbed are defined as resilient. According to Holling (1973: 17) '*resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb change of state variable, driving variables, and parameters, and still persist*'. Systems which are not resilient when disturbed change greatly in structure, levels of function, and delivery of goods and services (Scheffer & Carpenter, 2003).

The key to resilience in any complex adaptive system is in the maintenance of heterogeneity, the reservoir of essential ecosystem variation which enables adaptation, endogenous pattern formation, self-organisation and persistence (Levin, 1998). Heterogeneity, niche building and environmental discontinuity moves ecosystems towards a more stable state, whereas, homogenous landscapes, such as human monocultures, occupy unstable states that are prone to external influence, regime shift, irreversibility and associated uncertainty (Holling, 1973; Arrow et al., 1995; Norton, 1995). Maximal levels of heterogeneity are widely accepted as being associated with intermediate levels of disturbance, too little disturbance can lead to low diversity through the effects of competitive exclusion, and too much disturbance will eliminate species incapable of rapid re-colonisation (Begon et al., 1996).

As the global human population now passes eight billion, much of the earth is either directly or indirectly affected by human activities (Vitousek et al., 1997; Haberl et al., 2007; Dullinger et al., 2013). Many ecosystems of the world have become dominated by humans (Vitousek et al., 1997), where management reshapes landscape structure, composition and process to achieve predictable flows of goods and services with the reduction of undesirable ecosystem behaviours (Holling & Meffe, 1996). Where once ecologists sought to study pristine ecosystems to understand the workings of nature, without the influence of human activity, now with the realisation that few places if any on Earth are not touched by human activity a new approach is required. All ecosystems have become shaped by humans, directly or indirectly, and all people depend upon the capacity of ecosystems to provide essential ecosystem goods and services (Levin, 1999).

Since ecosystem goods and services are the benefits humankind receives from ecosystems, changes associated with ecosystems and biodiversity will have implications for human well-being (Levin, 1998). The Earth's biosphere provides the ecological services that support human life, in this sense humankind and ecosystems are interdependent social-ecological systems. Consequentially a reducing stock of natural resources becomes critical with respect to both current and future generations (Daly, 1977).

Having reached a place where ideas of ecosystems, complexity, heterogeneity and resilience become integrated with concepts of anthropogenic dependency to form social-ecological systems, this review will embark on a review of economic value. The focus will change from one where the biophysical consequences of continued anthropogenic consumption are becoming known to one where the economic tools, previously used in the rise of a consumer society to maintain continued economic growth are now employed to support the sustainable use of ecosystem goods and services.

## **2.5 Economic value: an integration of ecology and socio-economics**

### **2.5.1 Linking ecology and economy**

Throughout the 19<sup>th</sup> century, unprecedented agricultural, industrial and technological growth led to distinct changes in economic thought. The rise of agrarian capitalism shaped a world in which individuals manage natural resources to accumulate monetary wealth (Bryer, 2000b; Wrigley, 2006; Allen, 2011). Land and labour, as the primary focus of wealth and production inputs, became displaced by labour and capital (Ekins et al., 2003; Hubacek & van den Bergh, 2006; Gómez-Baggethun et al., 2010). The means by which economic process was valued moved from one of ‘value in use’ to that of ‘value in exchange’, with an emphasis on monetary instruments of measurement; land and natural resources had been removed from the function of production (Hubacek & van den Bergh, 2006). Objective valuation, as an indicator of value, had been replaced by the subjective quality of exchange.

Neo-classical economic analysis concentrates on a satisfactory exchange of commodities among members of an economy where the value of goods is defined solely by price and is exclusively the result of an exchange process (Spangenberg & Settele, 2010). Wherein the framework of neo-classical economic theory encompasses; (a) a market place for the sale and purchase of goods and services; (b) functional substitution and technological optimism; (c) a utilitarian desire built on anthropocentric values and a belief that natural resources are regarded as instruments for human satisfaction; and (d) the individuals choice is informed, rational and acts to maximise utility and satisfaction (Cleveland & Ruth, 1997; Chen et al., 2009).

However, not all neo-classical economic thought had completely divorced thinking from an interconnected relationship between humankind and the natural world. During the first half of the 20<sup>th</sup> century, notable authors such as Gray (1914), Pigou (1920), Ise (1925) and Hotelling (1931) developed ideas around the ethical considerations of discounting intergenerational resource allocation, the social costs of externalities and non-renewable resource depletion

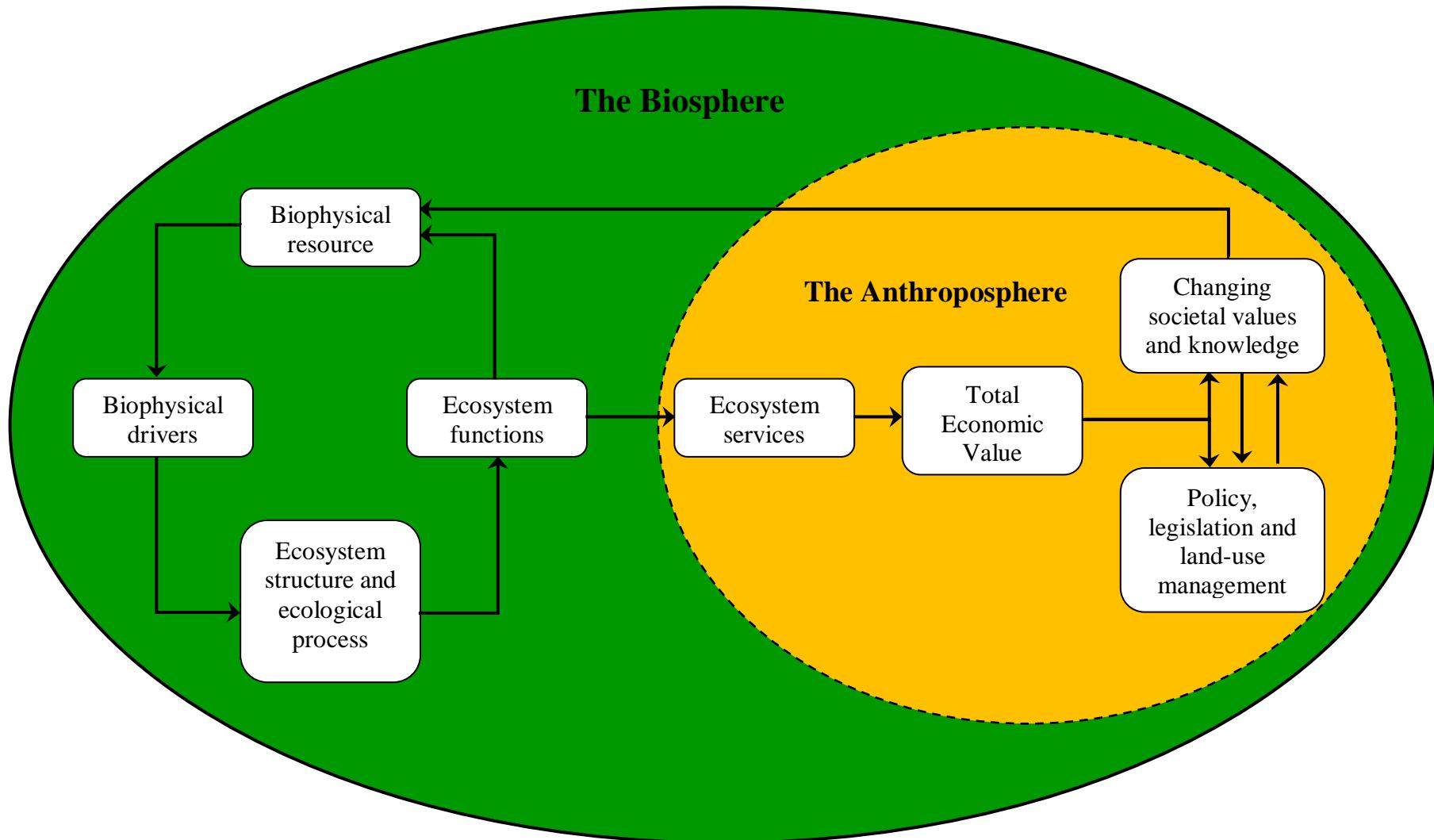
(Turner et al., 1994; Spash, 1999; Hubacek & van den Bergh, 2006; Gómez-Bagethun et al., 2010) . By the second half of the 20<sup>th</sup> century some economists had begun to integrate environmental concerns within economic analysis and decision making (Turner et al., 1994; Gómez-Bagethun et al., 2010). Boulding (1966) proposed that economic success, in a world of finite resources, should not be measured by terms such as production, consumption and throughput but through the maintenance of natural capital. This line of thought, where societal activities are constrained by the capacity of natural environments, led to a belief in the concept of a stationary state, that is to say, as economies develop and populations grow ecological, technological or social limits are reached (Daly, 1977). In this model economic growth is limited by the availability of resource stocks, sources, and the natural assimilative capacity for wastes, sinks (Boulding, 1966).

This broader focus acknowledges economic activity as an open subsystem within an interrelated complex of finite non-growing ecosystems, where the relationships of finitude, entropy and complex ecological interdependence combine to form fundamental biophysical limits to material growth (Daly, 1987). Current economic policies are largely based on the underlying principle of continued and unlimited material economic growth (Costanza et al., 1999), in spite of unsustainable consumption of the world's natural capital knowingly having serious ecological and socio-economic impacts ( Leopold, 1950; Thoreau, 1956; Boulding, 1966; Meadows et al., 1972; Arrow et al., 1995; Ehrlich & Holdren, 1971; Vitousek et al., 1997; Dullinger et al., 2013).

The economic assessment of ecosystems, ecological process, goods and services involve the conversion of ecological complexity into ecosystem functions, which in turn, provide services and goods that are valued by humans (de Groot et al., 2002; Kontogianni et al., 2010). Thus, natural capital, biophysical structures and processes build socio-economic capital, directly and indirectly, through ecological processes (Costanza et al., 1997; Balvanera et al., 2006; Luck et al., 2009). For example in figure 2.1 this chain of connection could operate in this manner;

woody and non-woody plants - sunlight and climate – respiration – photosynthesis – growth – carbon storage and biomass production – carbon trading and biomass markets – CO<sub>2</sub> reduction – changing energy use/production - climate legislation – woody and non-woody plants.

However, this cascade of interactions between ecosystem structure, ecological process, ecosystem service and socio-economic benefit is subject to change through environmental or economic fluctuations, and socio-cultural change (Kontogianni et al., 2010).



**Figure 2.1**

A framework for an integrated system approach for the structure of the natural capital – socio-economic capital relationship. Wherein, each system comprises two fundamental building blocks: elements and the connections between them, connections can be biotic, biological, and abiotic, chemical and physical or behavioural, in nature, adapted from de Groot et al. (2002) and Liu et al. (2010).

Using a systems perspective allows observation and analysis of each set of components that build the connective structure between components and the functions that arise from this structure (Straton, 2006). Here, natural ecological process and ecosystem function are the result of complex interactions between biotic and abiotic components of ecosystems through the common driving force of solar energy (Daily, 1997; de Groot et al., 2002; Straton, 2006). Ecosystem structure and, thus, ecological processes are influenced by available biophysical resources and key biophysical drivers, which in turn create the necessary conditions for ecosystem service provision that supports human well-being (Liu et al., 2010).

In this respect, difference is described between ecological process, ecosystem functions, and the anthropocentric and utilitarian characteristics of ecosystem goods and services. The utilisation of ecosystem goods and services produced provides benefit and human well-being, for example nutrition, health, recreation, which in turn can be valued in economic terms described by a monetary unit (de Groot et al., 2010). Ecological processes are essential for the provision of ecosystem services, but process should not be seen as synonymous with services; ecological processes only become services if there is a person somewhere who derives benefit from any given process (Tallis & Polasky, 2009).

Many systems of classification and definition exist reflecting the complex and dynamic nature of ecosystem functions, goods and services (Costanza, 2008). Whilst some argue for standardisation (Wallace, 2007; Luck et al., 2009), others work towards a pluralism of typologies each useful for different purposes (Costanza, 2008; Fisher et al., 2009). The naming of ecosystem services provides a key conceptual link between the social evaluation of ecosystems and their ecological processes (Diaz et al., 2007). Through reference to an appropriate quantitative and/or qualitative description, the complex, dynamic nature of ecological processes becomes visible to society (Kontogianni et al., 2010).

Whilst broad similarities exist between definitions, differences can be highlighted. Ecosystem services are thought of as either; ‘conditions and processes’ or; ‘goods and services derived from ecosystem functions and utilised by humanity’ or; ‘benefits humans obtain from ecosystems’ or; ‘ecological components directly consumed or enjoyed to produce human well-being’ (Fisher et al., 2009). The common thread between these definitions identifies ecological process and ecosystems as the ‘means’ by which the anthropomorphically defined flow of ecosystem services, becomes the ‘ends’ which satisfy human well-being (Boyd & Banzhaf, 2007; Wallace, 2007; Costanza, 2008; Fisher et al., 2009). This should not be taken to mean that ecosystems are not also valuable for other reasons, but that ecosystem services are instrumental in the valuation of ecosystems as ‘means to the ends’ of human well-being (Costanza, 2008). Ecological processes and ecosystem functions only become ecosystem services if there are humans that benefit from them, either passively or actively ( Fisher et al., 2009; Tallis & Polasky, 2009).

The existence of a functional ecosystem is a prerequisite before receipt of any use value from ecosystem structure and related functions can be realised and utilised for human well-being (Turner et al., 1994). There is then a certain minimum provision of ‘healthy’ ecosystem function necessary to ensure a continued flow of services and goods and avoid threshold effects, ecosystem collapse and regime shift (Farber et al., 2002; Balmford et al., 2008). Thus, contained within the natural capital of biophysical resources, ecosystems and ecological process there exists an inherent ‘primary value’ (Turner et al., 2003).

If one considers that biodiversity is the fabric that holds ecosystem structure and ecological process together it is indispensable, and has an ‘insurance value’ that is both highly significant and extremely difficult to quantify (Turner et al., 2003). In a meta-analysis of the biodiversity – ecosystem service link Balvanera et al. (2006) states that there is clear evidence for the positive effects biodiversity has on the provision of ecosystem services. Yet despite this fact

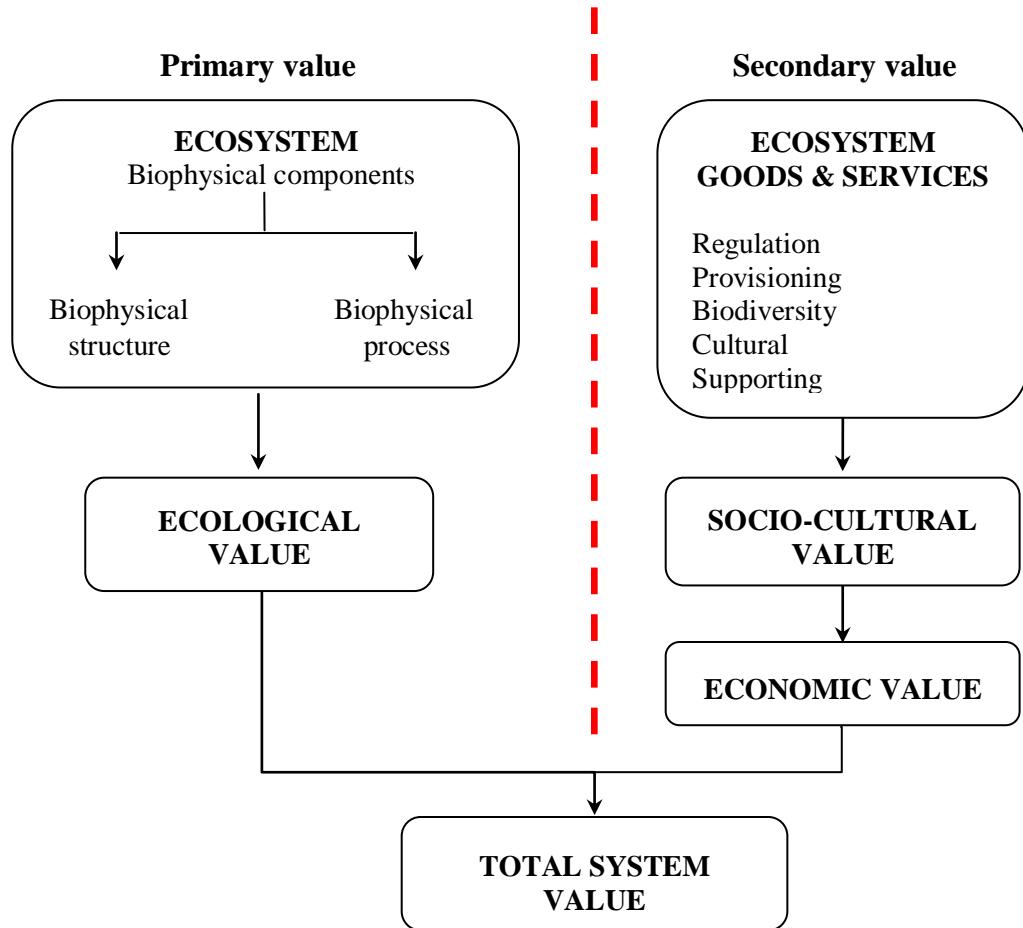
large scale biodiversity loss continues to be observed (Vitousek et al., 1997; Balmford et al., 2002; Dullinger et al., 2013).

Ultimately, to better meet human values, society endeavours to manage natural capital to maintain, re-organise or change ecosystem composition and structure which delivers the ecosystem services that benefit human well-being (Wallace, 2007; Liu et al., 2010). However, society's knowledge about ecosystem services is extremely limited, especially as we can expect many ecosystem services that are public, and never enter the private market place, to go unnoticed by the majority of society (Costanza, 2008). Decisions made as a society about ecosystems imply a valuation of those systems and these values reflect differences in culture, preference, technology, assets and income (Costanza et al., 1999).

Ecosystem services, as a concept, raises society's interest in and helps communicate societal dependence on ecological processes (Gómez-Baggethun et al., 2010). However a shift in direction has begun, emphasis is now placed on using the potential to market ecosystem services as commodities (Patterson & Coelho, 2009). This move towards monetisation and commoditisation of a growing number of ecosystem services, and their incorporation into markets and payment schemes comes as a result of the move from natural capital's value in use to its conception in terms of value in exchange (Gómez-Baggethun et al., 2010).

Commoditisation obscures the importance of both the biotic and abiotic factors that contribute to ecological process and consequently ecosystem services (Peterson et al., 2009). In a market place based on exchange value, payments may change society's judgment from doing what is considered the ethical obligation or communal requirement to purely economic self-interest (Gómez-Baggethun et al., 2010; Spangenberg & Settele, 2010). Therefore, a combination of the inherent quality of ecological resources (Straton, 2006), an associated 'primary value', plus a subjective evaluation of 'use' and 'non-use' values by the consumer (Turner et al.,

1994), and a socio-cultural perspective (Kumar & Kumar, 2008), an associated ‘secondary value’, is necessary for ecosystem valuation (Fig 2.2).



**Figure 2.2** A structure for the relationship of primary and secondary value components in the calculation of a ‘Total System Value’.

### 2.5.2 Economic valuation of ecosystem goods and services

Within the literature on environmental economic valuation, the value of environmental resources, for analytical purposes, is defined by the aggregated sum of the component parts of a Total Economic Valuation (TEV) calculation (Turner et al., 1994; Fromm, 2000; de Groot et al., 2010). The identification of a total economic value lies in the creation of a monetary value for ecological processes which are defined as the ecosystem goods and services received by society. These are considered to possess value from an anthropogenic and utilitarian point of

view (Turner et al., 1994). TEV studies typically set out to provide a monetary figure that reflects the economic importance of ecosystem goods and services and the potential costs involved in their loss. The basic principle of economic valuation, and thus TEV, therefore, is the effect that environmental resource supply and use has on the well-being of the individuals who make up society (Fromm, 2000; Vergano & Nunes, 2007).

Traditionally, economic valuation has been focussed on direct use values, quantifying goods and services that produce tangible benefits. Increasingly however, economists have broadened their scope in recognition of the growing appreciation for indirect use, non-use, option, existence and bequest values of ecosystems and have developed techniques to extend monetary valuations to these ecosystem services (Chee, 2004). Thus, economic valuation allows measurement of the costs or benefits associated with ecosystem service change using a common metric (Liu et al., 2010). The principal techniques for the economic valuation of environmental goods and services are described in Box 2.1. Economic valuation methods fall into four basic types, each with its own repertoire of associated measurement techniques: (1) direct market valuation, (2) indirect market valuation, (3) revealed preference, (4) stated preference (Chee, 2004; Spangenberg & Settele, 2010). Benefit transfer refers to the use of total economic valuations achieved through applying the methods above in one context in order to estimate values in a different context (Merlo & Croitoru, 2005).

**Box 2.1.** Ecosystem service valuation methods, adapted from Farber et al. (2002) and Chee (2004).

### Market goods

#### Direct use

- Market price

Where ecosystem services and goods are directly traded in normal markets, values can be directly calculated from what people are willing to pay for the service or good (e.g. timber, food).

#### Indirect use

- Damage cost

The cost of damages caused by a disservice (for example the damage costs of biological invasions).

- Repair cost

The economic expenditure required for management or repair costs to re-establish the flow of service or goods.

- Replacement cost

Assessment of the value of services and goods by how much it would cost to replace or restore after it has been lost (for example pollination services).

- Avoidance cost

Value is based on costs avoided, or the extent to which costly mitigating behaviour is avoided (for example watershed protection and water quality/flood protection).

### Non-Marketed Goods

#### Revealed preference

- Hedonic pricing

Value is derived from the willingness to pay for a good associated with an improved or diminished environmental quality change (for example house markets and scenic beauty).

- Travel cost

Reflects the implied value of individual preference for non-marketed goods and is commensurate with the associated costs of travel to acquire them (for example recreational sport).

#### Stated preference

- Contingent valuation

A stated willingness to pay or accept compensation for a change in ecosystem services or goods is elicited through questionnaires, which pose hypothetical scenarios that require a valuation of alternatives.

- Choice modelling

Respondents choose a preferred option from a series of alternatives, in which one parameter is price. The choice indicates a price considered adequate in the context described.

- Conjoint choice

Individuals choose or rank different ecosystem service or ecological condition scenarios that contain a mix of conditions (for example wetland protection and differing levels of flood protection and fishery yields).

#### Benefit transfer

The transfer of existing Total Economic Value data to new valuation exercises that have little or no data.

The key distinction between these standard economic valuation methods is based upon the data source. That is, whether they are arrived at through direct observations of an individual's actual behaviour, through a direct market price or a revealed preference from a surrogate market approach, or from responses to hypothetical scenarios and questionnaires (Farber et al., 2002; Spangenberg & Settele, 2010). A stated preference approach where monetary valuation is derived from hypothetical markets asking questions such as 'How much would you be willing to pay for.....?' or 'What would you do if.....?' (Farber et al., 2002; Spangenberg & Settele, 2010). However, all of these valuation techniques are context dependent with both spatial and temporal components. Individuals hold plural identities, which can lead to different expressions of interest in their capacities as both consumers and citizens (Plottu & Plottu, 2007; Kumar & Kumar, 2008). Preferences are mutable, and may change through, for example, education, advertising, peer pressure or legislation (Farber et al., 2002; Chee, 2004).

Through the use of these economic valuation techniques TEV studies express 'value' from the point of view of '[dis]-utility'. An individual's 'utility' becomes an objective measure of the degree to which 'value' is produced by a present state of ecological and economic systems. In this manner, economic valuation is thought to work from a position of rational choice which assumes individuals have perfect knowledge about the [dis]-utility of all available possible options, and that the individual will choose options that work to maximise 'utility' (Heylighen et al., 2006).

### **2.5.3 Social-ecological system evaluation**

When the provision of ecosystem services are considered ecologists tend to focus on the structure, composition, function and connectivity of the system components, 'primary values', whereas economists look towards the use of a variety of methods, based on consumer preference, which quantify the value of services to society, 'secondary values' (Kontogianni et al., 2010; O'Farrell & Anderson, 2010; Spangenberg & Settele, 2010). Ecologists build high

resolution temporal models based on long time horizons and long term consequences, economists tend to ignore the long term believing the future state of the system is virtually impossible to predict (Bockstael et al., 1995).

As Kontogianni et al. (2010) and Ring et al. (2010) suggest, quantification of how ecosystems provide services, and a clear understanding of this information is a pre-requisite for economic valuation. So, what is it that we describe as we begin to articulate an economic value for ecosystem goods and services? If our concept of ‘value’ is perceived solely in monetary terms, the effect of non-monetisation for any component part of the environment can result in its automatic exclusion from any kind of economic calculation. Therefore it will have no impact on the formation of a rational choice (Plottu & Plottu, 2007).

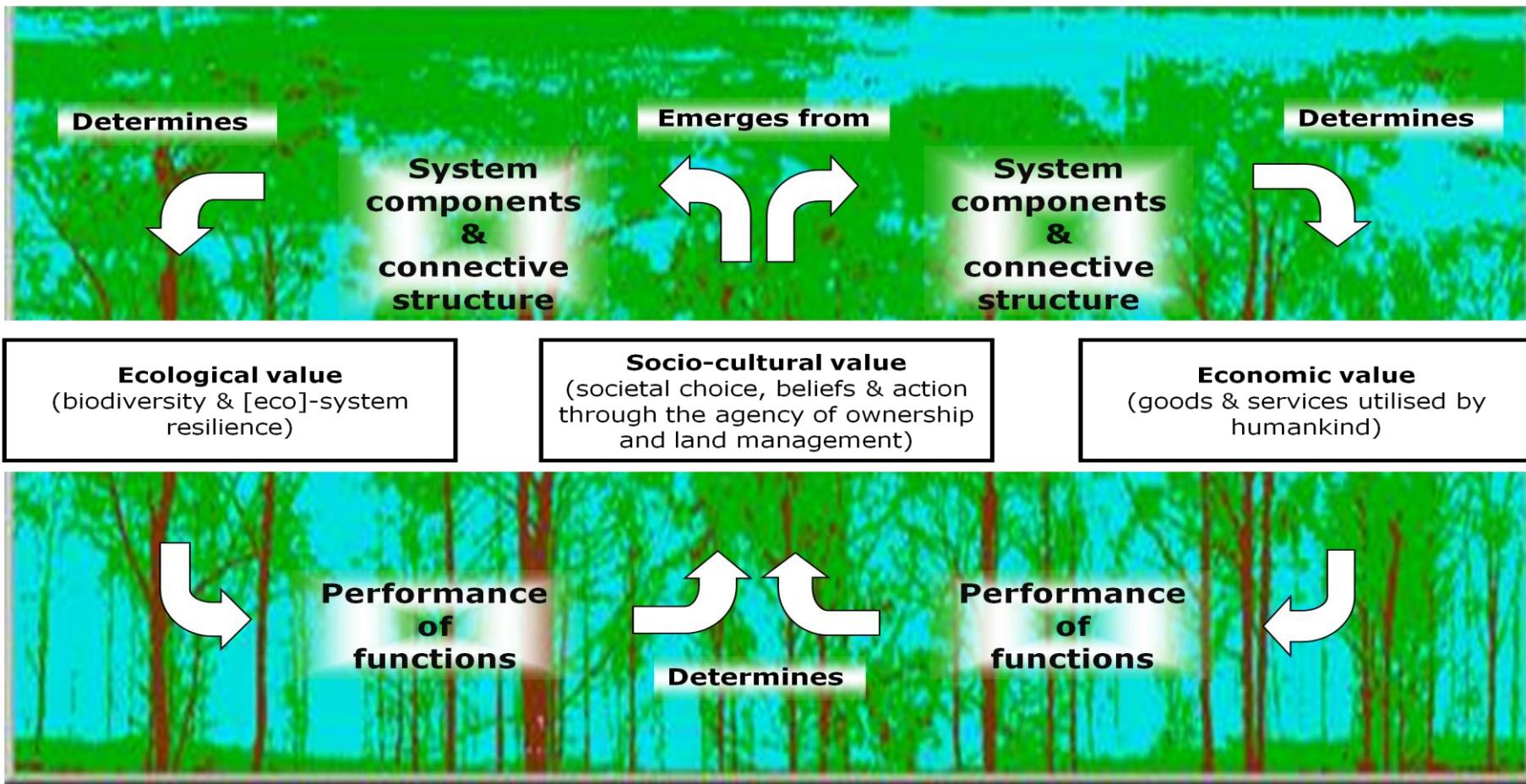
Economic valuation can be used to capture the utilitarian relationship between humankind and ecosystem goods and services but, it is not independent of the dynamics of the ecological systems which constitute their environment or the socio-cultural influence upon them (Turner et al., 1994; Arrow et al., 1995; Costanza et al., 1999; Turner et al., 2003; Stratton, 2006; Paetzold et al., 2010). Thus ‘value’ resides within three domains; the environment, society and the economy (Costanza, 2000; de Groot et al., 2002; Winkler, 2006; Peterson et al., 2009).

Table 2.2 identifies examples of the components associated with each value domain.

**Table 2.2** A general value typology, adapted from Costanza and Folke (1997) and de Groot et al., (2002).

Domain	Value	Value basis	Preference basis
Environment	Ecological	Integrity Resilience Complexity Diversity Resistance Rarity	Whole system
Society	Socio-cultural	Equity Equal allocation Cultural diversity & identity Education Physical & mental health Spiritual Freedom	Community
Economy	Economic	Efficiency maximisation Monetary valuation of goods, services & benefits received Use, non-use & option Utilitarian & intrinsic	Current individual

The evaluation of ‘value’ is derived from the outcomes of interactions between and within components of each of these domains (Straton, 2006) (Fig 2.3). Ecological value lies in the health state of ecosystems, which is maintained by the integrity of the habitat and regulation functions of the ecosystem, and measured by ecological indicators such as biodiversity and resilience (Arrow et al., 1995; de Groot, 2006; de Groot et al., 2010).



**Figure 2.3** A systems approach to showing the relationship and connections between environment, society, economy and value.

Socio-cultural values are expressed through the importance people give to cultural identity, belief systems, attitudes and intentions and the degree to which they are related to ecosystem services (de Groot et al., 2010; Sauer & Fischer, 2010). Economic evaluation is grounded in a utilitarian relationship, where the environment, viewed as an asset, provides a flow of services and goods which sustains the means of life support and perceived quality of life enhancement (Turner et al., 2003).

The economic valuation of ecosystem goods and services to calculate a value for global ecosystem services has significantly raised the public profile of ecosystem services and their importance in sustaining life on earth (Costanza, 2000). However, through the application of economic tools thoughts of the original concept must not be lost, monetary valuation should serve as means not as ends and help support the protection of ecosystems, their biotic and abiotic constituents and the ecological process therein (Vergano & Nunes, 2007; Gómez-Bagethun et al., 2010; Spangenberg & Settele, 2010) .

This use of market based analytical tools ignores the complex biophysical structure and ecological interrelationships of ecosystems that lead to the provision of ecosystem services and, therefore, any evolving future vision and social goals that define the degree to which services are perceived as benefits (Costanza, 2000; Stratton, 2006). The evaluation of ecosystem services needs to consider a broader set of goals that includes ecological sustainability and a societal perspective, alongside a solely monetary based economic valuation (Costanza, 2000; Stratton, 2006; Spangenberg & Settele, 2010) .

Spangenberg and Settele (2010) question the use of economic valuation tools to objectively calculate the value of ecosystem services. Primarily they suggest issues arise from a core set of assumptions, where economic valuation techniques isolate single services, from an ecosystem context, in order to value them (Stratton, 2006; Spangenberg & Settele, 2010).

These techniques run in to trouble with multi-objective approaches which are needed for ecosystem scale solutions because they;

- count only current demands and use estimated market prices for ecosystem services to be the value of the ecosystem.
- reflect current knowledge, preference and use structures in which values will change in accordance with production and consumption patterns which are themselves dependent upon development processes in general.
- do not reflect the intrinsic quality of ecological resources.
- calculate varied values dependent on the method of choice not the object of analysis.

In the TEV methodology we can see how an economic valuation of ecosystem services contributes to the idea of a construction of indicators to provide a value instrument for human welfare and sustainability. However, it is constrained by both the limitations of non-market valuation methods and the fact that market values reflect value in marginal utility and express a measure of market activity and do not capture values bound in any system of complex socio-cultural – ecological - economic relationships (Farber et al., 2002; Howarth & Farber, 2002). That is not to say that an economic valuation process has no part to play in understanding the complexities of socio-cultural – ecological - economic relationships, but that it should be one factor amongst others that are used to assess ecosystem status or the effectiveness of any actions taken (Spangenberg & Settele, 2010). As observed by Vatn (2010) the expression of an economic value for ecological resources may of its self influence individual behaviour. Economic valuation can highlight the potential of self regarding behaviour; economic self interest can be promoted in favour of individual or community ethical and moral obligation (Spangenberg & Settele, 2010).

#### **2.5.4 A complex systems approach to the evaluation of landscape; environmental or ecological economics**

The value of a location can be measured by its biodiversity, an inherent value in the landscape, and also have economic value which can be measured by direct, and indirect, monetary valuation techniques. Each value domain can be described as having different types of value. It is this unavoidable nature of incommensurability that prompts Martinez-Alier et al. (1998) to reject not just monetary reductionism but also any physical reductionism such as evaluations based on energetic values. However, incommensurability, the absence of a common unit of measurement across plural values, does not imply incomparability (Martinez-Alier et al., 1998). Different values can be thought of as being weakly comparable, thus comparison can be made without recourse to any single ‘value’ (Martinez-Alier et al., 1998). Making use of both quantitative and qualitative information can provide the basis for a more culturally inclusive and complex system description.

Ecosystems and economies are both examples of complex adaptive systems composed of a large and potentially increasing number of both components and relationships between them (Ramos-Martin, 2003). As Munda (2004: 663) describes, *‘a system is complex when the relevant aspects of a particular problem cannot be captured using a single perspective’*. Attempts to represent the structure, composition and function of any complex system will at best only reflect a sub-set of all possible representations (Munda, 2004).

Environmental economics<sup>2</sup> takes a neo-classical economic positivist approach to socio-cultural – ecological - economic system description, grounded in universal laws with observation and investigation based on the ‘scientific method’ (Costanza, 2001; Ramos-Martin, 2003). It describes a static physical world of closed systems and deals with testing

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<sup>2</sup> The review of environmental and ecological economics presented here should not be seen as a complete examination of the two disciplines. Papers such as Proops (1989); Faber et al. (1995); Costanza (1996); Costanza et al. (1999); Farber et al. (2002); Ropke (2004); Røpke (2005); Baumgärtner et al. (2008) offer further detail.

hypotheses, cause – effect analyses (Martinez-Alier et al., 1998; Costanza, 2001; Cilliers, 2005), where, consistent with a ‘normal science’ approach, these data are then used to predict some absolute truth about the future state of the system (Ramos-Martin, 2003).

The process of linear extrapolation does not reflect the dynamic, multifunctional, multidimensional, and thus multi trajectory nature of complex adaptive systems. This one dimensional interaction assumes monetary value taken from secondary qualities as equivalent to the value of primary qualities (Gren et al., 1994; Fromm, 2000). However, primary and secondary values are not substitutable; they should be viewed as complementary (Fromm, 2000). Primary value is found in the development and maintenance of ecosystems, in their capacity as self-organizing systems, secondary values are described by the output of anthropogenic goods and services (Gren et al., 1994).

Thus the evaluation of primary value is a consideration of the composition, structure and functionality of the ecosystem and as such cannot be valued in a monetary fashion, whereas secondary values reflect individual preferences which can, in principle, be evaluated through economic valuation methods (Fromm, 2000). However, because many of the ecological processes operating at local, regional, and global scales remain unrecognised, the value of natural resources, beyond its value from traded goods, rarely influences the decision making process (Farnworth et al., 1981). This perspective questions the use of a solely economic evaluation where science based investigation informs policy decision.

In contrast, ecological economics views the complex, adaptive socio-cultural – ecological - economic system from an interpretivist, phenomenological, position which deals with a biological world of open systems influenced by the internal characteristics of evolution, non-linearity, irreversibility and stochasticity (Costanza, 2001; Ramos-Martin, 2003; Cilliers, 2005). This approach takes a multidisciplinary perspective, which accepts differences in the units of measurements, populations of interest, spatial and temporal scales and their

anthropocentric ‘means and ends’ (Bockstael et al., 1995; Martinez-Alier et al., 1998; de Groot et al., 2002).

Mixed models, where ecological and economic values are seen through the lens of socio-cultural value, are developed from quantitative and qualitative data (Munda et al., 1995). Primary and secondary qualities and values are treated as separate and complimentary entities rather than surrogates (Funtowicz & Ravetz, 1994). Humans become a component of ecology, with ecology an integral component of inter and intra generational societal concerns (Costanza, 1996). The multi-criteria analysis position, taken by an ecological economics approach, rejects forcing multiple source data in to a single [monetary] evaluation ( Munda, 1997; Martin-Lopez et al., 2008; Gómez-Bagethun & Ruiz-Pérez, 2011). Economic valuation may result in the commodification of ecosystem goods and services with counter productive effects for the sustainable use of natural resources and equity of access to the benefits received from ecosystem goods and services provision (Gómez-Bagethun & Ruiz-Pérez, 2011).

Ecological economics takes a broader approach towards the understanding of the complex nature of the interactions between human and natural systems. However with this broad approach comes an acceptance of greater uncertainty, the dynamic nature of complex systems leads to fuzzy outcomes (Munda et al., 1995). Fuzzy outcomes develop possible scenarios not absolute truths. It is the interdisciplinary nature of this multi-criteria approach that has led to ecological economics being discussed as a post-normal science (Funtowicz & Ravetz, 2003; Funtowicz & Ravetz, 1994).

Decision making for sustainable use of natural resources need not always be based on discrete quantities such as the output from a traditional TEV calculation, with its associated commensurable and comparability issues. A fuzzy set multi-criteria approach which addresses decision making from a fuzzy relation scale may prove more appropriate when considerations

of data constraints and desired outcomes are addressed (Munda et al., 1995). This approach leads to questions such as; how does landscape x compare with landscape y, is x better than y, is x indifferent to y or is x worse than y (Munda et al., 1995).

## **2.6 Conclusion**

Humans have evolved as a component of the world's ecosystems; early in human history ecology was of practical interest, all individuals needed to know their environment, to understand the forces of nature and the plants and animals around them to survive. The survival nature of this relationship still holds true today, only the manner in which we express the inherent connectedness between social and ecological systems has changed. The value of natural resources has primarily been expressed in consumption, whether to sustain life or to provide financial benefit.

Despite society's growing realisation of being a component in an interconnected and interdependent complex social-ecological system, monetary valuation has become the dominant language in use to communicate the value of natural resources. Although societal, political and institutional decision-makers are well versed in the use of this common unit of 'value', the intrinsic value of the many benefits humankind currently receive from nature are often neglected, poorly understood and rarely adequately reflected in the daily decisions of citizens, society or business.

The fact that ecosystem goods and services have an economic value does not mean that economic benefits are the only focus for ecosystem evaluations. On the contrary, natural resources are essential to physical and mental well-being and survival for many reasons which the forcing of all values into an economic indicator will not capture. Whilst narrow definitions of the value provided by natural resources may be the most practical way to avoid issues that distinguish ecological 'means' from societal 'ends'. Allowance of both quantitative and

qualitative information that best describes the relationships in any specific social-ecological system can provide the basis for a more culturally inclusive and complex system description.

Ultimately the well-being of society and ecosystems are interdependent. The cultural perception of sense and experience of ecological and economic ‘values’ can be thought of as a meeting point between the worlds of ‘propositions’ and ‘things’. Here ‘value’ can be seen to be expressed from the view point of utility, where individuals measure the degree to which ‘value’ is produced by a present state of ecological and economic systems. In this manner ‘value’ can be described both by an expression of utility and also the extent to which ecological components, structures and functions are maintained. Society reconciles the natural world-human world dichotomy by becoming a component of a complex-adaptive social-ecological system.

This thesis now further explores the expression and integration of multiple values from social, ecological and economic value domains through the use of a fuzzy logic-based landscape evaluation. The following chapters describe the context for observations (chapter 3), social value (chapter 4), ecological value (chapter 5) and economic value (chapter 6) across a range of landscapes in which wood-fuel is produced. These values will then be brought together in a fuzzy logic model (chapter 7) where comparison of these evaluations and their component parts can be made. The approach taken in this thesis aligns itself with the principles of ecological economics which informs the work and discussions to come.

## **Chapter Three<sup>3</sup>**

### **Pilot studies; community landscape value and system boundaries**

#### **3.1 Summary**

Chapter 3 provides detail of pilot studies that took place at the projects outset, the objective of which was two fold. Firstly to explore preference-based expressions of community value held in their surrounding landscape. The intention here was to provide support for the use of a landscape evaluation technique that does not operate solely from the position of monetary valuation. Secondly to establish conceptual boundaries that limits observations and provides system definition for this thesis, as described by the selected case study sites.

This chapter examines the attributes of value held by natural resources within ecological, socio-cultural and economic value domains from the perspective of a rural UK community, and reflects upon the continued primacy for the monetary valuation of natural resources using two approaches – a scaled preference-based value typology and a place-based map measure. Here, data demonstrates that the societal relationships which inform the evaluation of natural resources are both multi-faceted and hierarchical. Moreover, that whilst aware of the utilitarian character of society's relationship with natural resources, the societal value-for-natural-resources relationship is primarily expressed using social-ecological qualities.

Society also needs a context within which to express value. Local institutional arrangements, formal and informal, describe community in a geographic sense. Community reflects the direct societal relationships with landscape through land-use. Thus, interaction between community, landscape and land-use through the agency of local municipal administrative boundaries is used to define boundaries within each case study location. Observation is conducted within an area where local social and economic structures interact with ecological resources to meet daily needs, connecting community and land-use with the local ecosystem.

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<sup>3</sup> Findings and analysis from this chapter have been brought together for publication. The paper is currently in review: Smith, D., Convery, I., Ramsey, A. & Kouloumpis, V. (in review) 'An expression of multiple values: the relationship between community, landscape and natural resource', *The Journal of Rural Studies*

The findings of this chapter provide support for exploring new methods of natural resource evaluation. New methods of evaluation must adopt multiple values that extend beyond a solely economic-based commodification concern to fully encompass the human relationship with the resources themselves. Wherein, a multi-faceted approach to attributing value to natural resources, set within an experiential framework, can provide a focal point for discussion and the decision making process.

### **3.2 The value of natural resources**

Despite reliance upon the capacity of ecosystems to provide essential ecosystem goods and services (Vitousek et al., 1997; Imhoff et al., 2004; Haberl et al., 2007), the loss of biodiversity and degradation of ecosystems continues on a large scale (Díaz et al., 2006; Butchart et al., 2010). The impact of human activities on the planet has now reached a stage where the cumulative losses in ecosystem goods and services are forcing society to re-appraise their evaluation and how their values can be better incorporated into societal decision making (Daly, 1991; Costanza et al., 1997; Daily et al., 2000; de Groot et al., 2002).

Out of these discussions ideas of finitude, resilience, diversity, equity and sustainability arise. However, the underlying ideology remains one of valuing natural resources (Costanza et al., 1997; Daily et al., 2000), where assessment of ecosystems, ecological process, and goods and services change ecosystem complexity and functions into the goods and services valued by humans (de Groot et al., 2002; Kontogianni et al., 2010). Contemporary concepts of ecosystem valuation use money as a common metric to translate environment and anthropogenic environmental impacts for political and institutional decision makers. Ecosystem components, structure and processes become synonymous with monetary value given to ecosystem goods and services (Spangenberg & Settele, 2010).

However, natural and socio-economic systems and landscapes are the result of many layers of natural process and human intervention, they are complex, adaptive, co-evolving systems, and

evaluation should completely reflect ideas of interconnection and integration (Norgaard, 1989; Martinez-Alier et al., 1998; Costanza et al., 1999; Spash, 1999; Røpke, 2005; Spash, 2012). Difference and incommensurability are also fundamental to any evaluation of system components, structure and process when described by ideas such as landscapes, communities, resource and service provision, diversity gradients, historical and cultural meanings (Martinez-Alier et al., 1998).

Systems that include humans can also be thought of as reflexively complex, in that awareness and purpose are also system components and should be considered when explaining, describing or forecasting their behaviour (Martinez-Alier et al., 1998). Correspondingly, there is a need for an interdisciplinary approach to the evaluation of society-natural resources dynamics (Munda, 1997; Costanza et al., 1999; Baumgärtner et al., 2008; Spash, 2012).

Arguably, complex social-ecological systems can only be understood through a heterodox approach to science (Martinez-Alier et al., 1998; Norgaard, 1989; Spash, 2012). Biological components are physical and thus embedded within the physical world, like-wise the socio-cultural world is embedded within the biological and the economic world operates within the socio-cultural (Spash, 2012).

### **3.2.1 The lexicon of value**

In terms of natural resources, the concept of value is complex. The concise Oxford dictionary, tenth edition, (Pearsall, 1999) definition describes value as '*the regard that something is held to deserve; importance or worth*'. Further the dictionary refers to a '*material or monetary worth*', value is ascribed units that express its '*regard, importance, usefulness or worth*'. These units cover a wide lexicological range *inter alia*; '*principals or standards of behaviour; a numerical amount; a magnitude, quantity, or number; the meaning of a word*' (Pearsall, 1999). Through the act of evaluation an estimation of importance or worth is carried out; a consideration of the '*value, quality, importance or condition*' (Pearsall, 1999).

Brown (1984) broadly summarises the conceptual sense of value as containing three elements; a preferential value, a numerical value, and a functional value. Values are also relatively abstract and situational; they hold spatial and temporal dimensions (Bengston, 1994; Brown et al., 2002; Jorgensen & Stedman, 2006; Brown & Raymond, 2007), attitudes toward value are place specific (Jorgensen & Stedman, 2006; Howley, 2011), they imply internal, subjective, user-specific goals, objectives or conditions (Farber et al., 2002), and preferences can vary between users, residents, outsiders and policy makers (Leiserowitz et al., 2006). In such instances placed-based social-ecological values can be seen as expressions of an underlying multi-dimensional network of factors involved in human-nature relationships (Convery et al., 2012). Values define or direct us to goals, frame our attitudes, and provide standards against which the behaviour of individuals and societies can be judged (Costanza, 2000; Farber et al., 2002).

In a definition of value that sought to encompass previous work on value typologies Schwartz and Bilsky (1987) describe values as; concepts or beliefs; about desirable end states or behaviours; they transcend specific situations; they guide selection or evaluation of behaviour and events; and are ordered by relative importance. Concepts of a preference related value directly involve choice and desirability, the placing of one thing before another because of some perception of '*better*' (Brown, 1984). In this context individuals assign value based on perception of the object under evaluation, their held values, preferences, and also the context of the evaluation (Brown, 1984).

Schwartz (1992) emphasises that values are cognitive representations of three universal human requirements; biologically based organism needs; social interactional requirements for interpersonal coordination; and social institutional demands for group welfare and survival. Thus, the outward expression of a society's values can describe the underlying normative and moral frameworks used to assign importance and necessity to beliefs and actions (Farber et al., 2002).

### **3.2.2 Community and natural resources**

Concepts of a value preference need a context in which to express the value, held values or underlying values (Brown, 1984). Ideas designed to connect held values with the landscape describe relationships where humans are considered as participative actors in the landscape; they live and work in it, and therefore value a landscape from this interactive perspective (Clement & Cheng, 2011). Environmental values have a spatial perspective that reflects commitment to a person's home and community (Brown et al., 2002). Here community describes a geographic situation where people meet their daily needs, with social and economic structure and a form of co-operatively engaged action such as local government (Brown et al., 2002).

Socio-cultural values are expressed through cultural identity, belief systems and attitudes that shape the normative and moral frameworks a society develops with the landscape that it creates and surrounds itself with (Farber et al., 2002; de Groot et al., 2010; Sauer & Fischer, 2010). A sense of place develops around the relationships and experiences humans have with natural resources, land, landscape and ecosystems (Williams & Stewart, 1998), and builds upon local knowledge and the connections people develop with their landscape (Borgstrom Hansson & Wackernagel, 1999). These experiences can be subjective, place specific and emotional (Schroeder, 1996). Individuals can hold plural identities, which may lead to different expressions of interest in their capacities as both consumers and citizens (Plottu & Plottu, 2007; Kumar & Kumar, 2008). In such instances preferences may appear mutable, and subject to change through, for example, education, advertising, peer pressure or legislation (Farber et al., 2002; Chee, 2004). Society's approach to the evaluation of landscapes should reflect connections between community and the local ecosystem and respect the significance of local lifestyles being adapted to a place specific context (Borgstrom Hansson & Wackernagel, 1999).

Schroeder (1996) suggests that in order to understand how people are related to environments we need to know how people experience these environments. However, modern societies have become removed from the local landscape as ecosystem goods and services are increasingly supplied from distant ecosystems (Borgstrom Hansson & Wackernagel, 1999). Signals that highlight the limits to human appropriation of ecosystem goods and services are lost, local lifestyles become less adapted to extant circumstances (Borgstrom Hansson & Wackernagel, 1999). Values become generic rather than specific as community becomes distanced from the consequences of its actions. However, observation of community incorporates the dynamics of society's direct relationship with landscape and land-use which influences the self-organisational properties and pattern formation of ecological systems, in a manner which acknowledges a role for social-ecological processes (Haila, 1999).

The objective of this component of the thesis is to explore the relationship between society and place-based value in a local landscape context, and identify boundaries that limit the scale of observation. The first element describes expressions of preference-based value towards the socio-cultural, ecological and economic evaluation of natural resources. The multi-faceted nature of value is investigated through the relationship community holds with natural resources in a local landscape context. Norms and attitudes towards value for natural resources are assessed using a preference-based value approach alongside an associated map-based measure of value.

In the second element conceptual boundary maps are produced from exploratory study trips that identified local connections between society and land-use within the two main study regions. These visits consisted of informal meetings and conversations with local government agencies, local institutional representatives and residents from each local community. This element takes a wholly descriptive approach to identify connections that define community relationships with the surrounding landscape.

### **3.3 Case study site selection**

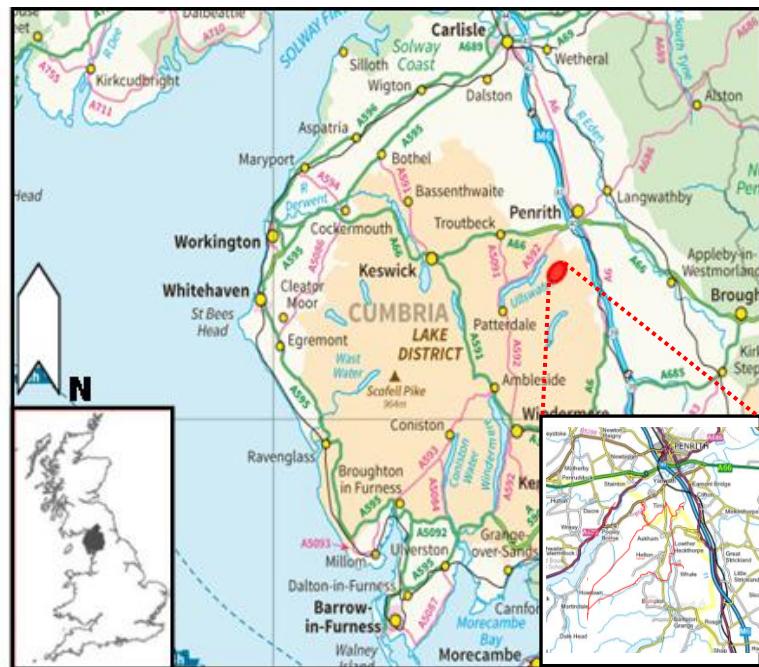
Case study site selection is based on similarity in economic and demographic attributes, relative to national levels, and difference in institutional arrangements towards woodland use. Using the county of Cumbria, in the northwest of England, as a reference point, European case study sites are found where economic and demographic data identify similarities in ‘marginal’ status but also, importantly, where there is a sustained functional, economic, cultural or historic relationship with a woodland landscape. ‘Marginal’, in the context of this study is described by levels of rurality, standards of living and economic activity.

The parish of Askham and Helton, Cumbria, in the United Kingdom was used to conduct a pilot study focused on the basis for a community’s expression of value held in the landscape that surrounds it. Exploratory observations from the European case study sites address the extent of connection between community, land-use and landscape. Perceived limits of interaction describe a boundary for study. Specific detail relating to the two study regions, within which the four study sites are located, is presented here to avoid repetition through the preceding data chapters

#### **3.3.1 UK pilot study area**

The parish of Askham and Helton is located in Cumbria, in the north-west of the United Kingdom, the parish covers an area of approximately 18 km<sup>2</sup>, of which 84% is classified as greenspace (Office for National Statistics, 2011) (Fig 3.1). Situated on the north-eastern edge of the Lake District National Park, the parish is a mixture of farmland, parkland and open fell, much of which is unenclosed common land, with a predominately agricultural and forestry focus (Askham Parish Council, 2010). Within the parish there are two villages Askham and Helton which comprise of 356 residents in 184 households, of which 164 are full time residences (Office for National Statistics, 2011).

National statistics provide characteristics that typify Cumbria, these show a lower than national average population density and lower than national amount of gross domestic product; 28.5% and 84.8% respectively (European Commission, 2013). Sheep represent the principal agricultural activity, and woodlands are a mixture of broadleaved and coniferous species mainly harvested for timber production, with a quantity of wood-fuel for local consumption (Pers. Obs.).



**Figure 3.1** Location of the study area, Askham and Helton parish, Cumbria in the UK; Askham and Helton parish identified by red circle, parish boundary identified by red line in the inset map. This map is reproduced from Ordnance Survey map data by permission of Ordnance Survey 2013, © Crown copyright.

### 3.3.2 European study areas

Case study sites were selected in the regions of Ioannina, North-West Greece, and Südbergenland, North-East Austria (Fig 3.2). These regions are described by comparative economic and demographic data (Table 3.1). Population densities are lower than their respective national average and, a lower than national average gross domestic product is indicative of the standard of living and economic activity.



**Figure 3.2** Location of European case study areas; Südburgenland, Austria, and Ioannina, Greece; red circles indicate study site locations. This map is reproduced from Google map, 2014.

Differences are identified across a spectrum of relationships, such as, land tenure, community institutions, local and national governance and the cultural lifescapes that inform ‘value’ decisions with respect to woodland, forestry and timber use (Hyttinen et al., 1999; Pelkonen et al., 1999; Zafeiriou et al., 2011). The respective woodland and forestry related sectors operate within different institutional environments, for example the mode of ownership and principal management techniques (Hyttinen et al., 1999). High levels of woodland cover and private ownership in Austria reflect the technological nature and high regional value of forest industry output (Czamutzian, 1999; Hyttinen et al., 1999). Whilst high levels of public ownership in Greece reflect specific historic and socio-economic conditions, the direct use value derived from pastoral grazing of wooded areas exceed timber revenue by a factor of 4:1 (Kazana & Kazaklis, 2005).

**Table 3.1** European case study sites profiles, selected countries follow a broad technological and socio-cultural gradient, data taken from (Pelkonen et al., 1999; Eder et al., 2005; Zafeiriou et al., 2011; European Commission, 2013).

	Südburgenland Austria	Ioannina Greece
<b>Regional demography:</b>		
Population density (% national figure)	66.8	43.3
Per capita GDP (% national figure)	62.1	67.5
<b>Woodland &amp; Forestry:</b>		
% of land cover	47.0	49.0
% of woodland used for forestry	60.0	26.0
Gross value of forestry (EUR)	846,000,000	92,000,000
Principal management techniques	Mechanised production & chainsaw forestry	Coppice, pastoral, production and chainsaw forestry
<b>Ownership structure (%):</b>		
Private	82	8
Public	15	65
Institutions, community, monastic	3	27
<b>Energy:</b>		
production from wood products	11% of total energy use. 22% – 40% of rural heating needs from biomass. Firewood represents 43% of total renewable use excluding hydro and 60% of total biomass use is in domestic and small installations.	69% of total wood production used as wood-fuel. Domestic use of wood provides 75% of energy produced from biomass

### 3.3.2.1 Case study sites, country profiles;

#### 3.3.2.1.1 Austria

Currently total woodland cover is 47% of total land area, of which 60% is actively managed (European Commission, 2013). Forest ownership structure is 82% private and 18% public, with private owners producing 88% of total roundwood production (Hyttinen et al., 1999).

Most holdings are small, many farmers own and manage their own woodlands and have become increasingly involved in biomass energy (Hyttinen et al., 1999). More than 213 000 owners manage forests of less than 200 hectares in area, which amounts to almost half of the total forest area. In 1993, about 140 000 forest enterprises of 1 – 5 hectares and 57 000 of 5 – 20 hectares were recorded (Czamutzian, 1999).

Biomass production currently accounts for 22% of rural heating and the aim is to increase this to 40% by 2020 (Eder et al., 2005). Entrepreneurial farmers are one of a number of factors that are thought to have significantly contributed to the success of the biomass sector (Eder et al., 2005). Around 10% of forest lands are pasture, many owners gain extra revenue from livestock grazing, hunting and increasingly from recreation (Czamutzian, 1999). Due to the high number of small forest owners and access difficulties in this mountainous country both harvesting machines and chainsaws are used for timber harvesting (Czamutzian, 1999). The mean annual removal/increment ratio is 0.66 (European Commission, 2013).

### **3.3.2.1.2 Greece**

Forest cover is currently 49% of total land area (Arabatzis & Malesios, 2011), however, only 26% is classified as productive from a forestry industry perspective (Hyttinen et al., 1999). The majority of this forest coverage, 98%, is considered to be natural whilst the remainder is plantation forestry (Hyttinen et al., 1999). Of the total productive forest land area 52% is managed for production purposes, both, timber and non-timber products or services are utilised (Kazana & Kazaklis, 2005). Sixty-five percent of forests and other wooded land are mainly publicly owned. Private ownership accounts for 8.0%, municipal 12%, while monasteries, charitable institutions and joint property make up 14.5% of total forest area (Zafeiriou et al., 2011). The principal types of silviculture system used are; coppice 46.8%, coppice with standards 16.8% and high forest 36.4% (Kazana & Kazaklis, 2005). The mean annual removal/increment ratio is 0.58 (European Commission, 2013).

Wood production is primarily of small dimension, less than 25cms in diameter, produced by coppice style management and used mostly for wood-fuel and biomass, circa 60%, with the remainder used for larger diameter technical wood production (Smiris, 1999). Aside from the direct timber related industries, the grazing of livestock in forests is an important component of the forest matrix (Hyttinen et al., 1999). Grazing is regulated by forest management plans, with open and closed areas for grazing operating around silviculture practice, stand condition

and susceptibility to grazing damage (Hyttinen et al., 1999). Forests are increasingly being used for recreational activities and are also extensively used by hunters, with watershed protection seen as an important element in the control of erosion and soil protection (Kazana & Kazaklis, 2005). In a Total Economic Valuation of forests, watershed protection and grazing accounted for 64% and 50%, respectively, of the total economic value (Kazana & Kazaklis, 2005). The high percentage reflects the importance within the context of forest resources management. The contribution of timber, firewood and hunting contributed 12%, 7% and 6% to TEV respectively (Kazana & Kazaklis, 2005).

### **3.4 Methods**

#### **3.4.1 The relationship between community, landscape and natural resources**

This pilot study consisted of two elements, a preference-based value questionnaire and a map-based value measure, both presented as components of a parish council survey to collect views from residents to update the local Parish Plan. Residents were invited to attend open sessions, held over a five day period.

##### **3.4.1.1 A preference-based value questionnaire**

The questionnaire contained nine preference-based value statements, three within each value domain; socio-cultural, ecological and economic (Table 3.2). Statements describe a value typology contextualised to represent the relationship between community, their surrounding landscape and the natural resources therein. The statements were constructed around descriptors used to express concepts of value associated with each value domain presented in Costanza and Folke (1997), Costanza (2000) and de Groot et al. (2002). Participants were asked to consider the qualities of their surrounding landscape, the areas, buildings and facilities within it that contribute most to the three value categories, as described by the value typology, and rate how closely each suggestion agreed with their own views. Typically the technique of quantifying individual attitudes and opinions, as described by its founder Rensis Likert, is conducted by asking participants to select one of five responses (McIver &

Carmines, 1981). In this thesis a preference-based value was indicated using a 5-point Likert scale where; 5 -strongly agree, 4 – agree, 3 – neutral, 2 – disagree, and 1 – strongly disagree.

**Table 3.2** A preference-based value typology; value preference statement, value basis, and value domain.

	<b>Value preference statement</b>	<b>Underlying value basis</b>	<b>Value domain</b>
1	A landscape that promotes vitality, physical and mental well-being.	Physical & mental health	Socio-cultural
2	A landscape that maintains local arts, customs, institutions and characteristics.	Cultural diversity & identity	
3	Fair and equal access to all aspects of the surrounding landscape.	Equity & equal allocation	
4	A landscape in which scarce and rare elements exist, now and in the future.	Scarcity & Rarity	Ecological
5	A mixed landscape of meadow, mountain, woodland, river and farmland.	Complexity & Diversity	
6	A landscape that protects and provides long term stability of the environment.	Integrity & Resilience	
7	A landscape that provides resources for consumption, now and in the future.	Sustainable & utilitarian	Economic
8	A landscape in which resources are produced efficiently and in large quantity.	Efficiency & Maximisation	
9	Landscape that provides resource which can be exchanged for monetary value.	Monetary valuation of goods, services & benefits received	

### **3.4.1.2 A map-based value measure**

Following the preference-based value exercise participants were introduced to a mapping element for soliciting place-based value. The method utilised is adapted from a series of projects by Brown (2005) which sought to identify and map landscape values to investigate human-landscape relationships. Participants were asked to identify places which hold a high sense of value in each of the three value domains within the Askham and Helton parish, three choices per value domain, and nine choices in total (Fig 3.3). Additionally participants provided a short descriptive sentence to capture the intended characteristics of each choice.



**Figure 3.3** Completion of the questionnaire and map exercise in Askham village hall.

### **3.4.2 Perceived limits of interaction describe a boundary for study**

This work draws from informal conversations with residents, local government and agencies, and observations of the researcher during initial exploratory visits to the selected study areas. These qualitative data are used to build conceptual maps of local connections between society and land-use for each of the study areas. Thematic grouping combines specific observations to build a single conceptual map which identifies potential points interaction at differing

hierarchical levels between and within the three ‘value’ domains, ecology, society and economy. This structure is then used to define a theoretical local system boundary, within which data collection and observations can be made for each European study location.

### **3.5 Analyses and results**

#### **3.5.1 Analyses**

##### **3.5.1.1 An exploration of preference-based values in a rural community**

Preference-based value statement data were non-normally distributed (Kolmogorov-Smirnov  $p<0.05$ ) so non-parametric statistical tests were used. A Kruskal-Wallis test explored difference in the expressions of value held in the surrounding landscape. Using the 5-point Likert scale, scores by participants grouped by value domain were aggregated. Participant scores indicate strength of agreement in each value domain; scores could range from 3 to 15. *Post-hoc* analysis, using the Nemenyi test, identified value domains where strength of agreement differs significantly. The Nemenyi test uses the sum of ranks instead of means for multiple pair-wise comparisons in a manner that parallels the Tukey test (Zar, 2009).

Ranking, using the sum of ranks, further examined community expressions of landscape value. To explore the possibility of a normative structure for preference-based value statements, a Kruskal-Wallis test sought to identify difference in the strength of agreement between the nine value statements. *Post-hoc* analysis, using the Nemenyi test, identifies preference-based value statements where strength of agreement differs significantly.

##### **3.5.1.2 A map-based value measure**

In contrast to the ideologically focused preference-based value statements, the map-based exercise asks participants to identify an attitudinal, physical and experiential reflection of the three value domain attributes, as defined by the preference-based value statements. This approach identifies value from a perspective of local knowledge and connection to the surrounding landscape.

Descriptive data characterises individual choices building primary groupings identified by specific landscape feature, area, building and facility within each value domain. Further consolidation into secondary level thematic groups builds a hierarchical model of participant's spatial responses to the value exercise. To explore the community lifescape relationships a Venn diagram visualises value connections. Intersections represent the connected nature of the community-landscape-natural resources value relationship.

### **3.5.1.3 Perceived limits of interaction describe a boundary for study**

Exploratory visits to the two case study locations were carried out through May-June 2011, Tsepelovo, Ioannina, Greece, and August 2011, Rechnitz, Südbergenland, Austria. Visits consisted of informal meetings and conversations with local government, representatives of regional government agencies, and local institutions, such as the mayoral administrative offices, government forest agencies, forestry co-operative representatives, local conservation groups, and bio-mass energy providers as well as residents from each local community.

These descriptive data informed the construction of conceptual maps for each case study location. Map construction was based on identification of components that describe interaction between community, landscape and land-use. Each component is further defined by connections between other components in the system, where pathways represent linkage points between and within the different components of each observed landscape.

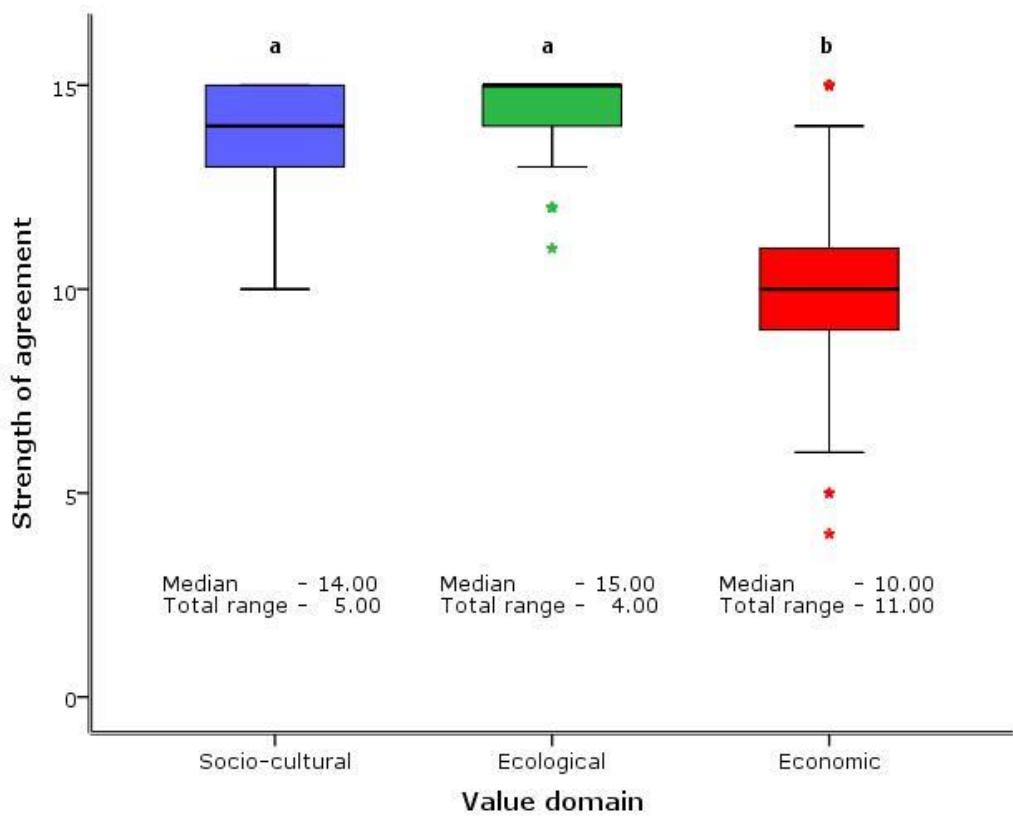
Broad thematic grouping around commonalities identifies a conceptual hierarchical structure between and within the three value domains. These thematic groupings inform the creation of an over arching conceptual structure that describes influence within each value domain for the conceptualised system. Spatial, organisational and temporal relationships are used to define a theoretical landscape boundary that connects community and land-use with the local ecosystem and sets the limits observation.

### **3.5.2 Results**

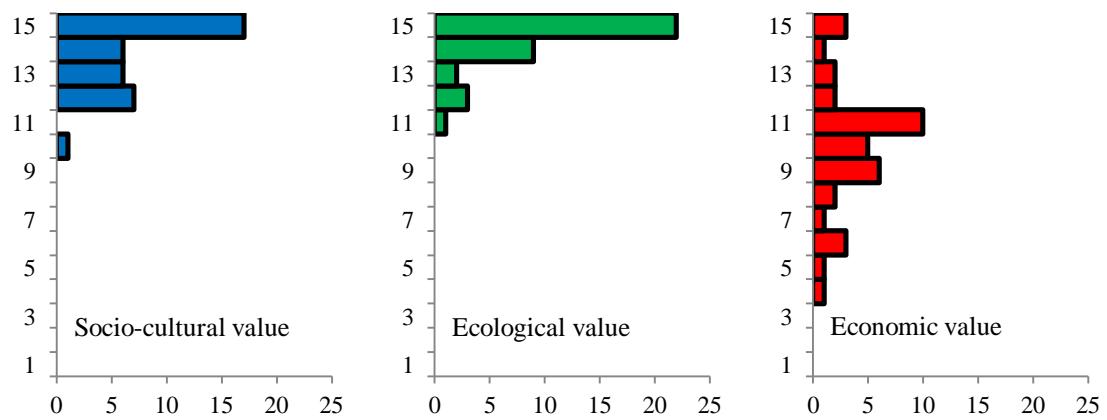
#### **3.5.2.1 An exploration of preference-based values in a rural community**

In total 37 responses were collected, these represent members from 25 of the 164 parish households in full time occupation. These data describe a participation rate of 12.5% from residents, 15.2% from households occupied on a full time basis. Responses to strength of agreement with the preference-based value statements, aggregated by value domain, were significantly different;  $\chi^2=52.993$ , df=2,  $p<0.001$  (Fig 3.4). Based on participant evaluation of the preference-based value statements parish residents express a higher and statistically significant different level of agreement with statements that reflect underlying socio-cultural and ecological values, compared against statements that reflect underlying economic values.

Figure 3.5 shows frequency data for participant strength of agreement by value domain. Participants show a higher level of agreement with socio-cultural and ecological value statements, described by the median figures, with a greater consensus about this expression of agreement as evidenced by the smaller total range of these data; ecological value – 4.00, socio-cultural value – 5.00, and economic value – 11.00. The strength of participant consensus around agreement with socio-cultural and ecological value preference statements becomes evident when proportional data for participant expression of agreement is set against those of neutrality and disagreement (Table 3.3). Proportionally more than 92% of participant responses express agreement with socio-cultural and ecological value preference statements, whilst only 44% express agreement with economic value statements.



**Figure 3.4** Difference in the strength of agreement between value domains,  $\chi^2=52.993$ , df=2,  $p<0.001$ ; agreement scores for the three questions within each value domain are aggregated by respondent prior to analysis; N=111. Black lines show medians, boxes show interquartile range and whiskers show total range (excluding outliers shown as stars). Letters denote homogenous subsets of value.



**Figure 3.5** Frequency data for the preference-based value questionnaire calculated by value domain; the x axis represents the number of participants; y axis represents score; and bars frequency; N=111.

**Table 3.3** Proportional data for strength of agreement responses by value domain.  
Participant responses for individual statement responses have been combined in to two groups, agree and neutral/disagree, for each value domain.

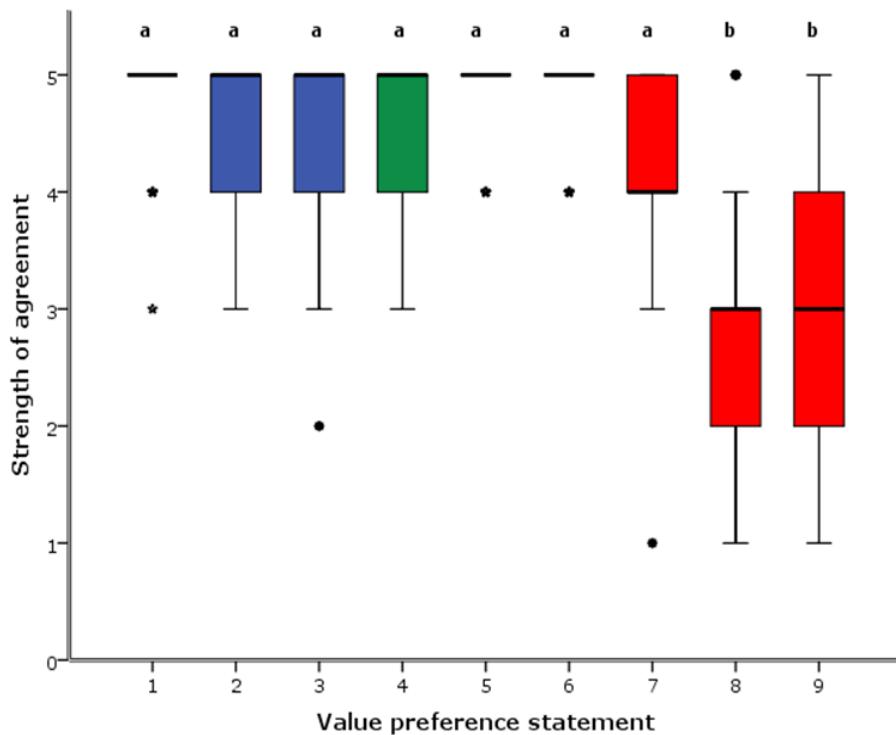
Value domain	Agree (%)	Neutral/Disagree (%)
Socio-cultural	92.8	7.2
Ecological	97.3	2.7
Economic	44.1	55.9

**Table 3.4** Ranking preference-based value statements by strength of agreement; the sum of ranks is used for ranking purposes, N=333.

Rank	Value domain	Value preference statement	Sum of ranks
1	Ecological	A mixed landscape of meadow, mountain, woodland, river and farmland	8211.41
2	Ecological	A landscape that protects and provides long term stability of the environment	8081.54
3	Socio-cultural	A landscape that promotes vitality, physical and mental well-being	8020.86
4	Ecological	A landscape in which scarce and rare elements exist, now and in the future	7119.91
5	Socio-cultural	Fair and equal access to all aspects of the surrounding landscape	6828.35
6	Socio-cultural	A landscape that maintains local arts, customs, institutions and characteristics	6669.62
7	Economic	A landscape that provides resources for consumption, now and in the future	5725.01
8	Economic	Landscape that provides resource which can be exchanged for monetary value	2543.38
9	Economic	A landscape in which resources are produced efficiently and in large quantity	2410.55

Ranking the individual preference-based value statements further demonstrates the strength of agreement around socio-cultural and ecological value statements over economic value statements (Table 3.4). Ecological value-based statements, which characterise the underlying values of complexity and diversity, integrity and resilience, and scarcity and rarity, occupy positions between ranks 1 - 4. Socio-cultural value statements, that characterise underlying

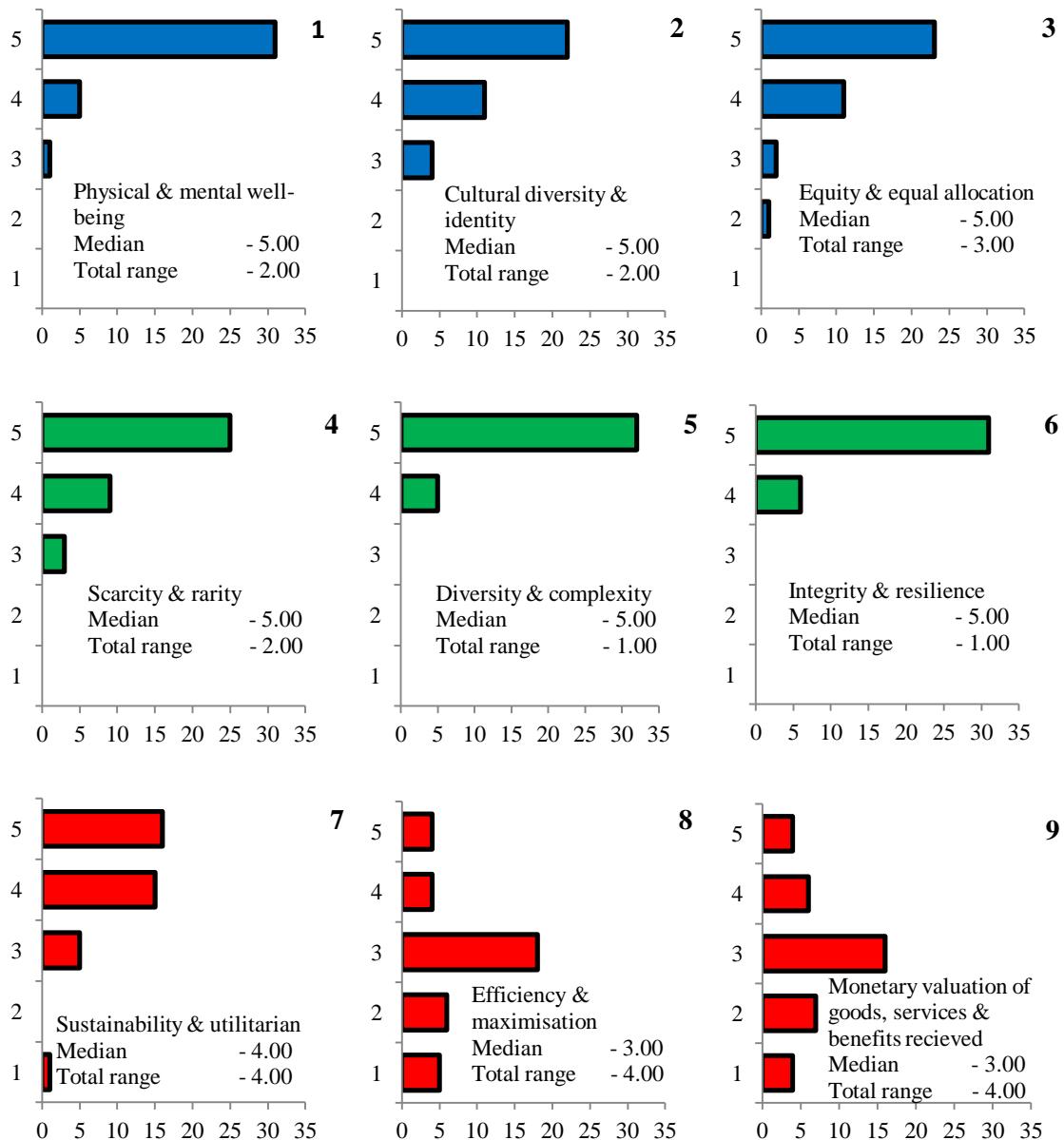
values of physical and mental health, equity and equal allocation, and cultural diversity and identity, occupy positions between ranks 3 - 6. Economic value statements, that are used to characterise underlying values of sustainability and utilitarianism, monetary valuation of goods, services and benefits received, and efficiency and maximisation, occupy ranks 7, 8 and 9.



**Figure 3.6** Difference between the strength of participant agreement for the nine preference-based value statements,  $\chi^2=145.738$ , df=8,  $p<0.0005$ ; N=333. Black lines show medians, boxes show interquartile range, and whiskers show total range (excluding outliers shown as stars and circles). Letters denote homogenous subsets by value statement.

Participant strength of agreement with the nine individual preference-based value statements shows significant difference;  $\chi^2=145.738$ , df=8,  $p<0.001$  (Fig 3.6). Parish residents express a higher and statistically significant different level of agreement with statements that are characterised by socio-cultural and ecological values along with the economic value basis of sustainability and utilitarianism. Participant strength of agreement is of a statistically significant lower level for value statements that reflect the economic value basis of monetary valuation of goods, services and benefits received, and efficiency and maximisation statements.

Figure 3.7 shows frequency data for participant strength of agreement by individual value preference statement. Participants express a higher level of agreement with socio-cultural and ecological value statements, with a greater consensus around this expression of agreement as evidenced by the smaller total range of these data.



**Figure 3.7** Frequency data for the preference-based value questionnaire calculated by statement, 1 – 9; the x axis represents the number of participants; y axis represents score; and bars frequency; N=333. Calculations are based on scores as follows; 5 – strongly agree, 4 – agree, 3 – neither agree nor disagree, 2 – disagree, 1 – strongly disagree.

The strength of a participant consensus around agreement is further evidenced, for all individual socio-cultural and ecological value preference statements as well as the underlying economic value of sustainability and utilitarian, when proportional data for participant expression of agreement is set against those of neutrality and disagreement (Table 3.5). Proportionally more than 83% of participant responses express agreement with value preference statements 1 – 7, whilst 73% express a neutral view or disagree with statements 8 and 9.

**Table 3.5** Proportional data for strength of agreement responses for individual preference-based value preference. Participant responses have been combined in to two groups, agree and neutral/disagree, for each value preference statement.

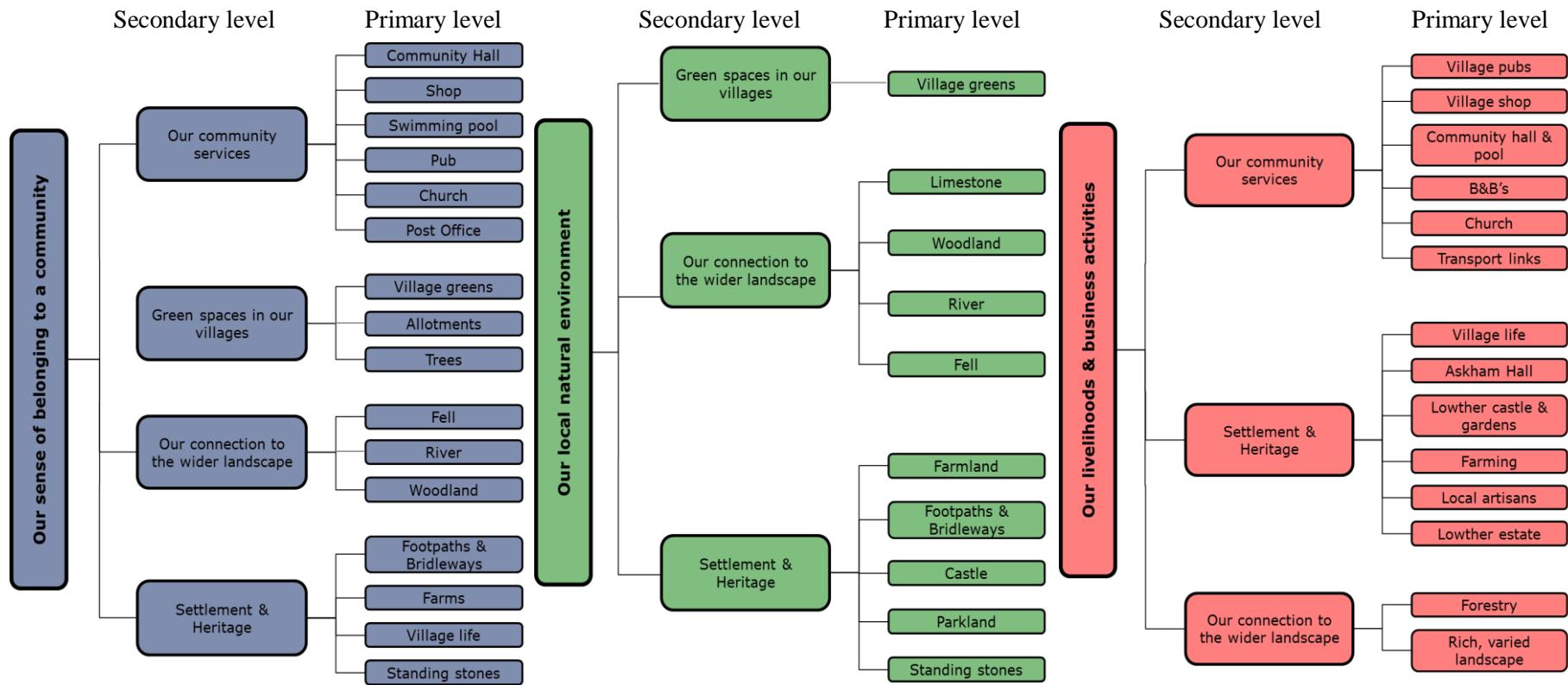
Value domain	Underlying value basis	Agree	Neutral/ Disagree
Socio-cultural	Physical & mental well-being	97.3	2.7
	Cultural diversity & identity	89.2	10.8
	Equity & equal allocation	91.2	8.8
Ecological	Scarcity & rarity	91.2	8.8
	Diversity & complexity	100.0	0.0
	Integrity & resilience	100.0	0.0
Economic	Sustainable & utilitarian	83.8	16.2
	Efficiency & maximisation	21.6	78.4
	Monetary valuation of goods, services & benefits received	27.0	73.0

### 3.5.2.2 A map-based value measure

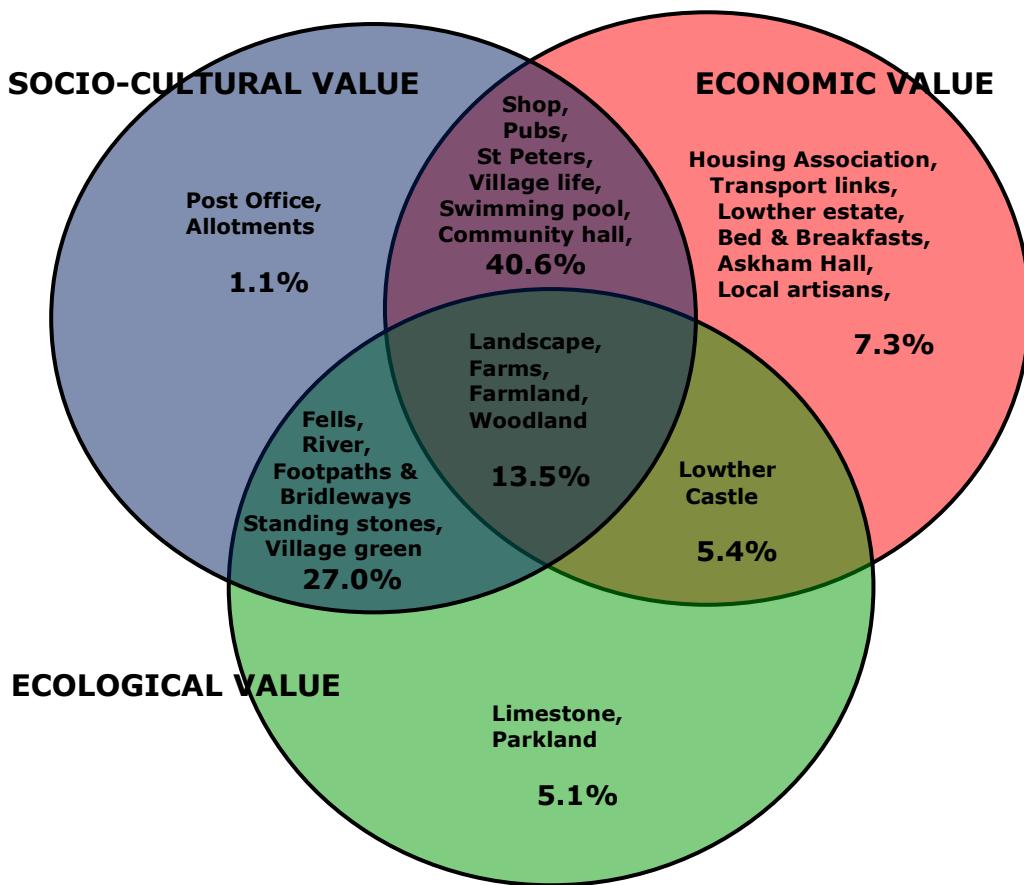
Location and descriptive data were grouped thematically within each value domain. These data informed the construction of hierarchical models (Fig 3.8); primary level labels were taken directly from location identifications and descriptive text, secondary level labels were assigned during the *post-hoc* thematic grouping process. Thematic groupings begin to describe the interconnected relationship between community and landscape. Only four thematic groups are required, across the secondary level, to capture all primary data from locations and descriptions over the three value domains. Further examination of the map-

based value data describes the level of connectedness between value domains, value in the landscape is multifaceted and interconnected (Fig 3.9).

Many of the selected landscape features, areas, buildings and facilities that participants feel contribute most to a sense of value in their community landscape represent multiple value domains. This suggests that participant selections are thought to simultaneously hold multiple value qualities. Using proportional data from the map-based value exercise selections that express qualities of two or more value domains represent 86.5% of all selections.



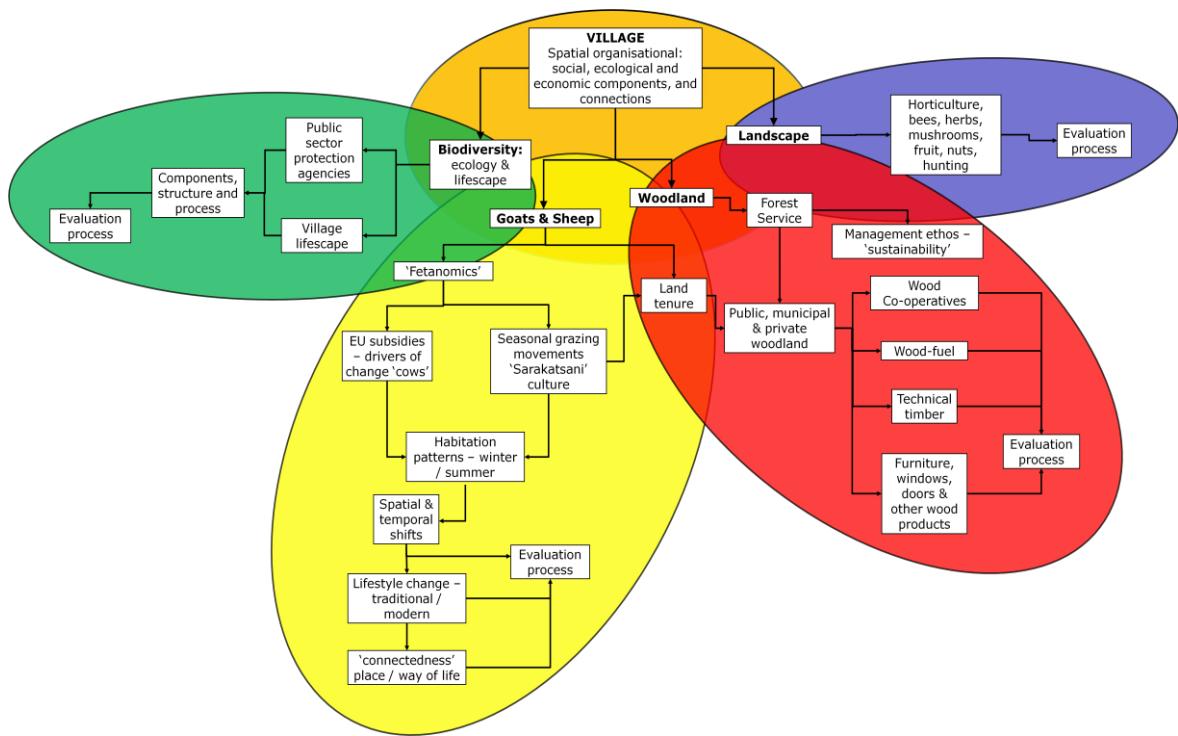
**Figure 3.8** Results of map-based value exercise, participants identified areas of the surrounding landscape, specific areas within it, buildings or facilities that contribute to a perceived sense of value within each of the three value domains. Within each value domain the identified elements have been grouped thematically, *post-hoc*.



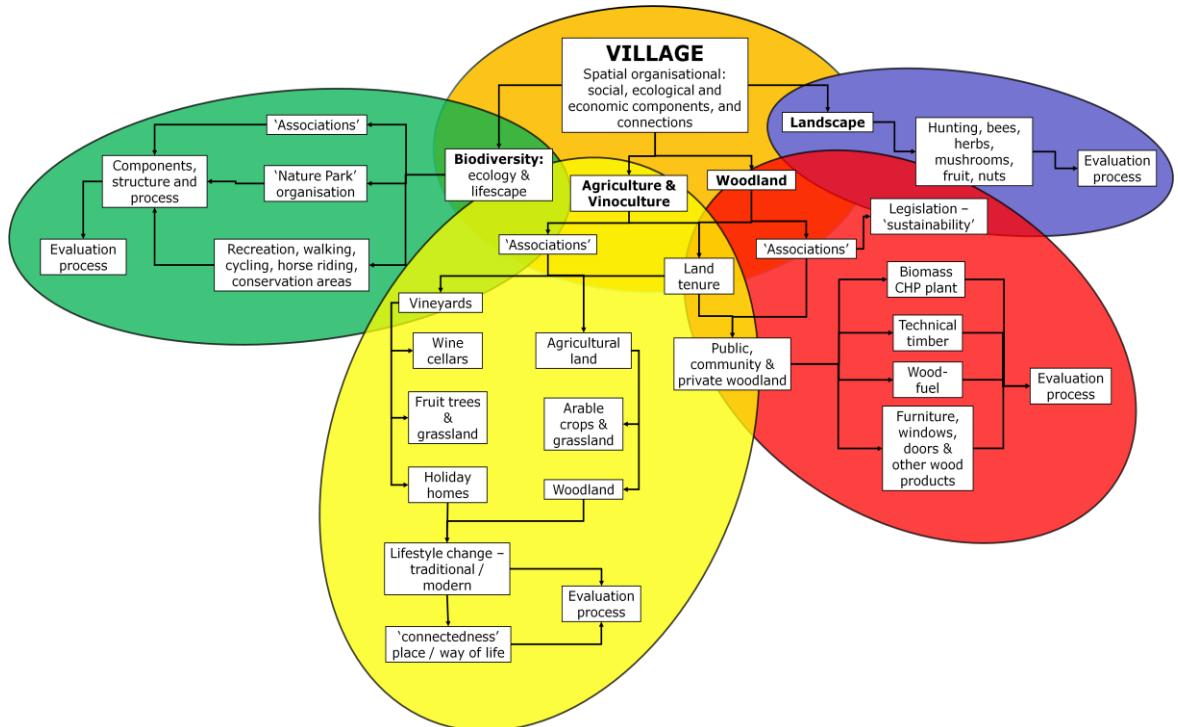
**Figure 3.9** A Venn diagram displays location choices by value domain; intersections represent the connected nature of the community-landscape value relationship. Selections centred on landscape, farms, farmland, and woodland were thought to hold a sense of value within socio-cultural, ecological and economic value domains. Numbers denote percentage of all selections; 86.5% of locations represent two or more value domains, 13.5% only one value domain.

### 3.5.2.3 Perceived limits of interaction describe a boundary for study

System components and connections identify interaction between community, landscape and land-use. Pathways which illustrate linkage between components create a conceptualised structure that describes the influence of community in to the surrounding landscape; Tsepelovo, Ioannina, Greece (Fig 3.10) and Rechnitz, Südburgenland, Austria (Fig 3.11). The proposed study communities display direct interaction with the landscape around them, principally through agricultural and arboriculture practices. In these relationships the dynamics of local land use will influence landscape components and structure which in turn influence the self organisational properties and pattern formation of the local ecological systems.



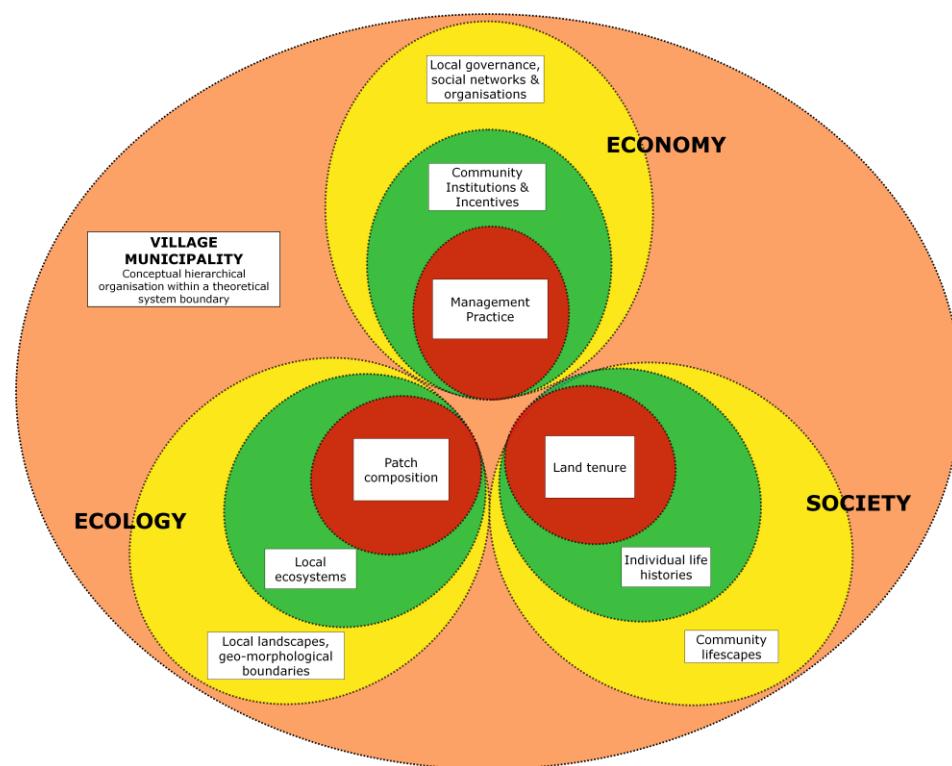
**Figure 3.10** A conceptual map of the local connections between community and land-use in Tsepelovo, Greece, study site.



**Figure 3.11** A conceptual map of the local connections between community and land-use in the Rechnitz, Austria, study site.

Thematic grouping creates a structure explained by local community influence. Figure 3.12 describes a simple two dimensional structure where interaction occurs within each of the three value domains, interaction will also operate between value domains on spatial, organisational and temporal scales. However, the aim here is to define a boundary explained by local community influence, within which this research will take place. In this context research observations suggest local socio-cultural, ecological and economic interactions take place within a conceptual space defined by the municipal administrative boundary.

This position accepts that boundaries are permeable, but allows for formal and informal socio-political institutional arrangements to translate external influence to local community. Thus, the influence of community on local landscape is seen as a determinative element in the community-land-use relationship, where natural resources are managed to produce goods and services for the benefit of humankind.



**Figure 3.12** Conceptual map of community influence on the local landscape, between and within the three value domains. Spatial, organisational and temporal relationships define a landscape boundary which connects community and land-use with the local ecosystem.

### **3.6 Discussion**

This element of the thesis examines value held in a landscape that surrounds a rural community through their strength of agreement for selected preference-based value statements and a map-based landscape value. The approach was designed to describe an underlying value basis which reflects difference in expressions of value towards natural resources and its use as described by three distinct value domains; socio-cultural, ecological and economic. Ideas rooted in underlying values, norms and attitudes are often seen to direct the concrete decisions and actions taken by individuals and groups (Bardi et al., 2008). Through the expression of value described by a community's relationship with natural resources the primacy for monetary value as the basis for a landscape evaluation exercise is considered.

Participants expressed strong agreement with preference-based value statements that promote socio-cultural and ecological value considerations to their surrounding landscape, over those that operate from a specifically economic position. These value statements describe a physical and experiential sense of connection to the surrounding landscape which clearly illicit strong expressions of preference, for example '*mixed landscapes*' where '*diversity and complexity*' build environments with '*integrity and resilience*' that '*protects and provides long term stability*' in a manner '*that promotes vitality, physical and mental well-being*'.

Consideration of the economic-based value statements further confirms this view. Participants express a preference for a utilitarian interaction with landscape when coupled with the idea of '*consumption now*' by the current community but also continued '*consumption*' for community '*in the future*'. Whilst the utilitarian nature of use comes from a position of self interest in the current individual, here, the idea is tempered with thoughts of community and insurance of use for future generations. However, attitudes toward statements that describe a relationship based on overt economic principals with a focus primarily on the current individual do not demonstrate a similarly high level of agreement, where '*resources are produced efficiently and in large quantity*' and '*can be exchanged for monetary value*'.

Strength of agreement, with value statements, is further consolidated by consensus around the level of agreement. A high level of consensus for agreement with ecological and socio-cultural value-based statements demonstrates the importance of the physical nature of the underlying relationship society has with landscape and land-use. Levels of consensus around the three economic value statements further describe distinct contrast between what maybe considered a physical and a transactional relationship with landscape. A high level of consensus around agreement for a sustainable utilitarian interaction with landscape is expressed, whereas value statements that directly imply transactional principals illicit a wider range of views. Consensus of opinion for value statements that reflect ideas of '*efficiency*', '*maximisation*' and '*exchange of natural resources for monetary value*' operate from a position of neutrality/disagreement.

Additionally, if one considers the map-based illustration of value held in the landscape, expressions of multiple value characteristics are observed. For example, landscape components thought to hold high value are considerably more likely to display qualities associated with more than one value domain. Inclusion of a place-based focus to ideas of value held in natural resources fosters acceptance of a broader range of values. Increasingly, to address the consequences of our utilitarian relationship with the natural world, the importance of biodiversity and ecosystems to human welfare is expressed by transactional concepts which produce a monetary valuation (Spangenberg & Settele, 2010).

Conventional monetary analyses convert both ecological and socio-cultural values to a currency based unit derived from artificial market solutions (Turner et al., 1994). Daly (1980) and Grant (2012) are amongst many who have written of the dangers of abstraction with respect to our relationships with natural resources. The creation of abstract entities, described by artificial market scenarios rather than concrete aspects of the physical environment, can work to separate behaviour from its physical consequences on environment (Grant, 2012). For Daly (1977; 1987; 1991), economics in a finite world employed without account for natural

capital stocks is ill-conceived and ignores outcomes of the community-landscape-natural resources relationship.

Natural capital stocks become substitutable with human capital (Daly, 1991; Costanza & Daly, 1992) and traditional community based societies move to a modern society model that operates from a position of self-interest (Wackernagel & Rees, 1997). The monetisation of natural resources feeds commercial interests and works to further the role of globalisation which introduces physical and emotional distance between production and consumption, and extends the role of self-interested individualistic behaviour (Wackernagel & Rees, 1997). This approach works to dis-embed cultural identity, belief systems, attitudes and intentions of humankind from any relationship with the natural world (Borgstrom Hansson & Wackernagel, 1999). Folke (2006) draws attention to the importance of considering human actions and their impacts upon ecosystem services, as part of a social-ecological system. Ecologists now recognise that most aspects of ecosystem components, structure and processes cannot be understood without accounting for the strong, dominant influence of humanity (Vitousek et al., 1997; O'Neill, 2001).

In the delineation of boundaries that describe the extent of direct influence the community has with its surrounding landscape system, albeit an open system, the intention here is to recognise that the scale of observation, for these studies, must be described at the outset. Community, as a geographical context, describes an area in which social and economic structures interact with ecological systems to meet the daily needs of its inhabitants (Brown et al., 2002). According to Brown et al. (2002) community can be a relatively distinct spatial area that reflects local values, attitudes and lifestyles. For this exploratory study, identification of system components and their linkage creates a structure that represents influence of the formal and informal institutional arrangements that connects community and land-use with the local ecosystem. '*Place is a powerful social influence in natural resource..... that can inform the study of natural resource politics*' (Cheng et al., 2003). Community presents a way to

integrate the biophysical and ecological attributes of place with social and political processes, and social and cultural meaning (Cheng et al., 2003). '*The concept of place embeds [natural] resource attributes back into the system of which they are a part...*' (Williams & Patterson, 1996).

Interaction with a local ecosystem provides a familiar institutional context, within which respondents can feel comfortable enough to express importance in a manner that reflects their preferred behaviour (Borgstrom Hansson & Wackernagel, 1999; Meinard & Grill, 2011). Where the expression of value seeks to capture local distinctiveness and aims to incorporate the role of multiple stakeholder views (de Chazal et al., 2008). Society and the values it holds are an integral component of a wider social-ecological system; nature should not be viewed as external to the expression of socio-cultural values (Adger, 2000; Chiesura & de Groot, 2003; Folke, 2006). Utilisation of this approach places the influence of society on landscape as a determinative element in the interactions between the ecological, societal and economic value domains. Here the aim is to describe the nature and fabric of ecosystems by plurality of concept, attribute and dimension, where complexity results from the multifaceted nature of connections, relationships and levels.

Conversion of ecological and socio-cultural values to a currency based unit, derived from artificial market scenarios (Turner et al., 1994), gives primacy to monetary based value solutions. The effects of non-monetisation for many components of the environment are ignored, with the focus shifting towards economic self-interest (Plottu & Plottu, 2007; Gómez-Baggethun et al., 2010; Spangenberg & Settele, 2010). Using monetary value as a measure of natural capital is misleading, change in market price imparts no information about changes to physical stocks and processes (Gómez-Baggethun et al., 2010; Spangenberg & Settele, 2010).

Expressions of socio-cultural value need to consider the relationships between community, landscape and natural resources; they should capture attitudes that influence this relationship and interactions with landscape and natural resources. The evaluation of ecosystem services needs to consider a broader set of goals that includes ecological sustainability and a societal perspective, alongside a monetary based economic component (Costanza, 2000; Straton, 2006; Spangenberg & Settele, 2010).

Acknowledgement of the interconnected nature of social and ecological systems (Folke, 2006) and the development of a pluralistic approach to value ( de Groot et al., 2002; Turner et al., 2003; Straton, 2006; Kumar & Kumar, 2008) encourages thoughts of variability and thus resilience. Here, the relationships between ecological dynamics, management practices and institutional arrangements express the inherent adaptive capacity of social-ecological systems (de Chazal et al., 2008). And what we know about nature becomes shaped by society's interaction with it ( Boulding, 1966; Meadows et al., 1972; Arrow et al., 1995; Costanza et al., 1997; Daily, 1997; Vitousek et al., 1997; Costanza et al., 2007; Ellis, 2011).

### **3.7 Conclusion**

Value can give meaning to landscape however meaning is not an inherent component of the nature of things. As demonstrated in this chapter, connections to physical space and an experiential knowledge gathered through the process of living in it allows meaning in landscape value to be fully expressed. Human perception, choice, and action drive political, economic, and cultural decisions that lead to or respond to change in ecological systems. This relationship is reciprocal; the physical nature of the environment will influence the socio-cultural interactions with it, but the nature of this interaction will influence the physical characteristics of the environment.

By necessity, such complex systems can not be evaluated, analysed and understood from one single point of view. Expansion of evaluation techniques that accommodate different values

and interests can provide models for sustainable landscape management in real landscapes with a functional ecosystem approach, applying economic, ecological and socio-cultural balance. Landscape evaluation must extend beyond the economic concerns of resource commodities to encompass the human relationship with the resource itself. Thus, a multi-faceted approach to attributing value to landscape set within an experiential framework will provide a concrete focal point where discussion can begin.

## **Chapter Four**

### **Socio-cultural value across a range of wood-fuel landscapes**

#### **4.1 Summary**

Chapter 4 explores the socio-cultural value, expressed by community, associated with a range of wood-fuel landscapes. These data inform the creation of socio-cultural value indices for use in building a wood-fuel landscape evaluation model, addressing research aim 1, and objective (a), of this thesis' identified thematic narrative:

- 1) To calculate a socio-cultural, ecological, and economic value for case study landscapes, in which land-use includes the provision of wood-fuel.
  - a) What is the socio-cultural value of the relationship between landscape, society and natural resources?

Adopting an approach consistent with Ajzen's Theory of Planned Behaviour (1991), community expressions of preference provide a measure of socio-cultural value held by each wood-fuel landscape. Individual assessment of attitudinal and normative-based socio-cultural value statements describes the socio-cultural, ecological and economic dimensions of the value relationship that community holds with the surrounding landscape.

Data collected exhibit similar patterns to the value relationships that community expresses for natural resources described in the preceding pilot study, chapter three. These data further demonstrate the multi-faceted and hierarchical nature of the societal relationships which inform the evaluation of natural resources. Societal value-for-natural-resources relationships are predominately expressed using social-ecological qualities. Moreover, whilst aware of the utilitarian character of society's relationship with natural resources, economic value statements that communicate overtly transactional characteristics do not illicit strong agreement.

These data also describe a contrasting nature between the attitudinal and normative-based socio-cultural value components. Attitudinal values differ to those that reflect the normative value response. Community attitudes towards natural resources value, across studied landscapes and value domains, differ significantly compared with community normative value expressions for the surrounding landscape. These findings are suggestive of a perceptual gap between society's attitudinal and normative behaviour towards natural resources.

Observed difference and similarity in participants' discriminative power for both attitudinal and normative-based behavioural preference statements, across the studied range of wood-fuel landscapes, provides support for inclusion into the wood-fuel landscape evaluative model (chapter 7).

#### **4.2 Introduction**

Chapter two outlined how society's relationship with natural resources might be described by a utilitarian ethic. Contemporary political and institutional decision making processes now operate from a perspective of hegemony which believes an answer to the sustainable use of ecosystem goods and services lies in the commodification of natural resources (Costanza et al., 1997; Balmford et al., 2002; Balmford et al., 2008). Increasingly total economic valuations have become the method of choice to measure the value associated with natural resources, for example see van Beukering et al. (2003); Jobstvogt et al. (2014); Morri et al. (2014).

However, research that illustrates the inherent qualities of a socio-cultural value for natural resources suggests that individuals struggle with the concept of assigning a monetary value to the many goods and services that ecosystem functions provide (Clark et al., 2000). Economic valuations continue to demonstrate that most 'value' resides outside of the traditional market place and is best considered as a '*non-tradable public benefit*' (de Groot et al., 2012; Morri et al., 2014).

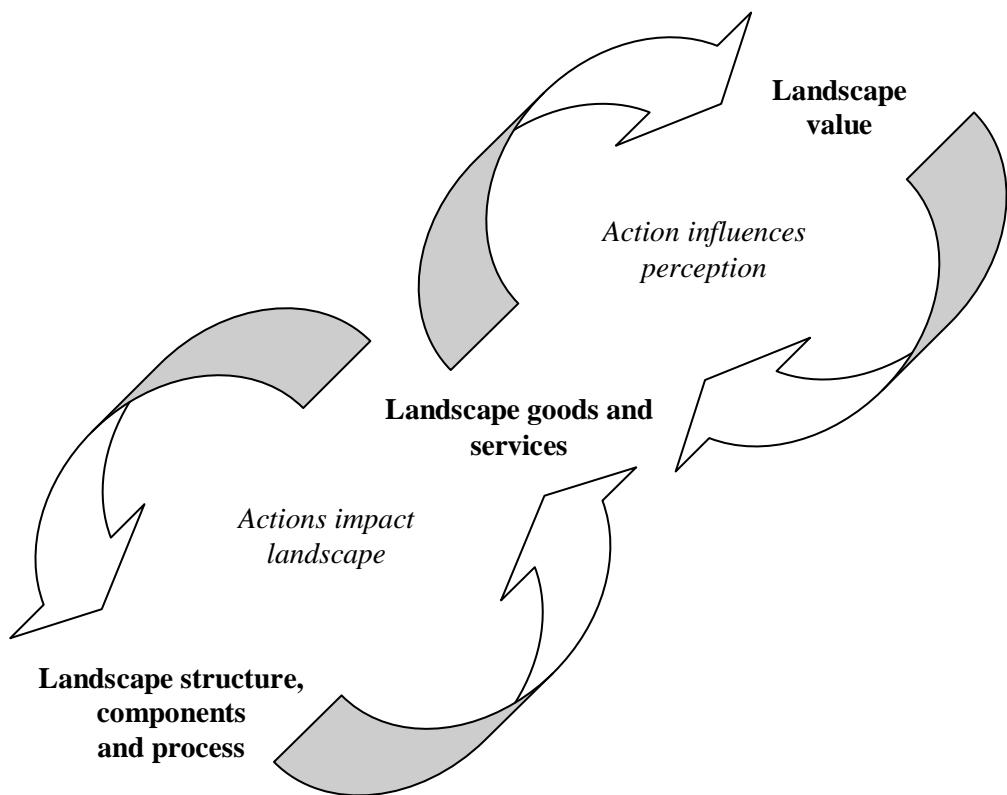
The pilot study, chapter three, indicates that an individual's expression of value for the landscape in which they live exhibits a preference for social-ecological qualities over economic qualities. Here, in chapter four, the community-landscape-natural resources value relationship is further explored through an investigation of individual response toward a normative-based value typology for natural resources, in two case study communities. Additionally an attitudinal-based socio-cultural expression of value is added to solicit community value across a range of woodland management scenarios, described within the two case study communities.

Community-based descriptors are presented to identify socio-cultural value associated with landscape by community. Interaction at a local scale provides a familiar context in which participants can express value in an informed manner that reflects attitudinal and normative preference. The aim of this chapter is to illustrate the nature of value held in the socio-cultural relationship with the physical nature of the environment from a reflexive, purposeful, participative perspective, within the specific context of each management scenario.

#### **4.2.2 Socio-cultural value in landscape**

Landscape as a concept can simultaneously be thought of as both place and the consequence of the human influence in a geographic space (Nassauer, 2012). When connected with ideas of sense of place, place-attachment, place-identity and place-dependence, landscape becomes a meeting point between nature and culture (Naveh, 1995; Manzo, 2003). The dualistic thoughts of a dichotomous human world-natural world relationship dissolve, and when viewed from an experiential position the twin subject-object perspectives of the natural world are left behind. Societal experience illustrates the community-landscape-natural resources value relationship from a holistic position. Society becomes more than just a consumer of landscape; people participate in ways that influence their understanding (Dakin, 2003).

The experiential place-based perspective gives voice to values and meanings which otherwise may not be expressed in contemporary political and institutional decision making (Cheng et al., 2003). People's relationship with place is a dynamic process, a conscious intentional contact between environmental and human phenomena in which people actively shape their own lives—here the process of perception leads to action which directly links human systems with ecosystems (Fig 4.1) (Gobster et al., 2007).



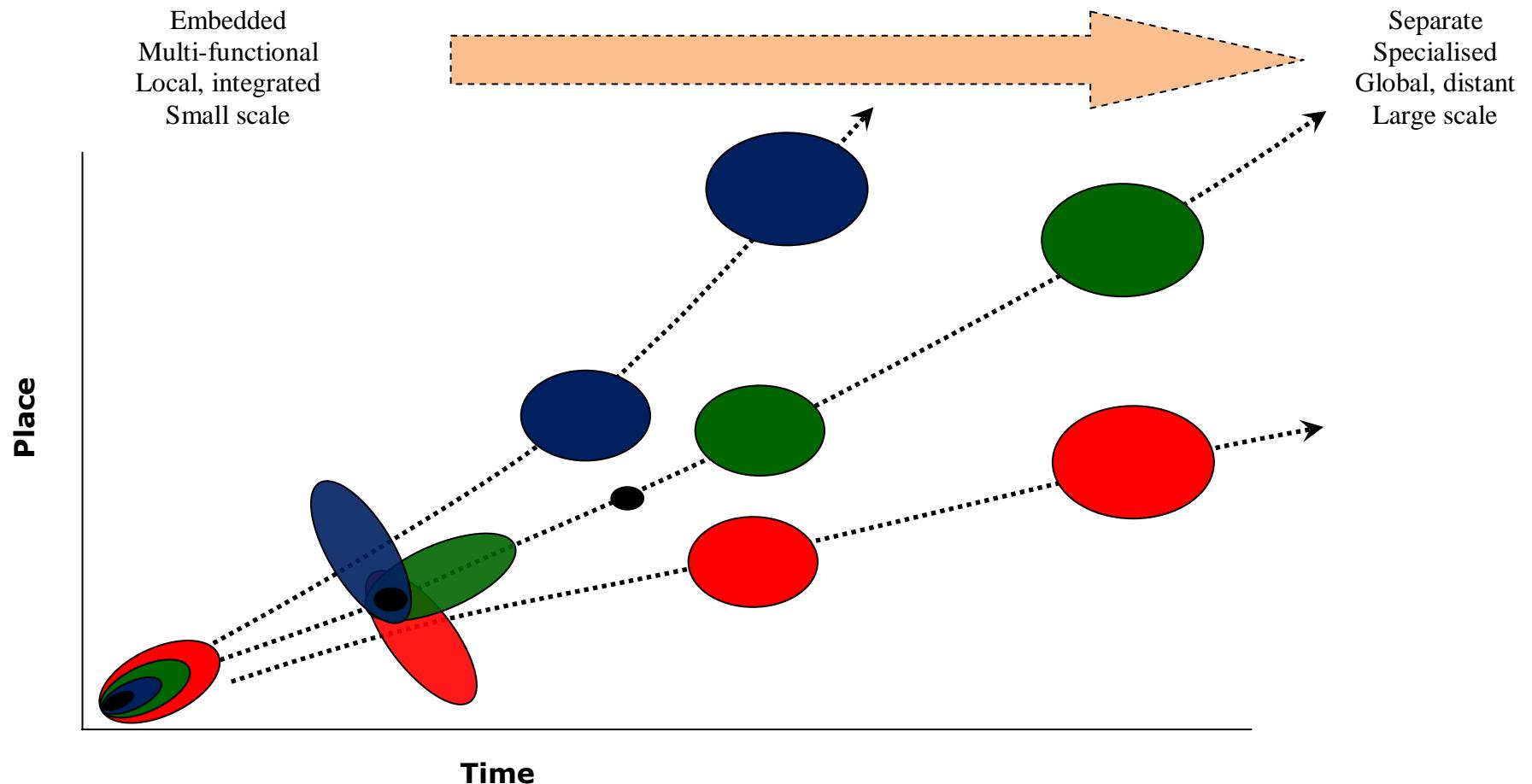
**Figure 4.1** The landscape structure, goods and services, value relationship in which human experience of landscape prompts human actions to change landscapes.

Whilst these processes of environmental change and human experience take place over a range of scales (Limburg et al., 2002), the scale of the surrounding landscape represents the human '*perceptible realm*' (Gobster et al., 2007). Landscape patterns become the locus around which people directly perceive environmental and landscape change (Nassauer, 2012). Thus, the experienced sense of landscape is arguably the most effective focal scale that

provides common ground to describe the interrelated nature of the community-landscape-natural resources value relationship (Wu, 2008). Through the medium of landscape, everyday experience can be linked with global scale phenomena: landscapes both integrate environmental processes and are visible (Nassauer, 2012).

Landscapes are the physical evidence of our cultural history and therefore the landmarks of the development of our culture. Landscapes are the expression of this dynamic interaction between environmental processes and cultural and personal experiences, as such they change over time (Antrop, 2005). Cultural changes to landscape result from repeated reorganisation of land to adapt its use and structure to better meet changing societal demands (Vos & Meekes, 1999; Jongman, 2002). Changes in the human relationship with the natural environment will define the essential characteristics of landscape (Jongman, 2002).

Prior to the end of the eighteenth century changes were local and gradual. Local needs determined local decisions and local problems were solved by local means (Vos & Meekes, 1999; Antrop, 2005). This approach was characterised by small scale multi-functional operations, where landscapes were created through gradual endogenous change influenced by pre-existing structures and components, refined by a variety of local and regional needs (Vos & Meekes, 1999). Modern society has evolved a more industrial approach to landscape grounded in a global dependency ethic, land-use became specialised with spatial segregation, such as monoculture fields and production forests, defined by conflicting interests (Jongman, 2002) (Fig 4.2).



**Figure 4.2**

Conceptualised view of society's changing relationship with landscape and land-use over time. Community moves from a position of local connectedness to one described by global distance; the black circle represents community and the coloured circles represent the concepts of functions, goods and services that community receives from landscape.

A functional production space approach removes society, and landscape only becomes landscapes when viewed from distance (Antrop, 2005). However, focus is now shifting toward a multifunctional sustainability space approach similar to a traditional management style, where landscape is made up of many parts which are at the same time both different and complementary (Claval, 2005). Landscape when refocused at the local scale removes distance between society and provides a vehicle to help integrate ecology, economy, people and place in sustainability research.

Through his examination of the human experience of 'place', Relph (1976: 61) concluded that the identity of a place is '*comprised of three interrelated components, each irreducible to the other - physical features or appearance, observable activities and functions, and meanings or symbols .....every identifiable place has unique content and patterns of relationship that are expressed and endure in the spirit of that place*'. Relph's three components of 'place' capture the ecological, '*physical features or appearance*', the economic, '*observable activities and functions*', and the socio-cultural, '*meanings or symbols*', constituents that express value for and in landscape. However, in a socio-cultural context these components of 'place' can not speak for themselves, they can only be identified when expressed by those who belong to the cultural context, and are in a position to observe and understand it (Brown et al., 2002).

Currently there is an emerging interest in research on relationships between individuals, communities and their environments, within the context of natural resources management. For example, Rogen et al. (2005) describe how environmental change, when perceived as degradation to the biophysical nature of landscape, influences the way community structure their relationship with their surroundings. Williams and Stewart (1998) describe how the concept of 'place' can be used as a framework for integrating the meaning and value ascribed to environment by society into the natural resources decision making process. However, Cheng et al. (2003) acknowledge that society's emotional and physical perceptions of place are typically excluded from natural resources decision making. Society's relationship with

‘place’ operates on emotional, symbolic and cultural levels that are typically excluded from the natural resources decision making process (Cheng et al., 2003). Landscape evaluation by society is composed of two basic elements, the biophysical characteristics influenced by human activities assessed from an objective perspective, and the perception of value assigned to the environment by people, assessed from a subjective perspective (Petrosillo et al., 2007).

#### **4.2.3 The evaluation of socio-cultural value**

Many contemporary methods of assessment centre on the use of monetary valuations that seek to translate socio-cultural value into an economic value context to address issues of lexicographic difference, incommensurability and weak comparability. Whereby, the accumulation of monetary expressions of value facilitates an aggregation exercise, in the manner of an information-processing exercise, to give meaning to the underlying societal expression of value (*c.f.* Ostrom, 2009; Hukkinen, 2014). The individual’s response derived from a market place setting becomes the nexus to enumerate value held by individuals and communities for the social-ecological systems that they participate in.

Socio-cultural values for the non-market social-ecological system goods and services received by society are revealed through observed economic behaviour based on in-direct market and hypothetical market scenarios (chapter 2). Values are then inferred from the induced economic utility/disutility decision (Turner et al., 1994). This approach allows for the inclusion of value obtained from the passive, indirect, or intrinsic [dis]-utility experience to a total value term (Turner et al., 1994).

Thoughts of passive use value first appeared in Krutilla’s (1967) paper, where Krutilla argued that society obtains utility through vicarious enjoyment of nature. This study and many others since its publication recognise that society expresses value for natural resources in ways not immediately captured by market-place valuation techniques. The evaluation of many goods and services derived from natural resources are difficult due to the absence of markets

(Venkatachalam, 2004). To overcome this problem many researchers have centred their interests on hypothetical market methods such as contingent valuation to recognise the importance of these passive, non-use, non-market goods and services (for a review of contingent valuation see Venkatachalam, (2004) and Carson et al. (2001)). Overlooking these components grossly underestimates the many goods and services that ecosystem functions provide (de Groot et al., 2012). The central thread of such studies is to reveal a monetary amount which would need to be taken from or given to an individual to keep their overall level of utility constant (Turner et al., 1994). However, the use of techniques like contingent valuation has been subject to much criticism both from inside and outside the discipline of economics.

Discussions around the use of market-based behavioural considerations to generate expressions of value for natural resources encompasses issues such as contextualising the hypothetical scenario and how much it might be worth in both monetary and non-monetary terms (Clark et al., 2000); feelings that values for nature were not commensurable with monetary valuation (Clark et al., 2000); whether people respond as consumers pursuing their own self interest, or as an ethical citizen judging matters from society's point of view (Nyborg, 2000; Ovaskainen & Kniivilä, 2005); the extent to which the task and context are sensitive to discussions about embedding, cultural identity and 'part-whole' biases (Bateman et al., 1997; Hoyos et al., 2009); whether something else such as buying moral satisfaction is being measured (Kahneman & Knetsch, 1992); do values represent prior preferences or artefacts, outside the question's intended scope, introduced in response to the question context (Fischhoff, 1991; Kahneman et al., 1999); and the possibility of trade-offs between wants and needs (Farber et al., 2002).

Notwithstanding these issues, economic valuation is seen as a pragmatic approach to convey information about the value of natural resources as means to halt the degradation of ecosystems and inform the sustainability agenda. However, many economic studies, such as

those referenced above, highlight some of the unintended consequences that can arise when using market-based behavioural considerations to generate expressions of value for natural resources. Utility/disutility trade-offs fail to fully capture the range of meaning and value that society perceives in the environment (Clark et al., 2000; Cheng et al., 2003).

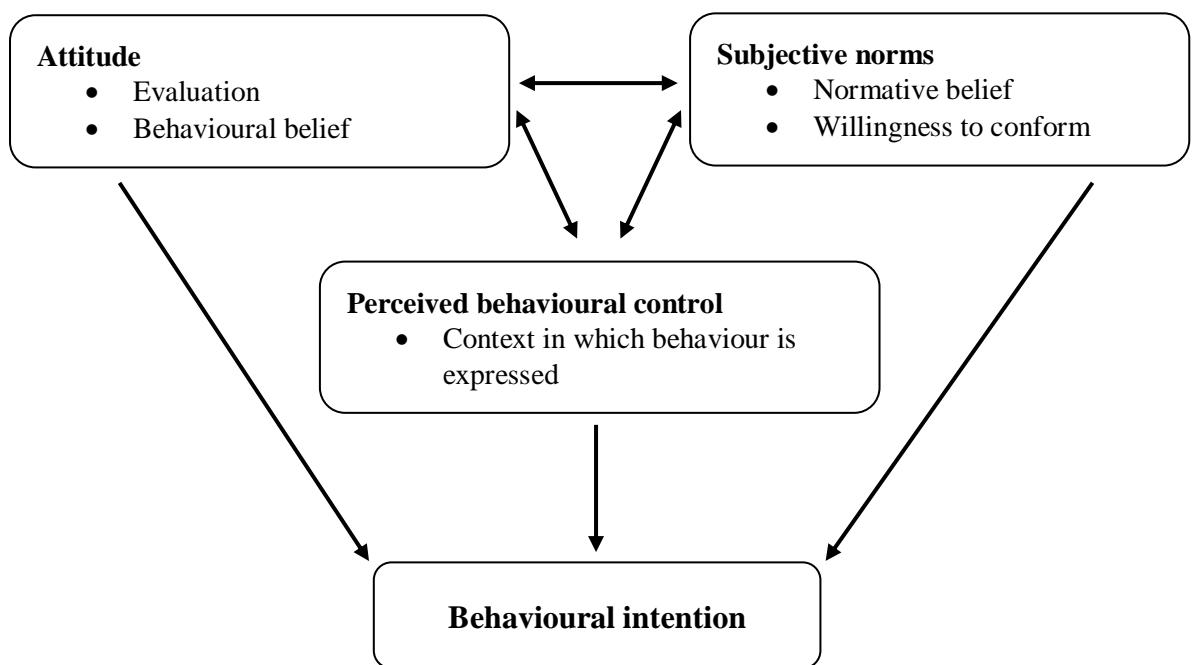
Society, when viewed as a component of a complex social-ecological system, is a reflexive, aware, and purposeful constituent of the community-landscape-natural resources relationship (Martinez-Alier et al., 1998; Munda, 2004). Money, when used to interpret the embedded qualities of this community-landscape-natural resources relationship, introduces focus on transactional qualities and fails to adequately account for the context specific, reflexive nature of human involvement and can work to remove ideas of methodological and individual value pluralism (Spash et al., 2009). Authors such as Spash (2002) and Spash et al. (2009) argue that standard socio-economic stated preference approaches are inferior to those of social physiology and philosophy, which offer better understanding of the motives behind responses to monetary valuation exercises.

#### **4.2.4 Theory of Planned Behaviour**

Different studies have measured respondent's behavioural-attitudinal responses in order to explain stated-preference monetary valuations for ecosystem goods and services, for example (Spash, 2002; Pouta, 2004; Ojea & Loureiro, 2007). In these studies the theory of planned behaviour has been used to explain monetary valuation, since a stated-preference can be considered as a behavioural intention (Ajzen, 1991). Ajzen's Theory of Planned Behaviour (1991) is grounded in rational choice deliberations (Kaiser et al., 2005). According to this theory, the immediate antecedent of any behaviour is the intention to perform the behaviour which itself is a function of the individuals' perceived control, their attitude towards the behaviour, and their subjective norms (Ajzen, 1991). Attitude is understood as a rational choice based evaluation of the behaviour's subjective utility, and an estimation of the likelihood of outcomes, whereas norms represent the strength of normative belief in socially

accepted standards as conveyed by peers, family, community or society (Ajzen, 1991). The perception of control refers to the ease or difficulty in performing the behaviour, and as such is context specific (Fig 4.3) (Ajzen, 1991).

Attitudes consist of an objective evaluative component, the degree to which carrying out the behaviour is positively or negatively valued by the individual, and a behavioural belief component, a subjective assessment of the consequences arising from the behaviour (Home et al., 2014). Norms consist of normative beliefs, the subjective assessment of what others may think of the behaviour, and the willingness to conform to the perceived wishes of others (Home et al., 2014).



**Figure 4.3** Diagram describing Ajzen's Theory of Planned Behaviour (Ajzen, 1991).

Much of the valuation of ecosystem goods and services literature makes use of economic trade-offs to determine a measure of value; preference is taken as the defining method by which individuals make choices (Spash, 2008). However, as Holland (1997: 486) argues, value for natural resources is more than just the external expression of an economic exchange

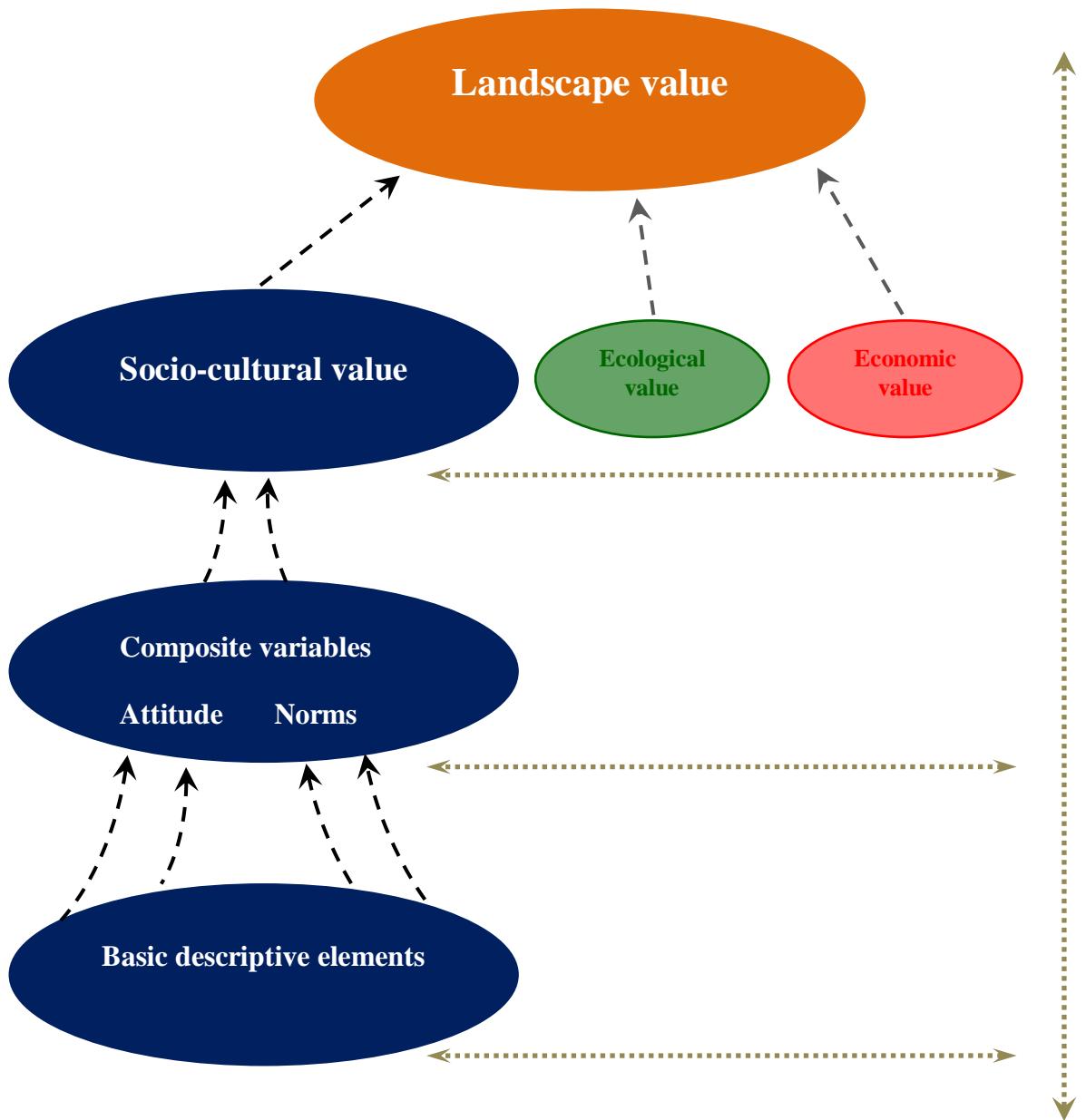
decision it flows from ‘.....deeply felt values and commitments which require a suitable context and process for their articulation....’. Concepts of preference formation involve choice and desirability, the placing of one thing before another because of some perception of ‘better’ (Brown, 1984). In this context individuals assign value based on perception of attitude, norms and the context of the evaluation. The use of concepts such as Ajzen’s Theory of Planned behaviour (1991) to measure a socio-cultural value reflects comments by Holland and Roxbee-Cox (1992: 20):

*Quite simply the proposal is to replace the view that values reflect preferences with the view that preferences reflect values. That is to say, preferences are no longer to be constructed as what constitute the environmental values; rather, they are to be constructed as surrogates for, or indicators of, some independently existing value’.*

Landscape is composed of social, cultural and physical elements that express form and function in an environment from a position where nature and culture are inseparable (Naveh, 1995). From this perspective socio-cultural values are expressed through cultural identity, belief systems and attitudes that shape the normative and moral frameworks a society develops with the landscape that it creates and surrounds itself with (Sauer & Fischer, 2010). It is this behavioural value rather than a monetary value that can best describe the socio-cultural component in any landscape evaluation. An approach grounded in behaviour deals with the issue of duality by placing landscape in an experiential context, communities and socio-cultural value are connected to economies and ecologies through landscape.

In adopting an approach similar to that of Ajzen’s Theory of Planned Behaviour (1991), the object of this component of research is to describe socio-cultural value associated with a range of woodland management and ownership case study landscapes, in which land-use includes the provision of wood-fuel. Attitudinal and normative variables are used to construct an index of socio-cultural value for each case study landscape. These variables are brought together in the fuzzy logic chapter of this thesis (chapter 7). These data describe the socio-cultural value

component to be used, alongside an ecological and economic value component, in the creation of a fuzzy logic landscape evaluation and assessment model (Fig 4.4). Relationships between and within ecological, socio-cultural and economic value components, observed across the studied range of woodland landscape and ownership, will also be described.



**Figure 4.4** Framework for the fuzzy logic landscape evaluation model; specific focus is given to the socio-cultural component. Black dashed arrows describe value pathway, brown dotted lines describe axes of relationship and interaction.

## **4.3 Method**

### **4.3.1 Study area**

Case study sites were selected in the regions of Ioannina, NW Greece, and Südbergenland, SE Austria. Study site selection is based on similarity in economic and demographic attributes, relative to national levels, and differences in institutional arrangements towards woodland use. Using the county of Cumbria, in the northwest of England, as a reference point, European case study sites are found where economic and demographic data identify similarities in ‘marginal’ status but also, importantly, where there is a sustained functional, economic, cultural or historic relationship with a woodland landscape. ‘Marginal’, in the context of this study is described by levels of rurality, standards of living and economic activity.

The regions of Ioannina, Greece, and Südbergenland, Austria provide areas with comparative economic and demographic data, whilst differences are identified across a spectrum of relationships, such as, land tenure, community institutions, local and national governance and cultural landscapes (Table 4.1). Landscape, seen as the interface between culture and an organism-centred natural perspective (Haber, 2004; Farina et al., 2005), provides a cognitive approach that informs ‘value’ decisions with respect to land, forestry and timber use. A review of study site characteristics and rational for study site choice has been completed elsewhere, see chapter three.

Hereafter, study sites will be referred to as: Forest Service (FS); wood pasture (WP); estate forestry (EF) and co-operative forestry (CF). Woodland boundaries are defined by the limits of local governance which reflect the extent of mayoral influence for each study community. This approach respects the observations described in chapter three where the dynamics of local land use, formal and informal socio-political institutional arrangements influence landscape components and structure. Community influence on local landscape is seen as a determinative element in the community-land-use relationship, where natural resources are managed to produce goods and services for the benefit of society.

**Table 4.1** Overview of case study landscape characteristics

<b>Location</b>	<b>Landscape</b>
Tsepelovo, Greece	<b>Forest Service</b> An area of Natura 2000 large scale near to nature woodland under public ownership, with a national management ethos that reflects contemporary issues of conservation and ecosystem goods and services
Tsepelovo, Greece	<b>Wood pasture</b> A cultural landscape of small scale wood and pasture under local private ownership, with a traditional multi-functional utilitarian approach to use and management
Rechnitz, Austria	<b>Estate forestry</b> large national scale forestry operation under private ownership, by a single entity, managed with a sustainable forestry approach
Rechnitz, Austria	<b>Co-operative forestry</b> woodland with many small scale local private owners brought together under a co-operative management association with a sustainable forestry approach

#### **4.3.2 Community questionnaire**

The study consisted of two elements, both presented as components of a community based questionnaire designed to collect views from residents. The components are considered as a normative and an attitudinal exercise, all documents relating to the collection these data can be found in appendix 1. Due to difference in community size, cultural views and practices the approach toward data collection was tailored towards methods that reflected local expert advice alongside the researcher's experience whilst employed in the collection of ecological and economic data. To this end two methods were used, face-to-face interviews and an online version of the questionnaire (using the Survey Monkey website). Tsepelovo data were collected June 2012 and the Rechnitz data were collected November 2013. Due to

In the Tsepelovo community residents were personally invited, by the researcher, to complete the questionnaire on a one to one basis. Residents of the Rechnitz community received an open invitation to complete an on-line version of the questionnaire through an article regarding the researcher and his work in the local community newsletter. Part one of the questionnaire consisted of a normative-based exercise which introduced respondents to

concepts of natural resource value described within three value domains; socio-cultural, ecological and economic. Part two consists of an attitudinal value measure which sought to ground value concepts presented in the first exercise in a place-based, experiential context. Questionnaire documents were translated using native Austrian and Greek speakers who were familiar with the thesis, understood the objectives and had an academic background. Face-to-face delivery in Tsepelovo was conducted using an interpreter also familiar with the study objectives.

#### **4.3.2.1 A normative-based value questionnaire**

The questionnaire contained nine preference-based value statements, three within each value domain; socio-cultural, ecological and economic (Table 4.2). Statements were constructed with reference to ideas presented in Costanza and Folke (1997), Costanza (2000) and de Groot et al. (2002) in which the relationships community holds with their surrounding landscape and the natural resources therein were examined through the creation of a value typology. Participants were presented with value statements adapted from the aforementioned typologies.

**Table 4.2** A normative-based value typology; value statement, value basis, and value domain.

	<b>Value statement</b>	<b>Value basis</b>	<b>Value domain</b>
1	A landscape that promotes vitality, physical and mental well-being.	Physical & mental health	
2	A landscape that maintains local arts, customs, institutions and characteristics.	Cultural diversity & identity	Socio-cultural
3	Fair and equal access to all aspects of the surrounding landscape.	Equity & equal allocation	
4	A landscape in which scarce and rare elements exist, now and in the future.	Scarcity & Rarity	
5	A mixed landscape of meadow, mountain, woodland, river and farmland.	Complexity & Diversity	Ecological
6	A landscape that protects and provides long term stability of the environment.	Integrity & Resilience	
7	A landscape that provides resources for consumption, now and in the future.	Sustainable & utilitarian	
8	A landscape in which resources are produced efficiently and in large quantity.	Efficiency & Maximisation	Economic
9	Landscape that provides resource which can be exchanged for monetary value.	Monetary valuation of goods, services & benefits received	

Prior to addressing the nine value statements participants were asked to consider qualities of their surrounding landscape, areas within it, buildings or facilities that contribute most to the three following categories of value; '*our sense of belonging to a community*'; '*our natural environment*'; and '*our livelihoods and business activities*'. Then, for each of the nine statements, participants were asked to rate how closely each suggestion agreed with their own views. Value preference was indicated using a 5-point Likert scale where; 5 – strongly agree, 4 – agree, 3 – neutral, 2 – disagree, and 1 – strongly disagree.

#### **4.3.2.2 An attitudinal-based token allocation exercise**

In contrast to the normative-based value statement exercise participants were next introduced to a token allocation element for soliciting value from a place-based, experiential perspective. The method utilised here is adapted from a series of projects by Brown (2005) which sought to identify and map landscape values in an investigation of human-landscape relationships. This approach identifies value from a perspective of local knowledge and connection to the surrounding landscape.

Participants were asked to consider the characteristics of each of the mapped, identified woodlands, the areas within them, the products and the facilities they provide that contribute most to the three following categories; '*our sense of belonging to a community*'; '*our natural environment*'; and '*our livelihoods and business activities*'. Participants were given twenty tokens of value for each category, sixty in total, and asked to allocate tokens between each identified area. Tokens were allocated according to the level that best describes the importance of the contribution participants felt each woodland area provides. Tokens could be distributed within each value category, and between woodland choices, to the value of twenty. Value was finite in nature and encouraged participants to express preference with only one combination that indicated equal value allocation, 10 – 10. The location constraints of the study sites resulted in the identification of two areas in Tsepelovo and four in Rechnitz.

Choices made by Rechnitz participants were aggregated, where areas 1 and 3 made up the estate-forest with 2 and 4 the co-operative-forest.

## **4.4 Analyses and results**

### **4.4.1 Analyses**

A primary comparison between normative and attitudinal based data was completed. Likert scale and token allocation data were converted to proportional values prior to analysis. Data displayed a mixture of normal and non-normal distributions so non-parametric statistical tests were used. Mann-Whitney U-tests explored difference between expressions of a normative response to natural resources and attitude toward natural resources in the local landscape for each of the case study landscapes. In test that require the ranking of observations, such as the Mann-Whitney U-test, a corrections for tied rank data is applied. Corrections are achieved by assigning the mean tied rank to all cases with tied values, and then a further tie correction is applied into the formula for the Z statistic.

#### **4.4.1.1 A normative-based value questionnaire**

The normative-based value statement data were non-normally distributed (Kolmogorov-Smirnov  $p<0.05$ ) so non-parametric statistical tests were used.

##### **4.4.1.1.1 Normative-based value aggregated by value domain**

A Mann-Whitney U-test explored difference between the two study countries in the strength of agreement for value statements when aggregated by value domain. Using the 5-point Likert scale, scores by participant grouped by value domain were aggregated. Participant scores indicate strength of agreement in each value domain; scores could range from 3 to 15. The Kruskal-Wallis test was used to identify difference within each country for the strength of agreement with the value statements, aggregated by value domain. Ranking and proportional frequency-based data assessments further examined community relationships with natural resources value.

#### **4.4.1.1.2 Normative-based value for individual value statements**

The comparison between norms at the country level was extended to cover the potential for difference between the strength of agreement for individual value statements. A series of Mann-Whitney tests examined difference in participant's strength of agreement for the individual value statements between the two study countries. To explore the possibility for normative structures in the strength of agreement for value statements, a Kruskal-Wallis test sought to identify difference in the strength of agreement between the nine value statements, within each country. Ranking and proportional frequency-based data assessment further examined community normative-based value structures.

#### **4.4.1.2 An attitudinal-based token allocation exercise**

The attitude-based token allocation data were tested for normality; token allocation for the individual value domains were non-normally distributed (Kolmogorov-Smirnov  $p<0.05$ ), and token allocation for total value were parametric (Kolmogorov-Smirnov  $p>0.05$ ), therefore non-parametric statistical tests were used throughout.

##### **4.4.1.2.1 Aggregation of the Rechnitz token allocation data**

Prior to the aggregation of token values derived from areas 1 with 3, and 2 with 4, in the Rechnitz token allocation exercise, data were tested for difference in participant response between each of the paired areas. Wilcoxon signed rank tests were undertaken to identify difference between token allocation for each value domain and total token allocation. Further examination of differences between Rechnitz areas 1 – 4, using Friedman's test, sought to identify community relationships between token allocation and geographic locations at this finer grain scale.

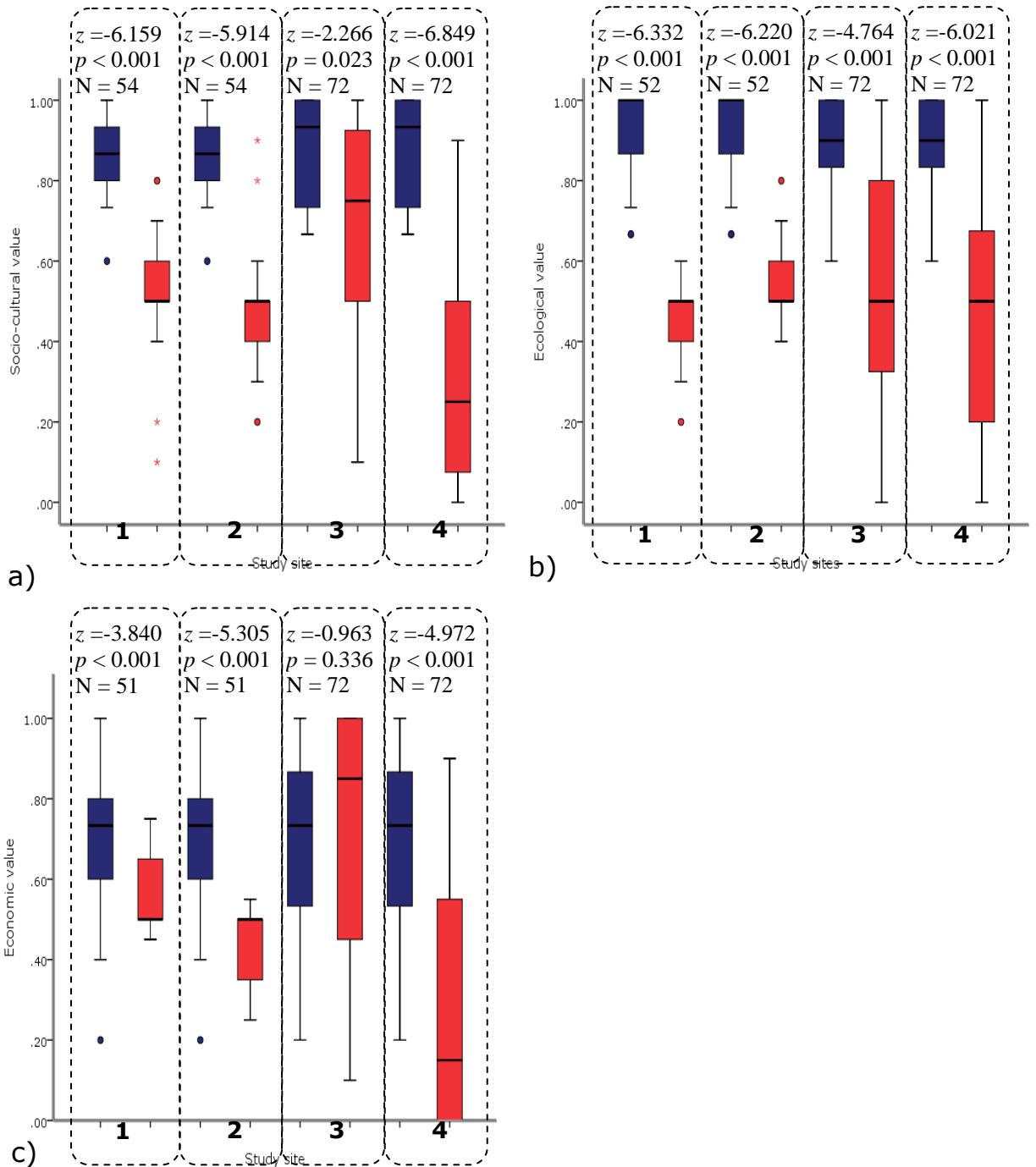
##### **4.4.1.2.2 Attitudinal-based token allocation by study site**

A Wilcoxon signed rank test explored difference between the total token allocations for each study site, within each country. A further series of Wilcoxon signed rank tests sought to

highlight community relationships between token allocation for specific value domains and geographic locations. Kruskal-Wallis and multi-sample median tests were used to describe the relationship of expressed value with the four woodland management scenarios.

#### **4.4.2 Results**

A total of 65 responses were collected across the two study countries. Responses represent 36 participants from the Tsepelovo community, Greece, and 29 from the Rechnitz community, Austria (23 complete and 6 incomplete). Comparison between normative and attitudinal responses for each value domain, across the four study landscapes, identifies statistically significant difference. Participant responses reveal difference between normative and attitudinal belief in regard to community relationships with natural resources and the use of landscape (Fig 4.5).

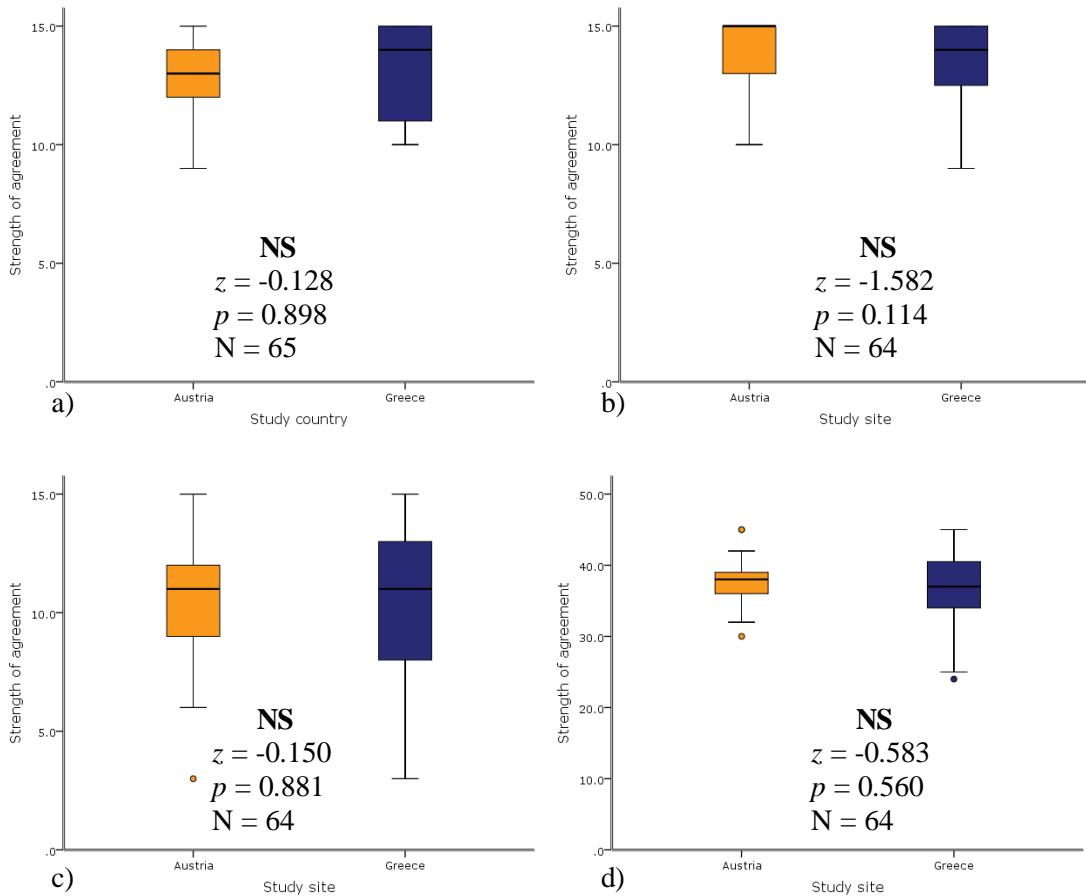


**Figure 4.5** Difference between normative and attitudinal belief in regard to participant's relationship with natural resource and use of landscape. Boxplots show responses to normative and attitudinal based questions by value domain; a) socio-cultural value, b) ecological value, and c) economic value. Responses are converted to proportional values prior to analysis. Black lines show medians, boxes show interquartile range, whiskers show total range (excluding outliers shown as circles). Colour indicates norms and attitude where; blue – norms, red – attitude. Numbers denote study site; 1 – co-operative forestry, 2 – estate forestry, 3 – wood pasture, and 4 – Forest Service.

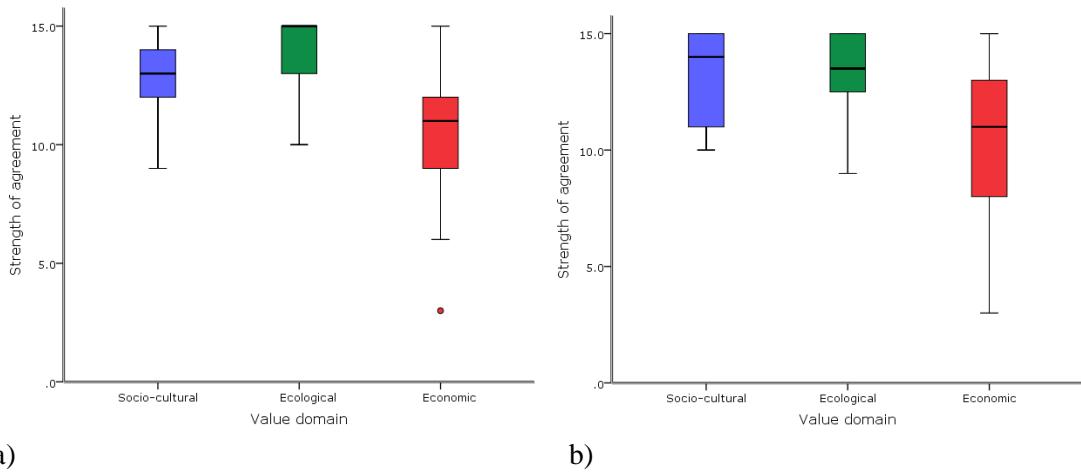
#### **4.4.2.1 Normative-based value aggregated by value domain**

Comparisons between the Greek and Austrian response did not identify statistically significant differences in participant strength of agreement with aggregated value statements. Participant strength of agreement with the normative-based value statements, when aggregated by value domain or as an aggregated total, was found to be comparable (Fig 4.6).

A similar participant response was observed in difference between the three value domains, within each of the two study countries. Results of a Kruskal-Wallis test show statistically significant difference between the strength of agreement with value statements aggregated by value domain (Fig 4.7). Higher levels of agreement are expressed with socio-cultural and ecological values in both Austria and Greece.



**Figure 4.6** Box plots show participant's strength of agreement with aggregated value statements; a) socio-cultural value, b) ecological value, c) economic value, and d) total normative value. Strength of agreement scores for the three questions within each value domain and the three value domains are aggregated by participant prior to analysis; NS – no significant difference. Black lines show medians, boxes show interquartile range, whiskers show total range (excluding outliers shown as circles). Colour indicates country where; orange – Austria, blue – Greece.



**Figure 4.7** Difference in the strength of agreement between value domains for each country; a) Austria,  $\chi^2=25.912$ , df=2, p<0.001, N=85; b) Greece,  $\chi^2=17.868$ , df=2, p<0.001, N=108; strength of agreement scores, for the three questions within each value domain, are aggregated by participant prior to analysis. Black lines show medians, boxes show interquartile range and whiskers show total range (excluding outliers shown as circles). Colour denotes specific value domain where; blue – socio-cultural, green – ecological and red – economic.

**Table 4.3** Proportional data for strength of agreement responses by value domain. Participant responses for individual statement responses have been combined into two groups, agree and neutral/disagree, for each value domain.

#### a) Austria

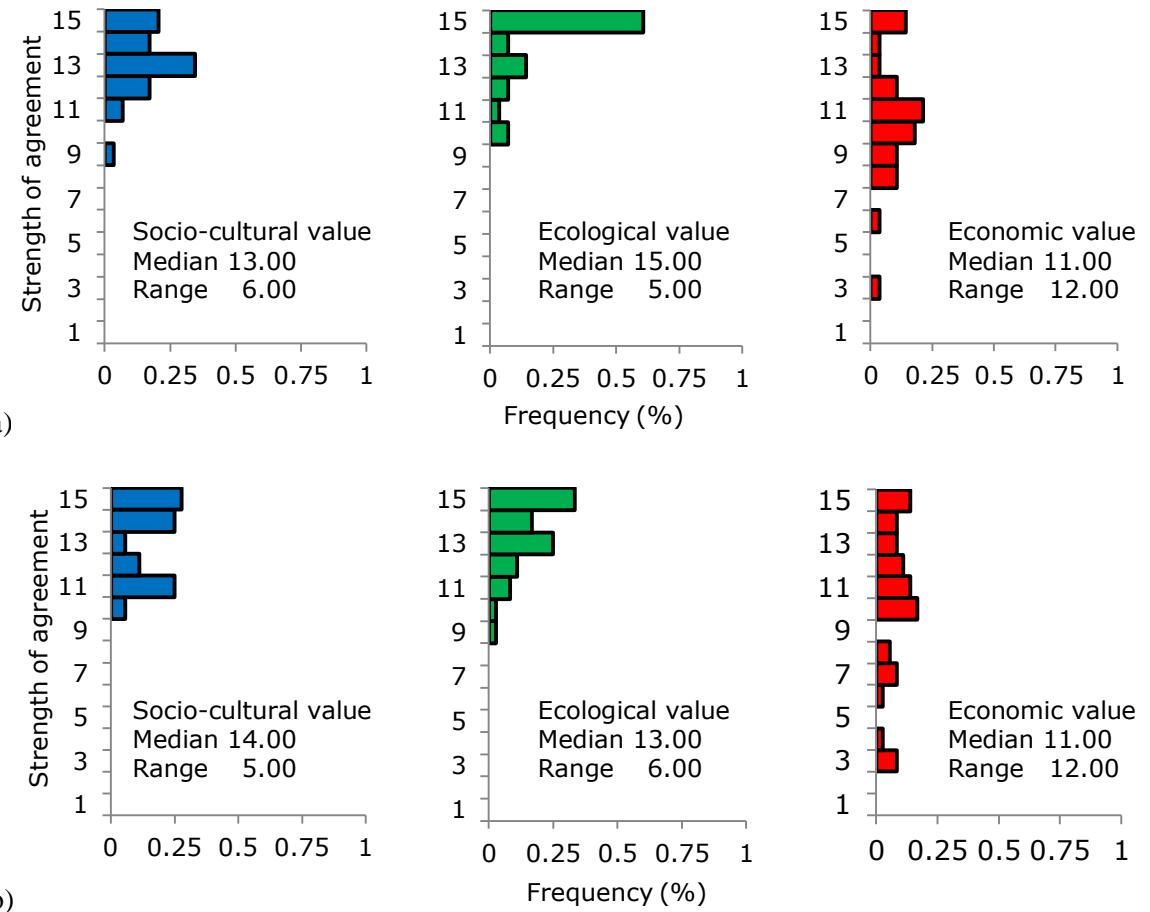
Value domain	Agree (%)	Neutral/Disagree (%)
Socio-cultural	86.2	13.8
Ecological	90.5	9.5
Economic	54.8	45.2

#### b) Greece

Value domain	Agree (%)	Neutral/Disagree (%)
Socio-cultural	83.3	16.7
Ecological	88.0	12.0
Economic	54.6	45.4

The strength of this agreement with socio-cultural and ecological value statements becomes evident when proportional data for participant expression of agreement is set against that of neutrality and disagreement (Table 4.3). Proportionally more than 83% of participant

responses express agreement with socio-cultural and ecological value statements, whilst only 54% express agreement with economic value statements.



**Figure 4.8** Frequency data for the normative-based value statement, calculated by value domain; a) Austria, b) Greece. The x axis represents a proportional figure based on score frequency and the number of participants; y axis represents strength of agreement; bars frequency;  $N_{a,SC}=29$ ,  $N_{a,Ecol,Econ}=28$ ;  $N_b=36$ . Using a 5-point Likert scale for scoring, strength of agreement scores, for the three questions within each value domain, are aggregated by participant. Scores could range from 3 to 15. Colour denotes specific value domain where; blue – socio-cultural, green – ecological and red – economic.

Figure 4.8 describes frequency data for participant strength of agreement by value domain.

Not only did participants express stronger agreement with socio-cultural and ecological value statements, described by median figures, the consensus about this level of agreement was greater as evidenced by the smaller total range of these data; social-ecological values – 6.00, and economic values – 12.00.

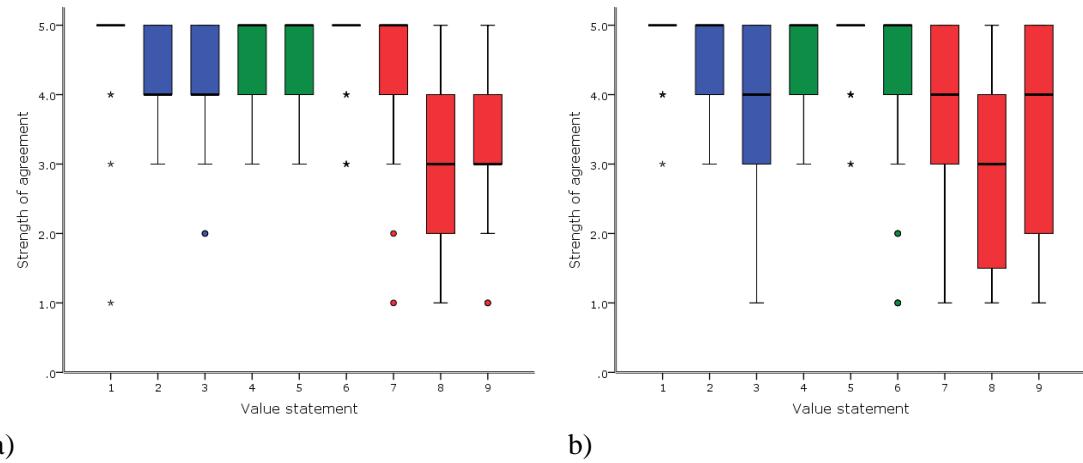
#### 4.4.2.2 Normative-based value for individual value statements

An analysis of the individual normative-based value statements further indicates comparability in participant responses across the two study countries. Mann-Whitney tests, looking to identify difference in strength of agreement, demonstrate that agreement with the individual value statements does not differ statistically between the two countries (Table 4.4).

**Table 4.4** A series of Mann-Whitney tests explores difference between participant's strength of agreement for the individual value statements across the two study countries.

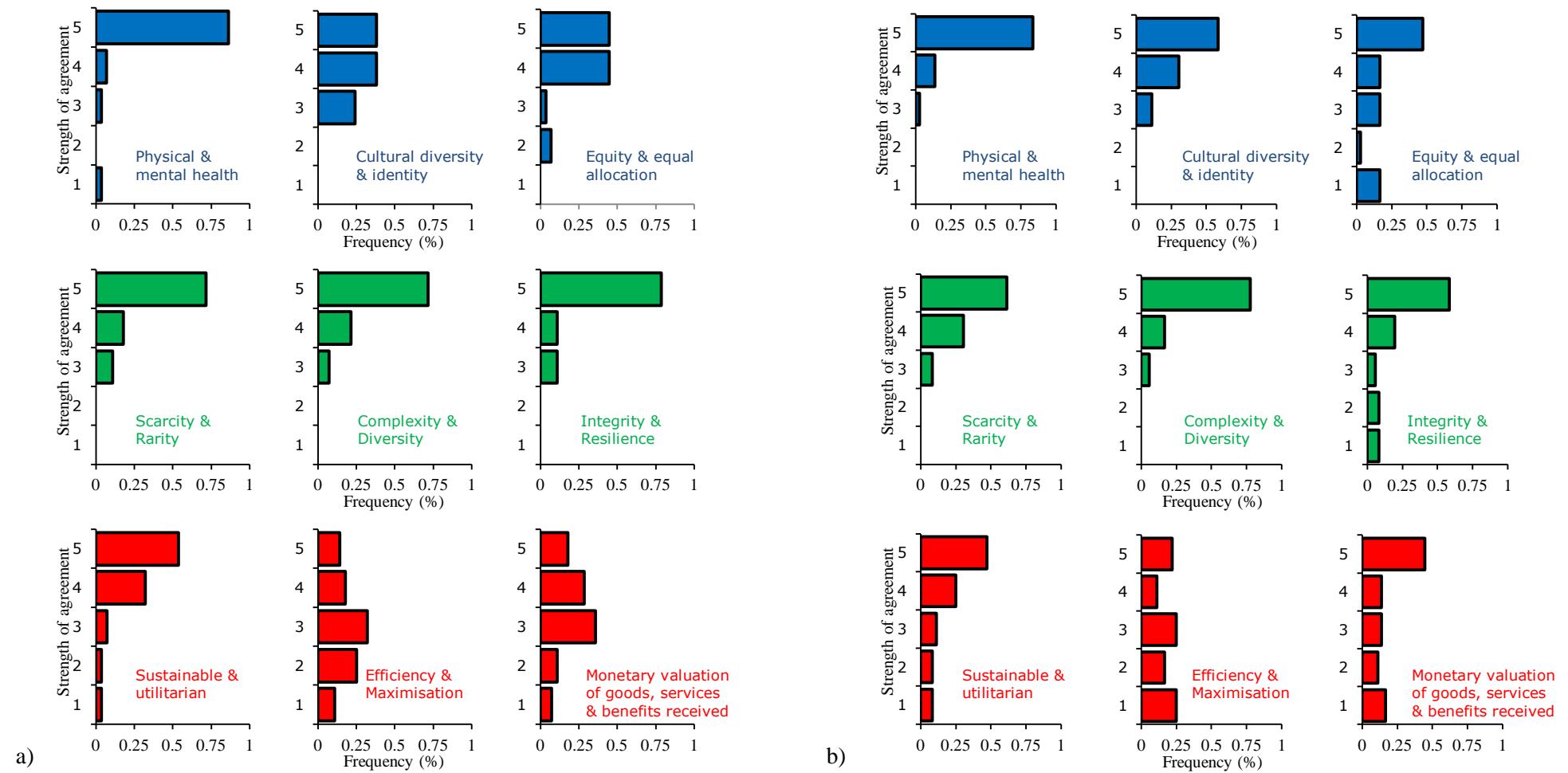
	1	2	3	4	5	6	7	8	9
<i>z score</i>	-0.221	-1.774	-0.938	-0.403	-0.428	-1.564	-0.760	-0.587	-0.661
<i>p-value</i>	0.825	0.076	0.348	0.687	0.669	0.118	0.447	0.557	0.509
	NS								
N	65	65	65	64	64	64	64	64	64

Exploration of normative expressions toward the individual value statements within each of the study countries reveals further similarities. Statistical analysis of participant strength of agreement shows significant difference difference between the strength of agreement with each of the nine individual value statements; Austria,  $\chi^2=74.945$ , df=8, p<0.001; Greece,  $\chi^2=57.933$ , df=8, p<0.001 (Fig 4.9). Participants from both countries express a higher level of agreement with value statements characterised by socio-cultural and ecological values, compared with statements that reflect economic values.



**Figure 4.9** Difference between strength of agreement with individual value statements;  
 a) Austria,  $\chi^2=74.945$ , df=8, p<0.001, N=255; b) Greece,  $\chi^2=57.933$ , df=8, p<0.001, N=324.

Figure 4.10 describes frequency data for participant strength of agreement by individual value statement. Participant response, from both countries, further suggests a higher overall agreement with socio-cultural and ecological value statements. The greater spread of response to economic value statements again conveys a pattern of a more varied normative approach to the economic value statements. The strength of participant consensus around agreement is further evidenced when proportional data for participant expression of agreement is set against that of neutrality/disagreement (Table 4.5).



**Figure 4.10** Frequency data for the normative-based value statements; a) Austria, b) Greece. The x axis represents a proportional figure based on score frequency and the number of participants; y axis represents strength of agreement; bars frequency;  $N_{a,SC}=29$ ,  $N_{a,Ecol,Econ}=28$ ;  $N_b=36$ . Colour denotes specific value domain where; blue – socio-cultural, green – ecological and red – economic.

**Table 4.5**

Proportional data for strength of agreement response by value statement.  
Participant responses for individual statement responses have been combined  
in to two groups, agree and neutral/disagree.

		Value statement								
		1	2	3	4	5	6	7	8	9
<b>Austria</b>	%									
	Agree	93.10	75.86	89.66	89.29	92.86	89.29	85.71	32.14	46.43
Rank	Neutral/ disagree	6.90	24.14	10.34	10.71	7.14	10.71	14.29	67.86	53.57
		1	7	3	4	2	4	6	9	8
<b>Greece</b>	%									
	Agree	97.22	88.89	63.89	91.67	94.44	77.78	72.22	33.33	58.33
	Neutral/ disagree	2.78	11.11	36.11	8.33	5.56	22.22	27.78	66.67	41.67
		1	4	7	3	2	5	6	9	8

Levels of participant agreement also add definition to the varied response given to economic value statements. Proportional data suggest stronger agreement with value statements that characterise the underlying socio-cultural value basis of physical and mental health, equity and equal allocation, cultural diversity and identity, along with the underlying ecological value basis of complexity and diversity, integrity and resilience, and scarcity and rarity, plus the underlying value basis of sustainability and utilitarian. Appreciably lower levels of agreement are expressed for value statements that reflect the underlying value basis of monetary valuation of goods, services and benefits received, and efficiency and maximisation.

Ranking strength of agreement across the nine individual value indicators presents a consistent pattern across ecological and economic value indicators, between the two study countries. However, whilst participants demonstrate high levels of agreement with the socio-cultural value statement that reflects physical and mental well health, ranked first in both study countries, with agreement levels of more than 93%. Value statements that describe cultural diversity and integrity, and equity and equal allocation are suggestive of dissimilar attitudes. Whereas Austrian participant agreement ranked equity and equal allocation third, 89.66%, with cultural diversity and identity seventh, 75.86%, Greek participant agreement

ranked cultural diversity and identity fourth, 88.89%, with equity and equal allocation seventh, 63.89%.

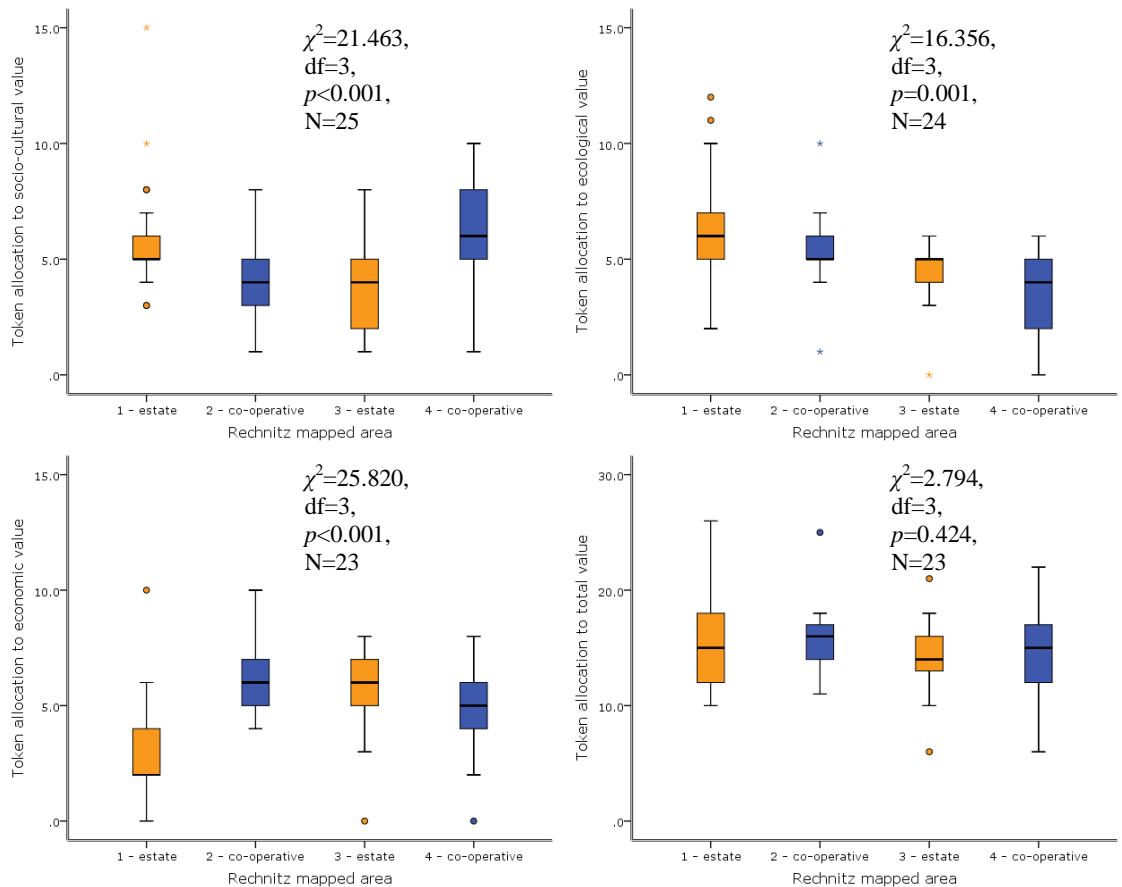
#### **4.4.2.3 Attitudinal-based token allocation exercise**

##### **4.4.2.3.1 Aggregation of the Rechnitz token allocation data**

Prior to aggregation of data from the four areas identified in the Rechnitz token allocation exercise, 1 with 3, and 2 with 4, Wilcoxon signed rank tests identified significant difference between token allocation for each value domain. However, no significant difference was identified between total token allocation values (Table 4.6).

**Table 4.6** A series of Wilcoxon signed rank tests identify difference between participant's token allocation on aggregated Rechnitz data; areas 1 & 3 – estate forest, areas 2 & 4 – co-operative forest.

	Estate Forest (1&3)				Co-operative Forest (2&4)			
	Socio-cultural	Ecological	Economic	Total	Socio-cultural	Ecological	Economic	Total
<b><i>z score</i></b>	-3.502	-2.343	-3.324	-0.516	-2.952	-2.546	-1.977	-0.507
<b><i>p-value</i></b>	<0.001	0.019	0.001	0.606	0.003	0.011	0.048	0.612
	***	*	***	NS	***	*	*	NS
<b>N</b>	25	25	25	25	25	25	25	25

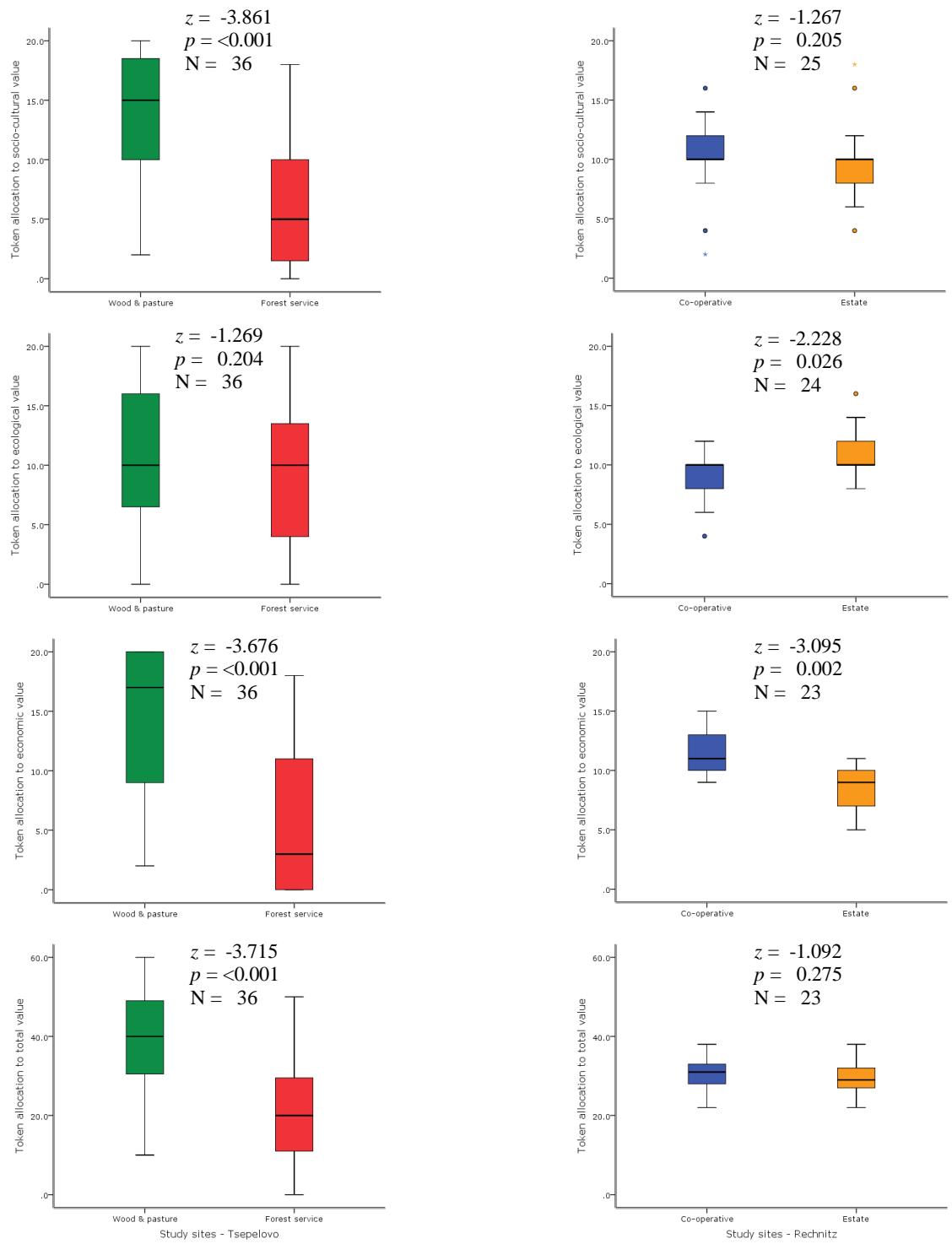


**Figure 4.11** Difference between token allocation to value domains across the four Rechnitz mapped choices. Black lines show medians, boxes show interquartile range and whiskers show total range (excluding outliers shown as circles and stars). Colour denotes specific study site identification where; blue – co-operative, orange – estate.

Due to the potential loss of significant patterns of difference, between value domains at the four identified choices, Friedman's test sought to highlight community relationships between token allocation and geographic locations at this finer grain scale (Fig 4.11). Statistically significant difference was described between the four identified areas within each value domain. Total token allocation between the four identified areas did not differ. In broad terms this pattern can be described by the highest and lowest mean rank sum where; socio-cultural value, high – area 4 (co-operative forest) 3.04, low – area 3 (estate forest) 1.86; ecological value, high – area 1 (estate forest) 3.06, low – area 4 (co-operative) 1.92; economic value, high – area 2 (co-operative forest) 3.04, low – area 1 (estate forest) 1.50.

#### **4.4.2.3.2 Attitudinal-based token allocation by study site**

Based on token allocation to each woodland landscape, within the two study locations, participants describe a pattern of preference (Fig 4.12). Whilst this statistical approach to preference is location specific, grounded in attitudinal behaviour that describes the relationships each community experience with the landscape they have created and surround themselves with. Levels of token allocation convey information regarding a measure of inherent preference for the wooded landscapes with respect to characteristics that define each specific value basis.



**Figure 4.12** Box plots show participant's token allocation to each value domain for the four study sites. Wilcoxon signed rank tests identify difference between study sites in each country; Rechnitz, Austria, and Tsepelovo, Greece. Black lines show medians, boxes show interquartile range, whiskers show total range (excluding outliers shown as circles and stars). Colour indicates study site where; green – wood pasture, red –forest service, blue – co- operative, and orange - estate.

Statistical difference in total value, described by the Wilcoxon signed rank tests, suggests that Greek participants hold a wood pasture landscape in greater regard, with respect to the described value characteristics, compared with the Forest Service woodland landscape. Furthermore participant's responses, split by value domain, describe significantly different, and higher, levels of token allocation for the socio-cultural and economic characteristics of the wood pasture area. No difference is described between the ecological characteristics of the wood pasture landscape and the Forest Service landscape.

Austrian participants place equal regard in the co-operative forest and estate forest, with respect to the described value characteristics. No statistical difference was observed in levels of total token allocation. However, statistically significant difference is found in levels of token allocation for the ecological and economic value domains. The estate forest area is thought to hold higher ecological value whereas the co-operative forest area is thought to hold higher economic value, as described by the respective value characteristics. In the area of socio-cultural value the estate and co-operative woodland area are held in equal regard, no statistical difference in token allocation was described.

If assumptions regarding the paired nature of the data are relaxed for descriptive purposes and token allocations are treated as discrete values, a broad, qualitative approach to individual and community value across the four study woodland landscapes appears to follow a general pattern. Using the Kruskal-Wallis test a ranking approach to token allocation in the value domains of socio-cultural, economic and total value, using mean ranks, describes difference and suggests the following; 1 – wood pasture, 2 – co-operative forest, 3 – estate forest, and 4 – forest service. In the ecological value domain an indeterminate ranking is described (Table 4.7).

**Table 4.7** The Kruskal-Wallis test and the ranking of token allocation across the four study woodland landscapes.

Value domain	Woodland landscape	Mean rank
Socio-cultural	$\chi^2=48.982, df=3, p<0.001, N=122$ Wood pasture	89.94
	Co-operative forest	67.66
	Estate forest	55.34
	Forest Service	33.06
Ecological	$\chi^2=6.716, df=3, p=0.082, N=120$ Wood pasture	67.49
	Co-operative forest	51.10
	Estate forest	71.90
	Forest Service	55.51
Economic	$\chi^2=33.837, df=3, p<0.001, N=118$ Wood pasture	83.44
	Co-operative forest	73.32
	Estate forest	49.56
	Forest Service	39.64
Total value	$\chi^2=38.468, df=3, p<0.001, N=118$ Wood pasture	87.15
	Co-operative forest	65.44
	Estate forest	57.44
	Forest Service	35.93

The use of multi-sample median tests to describe difference between all observations and a grand median further illustrates the spread of participant value attributed across the four studied woodland landscapes, within each of the value domains. The general pattern described by mean ranks is repeated and is suggestive of a degree of individual and community discrimination toward the concept of inherent woodland value (Table 4.8).

**Table 4.8**

The multi-sample median test describes token allocation and a measure of value distribution above and below a grand median of all observations; expected distribution frequencies are shown in brackets.

<b>Value domain</b>	<b>Wood pasture</b>	<b>Co-operative forest</b>	<b>Estate forest</b>	<b>Forest Service</b>
Socio-cultural	Median=10.00, $\chi^2=38.468$ , df=3, $p<0.001$ , N=122			
>median	26 (18)	12 (12.5)	5 (12.5)	3 (18)
$\leq$ median	10 (18)	13 (12.5)	20 (12.5)	33 (18)
Ecological	Median=10.00, $\chi^2=8.933$ , df=3, $p=0.030$ , N=122			
>median	15 (18)	2 (12.5)	10 (12.5)	12 (18)
$\leq$ median	21 (18)	23 (12.5)	15 (12.5)	24 (18)
Economic	Median=10.00, $\chi^2=24.312$ , df=3, $p<0.001$ , N=122			
>median	23 (18)	13 (12.5)	2 (12.5)	9 (18)
$\leq$ median	13 (18)	12 (12.5)	23 (12.5)	27 (18)
Total value	Median=30.00, $\chi^2=22.724$ , df=3, $p<0.001$ , N=122			
>median	27 (18)	13 (12.5)	8 (12.5)	8 (18)
$\leq$ median	9 (18)	12 (12.5)	17 (12.5)	28 (18)

#### 4.5 Discussion

This element of the thesis further explores the community-natural resources-value relationship. Individual responses towards normative-based and attitudinal-based expressions of value for natural resources are investigated in two case study communities across four woodland landscapes. Community focused descriptors were presented to identify a measure of socio-cultural value embedded in the landscape by community. The aim was to illustrate the nature of value held in the socio-cultural relationship with the physical nature of the environment from a reflexive, purposeful, participative perspective, within the specific context of each woodland management scenario.

A combination of normative and attitudinal based exercises, set within a local landscape context, allows participants to express a measure of behavioural intention with respect to natural resources. Consistent with Ajzen's Theory of Planned Behaviour (1991), subjective

norms with respect to the behaviour, attitudes toward the behaviour, and perceived control over the behaviour are usually found to predict behavioural intentions with a high degree of accuracy (Ajzen, 1991). Landscapes are the result of this behavioural interaction, where the dynamic process of societal intervention directly links social systems with ecological systems.

In spite of the potential for data inconsistency due to difference in data collection techniques, participants, across all case study locations, express strong agreement with normative-based value statements that promote socio-cultural and ecological value considerations to their surrounding landscape over those that operate from a specifically economic position. These preferred value statements describe the physical characteristics of a sense of connection to the surrounding landscape, for example, paraphrasing the value statements, '*mixed landscapes*' where '*diversity and complexity*' build environments with '*integrity and resilience*' that '*protects and provides long term stability*' in a manner '*that promotes physical and mental well-being*'.

Consideration of the economic value characteristics couples this physical connection perceived by the current community, voiced through the idea of '*consumption now*', with continued '*consumption*' for community '*in the future*'. The utilitarian relationship with natural resources, experienced by the current community, is tempered by thoughts of community and insurance of use for future generations. Economic value statements that communicate overt transactional characteristics, where, '*resources are produced efficiently and in large quantity*' and '*can be exchanged for monetary value*', do not illicit strong expressions of agreement. A consensus position around agreement for a physical, experiential grounding to society's relationship with natural resources is set against a market-based transactional relationship described in terms of neutrality and disagreement.

Society both influences and is influenced by landscape, it can reflect distinct local values, attitudes and lifestyles (Brown et al., 2002). Shared attitudes, customs, practices and social norms can identify a particular place, people, community, country or time to which they belong, in this respect landscape describes both a geographic and a perceptual space (Nassauer, 1995).

In this study, whilst broad similarities in normative-based values were observed for ecological and economic value characteristics, distinction between values held for '*local arts, customs, institutions and characteristics*' and '*fair and equal access to all aspects of the surrounding landscape*' were described. Difference in value profiles is linked to cultural discrimination across spatially distinct groups (Schwartz, 1994; Boer & Fischer, 2013). Through the context of community, and the relationships it holds with the landscape it creates and surrounds itself with, socio-cultural values are expressed (Sauer and Fischer, 2010). In the outward expression of placed-based values the underlying network of multi-dimensional factors involved in human-nature relationships become visible (Convery et al., 2012).

The discriminative ability of the attitudinal-based token allocation duplicates that of the normative-based value statements when applied to a specific geographic location in which community have experience of in a lived in sense. In this study, woodland landscape management scenarios wood pasture and co-operative forest, which can be defined by a continued and close relationship with community, are attributed higher attitudinal-based value. Where management systems are adaptive, reflexive and sensitive to local situations the historical experience of traditional resource use institutions direct future actions (Haila, 1999).

Further discrimination and connection between norms and attitude becomes apparent in consideration of socio-cultural value preference. In a community where '*fair and equal access*' is held in high regard an attitudinal preference for a co-operatively managed woodland over large single estate ownership is observed, whereas the community which values '*local*

*arts, customs, institutions and characteristics*' highly expresses an attitudinal preference for a cultural landscape over a publicly controlled woodland landscape.

When observed from the perspective of Relph's (1976) three components of 'place', characteristics that express economic value, '*observable activities and functions*', and socio-cultural value, '*meanings or symbols*', can illicit strong discriminative power. Clear difference and similarity in socio-cultural and economic normative and attitudinal values, between the two study communities and the four woodland landscape scenarios, are described in this work. In contrast, when communicating an ecological value, '*physical features or appearance*', across the four study woodland landscapes, this discriminative potential appears weaker. Interestingly the large physical differences in composition and structure of the four study landscapes are not mirrored in the ecological attitudinal-based value expression.

When we consider an experiential expression of value, thoughts, by necessity, turn to that of scale. Landscape as the result of interaction between human intervention and natural processes operates at a range of spatial and temporal scales defined by the interaction of biophysical limits, social and economic values at the landscape scale (Gobster et al., 2007). However, whilst the scale of the surrounding landscape represents the human 'perceptible realm' certain functions of the social-ecological system may operate at scales not immediately perceived. The scale of many essential ecological processes operates outside of the perceptible realm, in the short term at least (Gobster et al., 2007). Cummings et al. (2006) warns of the mismatch that can occur between the scales of ecological process and the society that is responsible for managing them. Nonetheless, through shared everyday experience of landscape even long term and global effects become visible in local environmental and landscape change (Nassauer, 2012).

Difference and similarity in the discriminative ability observed across a range of value characteristics and woodland management scenarios identify the need for a pluralistic

approach toward the evaluation of landscape value. Expressions of socio-cultural value need to consider the relationships between community, landscape and natural resources; they should capture attitudes that influence this relationship and interactions with landscape and natural resources (Tress and Tress, 2003).

The description of a behavioural intention toward landscape by society gives voice to cultural and personal choice. A purposeful and reflexive ‘choice space’ is created where preference constructs value, the geographic location of which is ‘place’ (Relph, 1976; Brown, 1984; Cheng et al., 2003). Value in complex social-ecological systems, where society is considered a participative actor in socio-cultural, ecological and economic value domains, can only be fully expressed through the multiple dimensions of cultural identity, beliefs and attitudes towards the landscapes that it creates (Farber et al. 2002; Sauer and Fischer, 2010).

#### **4.6 Conclusion**

Landscapes influence people in many ways; this component of the thesis evaluates behavioural beliefs and intentions of the physical expression of societal action on landscape structure, composition and process. The relationship between landscape patterns and the community that creates them integrates ecology and economy with people and place as components of a social-ecological system. In this respect the dynamics of landscape change both influences and are influenced by culture; landscape becomes a medium to express and evaluate cultural value. In keeping with the definition of the word ‘culture’, when used to describe the development and advancement of a society, socio-cultural value derived from a behavioural context provides a measure for the accumulation of culture rather than money.

## **Chapter Five**

### **Ecological value across a range of wood-fuel landscapes**

#### **5.1 Summary**

Chapter 5 explored ecological value from a perspective of the relationships between physical structures and the consequent biodiversity levels that land management creates. Structural indicators that represent ecological value across a range of wood-fuel landscapes are described. These data inform the creation of ecological value indices for use in building a wood-fuel landscape evaluation model addressing aim 1, and objective (b), of this thesis' identified thematic narrative:

- 1) To calculate a socio-cultural, ecological, and economic value for case study landscapes in which land-use includes the provision of wood-fuel.
- b) What is the ecological value of landscape that society creates in the pursuit of physical and mental well-being?

Landscape structural indicators are used to describe the influence of the human-landscape interaction on levels of biodiversity. These structural components of landscape express a measure of ecological value which reflects the ecological consequences of socio-cultural interaction on the physical nature of the environment. Using butterfly abundance and diversity as an indicator for wood-fuel landscape biodiversity, the interaction between structure and faunal diversity identifies those variables that will be used as indicators of ecological value. Through a process of correlation, principal component analysis and canonical correspondence analysis, a reduced set of structural variables was established as proxy indicators of ecological value. These analyses informed the creation of a reduced dimensional space that described the largest measure of variability, explained by the smallest number of variables, across the range of studied wood-fuel landscapes. Three wood biomass and five herb biomass variables were selected that described significant negative and positive relationships with faunal abundance, species richness, diversity and evenness.

Wood biomass components expressed both direct and indirect negative relationships with butterfly abundance, species richness, diversity and evenness. In contrast the herb biomass components demonstrated direct positive relationships with butterfly abundance, species richness, diversity, and evenness measurements. Separation of the selected variables into two distinct landscape compartments, wood biomass and herb biomass, reveals a butterfly diversity - structure relationship described by contrast. Where, the two distinct pathways of interaction are each connected to the main protagonist of this thesis, wood and wood-fuel.

Observed differences in biodiversity and the consequent relationships with landscape structural components, across the studied range of wood-fuel landscapes, provides support for inclusion into the wood-fuel landscape evaluative model (chapter 7).

## **5.2 Introduction**

Chapter two outlined society's growing understanding of the interconnected and interdependent nature of its utilitarian relationship with the natural world. Despite increasing evidence of the ecological consequences associated with continued consumption and an economic growth policy, contemporary political and institutional decision makers still believe an answer to the sustainable use of ecosystem goods and services lies in the commodification of natural resources (Costanza et al., 1997; Balmford et al., 2002; Balmford et al., 2008).

As global human population heads towards eight billion, much of the Earth is either directly or indirectly affected by human activity, with many ecological systems dominated by humans (Vitousek et al., 1997). This influence not only impacts areas where humans are present and engaged in their various daily activities but, also extends to many areas which have been established primarily to protect natural resources and biodiversity (Holling & Meffe, 1996).

Landscape, when seen as the meeting point between culture and an organism-centred natural perspective (Haber, 2004; Farina et al., 2005), provides a cognitive approach that informs ‘value’ decisions with respect to land-use and management. Landscape management builds connectance between humans and the biotic components in the landscape through the structures it creates (Laland & Boogert, 2010). Culture builds structure in our landscapes and through the land-use decision-making process ecological structure is changed (Nassauer, 1995). With biodiversity in mind, land-use and landscape management over time places society in the role of ‘*niche constructors*’ (Laland & Boogert, 2010).

### **5.2.1 The human-environment relationship**

Conventional land management achieves a well defined set of objectives through controlling target variables such as allowable annual harvest, a sustained yield or a given rotation period (Holling & Meffe, 1996; Gunderson, 2000) . Management policies apply fixed strategies to minimise or standardise the natural variability of processes in any given ecological system, for example the outbreak of wildfire or vegetative regeneration (Pastor et al., 1998). Much of society’s success involves the reduction of landscape variability to achieve positive economic results over short time scales (Paoletti, 1999; Tilman, 1999).

Societal land-use can lead to a reduction in the inherent spatial and temporal variability within ecological systems (Holling, 1973). Managed anthropogenic systems, such as agriculture or production forestry, operate with focus on a small number of species and monoculture becomes the standard mode of operation (Tilman, 1999). The current activities of society are beginning to influence the ability of ecological systems to respond to disturbance, leading to changes in the ability of natural systems to sustain the flow of ecosystem goods and services on which society relies upon (Ehrlich & Holdren, 1971; Vitousek et al., 1997).

Ecosystem simplification and fragmentation can lead to reductions in biodiversity and functional diversity; food chains shorten and simplify, and resistance to invasive species and

pathogens is reduced (Tilman, 1999; Western, 2001). Work on plant species richness suggests that greater biodiversity will maintain ecosystem function and productive stability to ensure ecosystem service provision over time (Tilman et al., 1996); '*....many species are needed to maintain multiple functions at multiple times and places in a changing world*' (Isbell et al., 2011: 199).

Societal decision making, with respect to landscape, operates with an expected economic value outcome, however, there is always a contingent ecological value for each land-use and management decision. Despite much evidence to the contrary, the biodiversity value of human modified landscapes can still be high, for example cultural landscapes see Farina (2000) and Naveh (1994). Human activities can be compatible with the development and maintenance of high biodiversity levels within managed systems (Bengtsson et al., 2003; Naveh, 1994). There are many examples where human activity and an interaction with nature have created landscapes with high ecological value for their diverse flora and fauna. These multi-functional traditional land-use systems, usually characterised by low intensity land management in association with some form of livestock, have become known as cultural landscapes (Amanatidou, 2006). Examples of such systems are traditional forms of managed forest and meadow usually in combination to form a landscape mosaic of grassland, cultivation and forests (Amanatidou, 2006).

Cultural landscapes have evolved and continue to exist, because of human intervention. These semi-natural habitats support many animal and plant species, some of these are considered rare or endangered and are strictly associated with particular anthropogenic ecosystems, for example see Peterken (1993); Thomas (1995); Warren (1995); and Rackham (2010) . Butterflies, a well documented biodiversity indicator group, provide a good characteristic example; 65% of the species found in Europe, a total of 576 species, are associated with cultural landscapes (Organisation for Economic Co-operation and Development, 2001, in Amanatidou, 2006). A continuation of management based on traditional land-use and practice

is thought essential for the conservation of many of these species. Landscapes change as a result of the dynamic interactions between culture and nature. Increasingly, biodiversity protection will depend upon maintaining biodiversity in human-dominated landscapes (Fahrig et al., 2011).

### **5.2.2 Environmental heterogeneity and biodiversity**

Before any anthropogenic impact was evident, natural disturbance would have created a diverse forest structure and biotic composition (Vera, 2000; Whitehouse, 2006). Cultural landscapes, described by human woodland-use systems, such as coppice and wood pasture, have created semi-natural forest structures and floral/faunal communities (Peterken, 1993; Fartmann et al., 2013). This manipulation of resource availability influences ecosystem structure, function and biodiversity (Laland & Boogert, 2010).

Understanding the complex nature of ecological systems involves understanding how structures, processes and relationships of interaction emerge from individual components and feed back to influence those components (Levin, 2005). Heterogeneity, niche building and environmental discontinuity move ecological systems towards a more stable state (Holling, 1973; Arrow et al., 1995; Norton, 1995). Here, we can think of spatial heterogeneity as a key functional component of ecological systems, meaning that the level of ecosystem functioning depends upon it (Levin, 2000).

Diversity and complexity build increased resilience. Woodlands with greater compositional and structural diversity resist disturbance more easily, regain a pre-disturbance compositional state more quickly, and in some cases, can be more productive than less diverse forests (Drever et al., 2006). Consequentially, woodland management practices that generate forest heterogeneity can be seen to have strong, positive associations with species richness (MacArthur & MacArthur, 1961; Dennis, 1997; Tews et al., 2004; Mitchell et al., 2006).

Ecological systems as components, structures, processes and the associated interactions are classically described using the concepts of ecosystem (Tansley, 1935), niche, (Grinnell, 1917; Hutchinson, 1957), and ecotope (Whittaker et al., 1973). Fundamental to their understanding is interaction between the organism and the constraints of its abiotic and biotic environment (Tansley, 1935; Odum, 1971). Environmental heterogeneity, which includes elements such as spatial variability and habitat diversity, is seen as a prerequisite to allow multiple species with different resource requirements to coexist (Whittaker et al., 1973).

Increasingly the work of ecologists demonstrates the importance of biodiversity as an essential component in the maintenance of a wide variety of the services that humans, and the resilience of ecological support systems, depend upon (Bengtsson et al., 2003; Duffy, 2008). The inherent properties of complex adaptive ecological systems buffer environmental fluctuation and provide a functional substitution capacity, a primary insurance value which is necessary for the continued availability of ecosystem services (Baumgärtner, 2007). Observed from a local perspective, heterogeneity of structural variables links community with biodiversity through the structures that societal land-use creates in the landscape (Nassauer, 1995).

Decreases in the levels of biodiversity become untenable as potential substitute ecosystem components are removed (Levin, 1999; Gunderson, 2000). Heterogeneous landscapes provide a range of microclimates and resources within which structural variability can promote diversity and population stability (Oliver et al., 2010). Diversity decline accelerates the simplification of ecological communities, which in turn will tend to increase the probability that ecosystems experience destabilising dynamics and collapse (McCann, 2000). In a largely human dominated world (Vitousek et al., 1997; Chapin III et al., 2000) the maintenance of our social systems and human well-being are inextricably linked to biodiversity and ecological systems through landscape management and the goods and services that ecosystems provide (Díaz et al., 2006; Folke, 2006; Chapin III, 2009).

### **5.2.3 Rationale for methods**

#### **5.2.3.1 Butterflies as indicators of biodiversity**

Diversity operates at multiple levels, it can be recognised in the primary attributes of system components, structure and function and further within a hierarchy of organisational attributes, such as population, community, and landscape (Niemi & McDonald, 2004). A calculation of diversity value can be seen as analogous to the value of system integrity, where the key to resilience in any complex adaptive system is in the maintenance of maximal heterogeneity (Dale & Beyeler, 2001; Carignan & Villard, 2002). However, given the inherent levels of complexity and the impossible scale of the task to measure and monitor the wide range of effects of environmental change on all levels of diversity, identification of bio-indicators is beneficial (Lindenmayer et al., 2001).

Composite indices or indicators can reduce this complexity to simple summaries. These indicators should be measurable surrogates for the assessment of environmental condition, identification of trends and the consequences of change (Noss, 1990; Niemi & McDonald, 2004). Additionally, the nature of ecological information collected from any suite of indicators must convey information to both policy makers and society in a comprehensible format (Carignan & Villard, 2002; Niemi & McDonald, 2004).

Butterflies, together with birds and vascular plants, represent the most frequently monitored taxonomic groups, due mostly to the existence of national recording schemes (De Heer et al., 2005; Thomas, 2005). Interest in Lepidoptera generates a wealth of ecological information, sound status evaluations and conservation management knowledge from around the world. This places butterflies among the taxonomic groups most suggested as indicators of species richness and ecological integrity (Kremen, 1992; New, 1997; Fleishman et al., 2005).

Many ecological characteristics make butterflies good candidates as biodiversity indicators; due to short, typically annual, life cycles and their interactions as larvae and adults with

different sets of host plants they are sensitive to habitat changes (Kremen, 1992; Thomas et al., 2004); breeding in small habitat patches they reflect change at a fine scale (Ehrlich & Hanski, 2004); change in population status is observed over a wide range of terrestrial habitats (van Swaay et al., 2006) and climates (Settele et al., 2008); importantly they have been shown to be indicators for other groups of terrestrial insects (Thomas, 2005); which constitute the largest fraction of global biodiversity (Thomas et al., 2004). Additionally they can, in many areas, be reliably identified in the field (Pollard & Yates, 1993; Pollard, 1977). Moreover butterflies have a positive image amongst the public and are incorporated as a component of the UK Governments biodiversity indicators (Brereton et al., 2011).

Results of many studies have shown correlations between butterflies and other taxonomic groups (Fleishman et al., 2005; Maes et al., 2005; Thomas, 2005), land-use and intensity of land-use (Dover et al., 2011a; Dover et al., 2011b), and anthropogenic disturbance (Stefanescu et al., 2004; Verdasca et al., 2012). Despite the number of studies to report a relationship between butterflies and other taxonomic groups this should not, however, be taken as certain (Perfecto et al., 2003; Kati et al., 2004; Fleishman et al., 2005; Thomas, 2005). Nonetheless, documented associations between butterflies and specific land-type and use are shown to be mediated through structure and composition of the studied system, for example topographic, moisture and disturbance gradients (Kremen, 1992; Weibull et al., 2000; Atauri & de Lucio, 2001; Fleishman & Murphy, 2009; Kumar et al., 2009), landscape diversity (Weibull et al., 2000), landscape heterogeneity (Atauri & de Lucio, 2001), and spatial heterogeneity (Kumar et al., 2009). Ultimately whichever indicators are used to describe a value index, in order to attain a greater reliability and broader acceptance the strength of any relationship between indicator and target variable should be tested (Duelli & Obrist, 2003).

### **5.2.3.2 Sampling effort and diversity**

Sampling effort, in any study, must be standardised in order to draw conclusions that reflect differences in assemblage across groups (Magurran, 2004). Magurran (2004: 133) further add

that for reasonable estimates of diversity the numbers of individuals observed should be in the region of 200 – 500, at which levels all but the rarest species will be represented. The construction of cumulative species effort curves allows for estimation of sampling effectiveness, where an asymptote is approached this indicates the completion of the inventory.

In instances where sampling is not sufficient to have reached an asymptote, estimations of the number of species that would be found by taking further samples are possible. Whilst complete enumeration of species richness based on extensive study is desirable, exhaustive sampling can prove difficult because it is rarely possible to collect enough samples or individuals to discover all species present (Gotelli & Colwell, 2001). Extrapolation of data can statistically enlarge smaller sample sets for comparison with larger ones at a comparable level of sampling effort (Colwell et al., 1994; Colwell et al., 2004; Colwell et al., 2012). Rarefaction allows for the estimation of species richness in a smaller sample, and statistical comparison of larger sample sets with smaller ones at a comparable level of sampling effort (Colwell et al., 2004; Colwell et al., 2012)

There are a variety of non-parametric estimators available which can be used to estimate total species richness from either incidence or abundance data (Magurran, 2004). Non-parametric estimators, which are based on frequency counts from either abundance or incidence data, use information on the number of infrequent or rare species in the described data to estimate the number of undetected species (Chao et al., 2009). As such high species richness estimates can be produced when used on data with high proportions of rare species (Melo, 2004). However, these estimators do not require any prior assumptions about community structure; whilst different species will have different probabilities of being observed these probabilities remain temporally and spatial constant with transects considered random samples of space not random samples of individuals (Chiarucci et al., 2003).

Another consideration is that some measures of biodiversity are more sensitive to the effects of sample size; for instance, species richness is particularly vulnerable to variation in sampling effort, whereas the Simpson index outperforms the Shannon index in respect of heterogeneity measurements (Magurran, 2004). Whilst species richness data provides one measure of community diversity, these data in combination with individual abundance data allow for the construction of indices that capture both the richness and evenness characteristics of community structure in a single statistic (Magurran, 2004; Justus, 2011). However, a diversity index should not be seen as a '*diversity*' itself but a numerical index used to express diversity (Jost, 2006). As such, species diversity is a measure of the number of species present and the evenness with which the individuals are distributed among these species (Hurlbert, 1971; Pielou, 1975).

Species diversity is distributed heterogeneously across habitats, landscapes and regions (Jost, 2007; Jost et al., 2010). As such, a single estimate of diversity is not readily informative, measurements of diversity, or heterogeneity, are fundamentally comparative. Diversity indices are used to describe temporal or spatial differentiation of sites, communities or landscapes which can then be used in comparative analyses (Magurran, 2004; Justus, 2011). Diversity should be considered as essentially a structural concept, which cannot be separated from theories of community organisation (Hill, 1973).

Different indices measure different aspects of the components species richness and abundance and thus may produce different rankings of sites. Conclusions regarding whether one site is more diverse than another can depend upon the choice of diversity measure (Hurlbert, 1971). Hill (1973) describes this difference in the tendency of each index to include or to exclude the relatively rarer species. Difference is observed in the emphasis given to species richness, a weighting towards uncommon species, or dominance, weighting towards abundant species (Pielou, 1975; Magurran, 2004).

Frequently used non-parametric measures of diversity, such as the Shannon and Simpson's index, make no assumptions about the underlying species abundance distribution, although their performance can be influenced by the distribution of species abundance (Magurran, 2004). The widely used Shannon index ( $H'$ ) weights uncommon species and is sensitive to sample size and despite its popularity of use is not well suited to statistical comparisons among communities because, like observed species richness, it is highly sensitive to small sample size (Lande et al., 2000; Justus, 2011). In contrast Simpson's index ( $D$ ) provides a robust measure of diversity across different sample sizes and ranks communities consistently at small sample sizes (Lande et al., 2000). However, the Simpson's index is weighted towards the most abundant species (Magurran, 2004). Yet despite this caveat Lande et al. (2000) advise ecologists and conservationists to employ a measure of Simpson's diversity alongside species richness when comparing communities.

These types of indices that are weighted by abundance of common species are typically known as either measures of dominance or evenness, although the Simpson's index is not strictly speaking a pure measure of evenness. In a review of evenness indices, in which performance against fourteen criteria was assessed, Smith & Wilson (1996) suggest that the primary criterion for any measure of evenness is independence from species richness. This was satisfied by the Simpson's evenness measure ( $E_{ID}$ ), along with three other indices that met the species richness criterion (Smith & Wilson, 1996).

The strong credentials of both the Simpson's and Simpson's evenness indices are important recommendations for use (Smith & Wilson, 1996; Lande et al., 2000; Magurran, 2004), and despite the reservations applied to the Shannon index it still continues to be used extensively. There is no clear consensus on which index to use. However, if one is clear that whichever diversity enumeration used relates only to the index used to measure it, and makes no claim to diversity in its broadest sense, a diversity index thus creates equivalence classes among

communities which can be used for comparison (Smith & Wilson, 1996; Lande et al., 2000 Magurran, 2004; Jost, 2006).

In this thesis, due to the propensity of different biodiversity measurements to measure different aspects of diversity, a range of non-parametric indices that make no assumptions about the underlying nature of the collected data are used. This approach creates a collection of multiple concordant observations against which the land-use structure-faunal diversity relationships can be compared, across the range of case study wood-fuel landscapes.

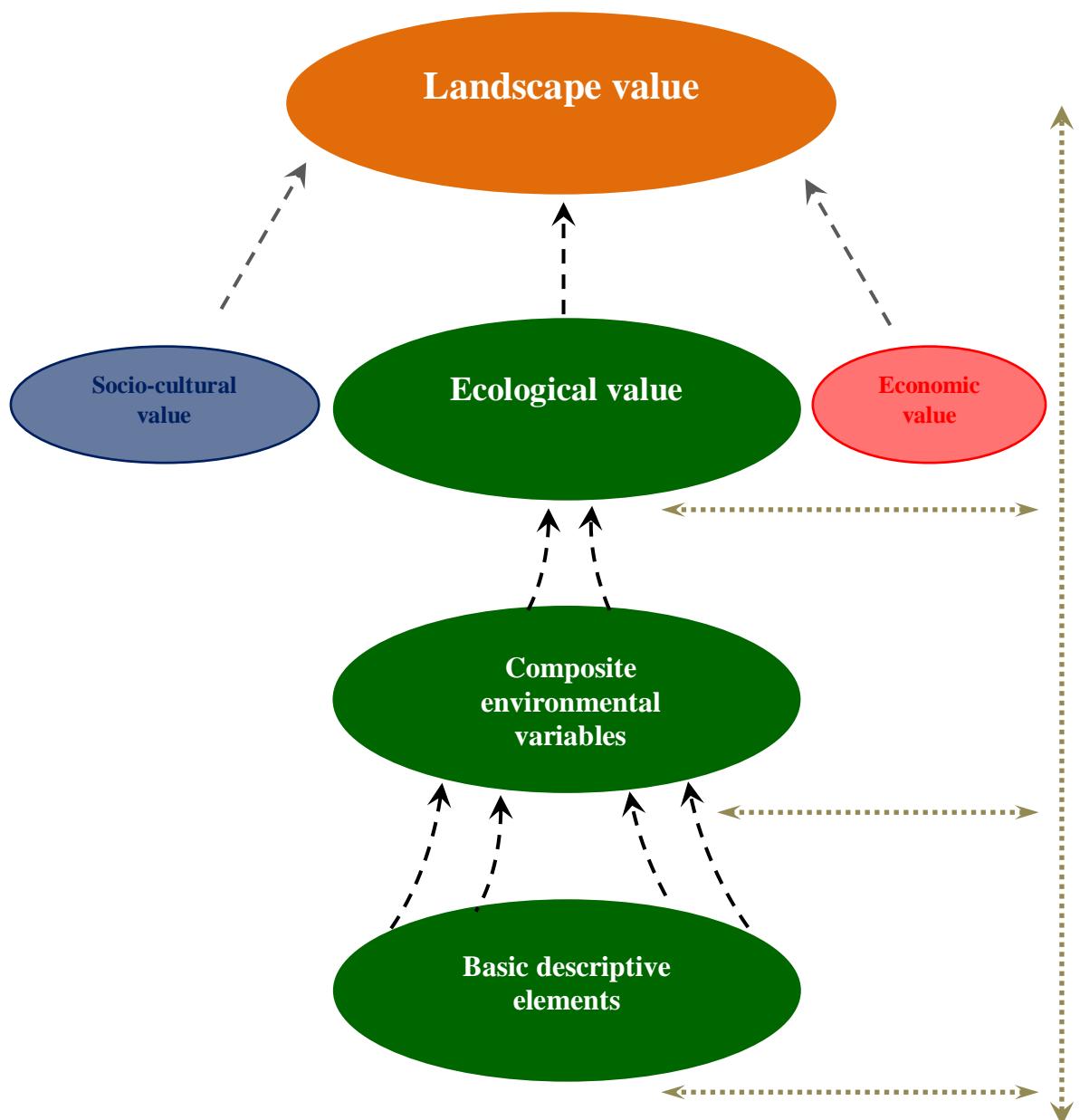
### **5.2.3.3 Environmental data**

The collection of environmental data sought to cover aspects of the biophysical characteristics which have previously been described as possessing the potential to influence butterfly presence and absence (Kumar et al., 2009; Dover et al., 2011a; Sanford et al., 2011). The intention here was to describe the relationships between heterogeneity in the landscape of each study site, at differing scales, with the measured diversity of the observed butterfly populations.

In the investigation of faunal diversity and the consequent relationships with observed landscape structural variables, the object of this component of research was to describe ecological value associated across a range of woodland management and ownership case study landscapes, in which land-use includes the provision of wood-fuel. The principle environment structural and compositional components that contribute to the maximum amount of observed variance across the studied wood-fuel landscapes are identified. These variables are used to construct an index of ecological value for each case study landscape

The selected variables are brought together in the fuzzy logic chapter of this thesis (chapter 7). These data describe the ecological value component to be used, alongside a socio-cultural and economic value component, in the creation of a fuzzy logic landscape evaluation and

assessment model (Fig 5.1). Relationships between and within ecological, socio-cultural and economic value components, observed across the studied range of woodland landscape and ownership, will also be described.



**Figure 5.1** Framework for the fuzzy logic landscape evaluation model; specific focus is given to the ecological component. Black dashed arrows describe value pathway, brown dotted lines describe axes of relationship and interaction.

## **5.3 Methods**

### **5.3.1 Study area**

Case study sites were selected in the regions of Ioannina, NW Greece, and Südbergenland, SE Austria. The choice of study site reflects similarity in economic and demographic attributes, relative to national levels, and difference in institutional arrangements towards woodland use. Using the county of Cumbria, in the northwest of England, as a reference point, European case study sites are found where economic and demographic data identify similarities in ‘marginal’ status but also, importantly, where there is a sustained functional, economic, cultural or historic relationship with a woodland landscape. ‘Marginal’, in the context of this study is described by levels of rurality, standards of living and economic activity.

The regions of Ioannina, Greece, and Südbergenland, Austria provide areas with comparative economic and demographic data, whilst differences are identified across a spectrum of relationships, such as, land tenure, community institutions, local and national governance and cultural landscapes (Table 5.1). Landscape, presented as the focal point through which the community-landscape-natural resources value relationship is experienced, provides a cognitive approach that informs ‘value’ decisions with respect to land, forestry and timber use. A review of study site characteristics and rational for study site choice has been completed elsewhere, see chapter three.

Hereafter, study sites will be referred to as: Forest Service (FS); wood pasture (WP); estate forestry (EF) and co-operative forestry (CF). Woodland boundaries are defined by the limits of local governance which reflect the extent of mayoral influence for each study community. This approach respects the observations described in chapter three where the dynamics of local land use, formal and informal socio-political institutional arrangements influence landscape components and structure. Community influence on local landscape is seen as a determinative element in the community-land-use relationship, where natural resources are managed to produce goods and services for the benefit of society.

**Table 5.1** Overview of case study landscape characteristics

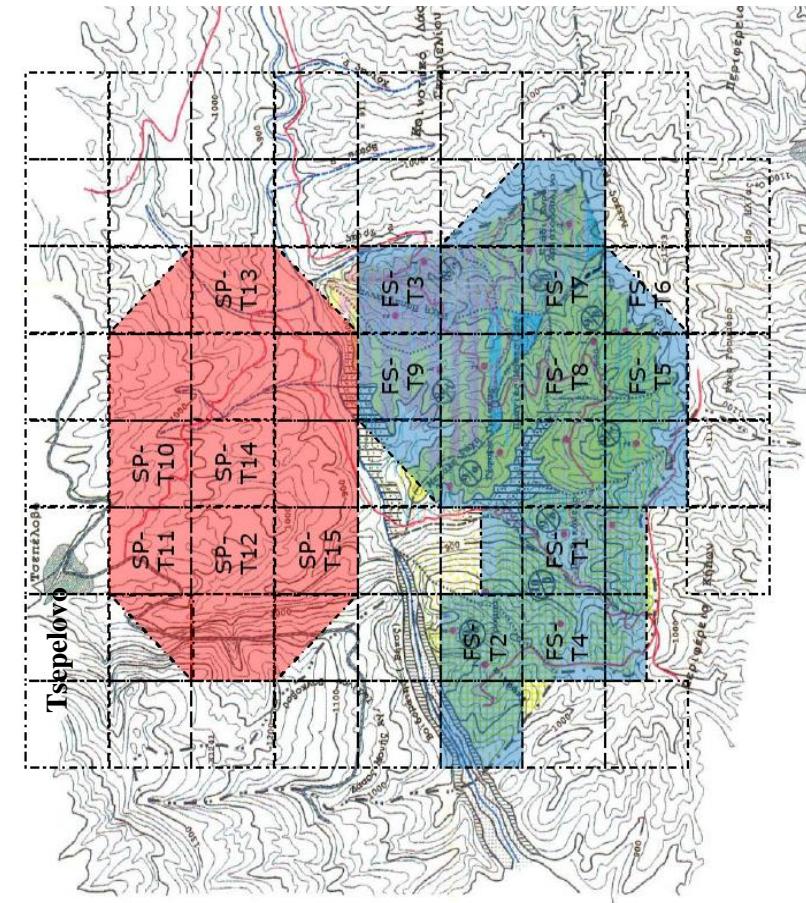
<b>Location</b>	<b>Landscape</b>
Tsepelovo, Greece	<b>Forest Service</b> An area of Natura 2000 large scale near to nature woodland under public ownership, with a national management ethos that reflects contemporary issues of conservation and ecosystem goods and services
Tsepelovo, Greece	<b>Wood pasture</b> A cultural landscape of small scale wood and pasture under local private ownership, with a traditional multi-functional utilitarian approach to use and management
Rechnitz, Austria	<b>Estate forestry</b> large national scale forestry operation under private ownership, by a single entity, managed with a sustainable forestry approach
Rechnitz, Austria	<b>Co-operative forestry</b> woodland with many small scale local private owners brought together under a co-operative management association with a sustainable forestry approach

### 5.3.2 Sampling design

A stratified random sampling design informed the collection of all biophysical data. Using a numbered 500 m x 500 m grid overlaid directly on to maps at each case study location, a random numbers generator directed grid selection for subsequent butterfly and environmental sampling (Fig 5.2).

Within each of the selected grid squares a 200 m transect was laid out. Transect placement ensured a continuous representative sampling of characteristic vegetation type and structure within each selected grid square. The potential for an introduced influence from landscape inconsistency and edge effects, such as change in dominant vegetation type, structure or the presence of forest tracks and roadways, was moderated by keeping changes in dominant vegetation type and forest tracks at least 50 m distant (van Halder et al., 2011). Sampling effort over the four case study sites was standardised by the number of transects undertaken in relation to the size of each sample area, when described by the number of 500 m x 500 m grid squares (Table 5.2).

**ΔΙΑΧΕΙΡΙΣΤΙΚΟΣ ΧΑΡΤΗΣ  
ΚΟΙΝΟΤΙΚΟΥ ΔΑΣΟΥΣ  
ΤΣΕΠΕΛΟΒΟΥ**  
 Κλίμακα 1 : 20.000  
 Ισοδιάσταση 20μ.



Rechnitz



**Figure 5.2**

Case study sites (a) Tsepelovo, Greece, and (b) Rechnitz, Austria. A 500 m x 500 m square grid and random number generator directs transect selection. Squares were selected using a random stratified pattern; Tsepelovo - selection in the FS area, blue grid, was stratified to ensure at least one representative transect per forest compartment and selection in the WP area, red grid, ensured representation of pastoral land use; Rechnitz – stratification ensured representative coverage of EF ownership area, green grid, and CF ownership, red grid

**Table 5.2** Study site sampling effort; proportion of sampled 500 m x 500 m grid squares per study site.

Study site	Total 500 m x 500m squares	Sampled 500 m x 500m squares	Proportion of squares sampled (%)
WP	13	6	46.15
FS	18	9	50.00
EF	46	21	45.65
CF	31.5	15	47.62

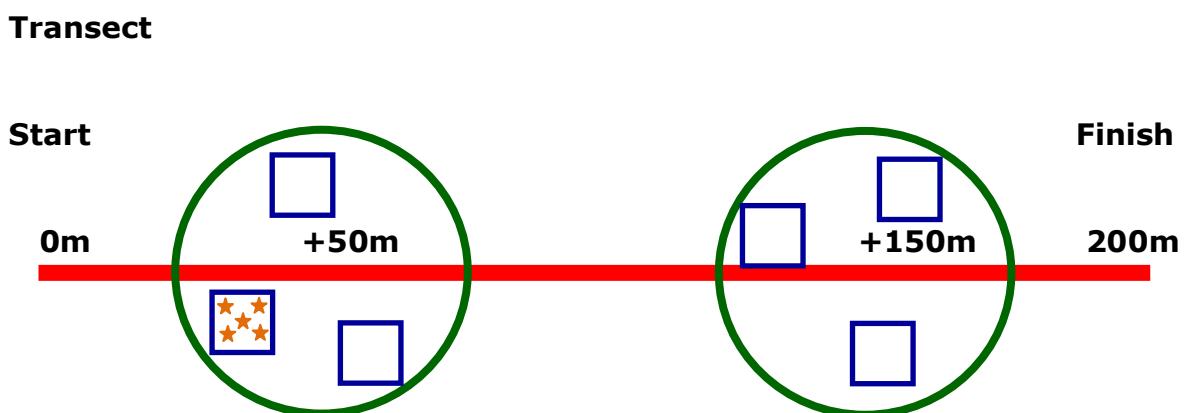
### 5.3.3 Butterfly data

To record individual butterfly presence the line transect method was used (Pollard & Yates, 1993; Pollard, 1977). Data were collected over two visits to each study location during June – August, between 2011 and 2013 (Daily & Ehrlich, 1995; Simonson, 1998; Simonson et al., 2001). Transects were walked at a uniform pace with all butterflies within 5 m on both sides, to the front and above noted. Butterfly species were identified by sight or when closer identification was necessary a digital camera was used to ‘capture’ a specimen image; during the capture process the transect walk was stopped and counting resumed on restarting the walk. Observations were made only in sunny conditions where temperatures exceeded 17° C, under calm to light winds and at times favourable to butterfly flight: between 10.00 and 16.00. All species identifications were based on information in Tolman and Lewington (1997).

To avoid double counting of individual butterflies, transects in adjacent grid cells were not completed on the same day with a minimum distance of 1000 m between transects completed on any one day. This distance is larger than the range of daily movement for most individuals of the butterfly species encountered (Dennis, 2001; Grill & Cleary, 2003). Thus each transect can be considered an individual sample, this allows for data to be used in a broad sense to identify general patterns, as well as aggregated, by landscape type, and used to identify more specific patterns.

### **5.3.4 Environmental data**

Observations for all biophysical measurements were collected from a series of nested quadrats placed at pre-defined intervals within each butterfly line transect (Fig 5.3). At each sampling point the first, larger quadrat, for measurement of the wood biomass characteristics, was centred on the transect line. Here, size determination of this larger quadrat results from a function of the basal area calculation, see Matthews and Mackie (2006). Within each of the larger quadrats three randomly selected one metre square quadrats were established to collect measurement of the herb biomass characteristics. Location of these smaller sampling points was a random selection process using a pre-determined co-ordinate rule which incorporates compass direction and distance components. Thus each butterfly line transect contained two wood biomass quadrats and six nested herb biomass quadrats. A full list of biophysical variables and units of measurement is presented in Table 5.3 below.



**Figure 5.3** Schematic diagram of line transect to identify sample points; green circle represents wood biomass quadrat and blue square herb biomass quadrat. Orange stars denote placement of herb height measurements within each nested herb biomass quadrat.

**Table 5.3** Biophysical variables and units of measurement.

Variable	Metric
<b>Butterfly data</b>	
Abundance	Individual count
Species richness	Species count
Heterogeneity	Diversity indices
<b>Wood biomass</b>	
Cover 0 -0.5 m	
Cover 0.6 – 2.0 m	
Cover 2.1 – 4.0 m	
Cover > 4.0 m	
Basal area	$m^2 ha^{-1}$ ; a function of tree diameter at breast height (1.3m) and quadrat area data
<b>Herb biomass</b>	
Cover at 0 m	
Cover at 0.2 m	
Cover at 0.4 m	
Cover at 0.8 m	
Cover at 1.0 m	
Cover at $\geq 1.5$ m	
Herb structure	Diversity index
Herb height	Centimetre
Leaf litter	
Bare ground	
Forb cover	Visual assessment of % in-flower cover
<b>Other</b>	
Aspect	Degree ( $^{\circ}$ )
Altitude	Metre

In each wood biomass quadrat percentage woody biomass cover was visually assessed at the specified discrete heights on an ordinal scale; 0%, 1 – 10%, 11 – 25%, 26 – 50%, 51 – 75% and >75%. Basal area calculations use diameter at breast height (1.3m), minimum size assessed  $\geq 7$  cms, and quadrat area data, see Matthews and Mackie (2006). Percentage

coverage of herb biomass at the specified discrete heights, leaf litter, bare ground and forb cover were assessed as interval data, on the scale 0 – 100%. Herb height was calculated as the mean taken from five measures of herb vegetation height; one from each corner, 10 cms interior, plus the quadrat centre, five measurements in total. Transect aspect and altitude data were calculated to reflect the main direction of slope and mean altitude over the length of each transect route. The reported unit of aspect used for further analysis in this work is adjusted to reflect a thermal gradient bias for southerly facing slopes. Compass directions are adjusted whereby a south-westerly direction equals  $360^0$ , all other directions are re-valued accordingly.

In addition to herb biomass cover, at the pre-determined height categories, and measurement of herb heights, a spatial diversity assessment of the herb structural variability was calculated (Freemark & Merriam, 1986). Using the herb biomass percentage cover figures, a measure of spatial Shannon diversity,  $H'_{spatial} = -\sum_i \sum_j P_i p_{ij} \ln p_{ij}$ , was calculated for each set of three nested quadrats, for each wood biomass quadrat (Pielou, 1975; Freemark & Merriam, 1986). Where the observed frequency with which a point in the  $i$ th phase is succeeded by a point in the  $j$ th phase informs the creation of an  $r \times c$  matrix (Pielou, 1975:74), for an example of a constructed matrix see figure 5.4. For this component measurements of herb biomass coverage data are described on an ordinal scale; 0%, 1 – 10%, 11 – 25%, 26 – 50%, 51 – 75% and >75%.

		Second element of the transition						
		0%	1–10%	11–25%	26–50%	51–75%	>75%	
First element of the transition	0%	11	0	0	0	0	0	11
	1–10%	3	1	0	0	0	0	4
	11–25%	1	0	0	0	0	0	1
	26–50%	2	2	0	0	0	0	4
	51–75%	0	1	0	1	0	0	2
	>75%	0	1	0	3	2	2	8
		17	5	0	4	2	2	30

**Figure 5.4** An  $r \times c$  matrix for herb biomass cover. Here  $p_{ij}$  may be taken as an estimate that a point in the  $i$ th phase will be succeeded by a point in the  $j$ th phase, (3/4); row totals give total number of sampling points that fall in phase  $i$ , and  $p_i$  becomes an estimate of the proportion of phase  $i$  in the mosaic, (4/30), (Pielou, 1975); for this matrix  $H'_{spatial} = 0.566$ .

## **5.4 Analyses and results**

### **5.4.1 Analyses**

Analyses of the observed data feeds two strands of investigation; firstly to describe measurements of butterfly diversity across the four case study wood-fuel landscapes; secondly to identify the direction and the strength of relationships between calculated butterfly diversity measurements and observed environmental variables. A reduction in the dimensionality of the environmental data defines variables that become proxy measurements for the biophysical characteristics that describe an ecological value.

#### **5.4.1.1 Butterfly data**

Data for both Rechnitz study sites, Estate Forest and Co-operative Forest, were collected over two sampling periods in different years, 2011 and 2012. To ensure consistency of data across years, and prior to any aggregation, a Mann-Whitney test was undertaken to test for statistically significant difference between years for each study site. Prior to all analyses observed data were standardised to a species and individual per kilometre metric.

##### **5.4.1.1.1 Abundance and species richness to describe and compare study landscapes**

Rarefaction and extrapolation, using the EstimateS programme 9.1.0 (Colwell, 2013), produced data sets for each study site that can be used to describe species sampling effort curves. These curves allow for description and comparison across the four study sites. Multiple species richness estimations from the following non-parametric statistical sampling estimators are generated for the purpose of comparative analysis; Chao 1 (Chao, 1984) and Abundance Coverage-based Estimator (ACE) (Chao & Yang, 1993) derived from abundance data; Chao 2 and Incidence Coverage-based Estimator (ICE) (Chao, 1987) derived from incidence data.

An ANOVA test, on  $\log_{10}$  transformed data using the calculated asymptotic species richness estimates, was performed to test for difference between species richness estimations across the

four study sites, with Tukey's HSD *post-hoc* testing to identify where difference was located. Data transformation removed issues of non-normal distribution, normality of the  $\log_{10}$  transformed data was tested using the Shapiro-Wilk test. To further qualify the scope of difference between the four study sites Kruskal-Wallis tests, with Nemenyi *post-hoc* testing, were performed on the observed sample-based species richness and abundance per kilometre data. A Spearman's Rank correlation explored the relationship between individual abundance and species richness across the case study wood-fuel landscapes.

For calculations in the EstimateS software 100 randomised runs were performed on each study site dataset, with the upper abundance limit for rare species set at 2 to moderate any influence from single observations with the potential to be described as rare species. The spatial patchiness parameter was set at zero, such that the patchiness of each dataset was unaffected. Sample affiliations of individuals are randomised within species and spatial homogeneity is assumed; the larger the patchiness setting the greater the patchiness of distribution becomes (Colwell, 2013).

#### **5.4.1.1.2 Diversity indices to describe and compare study landscapes**

Butterfly individual abundance and species richness data are used to create a collection of multiple diversity indices for comparison across the range of wood-fuel study landscapes. Using the EstimateS programme 9.1.0 (Colwell, 2013) collected abundance and species richness data allow for the calculation of Shannon ( $H'$ ), where  $H' = -\sum p_i \ln p_i$ , Inverse Simpson's ( $I/D$ ), where  $D = \sum p_i^2$ , and Simpson's Evenness ( $E_{I/D}$ ) indices are calculated;  $E_{I/D} = (I/D)/S_{est}$  where species richness ( $S_{est}$ ) and Simpson's index ( $D$ ) data for this calculation are taken from estimated values generated in the rarefied data set.

ANOVA tests, using rarefied sample-based data, were performed to test for difference between each diversity index across the four study sites, with Tukey's HSD *post-hoc* testing to identify where difference was located. The Shapiro-Wilk test was used to check for

normality. A Spearman rank correlation between observed individual  $\text{km}^{-1}$  and diversity indices data explores the underlying relationships between individual abundance, diversity and evenness/dominance components across the wood-fuel study landscapes.

#### **5.4.1.2 The relationship between biodiversity and environmental variables**

Spearman Rank correlation analyses between individual abundance, species richness, and diversity indices data, and all measured environmental variables described associations between the two ecological components of butterfly and environment. Having established the strength and direction of associations between butterfly and environmental data, a principal components analysis (PCA) reduced the dimensionality of the environmental space described by the observed variables. This technique allows for reduction of the data to a smaller number of descriptors with low information loss (Jolliffe, 2002; Legendre & Legendre, 2012).

In this use of PCA, component retention is considered successively, starting with the first principal component, and its associated variables (Jolliffe, 1972; Grossman et al., 1991; King & Jackson, 1999; Jolliffe, 2002). Principal components are retained as a function of the broken stick method, where, for each principal component selected for retention, eigenvalues are considered to be different from random expectation if they exceed the values generated by the broken-stick model (Jolliffe, 1972; King & Jackson, 1999; Jolliffe, 2002; Abdi & Williams, 2010). To aid interpretation of the results Varimax rotation was applied, which works by loading variables more strongly on fewer principal components (Jolliffe, 2002; Abdi & Williams, 2010; Legendre & Legendre, 2012).

Prior to running this analysis, all environmental variables were standardised by subtracting the mean of each value and dividing by the standard deviation thus all variables were rescaled, thus all variances are given equal weight; a mean value of 0.0 and a standard deviation of 1.0 (Legendre & Legendre, 2012). This transformation brings data measured in many different units to a single dimensionless unit, reduces heteroscedasticity of descriptors and removes

issues of double zeros (Legendre & Legendre, 2012). To run a PCA the Kaiser-Meyer-Olkin Measure of Sampling Adequacy must be greater than 0.5, and the probability associated with Bartlett's Test of Sphericity be less than the level of significance,  $p=0.05$ . PCA can also be sensitive to outliers therefore cells containing outliers are discarded prior to running this PCA analysis in order to diminish the potential effects of these data (Jolliffe, 2002). Outliers were defined as those measurements with a standardised value outside of the range +3.29 to -3.29, 2.02% (37/1836) of all collected data were removed.

To assess the ability of a reduced environmental space in describing the observed butterfly – wood-fuel relationship, a canonical correspondence analysis (CCA) was performed. CCA is a multivariate analysis that ordines species and samples such that the ordination axes represent a constrained multivariate space, an *a priori* defined environmental gradient on to which species can be plotted (Hill & Gauch Jr, 1980). The resulting scatterplot derived from the species ordination scores facilitates an interpretation of the environmental gradient suitability (Hill & Gauch Jr, 1980).

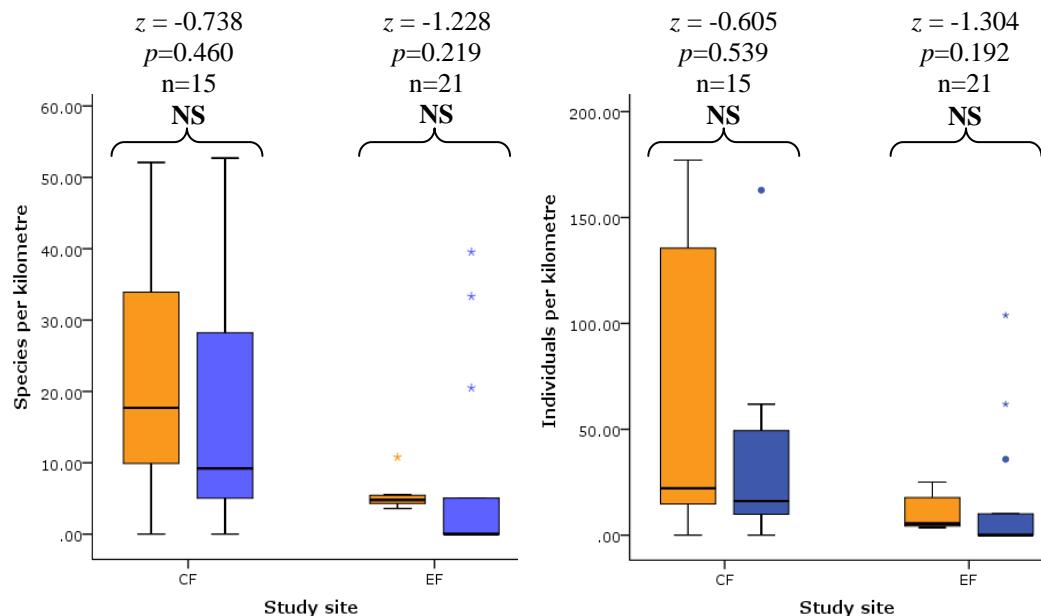
Criteria for species selection were based on observed abundance data; (1) species must be representative of either a woodland, woodland edge/clearing, or open meadow type habitat, (2) have been observed in two or more study sites, and (3) have been observed in two or more transects. Butterfly species habitat preference is taken from descriptions by Tolman & Lewington (1997).

## 5.4.2 Results

### 5.4.2.1 Butterfly data

Mann-Whitney tests across species and abundance observations for the Rechnitz study sites estate forest and co-operative forest data, 2011 and 2012, did not identify significant differences (Fig 5.5). Therefore, the 2011 and 2012 data were combined in all further analyses. Across the four wood-fuel landscape study sites a total of 518 individuals from 41

species were observed over 51 transects (for a full list of individuals and species recorded see Appendix 2); wood pasture – 322 individuals, 29 species, 6 transects; co-operative forest – 118 individuals, 19 species, 15 transects; estate forest – 64 individuals, 12 species, 21 transects; Forest Service – 14 individuals, 8 species, 9 transects.



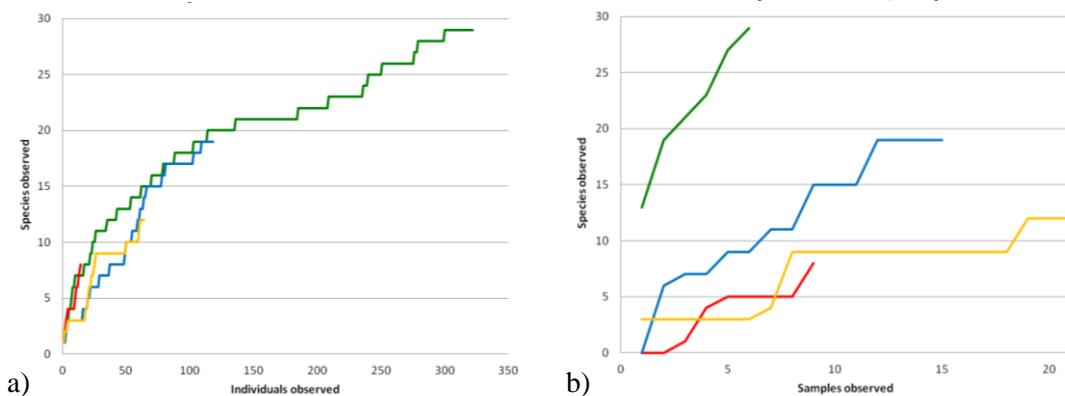
**Figure 5.5** Box plots show species  $\text{km}^{-1}$  and abundance  $\text{km}^{-1}$  data for CF and EF study sites, 2011 (orange) and 2012 (blue); NS - no statistical difference. Black lines show medians, boxes show interquartile range, whiskers show total range (excluding outliers shown as circles and stars).

#### 5.4.2.1.1 Abundance and species richness to describe and compare study landscapes

As described by Gotelli and Colwell (2001) comparison of species or higher taxon richness, without reference to a species sampling curve, is problematic. These curves are used to assess patterns of species richness, and differences between sites. Comparison of observed richness between landscapes is only possible if a clear asymptote has been reached in the species accumulation curve (Gotelli & Colwell, 2001). This was not the case in this study, the species sampling curves confirm the need for further sampling to reach any asymptote (Fig 5.6).

Rarefaction and extrapolation, using the EstimateS programme 9.1.0 (Colwell, 2013), produced data sets for each study site. The observed data generated sampling effort curves

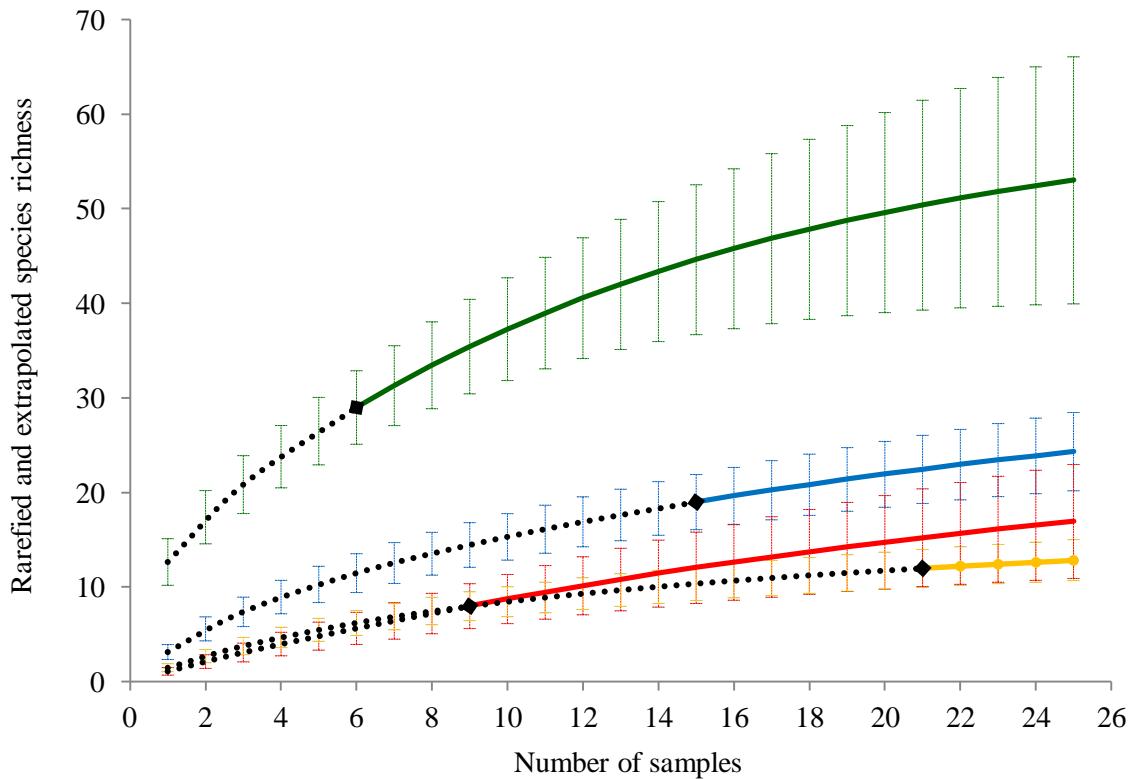
which allowed for description and comparison of species richness at a comparable point of sampling effort across the four study sites (Fig 5.7). These data described a continuum whereby the wood pasture study site was described by the highest level of species richness, with an estimated total of fifty-one species from an extended sample of twenty-two transects. Forest Service and estate forest are positioned at the lower end with fifteen and twelve species respectively, and co-operative forest was described by an intermediate level with an estimated twenty-three species at the twenty-two transect level.



**Figure 5.6** Species sampling curves for the four case study locations; (a) species observed as a function of individuals observed, and (b) species observed as a function of samples undertaken; Colour denotes study site; wood pasture – green, co-operative forest - blue, estate forest - orange and Forest Service - red.

Asymptotic species richness estimators derived from both an individual-based abundance and sample-based incidence perspective further illustrated a pattern of decreasing species richness across the four wood-fuel landscape study sites (Table 5.4). A statistical basis to difference between study sites across the estimated species richness continuum was given by an ANOVA test with Tukey's HSD *post-hoc* analysis;  $F_{3, 12}=22.282$ ,  $p<0.001$  (Fig 5.8). In which wood pasture was described by the highest species richness,  $\mu=68.525 \pm 5.894$ , and was different to the co-operative forest, estate forest and Forest Service study sites. Co-operative forest had an intermediate level of species richness by comparison,  $\mu=28.945 \pm 4.280$ , which was different to wood pasture and estate forest, whereas estate forest and Forest Service were described

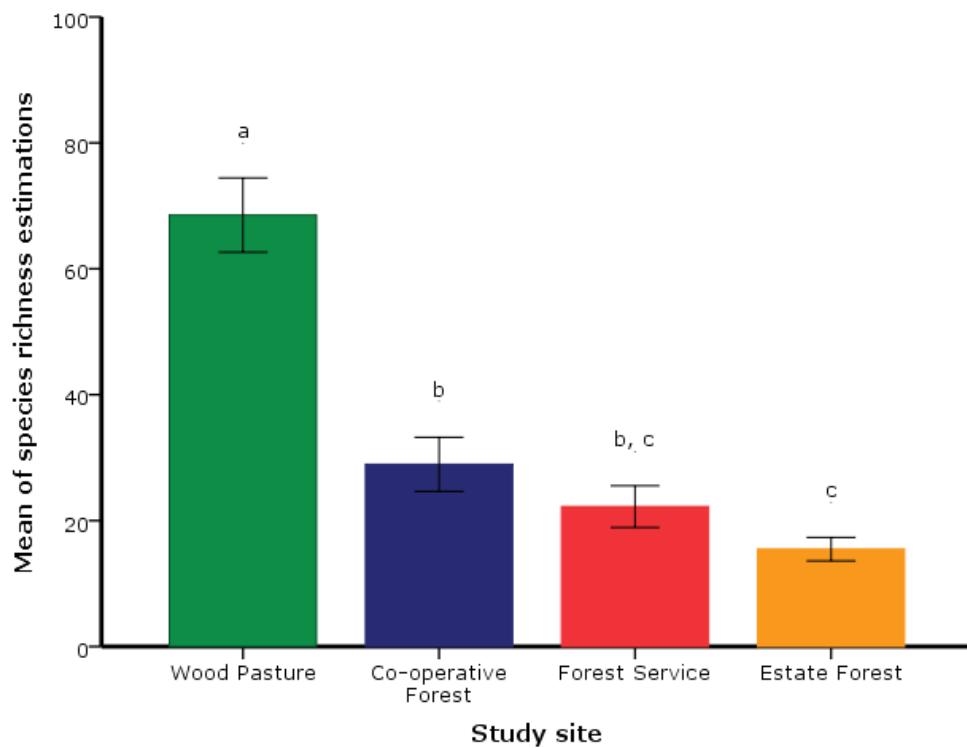
statistically similar levels of species richness,  $\mu = 15.460 \pm 1.861$  and  $\mu = 22.228 \pm 3.309$  respectively.



**Figure 5.7** Sample-based rarefaction and extrapolation from the four study sites based on observed data using the EstimateS programme 9.1.0; black dashed lines and filled circles show rarefied data; solid coloured lines extrapolation; bars indicate a measure of standard deviation; Colour denotes study site; wood pasture – green, co-operative forest - blue, estate forest - orange and Forest Service - red.

**Table 5.4** Four asymptotic estimates characterise species richness across the four wood-fuel landscape study sites, calculated using EstimateS 9.1.0 software (Colwell, 2013). Estimates reflect both sample-based and individual-based data.

	Abundance-based estimators		Incidence-based estimators	
	ACE	Chao 1	ICE	Chao 2
WP	73.86	73.86	75.50	50.88
CF	24.63	20.98	40.67	29.50
FS	23.00	12.64	26.60	26.67
EF	13.67	12.25	20.75	15.17

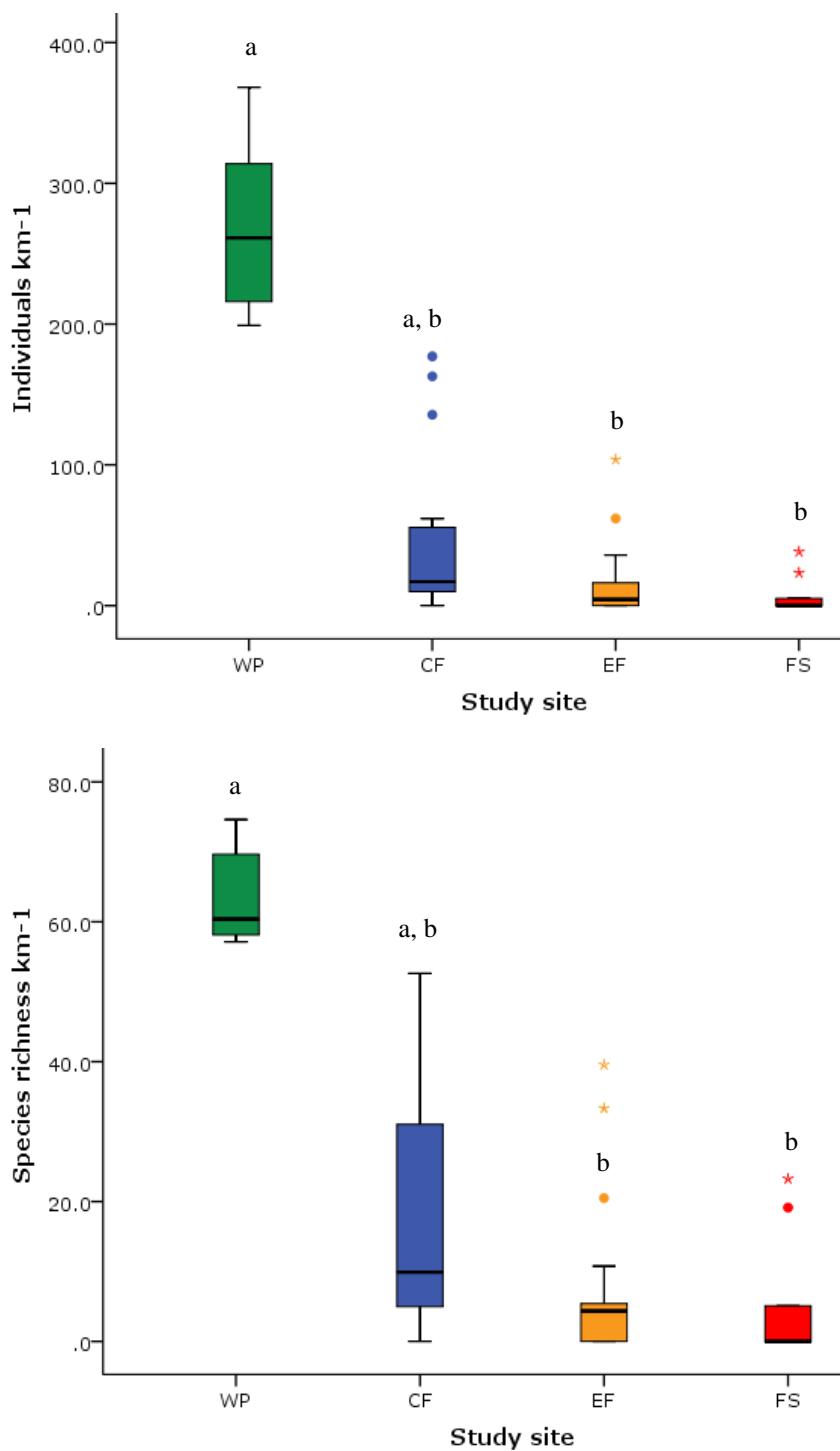


**Figure 5.8** Estimated species richness for the four study sites, bars show mean numbers per study site  $\pm$  standard error. Statistical difference between sites is described by an ANOVA,  $F_{3, 24} = 26.656, p < 0.001$ ; variances were homogenous, Levene's statistic = 0.555,  $p = 0.655$ . Letters denote homogenous subsets described by Tukey's HSD *post-hoc* multiple comparisons.

Statistical analysis of the observed individual abundance and species richness  $\text{km}^{-1}$  data further qualified the description of an abundance and species continuum across the four wood-fuel landscape study sites. Observed abundance and species richness differed across the four study sites; abundance  $\chi^2 = 20.844, \text{df} = 3, p < 0.001$ , and species richness  $\chi^2 = 20.361, \text{df} = 3, p < 0.001$  (Fig 5.9). Individuals  $\text{km}^{-1}$  median values; WP = 261.24, CF = 17.07, EF = 4.35, FS = 0.00. Species richness  $\text{km}^{-1}$  median values; WP = 60.38, CF = 9.89, EF = 4.35, FS = 0.00.

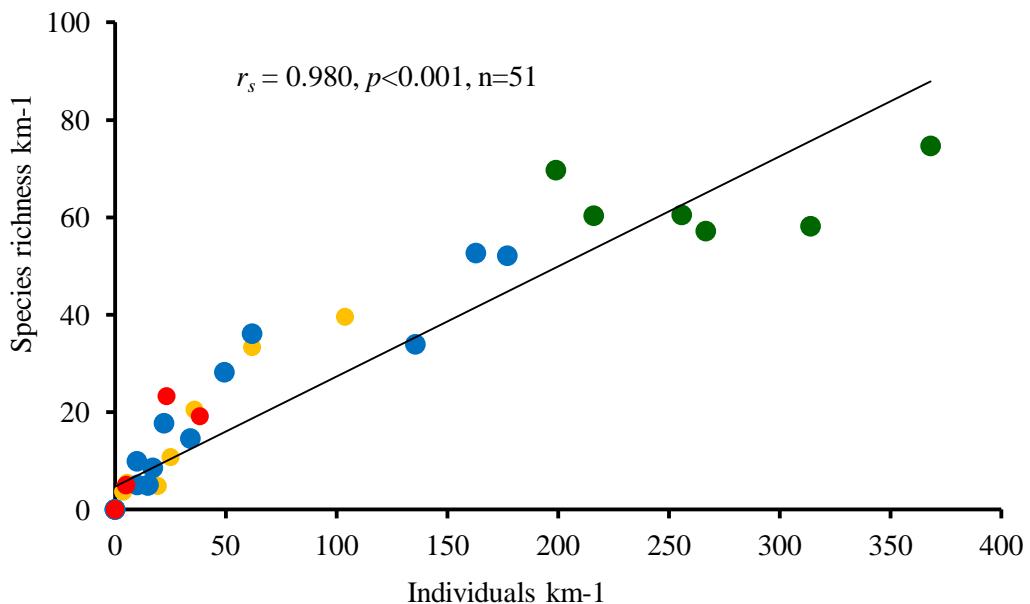
These observed data showed a statistically significant difference across the four wood-fuel landscape study sites. Mean rank values were highest at the wood pasture site and statistically similar to those of the co-operative forest study site but were different to those calculated for estate forest and Forest Service study sites. However, the mean rank value for the co-operative

forest study site showed no statistical difference to that of the Forest Service, and therefore the estate forest, study sites.



**Figure 5.9** Difference in observed individuals  $\text{km}^{-1}$ ,  $\chi^2=20.844$ ,  $\text{df}=3$ ,  $p<0.001$ , and species richness  $\text{km}^{-1}$ ,  $\chi^2=20.361$ ,  $\text{df}=3$ ,  $p<0.001$ , across the four study sites. Black lines show medians, boxes show interquartile range and whiskers show total range (excluding outliers shown as circles and stars). Colour denotes study site; wood pasture – green, co-operative forest - blue, estate forest - orange and Forest Service - red.

A Spearman's Rank correlation clearly demonstrated the strongly significant and positive relationship between observed individual abundance and species richness (Fig 5.10). These observed and calculated data, and the associated analyses, described a pattern of increasing butterfly abundance with an associated increase in species richness across the four case study wood-fuel landscapes.



**Figure 5.10** Correlation between observed individuals  $\text{km}^{-1}$  and observed species richness  $\text{km}^{-1}$ ; Spearman's rank correlation  $r_s=0.980, p<0.001, n =51$ ; Colour denotes study site; wood pasture – green, co-operative forest - blue, estate forest - orange and Forest Service - red.

#### 5.4.2.1.2 Diversity indices to describe and compare study landscapes

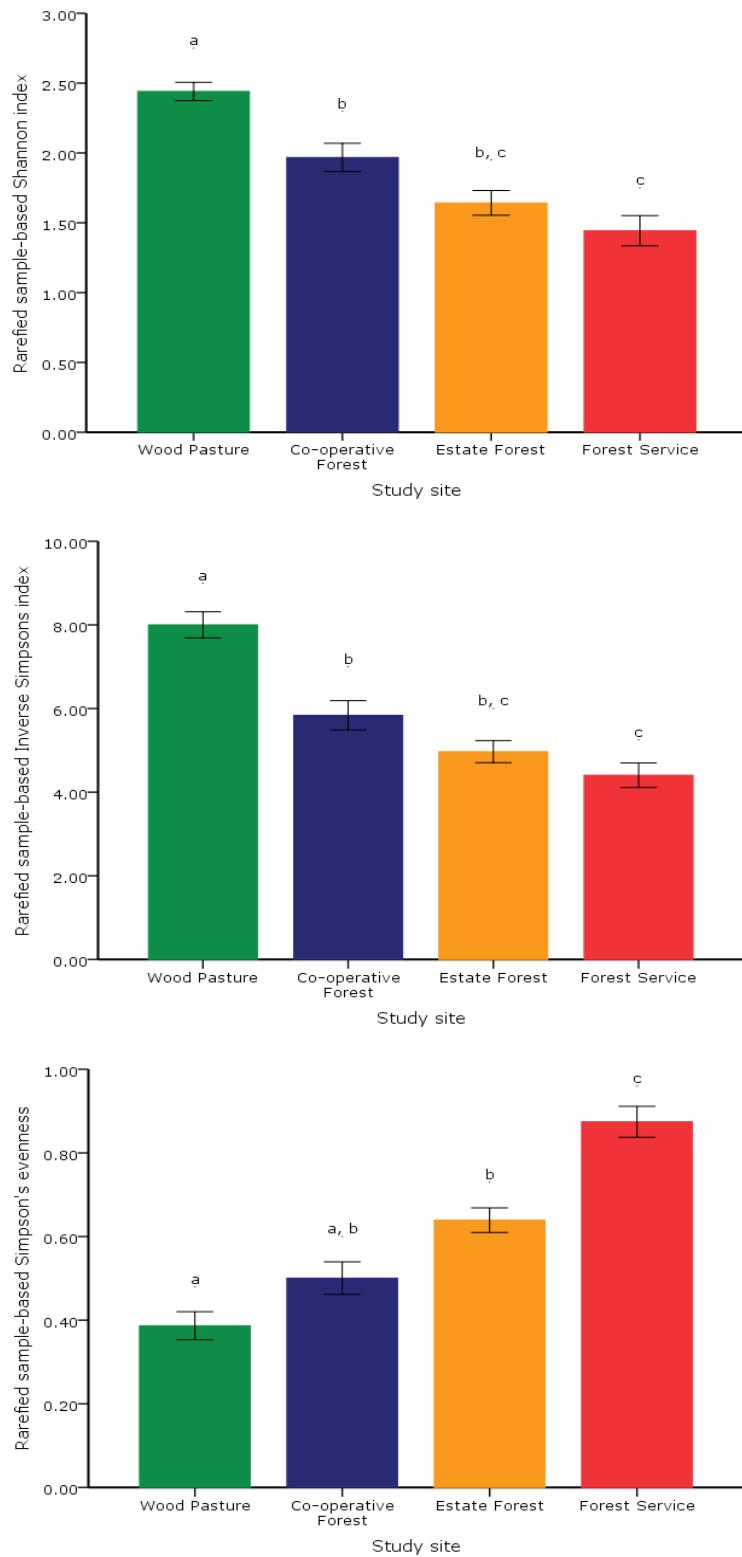
Species diversity indices varied across the four study sites; Shannon index ( $H'$ ) ranged from 1.91 to 2.58, the Inverse Simpson's index ( $I/D$ ) from 5.76 to 8.58 and the Simpson's evenness measure ( $E_{I/D}$ ) from 0.72 to 0.30 (Table 5.5). Ranking for each study site across the three diversity indices demonstrated exact concordance.

**Table 5.5** Diversity indices calculated for each study site using the EstimateS software 9.1.0 (Colwell, 2013); Shannon index ( $H'$ ), Inverse Simpson's index ( $1/D$ ), and Simpson's Evenness index ( $E_{1/D}$ ). Figures in brackets indicate ranks.

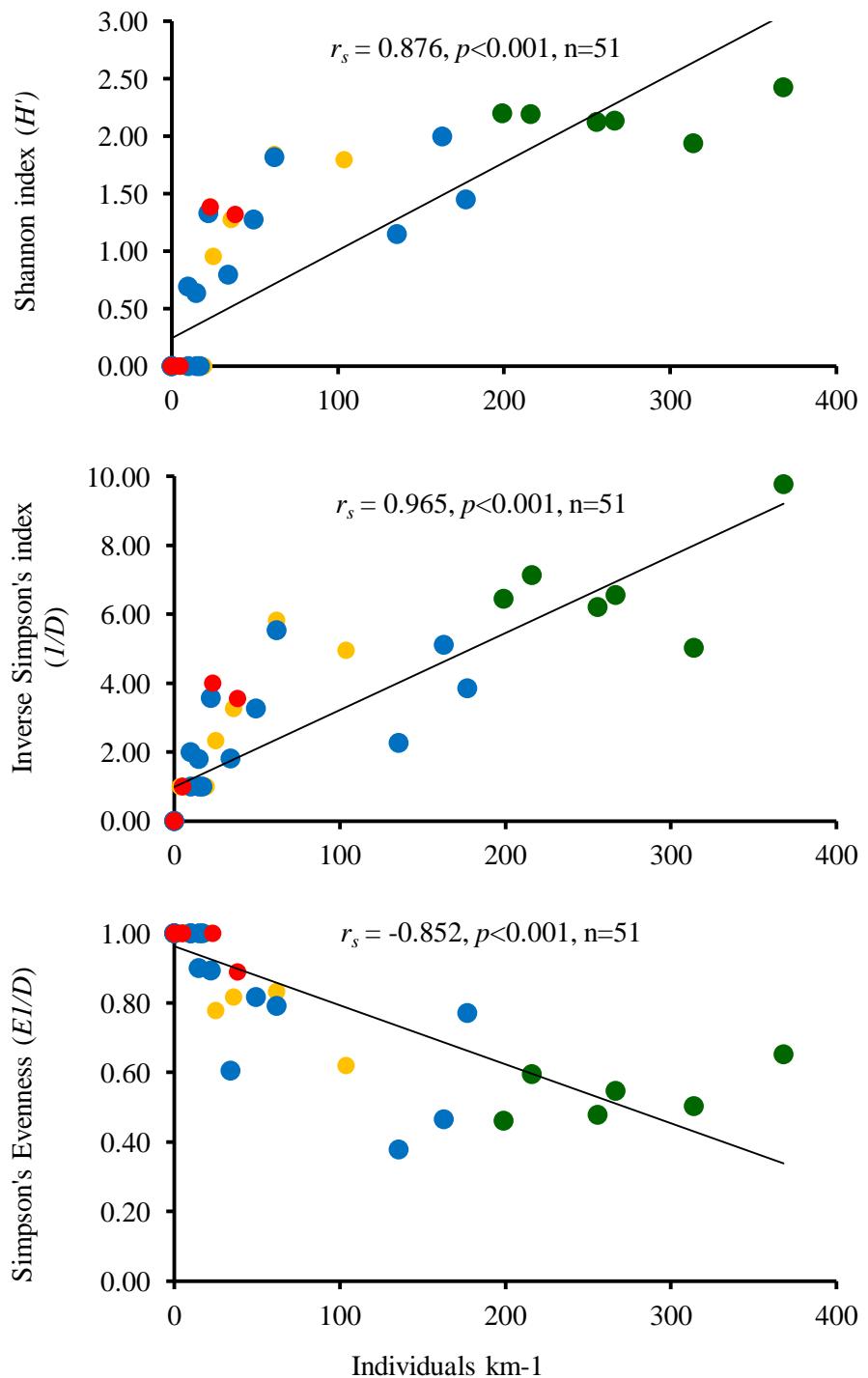
	<b>Shannon</b>	<b>Inverse Simpson's</b>	<b>Simpson's Evenness</b>	<b>Mean rank</b>
WP	2.58 (1)	8.58 (1)	0.30 (1)	1
CF	2.35 (2)	7.29 (2)	0.38 (2)	2
EF	2.13 (3)	6.59 (3)	0.55 (3)	3
FS	1.91 (4)	5.76 (4)	0.72 (4)	4

At the study site level statistical difference between the four case study wood-fuel landscapes, for each of the diversity indices, further described this continuum of diversity. Difference was found across the four study sites, based on the rarefied sample-based indices of diversity; Shannon index,  $F_{3,47} = 11.136, p < 0.001$ ; Inverse Simpson's index,  $F_{3,47} = 13.617, p < 0.001$ ; and Simpson's Evenness  $F_{3,47} = 21.728, p < 0.001$ . Tukey's HSD *post-hoc* tests described a pattern which mirrored that of the observed abundance and species richness data. Wood pasture was associated with the highest level of diversity alongside the lowest level of evenness, estate forest and Forest Service were described by low levels of diversity and a high level of evenness, thus dominance, whilst co-operative forest had intermediate levels of both diversity and evenness (Fig 5.11).

The relationships between abundance, species richness and diversity across the four study sites illustrate a pattern of positive reinforcement. An increase in abundance has the potential to increase species richness and diversity with an associated decrease in evenness, and therefore reduced dominance by any one individual species (Fig 5.12). In respect to the four study sites, a continuum of increasing diversity and a reduction in dominance is suggested moving from Forest Service through estate forest and co-operative forest on to wood pasture.



**Figure 5.11** Differences between study sites for Shannon and Inverse Simpson's diversity indices and the Simpson's Evenness index; Shannon index,  $F_{3,47}=11.136, p<0.001$ ; Inverse Simpson's index,  $F_{3,47}=13.617, p<0.001$ ; and Simpson's Evenness  $F_{3,47}=21.728, p<0.001$ . Bars show mean values  $\pm$  standard error. Letters indicate subsets of similar groups described by Tukey's HSD *post-hoc* tests.



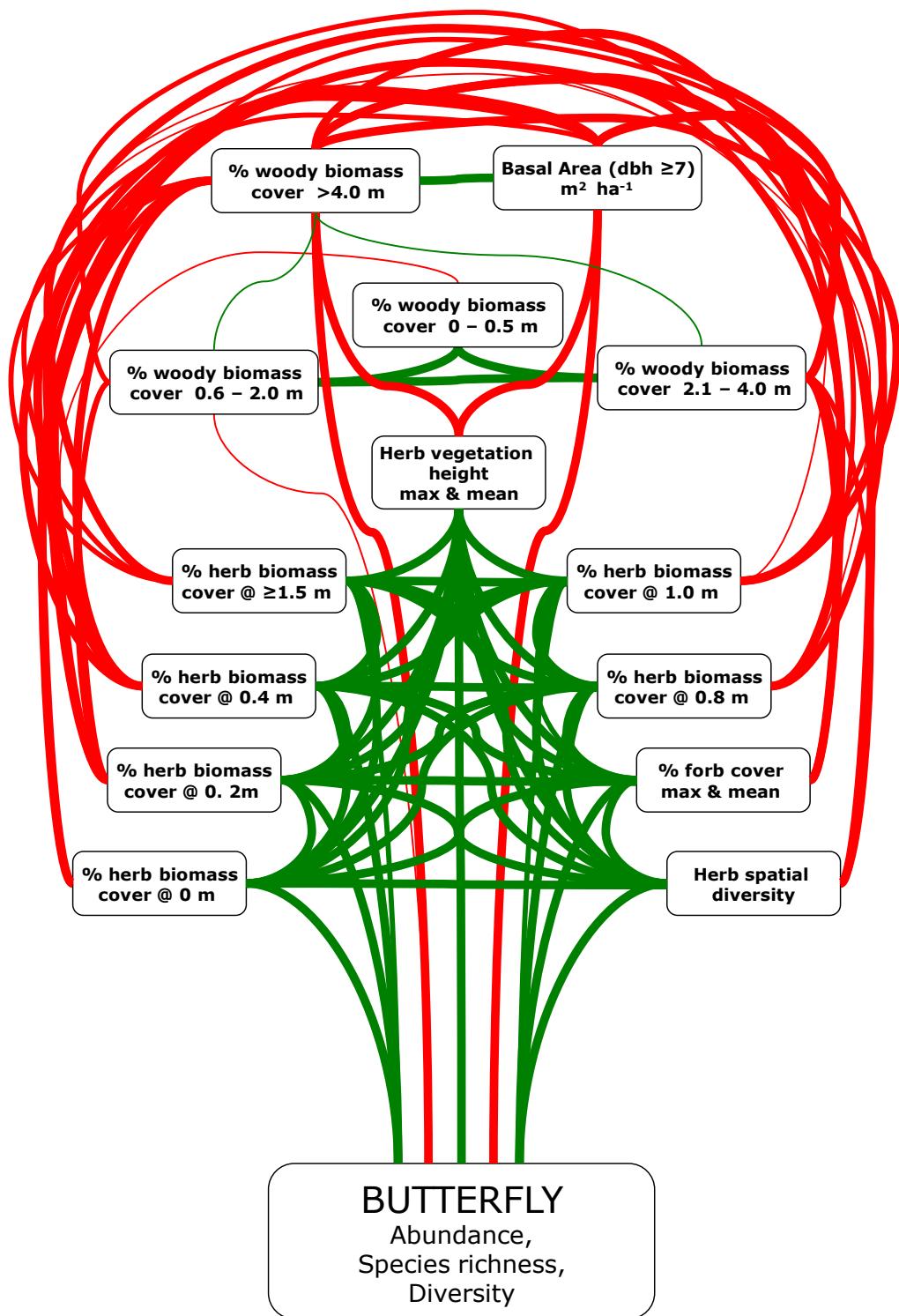
**Figure 5.12** Scatterplots show relationships between observed individuals km<sup>-1</sup>, diversity indices and evenness across the four study sites. Colour denotes study site; wood pasture – green, co-operative forest - blue, estate forest - orange and Forest Service - red.

#### **5.4.2.2 The relationship between biodiversity and environmental variables**

Taking the biological gradients described by these data, in the shape of abundance, species richness, diversity and evenness, and applying them to the physical structure, as measured in this component of the thesis, describes the relationships between these two ecological components. Correlations illustrated the relationships between environmental structure and the faunal element described by butterflies.

A schematic map of the connections between measured environmental variables and indicators of butterfly abundance, richness, and diversity demonstrated direct and indirect pathways for positive and negative influence (Fig 5.13). Environmental variables that describe the herb biomass component (see Table 5.3) expressed a direct and positive influence on abundance, species richness and diversity. In contrast environmental variables that describe the wood biomass component (see Table 5.3) expressed a direct, negative association through the influence of basal area and woody biomass cover >4.0 m, and also indirectly through the negative influence of woody biomass variables on the herb biomass variables.

The relationships between measured environmental variables and Simpson's evenness, where dominance is seen as an opposite measure to diversity, were characterised by a contrasting response. Evenness a negative relationship with wood biomass and a positive relationship with herb biomass, increasing wood biomass is associated with an increase in dominance and increasing herb biomass is associated with a decrease in dominance (Table 5.6).



**Figure 5.13** A schematic representation of the significant relationships between butterfly abundance, species richness, diversity, herb biomass and wood biomass variables, determined from a Spearman's rank correlation. Positive relationships are shown in green, with negative relationships in red. The thickness of connecting lines denotes the strength of the relationship, as derived from the calculated p values;  $p \leq 0.05$ ;  $p \leq 0.01$ ;  $p \leq 0.001$ .

**Table 5.6** Results of Spearman's rank correlation between Simpson's evenness and butterfly abundance, species richness, diversity, wood biomass and herb biomass variables (n=102). Colour denotes direction of relationship; red = negative, green = positive, NS = not significant.

	Variable	$r_s$	p value
Butterfly abundance, species richness and diversity	Species richness $\text{km}^{-1}$	-0.831	<0.001
	Abundance $\text{km}^{-1}$	-0.852	<0.001
	Shannon	-0.915	<0.001
	Inverse Simpson's	-0.826	<0.001
Wood biomass variables	Basal area $\text{m}^2 \text{ha}^{-1}$	0.704	<0.001
	Wood biomass 0 - 0.5 m	0.108	NS
	Wood biomass 0.6 - 2.0m	0.169	NS
	Wood biomass 2.1 - 4.0m	0.109	NS
Herb biomass variables	Wood biomass <4.0 m	0.769	<0.001
	Mean forb cover	-0.851	<0.001
	Max forb cover	-0.848	<0.001
	Herb biomass 0 m	-0.684	<0.001
	Herb biomass 0.2 m	-0.651	<0.001
	Herb biomass 0.4 m	-0.570	<0.001
	Herb biomass 0.8 m	-0.428	<0.001
	Herb biomass 1.0 m	-0.357	<0.001
	Herb biomass 1.5 m	-0.340	<0.001
	Herb spatial diversity	-0.573	<0.001
	Herb height (mean cms)	-0.692	<0.001
	Herb height (max cms)	-0.606	<0.001

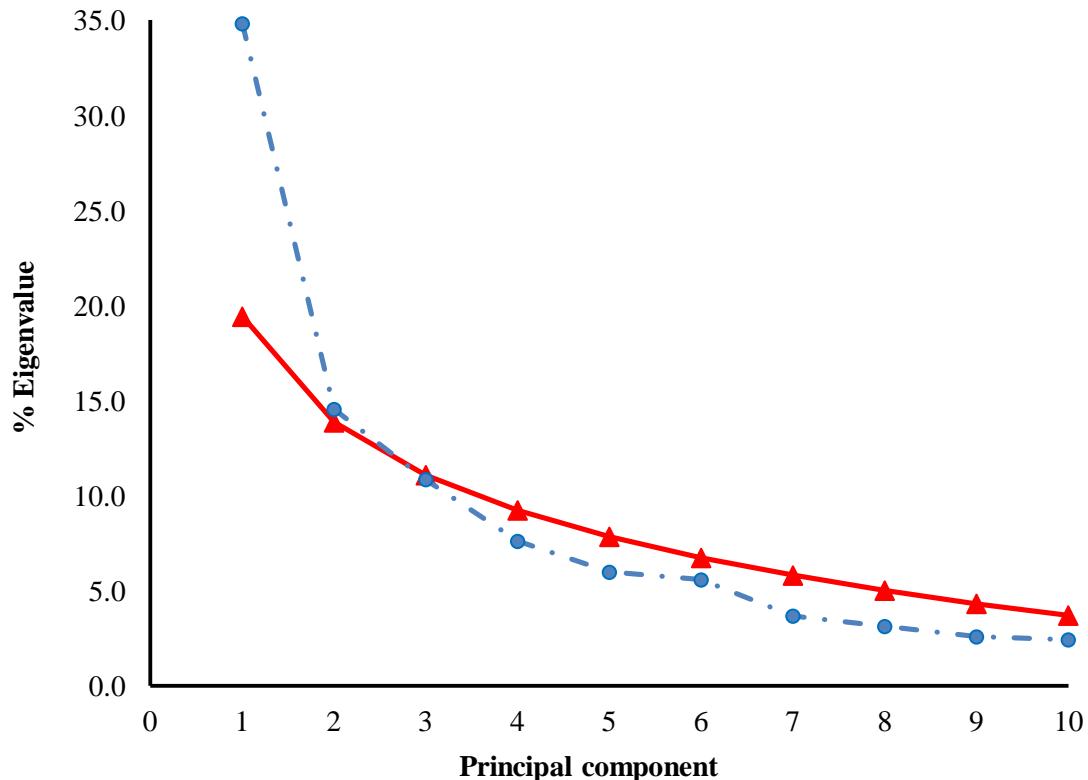
A Principal Components Analysis reduced the dimensionality of the measured environmental variables (Table 5.7). Analysis of the measured variables satisfied the criteria for appropriateness of factor analysis; Kaiser-Myer-Olkin Measure of Sampling Adequacy (MSA) = 0.785, and the probability associated with Bartlett's Test of Sphericity p <0.001. However, the amount of variance explained by the first three principal component axis, 60%, and the strength of component loadings on each principal component demonstrates the complexity of the ecological trends to be visualised, and may constitute a limitation of the reliability of the PCA results (Jolliffe, 2002; Abdi & Williams, 2010). Therefore, as an aid for interpretation, only those variables with a component loading  $\geq 0.7$  on the selected principal component axes are considered further.

**Table 5.7**

Eigenvector, eigenvalue and variance explained by the first two axes (PC1 and PC2) in PCA with environmental variables from the four study sites. Bold values indicate eigenvectors that contribute most to the axes formation,  
 \* denotes non-random principal component based on broken-stick eigenvalue.

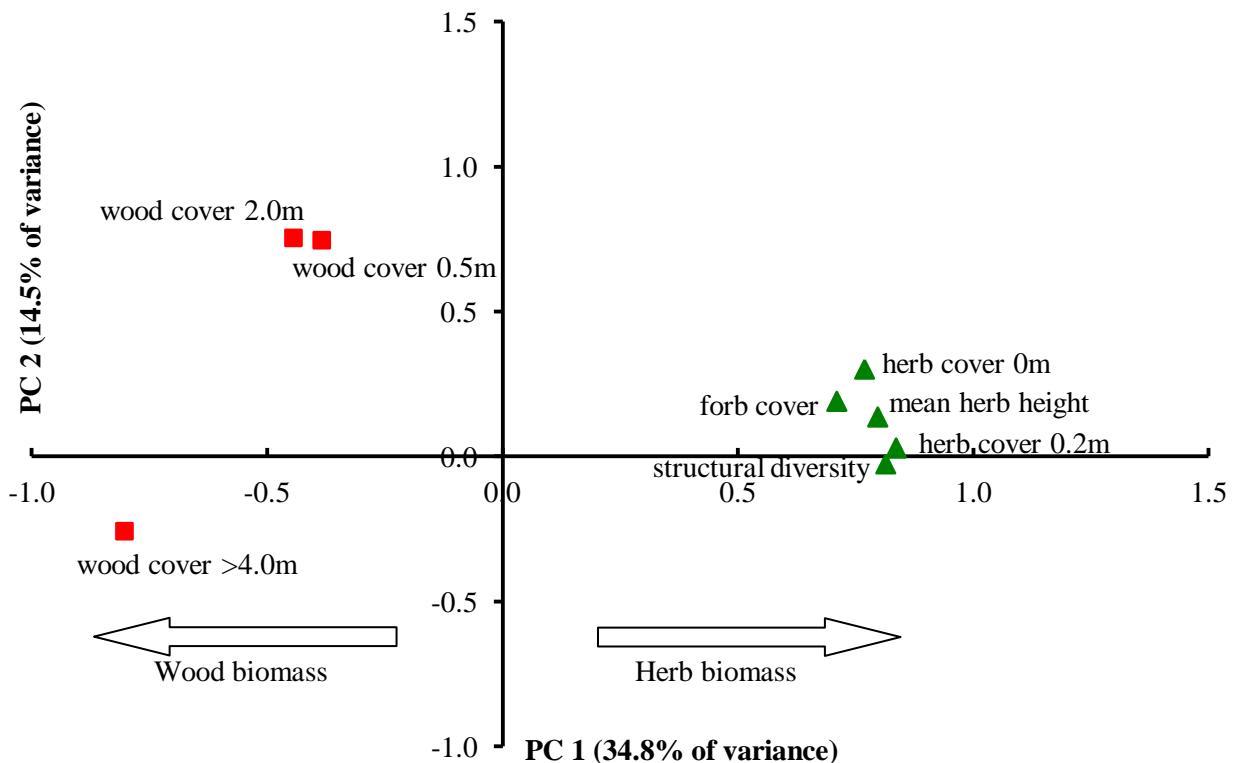
Eigenvalue	6.269	2.617	1.953
% variance	34.825	14.540	10.849
Broken stick eigenvalue	3.495	2.495	1.995
Environmental variable	PC1*	PC2*	PC3
basal area ( $m^2 ha^{-1}$ )	-0.654	-0.484	
% wood biomass 0 - 0.5 m	-0.384	<b>0.747</b>	
% wood biomass 0.6 - 2.0 m	-0.444	<b>0.755</b>	
% wood biomass 2.1 - 4.0 m	-0.355	0.675	
% wood biomass $\geq 4.0$ m	<b>-0.803</b>	-0.257	
% bare ground	0.227	0.076	
% leaf litter	-0.644	-0.307	
% forb cover	<b>0.710</b>	0.191	
% herb biomass 0 m	<b>0.769</b>	0.301	
% herb biomass 0.2 m	<b>0.836</b>	0.030	
% herb biomass 0.4 m	0.633	-0.037	
% herb biomass 0.8 m	0.549	-0.132	
% herb biomass 1.0 m	0.495	-0.140	
% herb biomass 1.5 m	0.311	-0.089	
herb spatial diversity ( $H'$ )	<b>0.814</b>	-0.026	
mean herb height (cm)	<b>0.797</b>	0.137	
altitude (m)	-0.195	0.651	
aspect ( $^{\circ}$ )	0.290	-0.123	

Broken-stick eigenvalues for the data indicated that the first two principal components (PC1 and PC2) captured more variance than expected by chance (Fig 5.14); together these axis account for 49.3% of the data variability. PC1, which contributes 34.8% of variability, is described by five herb biomass variables with positive scores; mean height, spatial diversity, % forbs, % herb biomass at 0 m and 0.2, also the wood biomass component % wood biomass  $>4.0$  m, with a negative score. PC2, which contributes 14.5% of variability, is described by two wood biomass components; % wood biomass 0 – 0.5 m and 0.6 – 2.0 m, with positive scores.



**Figure 5.14** Eigenvalues for PCA result and broken-stick model. Principal components with eigenvalues (%) higher than those generated by chance, derived by the broken-stick model, are selected for interpretation. Broken blue line – PCA result, solid red line – broken-stick model.

A scatterplot of factor scores illustrates relationships between the selected environmental variables (Fig 5.15). In the first principal component axis, selected herb biomass variables are described by positive values. In contrast, the selected wood biomass variables are described by negative values. This pattern mirrors the tension between wood biomass and herb biomass compartments as defined in the previous correlation exercise.



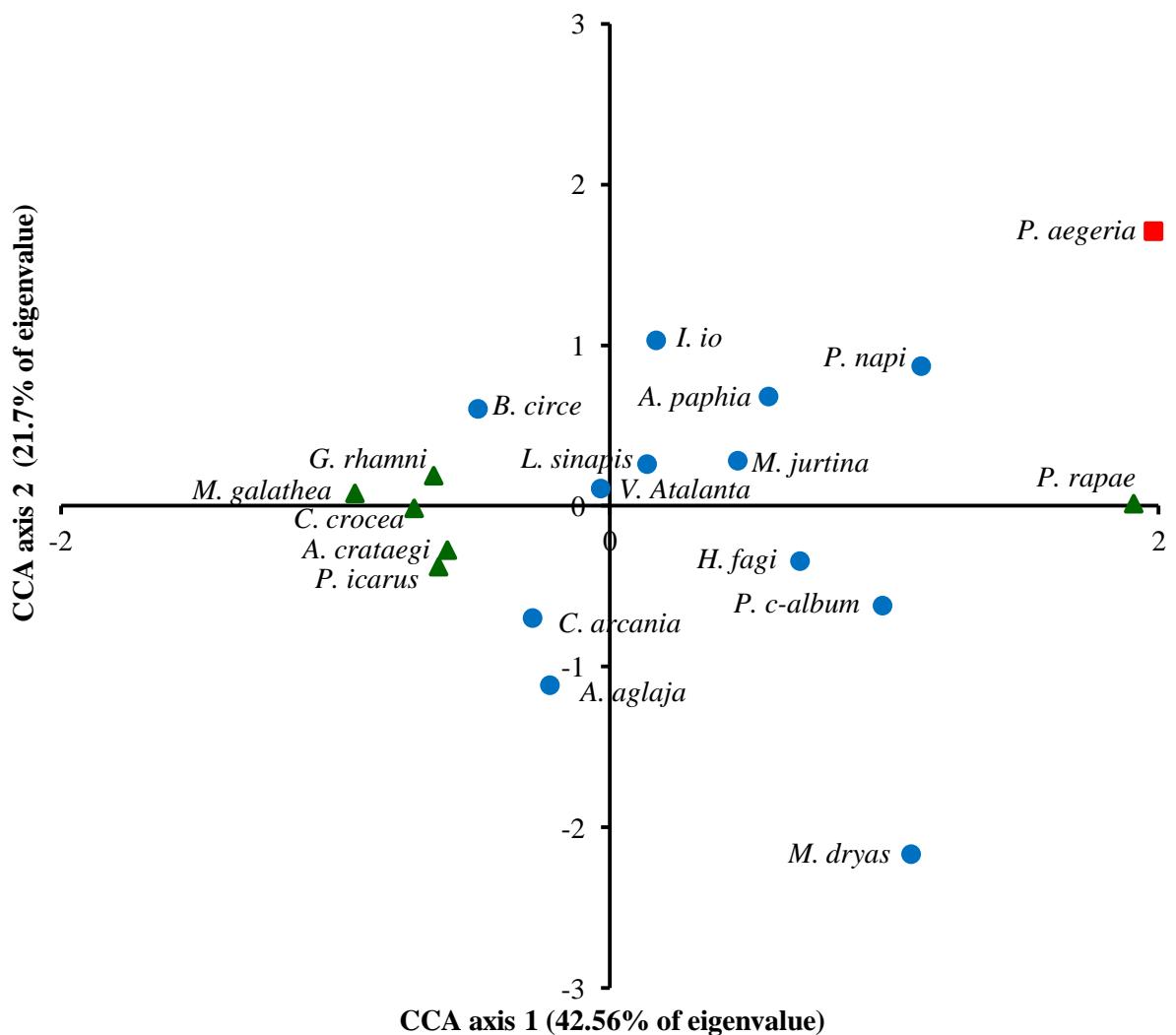
**Figure 5.15** Scatterplot using PCA factor scores. Selected non-trivial principal components describe an environmental continuum defined by the first two axes of the principal component analysis. Red squares identify wood biomass variables and green triangles identify herb biomass.

The tension between wood biomass and herb biomass components is also expressed in the relationship between the selected environmental variables, individual abundance, species richness, diversity, and evenness. These relationships are quantified by a Spearman's rank correlation between the reduced set of environmental variables and the measurements of abundance, richness and diversity (Table 5.8).

**Table 5.8** Results of a Spearman's rank correlation between the reduced set of environmental variables and measures of species abundance, richness and diversity (n = 102). Colour denotes direction of relationship; red = negative, green = positive, NS = not significant, \* significant at  $p<0.05$ , \*\* significant at  $p<0.001$ .

	Individual abundance ( $km^{-1}$ )	Species richness ( $km^{-1}$ )	Shannon ( $H'$ )	Inverse Simpson's ( $I/D$ )	Simpson's evenness ( $E_{(I/D)}$ )
Wood 0 - 0.5 m (%)	-0.168 (NS)	-0.142 (NS)	-0.074 (NS)	-0.149 (NS)	0.108 (NS)
Wood 0.6 - 2.0 m (%)	<b>-0.213*</b>	-0.190 (NS)	-0.129 (NS)	-0.180 (NS)	0.169 (NS)
Wood >4.0 m (%)	<b>-0.708**</b>	<b>-0.693**</b>	<b>-0.753**</b>	<b>-0.714**</b>	<b>0.769**</b>
Forb cover (%)	<b>0.775**</b>	<b>0.771**</b>	<b>0.790**</b>	<b>0.751**</b>	<b>-0.851**</b>
Herb 0 m (%)	<b>0.716**</b>	<b>0.685**</b>	<b>0.655**</b>	<b>0.702**</b>	<b>-0.684**</b>
Herb 0.2 m (%)	<b>0.711**</b>	<b>0.679**</b>	<b>0.629**</b>	<b>0.676**</b>	<b>-0.651**</b>
Herb spatial diversity ( $H'$ )	<b>0.695**</b>	<b>0.673**</b>	<b>0.575**</b>	<b>0.677**</b>	<b>-0.573**</b>
Mean herb height (cms)	<b>0.725**</b>	<b>0.711**</b>	<b>0.692**</b>	<b>0.729**</b>	<b>-0.692**</b>

The subsequent canonical correspondence analysis (CCA) exercise provides an opportunity to assess the ability of this reduced set of environmental variables to describe an ecological value in respect of specific butterfly species abundance characteristics (Fig 5.16). Here butterfly species' positions in ordination space, along the *a priori* described environmental gradient, illustrate relationships between the biophysical structural component and faunal component across the four wood-fuel case study landscapes.



**Figure 5.16** CCA of constrained environmental variables and species  $\text{km}^{-1}$  data, first and second ordination axes. The ordination was performed using all quadrat data from the selected reduced set of environmental variables identified in the PCA and all transect data for species abundance observations. Only those species that met selection criteria are plotted. Habitat associations are denoted by symbol; ■ – woodland, ● – woodland edge/clearing and ▲ – open, meadow.

## **5.5 Discussion**

The purpose of this component of the thesis has been to define a suite of ecological value indicators that connects the provision of wood-fuel to ecological value through the impact of anthropogenic land use, the resultant landscape structures and the consequent levels of biodiversity. The relationships between environmental structure and biodiversity were explored through two strands of investigation; firstly the measurement of butterfly diversity across the four case study wood-fuel landscapes; secondly through relationships between butterfly diversity and the observed environmental variables. A subsequent reduction in the dimensionality of the observed environmental data identified variables to become proxy measurements for the biophysical characteristics that describe an ecological value.

The measured environmental variables that characterise the four studied wood-fuel landscapes describe differences in the approach to timber and wood-fuel provision. These differences allow for a comparative approach to illustrate structure and the associated patterns of butterfly diversity connected with differing methods of timber and wood-fuel provision. In describing patterns of butterfly diversity driven by relationships between the cultural component of timber and wood-fuel provision and the consequent landscape structures created recognition must be given to the potential for difference between local species pools. Diversity relationships with local landscape structures should be set against a background in which local pools of diversity are imbedded within larger regional pools, and difference between local pools may exist (Begon et al., 1996). However results in this chapter demonstrate that difference in butterfly diversity is statistically associated with differences in landscape structure, across the four wood-fuel landscapes. Description of this relationship allows for the construction of a suite of indicators that can be used to illustrate an ecological value for wood-fuel landscapes.

This selection of a suite of ecological value indicators is focused on an output that retains an ability to convey information. In this use of ecological value indicators, the selected

environmental variables need to retain a capacity to summarise biodiversity as a measure of biophysical characteristics influenced by anthropogenic management. Support for the use of a reduced environmental dimensionality for the ecological value indicators, described through a principal component analysis, is provided by a subsequent canonical correspondence analysis. Interpretation of species placement in ordination space strengthens the argument for inclusion of the selected environmental variables as indicators of ecological value into the wood-fuel landscape evaluative model (chapter 7).

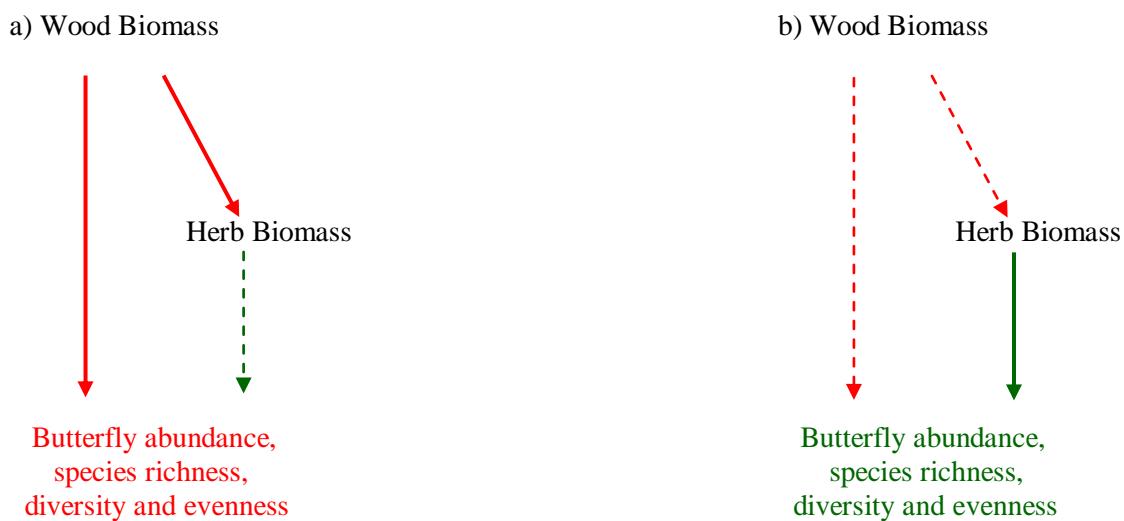
The canonical correspondence analysis describes an environmental continuum; butterfly species predominately associated with woodlands are characterised by positive ordination scores, whereas species associated with a more open, meadow type habitat are characterised by negative ordination scores (see Fig 5.16). Butterfly species that exhibit a propensity for a woodland edge/clearing habitat are placed in the middle of this *a priori* described environmental gradient. Further examination of the faunal pattern identifies a partial separation of species associated with the woodland edge/clearing habitats. Species position can be interpreted based on preference towards either a more wooded or a more open, meadow based environmental structure. *C. arcania*, *B. circe* and *A. aglaja* being species that are predominately found in meadow tending towards woodland edge, whereas *H. fagi*, *P. c-album*, *A. paphia* and *P. napi* exhibit preference for a woodland edge tending toward clearing type habitat.

However, there were some unexpected patterns such as the position of *P. rapae*, a species that would be expected to be associated with a meadow type habitat. This species is considered a common generalist (van Swaay et al., 2006) which may account for mis-placement. Also *M. jurtina*, another common generalist species (van Swaay et al., 2006), with a preference for a more open, meadow type habitat would be expected to be found to the left of the woodland edge/clearing grouping.

Notwithstanding these cases, this visual application of species plotted against a reduced set of environmental indicators, in an ordination space, suggests a capacity to communicate information that relates to the objective of this element of the thesis. A reduction in the number of ecological indicators has not removed the ability to describe relationships between physical structure and a faunal component in the landscape. The use of eight environmental descriptors provides information that can be used to evaluate the influence of anthropogenic created landscape structure on measures of butterfly abundance, species richness, diversity and dominance.

Butterfly abundance, species richness, and diversity measurements demonstrate relationships associated with land use management. The wood pasture approach is characterised by high levels of abundance, species richness, diversity, and evenness, whilst management within Forest Service woodland is associated with low abundance, species richness, diversity and evenness. The commercial approach to sustainable forestry described by the estate and co-operative forest enterprises is connected with intermediate levels in all butterfly community measurements.

Measurements used to describe the observed butterfly communities show strong correlations with the environmental characteristics used to explain the landscape created by each management approach. Wood biomass components of the measured environment are characterised by negative relationships toward abundance, species richness, diversity and evenness. This relationship is expressed via two distinct pathways; (1) a direct influence on the butterfly community itself and (2) as an indirect influence via the negative interaction the wood biomass compartments exhibit on herb biomass compartments. In contrast the herb biomass components have a direct positive relationship with individual abundance, species richness, diversity, and evenness measurements (Fig 5.17).



**Figure 5.17** Interactions between wood biomass and herb biomass woodland compartments; (a) A strong negative wood biomass influence will overwhelm the positive influence of the herb biomass components leading to reduced abundance and diversity; (b) Whereas a reduced influence from the wood biomass components allows the positive nature of the herb biomass – butterfly relationship to maintain higher levels of abundance and diversity. Colour denotes direction of influence, red – negative, green positive; dotted arrows indicate weak interactions between compartments.

As a surrogate for ecological value, a range of indicators are presented that describe the performance of a selected ecosystem service, timber and wood-fuel provision, through the landscape structures created with respect to the specific ecological properties of faunal abundance, species richness, diversity and evenness. The tension between wood biomass and herb biomass compartments, described here with respect to butterfly diversity across the four studied wood-fuel landscapes, reveals elements of the cultural landscape – modern economic landscape dichotomy.

Focus on the wood biomass compartment, from a timber and wood-fuel economic production perspective, will have a negative influence on the herb biomass compartment which may lead to woodland configurational simplification, with reduced levels of biophysical diversity and potential system instability. Management approaches which tend to improvement in the herb biomass direction, with potential for consequent increased biophysical diversity, may require

multiple land-use functions alongside that of wood production more akin to a cultural landscape approach.

Patterns of structural influence on invertebrate communities have been variously reported in studies, many of which include butterflies (van Swaay et al., 2006; Smith et al., 2007; Nilsson et al., 2008; Fartmann et al., 2013). Woodland simplification following a shift from traditional management, such as wood-pasture systems, to high forest systems has been seen to result in lowered levels of floral and faunal diversity ( van Swaay et al., 2006; Fartmann et al., 2013). Similar impacts have been observed in relation to herbivorous grazing, described with particular reference to deer in Britain, where both under and over grazing reduces woodland structural complexity and levels of diversity (Feber et al., 2001; Stewart, 2001).

Traditional, cultural landscapes can be described as aggregations of hierarchical organised heterogeneous units which create complex landscapes at scales from metres to kilometres (Farina, 2000). The inherent complexity of cultural landscapes creates structural heterogeneity in which biodiversity is often higher (Bugalho et al., 2011; Middleton, 2013). A traditional approach to landscape management and land-use communicates at a local level supplying goods to satisfy a local market operating through short feedback (Farina, 2000). Whereas in modern economic landscapes fewer resources are used heavily through simplified techniques, they are large scale homogeneous areas created by large scale economies (Farina, 2000). They operate via long diffuse feedback loops supplying a global market (Farina, 2000).

Large scale global systems work to overcome local biophysical limitations providing spatial and temporal independence. Space and time become components disconnected from any regional physical and biological constraints (O'Hara & Stagl, 2001). Greater distance between production and use removes societies from first hand experience of the consequences of their actions (Constanza et al. 1997). Values become generic rather than specific, and community becomes disembedded. The resultant disembedded societies fail to perceive local signals as

the global economy rarely communicates the warning signals of unstable local ecosystems and local social systems (O'Hara & Stagl, 2001).

To perceive value in complex social-ecological systems, where society is considered a purposeful and reflexive component, relationships between landscape patterns and the communities that create them should work to integrate economy and society with ecology. Society, through the agency of purpose and reflexivity, must consciously accept they are a component of the natural world, intimately connected with the ecological systems that sustain their lives (Cronon, 1996).

## **5.6 Conclusion**

This component of the thesis builds a wood-fuel landscape ecological value set in a physical space where knowledge is gathered through the structures created in the course of living in it. This relationship is reciprocal, the physical nature of the environment both influences and is influenced by the socio-cultural interactions with it. Diversity, as a consequence of certain spatial configurations, is used to explore the creation of a suite of ecological value indicators. In this manner diversity, as a concept, is used to describe the relationships between physical space and biological time with the potential to describe an ecological component of social-ecological system integrity.

Nature and society are two ecosystem components that drive landscape level processes and shape landscape structure. Anthropogenic influences affect most ecological communities on Earth, and are a fundamental component of many ecosystems. Working with normative models of landscape structure places human experience within an ecological framework. Culture can change when people begin to recognise different landscape patterns, as part of their normative experience, that connect ecological function to a landscape which is constructed and managed. Maintenance of a healthy society not only requires a healthy economy but is also fundamentally reliant upon a well conserved natural system. Observed

from a local perspective, heterogeneity of structural variables links community with biodiversity, and system stability, through the structures that human land-use creates in the landscape. Society must be conscious that they are a part of the natural world, inseparable from the ecological systems that their lives and livelihoods depend upon.

## **Chapter Six**

### **Economic value across a range of wood-fuel landscapes**

#### **6.1 Summary**

Chapter 6 explored the direct-use value of the goods and services produced across the range of case study wood-fuel landscapes. Economic values that represent a measure of direct revenue received are described. These data inform the creation of economic value indices for use in building a wood-fuel landscape evaluation model addressing aim 1, and objective (c), of this thesis' identified thematic narrative:

- 1) To calculate a socio-cultural, ecological, and economic value for case study landscapes in which land-use includes the provision of wood-fuel.
  - c) What is the direct-use value of the tangible, monetary revenue, society receives from real markets for goods and services produced?

Anthropogenic land-use and land management places structure and components into the landscape in the pursuit of economic well-being. Differences in these components and the associated structures created produce different economic outcomes. These outcomes are captured to describe the economic dimensions of the value relationship community holds with the surrounding landscape across a range of wood-fuel producing landscapes. Economic value was identified from tangible, marketed goods and services, in a manner that sought to express the informative nature inherent in the communication of a direct revenue-based expression of economic value.

These data begin to show a contrasting nature in the described economic outcomes, principally difference is found in management for either timber-based forest products or non-timber-based forest products. The Greek publicly owned forest demonstrates a private goods – public goods dichotomy; the Austrian estate forest approach highlights the higher revenues gained from a timber-based production focus; whereas the Austrian co-operatively owned and

Greek silvo-pastoral approaches are characterised by the provision of socio-cultural benefit to the local community at the expense of overall economic return.

Observed differences in the direct, tangible, monetary revenues realised by landowners and community, across the studied range of wood-fuel landscapes, provides support for inclusion into the wood-fuel landscape evaluative model (chapter 7)

## 6.2 Introduction

Woodlands and timber have been continuously used over an extended period of human history (Rackham, 2010). Broadly Kimmins (1992) identifies four basic stages of this history;

- Unregulated exploitation of local forests and clearing for agriculture and grazing.
- Institution of legal and political mechanisms or religious taboos to regulate exploitation.
- Development of an ecological approach to silviculture and timber management and the goal of sustainable management of the biological resources of the forest.
- Social forestry, which recognises the need to manage the forest as a multi-functional resource in response to the diverse demands of modern society.

Even before the affects of an even-aged, single species approach to forestry became noticeable, European woodlands had been profoundly influenced by woodland use and management practices (Johann, 2007; Rackham, 2010). Rackham (2010) estimated, from the Domesday survey, that England in 1086 was poorly wooded with approximately 15% land cover. He also believed that it is unlikely that any of this woodland cover could be thought of as wildwood; '*....every woodland belonged to someone and was used...*' (Rackham, 2010). Although, in general, woodland in other European countries was not as heavily modified as this, it can be said that European woodland was not, '*in any strict sense of the word*', untouched even 900 years ago (Farrell et al., 2000).

Whilst management of woodland landscapes has long been one grounded in multiple-use, current practice operates from a position of multi-functionality. Where management attempts to simultaneously satisfy the economic, social and aesthetic demands we place on forest resources (Farrell et al., 2000). Interestingly, given considerable progress made by the scientific approach to forestry, the significance and relevance of traditional forest knowledge and utilisation practices, as well as the need to take account of this knowledge, still retains interest (Farrell et al., 2000). An interest which informs the development of political strategies that aims for a sustainable approach to forest management (Farrell et al., 2000).

The following section outlines the principles and practices involved in management of the case study wood-fuel landscapes, before moving on to identify goods and services that define value perceived by community from each woodland study site. This summary broadly outlines the approach taken towards utilisation and production of goods and services from each of the described woodland landscapes. The approach taken builds upon and adds detail to each case study wood-fuel landscape described in chapter three. Where, with reference to components such as ownership, designation, management and characteristics, differences across the range of wood-fuel landscapes describe the relationships that these communities have built with the landscape that surrounds them (Table 6.1).

Community interaction, through management and use of the woodland landscape, creates structures and composition that in turn produce a flow of goods and services. Management for community use and economic gain, in the context of this research, is used to enumerate the economic value relationship between community and the physical nature of the environment from a reflexive, purposeful, participative perspective, within the specific context of each wood-fuel landscape scenario.

**Table 6.1** A woodland typology to describe difference across the studied wood-fuel landscapes; for definitions see below; definition source  
<sup>1</sup> Food and Agricultural Organisation of the United Nations Forestry Department, 2010c, <sup>2</sup> Eichhorn et al., 2006, <sup>3</sup> Rackham, 2010.

Study site	Type	Ownership	Designation	Management	Characteristics	Removals
Co-operative forest	Forest	Private-institutions	Production – timber	Sustainable forest	Naturally regenerated – clear cut between 2 & 0.5 ha only under licence	Roundwood, Wood-fuel, Non-timber forest products
Estate forest	Forest	Private – individual	Production – timber	Sustainable forest	Naturally regenerated – clear cut between 2 & 0.5 ha only under licence	Roundwood, Wood-fuel, Non-timber forest products
Forest Service	Forest	Public	Protected area – ecosystem services	Sustainable forest	Naturally regenerated – individual tree selection for felling	Roundwood, Wood-fuel, Non-timber forest products
Wood pasture	Other wooded land	Private - individual	Multiple use	Silvo-pastoral	Wood & pasture; groups of trees and shrubs with pasture	Wood-fuel, Non-timber forest products
Category	Definition					
Forest <sup>1</sup>	Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10%, or trees able to reach these thresholds <i>in situ</i> .					
Multiple use <sup>1</sup>	Forest area designate primarily for more than one purpose and where none of these alone is considered as the predominant designated function.					
Naturally regenerated <sup>1</sup>	Forest predominately composed of trees established through natural regeneration.					
Non-timber forest products <sup>1</sup>	Goods derived from forests that are tangible and physical objects of biological origin other than wood.					

Other wooded land <sup>1</sup>	Land not classify as forest, spanning more than 0.5 hectares; with trees higher than 5 metres and a canopy cover of 5-10%, or trees able to reach these thresholds <i>in situ</i> ; or with a combined cover of shrubs, bushes and trees above 10%.
Protected area <sup>1</sup>	Areas especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and manage through legal or other effective means.
Production <sup>1</sup>	Forest area designate primarily for production of wood, fibre, bio-energy and/or non-wood forest products.
Private ownership <sup>1</sup>	Land owned by individuals, families, or institutions such as private co-operatives, corporations, companies and other business entities, as well as organisations such as NGO's, nature conservation associations, and private religious and educational institutions.
Public ownership <sup>1</sup>	Land owned by the State (national, state and regional governments) or government-owned institutions or corporations or other public bodies including cities, municipalities, villages and communes.
Roundwood <sup>1</sup>	The wood removed for production of goods and services other than energy production.
Silvo-pastoral <sup>2</sup>	Areas where a long-term tree crop is combined with cultivation of a short-term (usually one year) crop on the same land. Silvo-pastoral systems produce fodder crops, legumes, or grasses, which are grazed by livestock <i>in situ</i> .
Sustainable forest <sup>1</sup>	Forest areas that fulfil any of the following conditions: have been independently certified or in which progress towards certification is being made; have fully developed, long-term forest management plans (10 years or more) with firm information that these plans are being implemented effectively; are considered as model forest units in their country and information is available on the quality of management; are community-based forest management units with secure tenure for which the quality of management is known to be of high standard; are protected areas with secure boundaries and a management plan that are generally considered in the country and by other observers to be well managed and that are not under significant threat from destructive agents.
Wood pasture <sup>3</sup>	Other wooded land on which farm animals or deer are systematically grazed; pasture with scattered trees and shrubs, or groups of trees and shrubs, as well as grazed closed-canopy woodland.
Wood-fuel <sup>1</sup>	The wood removed for energy production purposes, regardless whether for industrial, commercial or domestic use.

### **6.2.1 Woodland management**

European forests and other wooded land cover is approximately 40% of the world's forests, and European forests account for 36% of the total European land area (United Nations Economic Commission for Europe and the Food and Agricultural Organisation of the United Nations, 2013). Woodlands are owned, controlled and managed by a wide variety of people and organisations to meet an equally wide range of objectives. In Europe 54% of forest and other wooded land area is under private ownership, with 23% of timber production going to wood-fuel markets and fellings represent on average 62% of the net annual increment. Figures for the European forestry industry estimate the value per hectare of marketed roundwood at €84/ha, non-wood products, such as hunting and honey, account for €12/ha on average, and marketed services, such as tourism, for €3/ha (United Nations Economic Commission for Europe and the Food and Agricultural Organisation of the United Nations, 2013). Owners include farmers that operate small agri-silvo-pastoral enterprises, estate owners who integrate forestry with other land management operations, timber focused companies who harvest many tonnes of wood products and investors in financial institutions.

#### **6.2.1.1 Traditional silvo-pastoral management – Tsepelovo, Greece**

Most of Europe's cultural landscapes result from a traditional land use history shaped by the tangible aspects of climate and physiography and the intangible elements of local culture (Naveh, 1995; Wrbka et al., 2004). The village, with characteristic zones of different land uses spreading outward from its centre, describes the basic unit of Europe's cultural landscapes (Vos & Meekes, 1999; Angelstam et al., 2003; Elbakidze & Angelstam, 2007). Managed by farmers these landscapes became multipurpose, integrating forests and tree pastures, in mixed agricultural systems to produce grazing, timber, wood-fuel, arable crops, fruit and nuts (Vos & Meekes, 1999). At the core of this relationship stood the trinity of trees-arable agriculture-grazing, where, over many centuries of use, systems became adapted to local conditions leading to regionally distinct landscape patterns (Vos & Meekes, 1999). Local problems from

extreme conditions were solved by local knowledge with local means (Vos & Meekes, 1999; Antrop, 2005).

In the North-West of Greece these systems were originally characterised by a combination of permanent residents and a transhumance population. In the mountainous Zagori region of North-West Greece, while the Sarakatsani shepherds grazed the high pastures of the summits in summer, a large population of more sedentary villagers developed small-scale, highly diversified field and garden cultivation systems coupled with stock rearing (Halstead, 1998). The main components of the system being cultivated land, community woodlands and the livestock. The system involved land-use practices, such as cultivation on terraces, establishment of hedgerows and scattered multipurpose wooded lands, animal rearing, pollarding of trees and grass-cutting for fodder and forest management in the form of selective harvesting, coppicing and woodland grazing (Amanatidou, 2006). Land reforms in the early twentieth century resulted in changes to winter grazing and began a continued reduction in the numbers of people and livestock involved in seasonal movement of livestock (Hadjigeorgiou, 2011).

Economic emigration to larger urban centres and an increase in touristic employment continues to influence the landscape pattern, as farmsteads and land become managed on a ‘part-time’ or ‘hobby’ basis (Kizos et al., 2011). Notwithstanding these changes, use of a mixed farming system, in the form of agro-silvo-pastoralism, has shaped the landscape around permanent villages in the Zagori region since the 16th century (Amanatidou, 2006). Today’s landscape patterns are the result of traditional agricultural, forest and pastoral activities that take place at the same time in different spatial units, or alternate with each other during the year in the same area (Halstead, 1998). These landscapes represent relationships characterised by a living-in-place perspective, described by a long and rich cultural value (Halstead, 1998; Amanatidou, 2006; Papanastasis et al., 2009; Hadjigeorgiou, 2011) as well as high biological and ecological value (Amanatidou, 2006; Kati et al., 2009).

### **6.2.1.2 Privately owned sustainable forest management – Rechnitz, Austria**

Definitions for what constitutes sustainable forest management differ by country (Food and Agricultural Organisation of the United Nations Forestry Department, 2010c), so for this summary standards that govern the Austrian forest industry are used. Austrian forests cover 47% of the country, 80% of which is in private ownership, 4% in corporate ownership and 16% is owned by the state (Czamutzian, 1999). Austrian forests are dominated by coniferous tree species, for economic reasons the planting of spruce and pine was encouraged, however artificial monocultural practices are increasingly being replaced by natural regeneration and the promotion of mixed stands (Czamutzian, 1999). Mixed natural and semi-natural species make up on average 60% of the total forest area, of which coniferous tree species represent over 80% of the total timber harvest with wood used to generate 10.4% of the gross domestic energy consumption (Foglar-Deinhardstein et al., 2008).

Whilst differences exist in the definition of sustainable forest management, the core of much of sustainable forest management policy aims at satisfying the social, economic, ecological and cultural needs of present and future generations. Broadly speaking the Austrian Forest Act of 1975, amended in 2002, attributes four functions to the forest; a productive function, which covers sustainable timber production, a protective function against erosion and natural hazards, a welfare function with protection of environmental goods like drinking water, and a recreational function (Weiss, 2000). In general, principles of the Forest Act ensure the preservation of the forest area, the preservation of forest productivity and functions, and the maintenance of timber yields for future generations (Weiss, 2000). Forests may not be used for any other purposes other than forest culture, which is restricted to addressing the four defined functions of the forest (Weiss, 2000).

The Austrian Forest Act presumes active forest management by owners, with timber production prescribed as the main forest use (Weiss, 2000). Other uses such as berry and mushroom production, wildlife habitat management, enhancing biological diversity, nature

protection are not regarded as forest culture and therefore only allowed as by-uses if timber production is not significantly affected, with the exception of designated protective forests, urban forests and recreation forests (Weiss, 2000).

A basic principle of Austrian forestry is that of sustained yields which preserves the primacy of economic timber production, when compared with ecological and socio-cultural goals, albeit in a manner that combines ecological value with economic value. In practice this approach results in a predominately economic focus. Data from the United Nations Food and Agriculture Organisation Forest Resources Country Assessment (2010a) describes this economic dominance where the key functions of Austrian forests, by area, are defined as economic value, 62.5%, ecological value characterised as soil and water protection, 36.5%, with only 1% social value (Food and Agricultural Organisation of the United Nations Forestry Department, 2010a).

#### **6.2.1.3 Publicly owned sustainable forest management – Tsepelovo, Greece**

According to the Food and Agricultural Organisation of the United Nations Forestry Department Forest Resources Global Assessment (2010b) the majority of forests and other wooded land in Greece are publicly owned, 77.5%, with 92% of the identified forest area being available for wood supply and a small amount for conservation and protection purposes, 4.2%. No forests ‘undisturbed by man’ are reported to exist in Greece, and only 3.5% are identified as plantation woodland with the remainder being described as ‘unmodified’ semi-natural; 57.5% broadleaved, 42.5% coniferous (Food and Agricultural Organisation of the United Nations Forestry Department, 2010b).

In Greece forest policy aims to manage and protect forests and other wooded land through implementation of a ‘sustained yield’ principle (Smiris, 1999). However, management is primarily focused on the protection of the environment and ecosystem functions, with an emphasis on issues of watershed protection, the reduction of soil erosion and losses due to

forest fires (Kazana & Kazaklis, 2005; R. Tsiakiris pers. comm.). With regard to the public forest area in the Tsepelovo study area, this is achieved through a controlled and monitored harvest regime where no more than 10% of the standing volume is removed once every ten years (R. Tsiakiris pers. comm.).

The protection and management of state forests, as well as the supervision of private forests is the responsibility of the Forest Service, operating within the Ministry of Agriculture through regional administrative Forest Service District offices (Kazana & Kazaklis, 2005). Local co-operatives of forest workers also participate in forest management, in doing so, the forest workers apply both traditional knowledge inherited from previous generations, plus modern technological methods (Smiris, 1999). Worker co-operatives pay a fee to acquire the right to harvest wood, with production and sales under specific regulations and supervision of the Forest Service (Smiris, 1999).

The productivity of Greek forests is low compared to the average of other European forests (Zafeiriou et al., 2011). Their status in respect of density, height and stock/volume quality is not of a comparable level, this is due mainly to man-made interventions such as forest fires, illegal logging, and the lack of systematic forest cultivation (Zafeiriou et al., 2011).

Harvesting operations are not extensively mechanised due to the mountainous nature of the more productive forests and an approach to silviculture practice that takes account of natural regeneration and the protection of forest ecosystems (Smiris, 1999).

Wood-fuel has been a key component of the Greek timber industry (Koulelis, 2011). The Food and Agricultural Organisation of the United Nations Forestry Department Forest Resources Country Assessment (2010b) describe a five year production average to 2005 of 63.5% wood-fuel against 36.5% roundwood. However, recent decreases in the production of wood-fuel have been observed, in the main attributed to the rural forest co-operatives

preference for the production of technical industrial wood (Zafeiriou et al., 2011). This preference is related to the higher price received for this type of wood (Zafeiriou et al., 2011).

A management focus directed at the protection of ecosystem functions reflects the findings of a Total Economic Value study of Greek forests, where watershed management accounted for 40% of the total economic value, three and a half times greater than the value of timber and wood-fuel production (Kazana & Kazaklis, 2005). In the same study negative externalities, mainly erosion, floods and landslides due to poor or no forest management, represent a value equivalent to 36% of the total economic value (Kazana & Kazaklis, 2005). The high indirect economic value attributed to the ecosystem service component of Greek forest function informs policy formulation in terms of protection and management of Greek forests, within the wider context of sustainable development (Kazana & Kazaklis, 2005).

### **6.2.2 Rationale for methods**

Continued degradation of the ecosystem goods and services society has become accustomed

to receiving, has generated interest in techniques that seek to capture the nature of ‘value’ for

natural resources. Contemporary methods have become centred on market-based economic

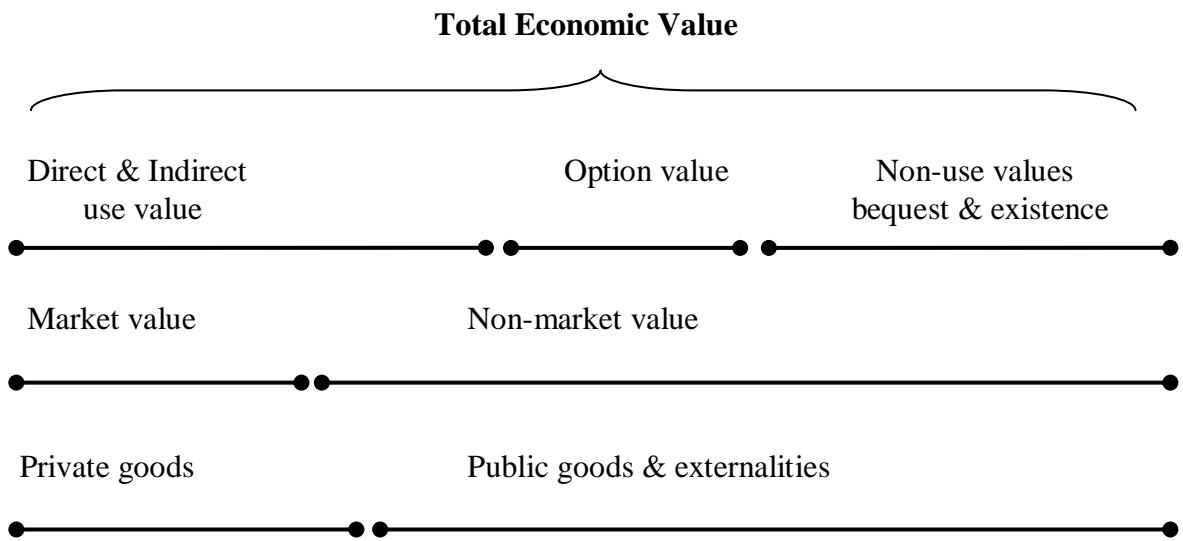
valuation techniques, an overview of which has been presented in chapter 2 of this thesis.

Traditional use and exchange values are complemented by other value types such as option

value (Weisbrod, 1964), and non-use values of bequest and existence value (Krutilla, 1967).

Figure 6.1 shows the nature of direct-use values as marketed private goods, as you move to

the right in-direct and non-use values become non-marketed public goods and externalities.



**Figure 6.1** The relationship between marketed, private goods and non-marketed, public goods (Merlo & Croitoru, 2005: 20).

In this thesis the economic approach to the valuation of natural resources is based on the proposition that the lack of recognition and appropriate methods to internalise public goods and services, such as scenic beauty or watershed protection, and externalities, such as soil erosion, results in their exclusion from public policy and the private management revenue decision making processes (Turner et al., 1994; United Nations Economic Commission for Europe and the Food and Agricultural Organisation of the United Nations, 2013). A total economic valuation approach relies upon the permutability of all ‘values’. Exchangeability, market-based valuation, requires comparability; for things to be exchanged they have to be made commensurable, made comparable on a common measured scale (Mendes, 2007).

The results of studies such as Costanza et al. (1997), Merlo & Croitoru (2005), and de Groot et al. (2012) demonstrate that much of the ‘value’ associated with ecosystems and natural resources lies in public goods and externalities, the cash equivalent of which people do not physical hold. In many instances the vastness of the numbers involved combined with the non-tangible nature of the financial valuations can take the value of natural resources into a

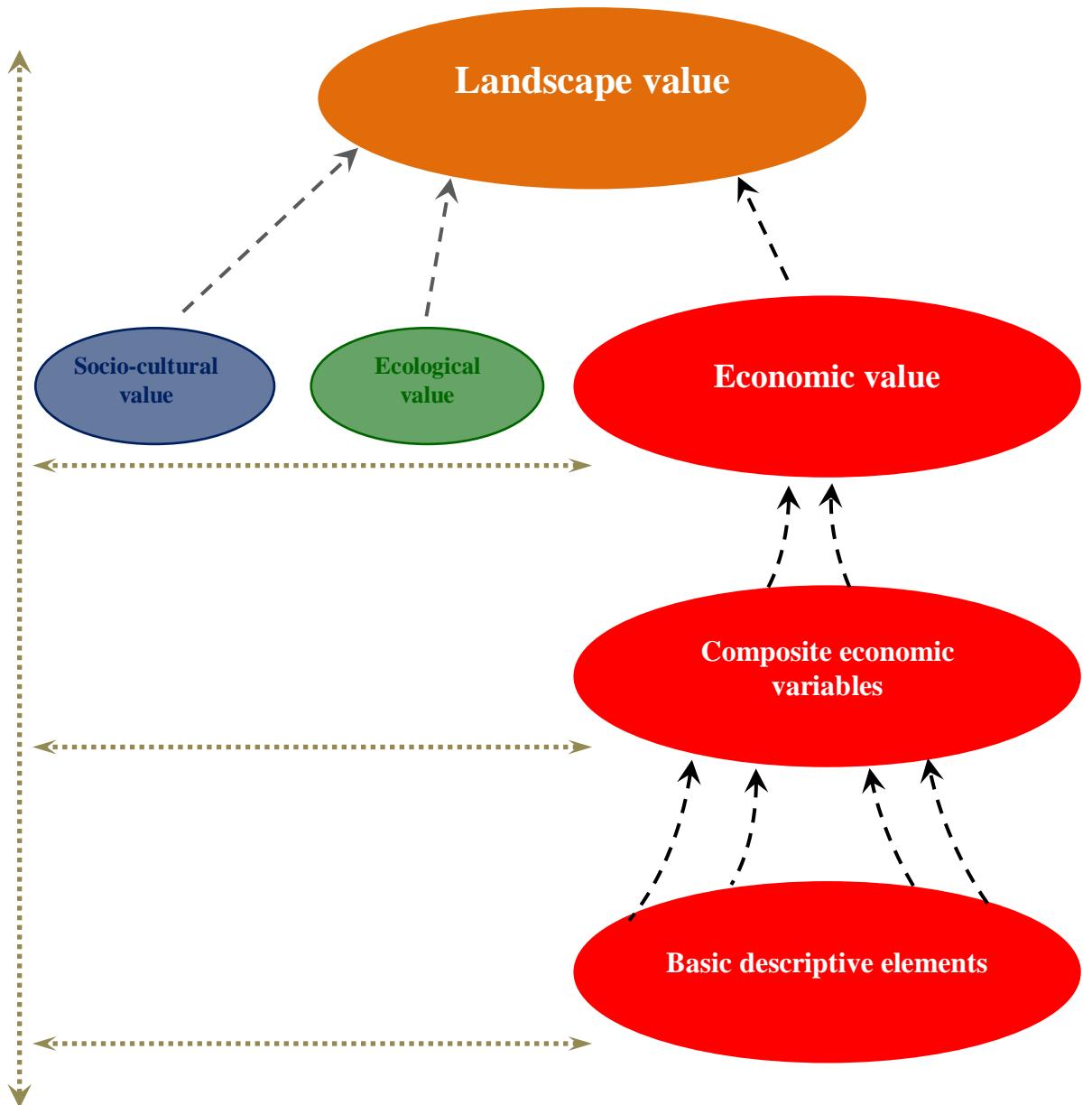
place best described by a given invaluable, priceless quality and as such value can become almost meaningless (Costanza et al., 1997; Clark et al., 2000).

Values are embodied mental images society makes about things and actions in their lives; value is dependent upon the physical, psychological, and social dimensions of the relationships that link the subject of value with the object of value (Mendes, 2007). In this sense values convey information about the nature of things based on three components; 1 – an understanding of the statement, 2 – truth of its content, and 3 – the correct and appropriate nature of its components (Mendes, 2007). This thesis takes the position that an exchange value concept can not fully reflect the true nature and understanding of the subjective component of value. Approached from this perspective, incommensurability is retained in order to maintain the informative nature of value in units which society readily use to communicate amongst themselves; economic values such as revenue received, cultural and symbolic values such as feelings and identity, ecological values such as effective population size.

The object of this component of research is to quantify the economic value associated with a range of woodland management and ownership case study landscapes, in which land-use includes the provision of wood-fuel. Adopting an approach that takes a marketed goods perspective, the monetary value of tangible goods and services from actual market places describes an economic value. These data will express observed direct-use economic values for each of the wood-fuel landscape study sites.

Data identified with these variables will be brought together in the fuzzy logic chapter of this thesis (chapter 7). These data will describe an economic value component to be used, alongside an ecological and socio-cultural value component, in the creation of a fuzzy logic landscape evaluation and assessment model (Fig 6.2). Relationships between and within

ecological, socio-cultural and economic value components, observed across the studied range of woodland landscape and ownership, will also be described.



**Figure 6.2** Framework for the fuzzy logic landscape evaluation model; specific focus is given to the economic component. Black dashed arrows describe value pathway, brown dotted lines describe axes of relationship and interaction.

## **6.3 Methods**

### **6.3.1 Study area**

The regions of Ioannina, Greece, and Südbergenland, Austria provide areas with comparative economic and demographic data, whilst differences are identified across a variety of relationships, such as, land tenure, community institutions, local and national governance and cultural landscapes. Landscape, seen as the interface between culture and an organism-centred natural perspective (Haber, 2004; Farina et al., 2005), provides a cognitive approach that informs ‘value’ decisions with respect to land, forestry and timber use. To avoid repetition a review of study site characteristics and rational for study site choice has been completed elsewhere, see chapter 3.

### **6.3.2 Collection of economic data**

Due to the personal and confidential nature of economic data individual stakeholders declined to provide specific detail with regard to their financial situations. However, two avenues of data collection were pursued; 1 – general information regarding management practice provided by key informant participants alongside evidence taken from current management plans. Direct observation during fieldwork corroborated information provided regarding actual management practice during the data gathering exercises associated with the socio-cultural and ecological value components of this thesis; 2 – a desktop data gathering exercise informed by the detail collected above. Fieldwork was conducted between June 2012 and August 2013; Greece, Tsepelovo, data were collected June 2012 and the Austrian, Rechnitz, data were collected August 2013. The desktop exercise was completed in April 2014.

Organised forestry management of the Greek Forest Service and Austrian Co-operative society provided detail derived from current management plans. Opportunistic interviews from key informant participants such as representatives of forestry management organisations, Greek Forest Service managers, livestock owners and villagers provided information on items

such as management ethos, timber and non-timber production, actual yields and livestock numbers.

Detail collected from the first element helped to create a descriptive skeleton of practice for each of the study landscapes. Data provided from the literature, livestock and forest industry reports, and figures provided by actual management plans allowed for a ‘fleshing out’ of this descriptive skeleton providing a calculation of estimated economic returns. Whilst the final figures may not fully reflect actual economic returns received by individual stakeholders every care is taken to ensure values are representative of the management practices that describe each study site.

### **6.3.3 Calculation of economic value**

In order to estimate the economic value attributed to direct-use marketed, tangible and observable, goods, values are aggregated to calculate a total direct-use economic value as follows:

$$\text{Total}_d = \text{TFP}_{ro,f} + \text{NTFP}_{re,l,m}$$

where  $\text{Total}_d$  is total direct-use economic value,  $\text{TFP}_{ro,f}$  is the income from timber forest products (TFP), roundwood and fuel-wood, and  $\text{NTFP}_{re,l,m}$  is the income derived from the non-timber forest products (NTFP) of recreational activities, hunting, walking, and mountain biking, the products of livestock, milk, cheese, meat, honey, and other non-timber products, mushrooms, fruit and nuts.

Where estimates of current harvest are unavailable data obtained from national statistics are used (Table 6.2). Market prices, from the country of origin, are used to value both TFP and NTFP based on quantities produced calculated on a per hectare basis. The value of TFP and NTFP collected for free by forest users are not calculated as these goods provide for subsistence use; they have an in-direct use value but do not enter the market place (Merlo & Croitoru, 2005). In this thesis the nature of value for in-direct use goods is thought to be captured by the evaluation of socio-cultural value in the context of the relationship that

community holds for the landscape that surrounds it and the natural resources therein, see chapter four.

All currency results are converted to year 2009-2013 international dollars (PPP), a unit of currency that adjusts for local currency purchasing power for the purpose of comparability. The conversion rates used were; Greece €0.68 and Austria €0.83 per \$1 international dollar (World Bank, 2012). Adoption of a common approach to data presentation intends to provide homogenous, comparable information across countries. The aim of this component of the thesis is to arrive at estimates of direct-use forest goods for each of the identified management scenarios.

**Table 6.2** Summary of valuation method and data used for valuation.

Goods	Valuation method	Data used
TFP	Market pricing	Forest management quantitative data Harvested wood quantities National forestry statistics Area of forest Key informant data
NTFP	Market pricing	Forest management quantitative data Regional and national statistics Milk, meat, honey prices Area of use Livestock per unit area data Support capacity of the area Key informant data

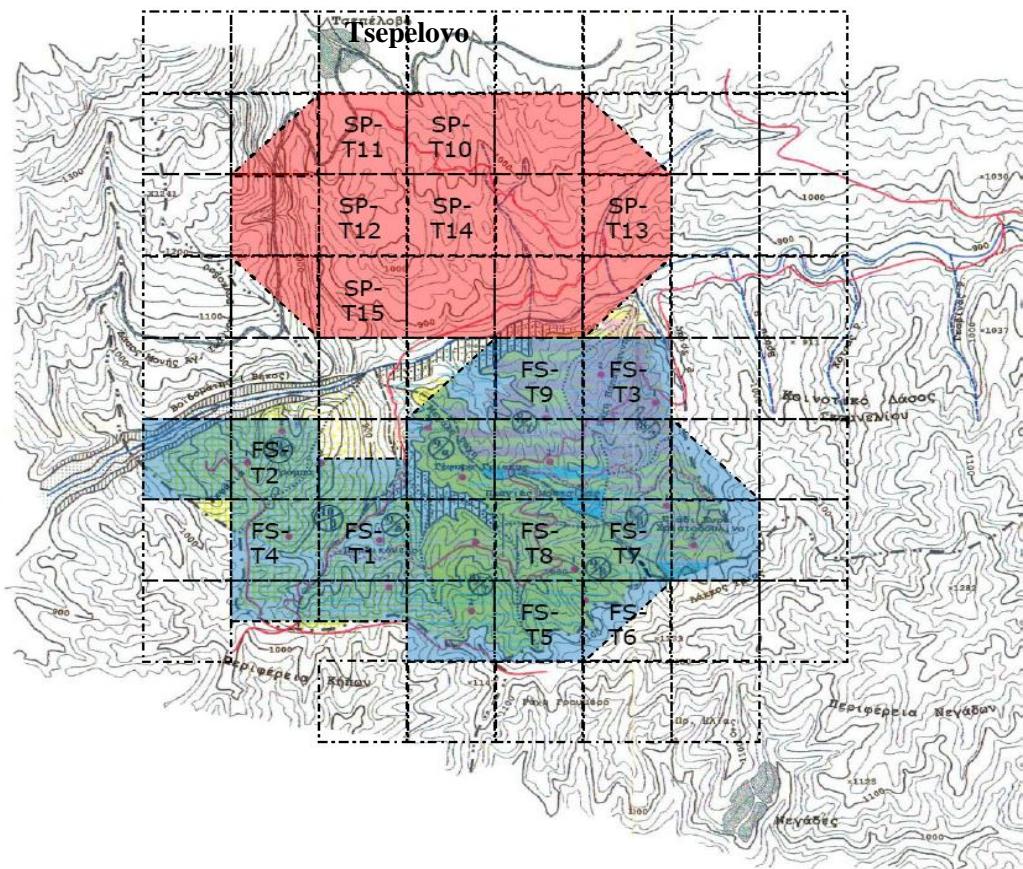
## 4 Results

### 6.4.1 Traditional silvo-pastoral management – Tsepelovo, Greece

The sampled area corresponds to that of the wood pasture under daily use within the village administrative boundaries, not the wider higher altitude pastures used seasonally. Using the 500m x 500m grid square maps produced for ecological sampling the area under silvo-pastoral use, for the purpose of this study, was estimated as 325 hectares (Fig 6.3).

**ΔΙΑΧΕΙΡΙΣΤΙΚΟΣ ΧΑΡΤΗΣ  
ΚΟΙΝΟΤΙΚΟΥ ΔΑΣΟΥΣ  
ΤΣΕΠΕΛΟΒΟΥ**

Κλίμακα 1 : 20.000  
Ισοδιάσταση 20μ.



a)



b)

**Figure 6.3**

a) Identified silvo-pastoral study area, Tsepelovo, Greece, 500m x 500m squares highlighted in red; b) example of the typical pasture found within the silvo-pastoral management area, fruit and nut trees, wild plum (*Prunus domestica*), sweet chestnut (*Castanea sativa*) and hazel (*Corylus avellana*), in the foreground.

Table 6.3 presents the economic value of direct-use goods for the traditional silvo-pastoral management scenario, based on activities of villagers and landowners from the village of Tsepelovo, estimated as International \$221.61 ha<sup>-1</sup>. Only non-timber products derived from livestock generate tangible economic value. Timber products, in the form of wood for fuel, are taken for subsistence use. Recreational activities produce a quantity of regional in-direct use value in the form of hospitality and accommodation from tourism, but these facilities are provided at the expense of traditional land management which itself contributes to the maintenance of the ‘natural’ beauty responsible for bringing visitors to the region (Kati et al., 2009; Kizos et al., 2011).

**Table 6.3** Direct-use economic value of Tsepelovo silvo-pastoral woodland;  
<sup>1</sup> – international dollar conversion rate = €0.68/\$1.

	Quantity/ha yr <sup>-1</sup>	Value €/ha yr <sup>-1</sup>	Value \$/ha yr <sup>-1</sup>
<b>TFP</b>			
- Roundwood	0	0	0
- Wood-fuel	0	0	0
<b>NTFP</b>			
- Recreation	0	0	0
- Livestock			
- milk (ltrs)	68.26	68.26	100.38
- meat (carcass)	0.68	33.74	49.62
- honey (kgs)	4.87	48.70	71.61
- Mushroom, fruit, nuts	0	0	0
<b>Economic value</b>		<b>150.70</b>	<b>221.61</b>

Observation and participant information determined that no roundwood timber is either harvested or marketed. However, the harvesting of wood for fuel was observed, mainly small diameter oak. No evidence of a local market for selling this product was found, all wood taken was for subsistence use (T. Kittas & T. Papigiotis pers. comm.) (Fig 6.4).

In respect of the non-timber forest products participant responses identified that hunting was undertaken, although the only focus was as a livestock protection activity, sheep, goats and bee hives are predated upon (T. Papigiotis & M. Sanosides pers. comm.). No evidence of

economic return on the part of the landowners or village was found. Other activities of a recreational nature, based on regional tourism, were observed in small amount. The Zagori region is marketed as a tourist destination for walkers and nature lovers. Low numbers of touristic visitors were observed in and around the village of Tsepelovo (Smith pers. obs.). However, the majority of visitors observed during the research period were local, having social or familial connections with the area, rather than international, visiting friends, relatives, families or attending religious festivals spending time in the mountains from the nearby regional city centre of Ioannina (Smith pers. obs.).



**Figure 6.4** a) small diameter oak trees (*Quercus spp.*) felled and ready to split within silvo-pastoral area; b) harvested wood for fuel stored in Tsepelovo village.

Observation of nut bearing trees, such as sweet chestnut, *Castana sativa*, and hazel, *Corylus avellana*, and participant comment regarding mushroom, fruit and aromatic and medicinal herb collection provide evidence for harvest activities but no evidence of a local market for selling these products was found, all are taken for subsistence use (V. Pappanastasiou pers. comm.). The produce of fruit trees, wild plum, *Prunus domestica*, were fed to the livestock on an ad hoc basis as a compliment to grazing (Smith pers. obs). Milk, meat and honey are the only products that generate an economic value from the silvo-pastoral area (Figure 6.5).



a)



b)

**Figure 6.5**

Typical examples of livestock production in Tsepelovo, Greece; a) Sheep and goat flocks for milk and meat production, hand milking is carried out in the building in background, b) bee hives for honey production, surrounded by electric fencing to stop bears destroying the hives to feed on honey.

The village is home to three mixed flocks of sheep and goats which total 1000 individuals, the primary product is milk sold in to the local feta cheese manufacturing industry with meat as a secondary product sold locally (K. Vaggelis pers. comm.). The ratio of sheep to goats in the region is 77.5/22.5 (Zervas & Samouchos, 2005), and all calculations use this ratio. Based on a regional stocking rate of 0.66 LU per hectare (Zervas & Samouchos, 2005) producing 103.43 Kgs of milk per individual per annum (Table 6.4) sold at €1 per litre (K. Vaggelis pers. comm.) the economic value from milk production is estimated at €68.26 per hectare. This figure, calculated on the assumption that all land is available and used for grazing, will represent an overestimate.

Meat produced from the offspring of milking mothers is based on a rate of fecundity and prolificacy of 0.934 and 1.244 respectively, with a replacement level of 12% (Zervas & Samouchos, 2005), and 88% sold in to the local market at €50 per carcass (K. Vaggelis pers. comm.). The economic value from meat production is estimated at €33.74 per hectare. Honey production comes from one producer with 200 hives sited in the study area, the production system utilises a 10% annual replacement rate of hives (M. Sanosides pers. comm.). Each hive will produce 20 kgs of honey for local sale annually (M. Sanosides pers. comm.), honey is

sold locally at a premium price of €10 per kg (M. Sanosides pers. comm.). Adjusting honey volumes for a foraging area factor (Table 6.5), the economic value from honey production in the study area is estimated as €48.70 per hectare. This study does not include additional honey-based products such as royal jelly and pollen; production is on an ad-hoc basis and omission will represent an underestimation of revenue in this instance.

**Table 6.4** Calculation of milk yield per livestock unit using data from the literature, length of lactation in brackets; <sup>1</sup> – ratio of sheep (77.5) to goats (22.5) in the Ioannina region is used for final calculation (Zervas & Samouchos, 2005).

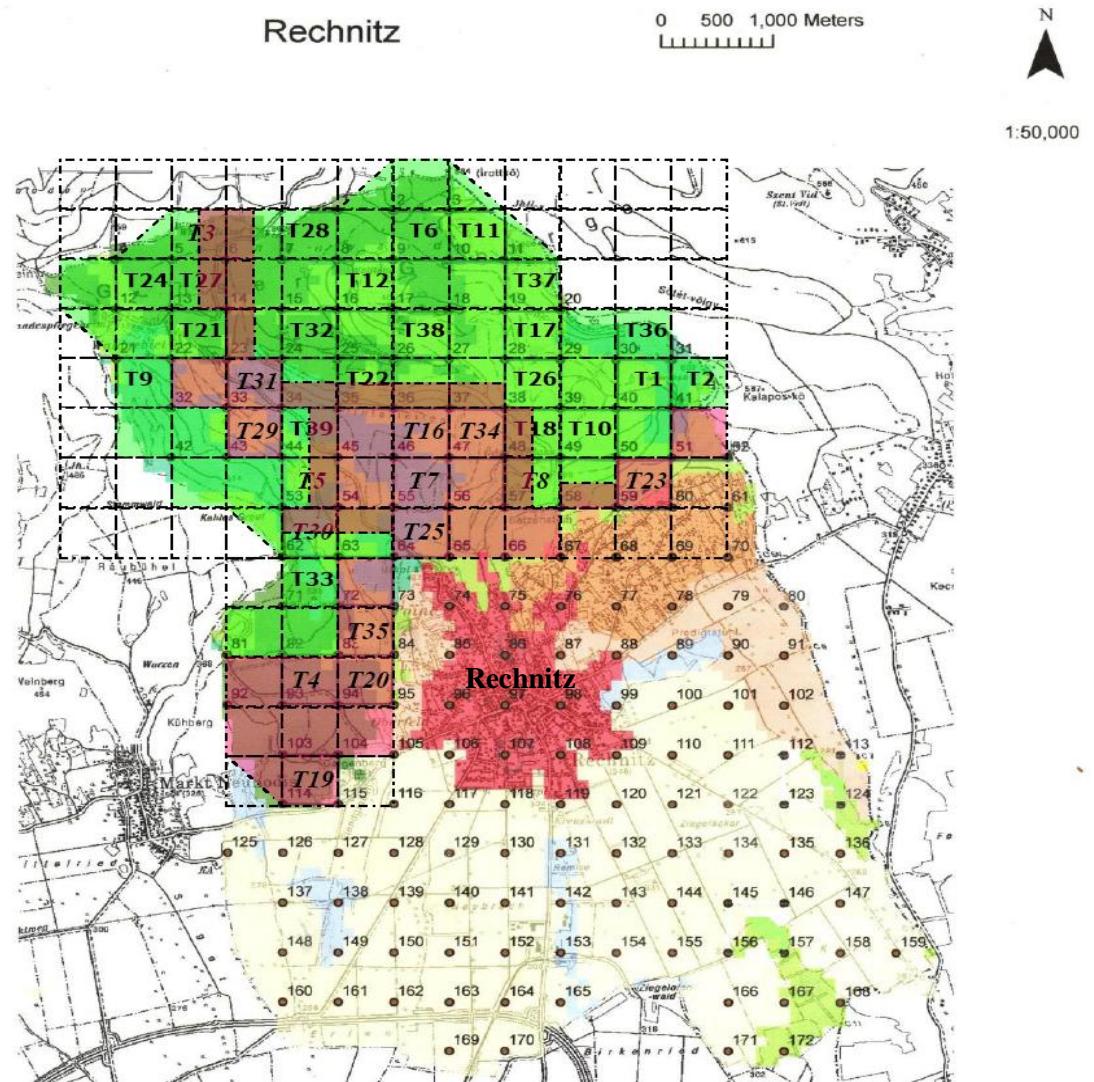
Data source	Sheep (kgs)	Goats (kgs)
Simos et al. (1991)		90
Simos et al. (1996)	92 (217 days)	
Zervas & Samouchos (2005)	118 (220 days)	116 (202 days)
<b>Mean</b>	105	103
		103.43 <sup>1</sup>

**Table 6.5** Calculation of honey bee foraging factor adjustment; <sup>1</sup> mean foraging distance taken from Steffan-Dewenter & Kuhn (2003).

Mean foraging distance <sup>1</sup> (m)	Estimated foraging area (ha)	Estimated study area (ha)	Foraging factor adjustment (study area/forage area)
1526	731.2	325.0	0.44

#### 6.4.2 Privately owned sustainable forest, co-operatively managed – Rechnitz, Austria

The sampled area corresponds to that of the co-operatively owned and managed woodland under daily use within the village administrative boundaries (Fig 6.6). Using the 500m x 500m grid square maps produced for ecological sampling the area under co-operative use, for the purpose of this study, was estimated as 787.5 hectares.



a)



b)

**Figure 6.6** a) Identified co-operative study area, Rechnitz, Austria, 500m x 500m squares highlighted in red; b) examples of the typical woodland found within the co-operative management area.

Table 6.6 presents the economic value of direct-use goods for the co-operative management scenario, described by the Rechnitz study site, estimated as International \$513.58 ha<sup>-1</sup>. Both timber and non-timber products were observed to generate tangible economic value; timber products, in the form of roundwood and wood for fuel, and non-timber products based on recreational activities in the form of hunting. Other recreational activities such as walking, mountain biking, and horse riding produce a quantity of regional in-direct use value from tourism (Smith pers. obs). However, these activities are characterised by a non-forest culture approach, in respect of forest management, and as such are not incorporated into defined management economic aims (A. Laschober pers. comm.).

**Table 6.6** Direct-use economic value of Rechnitz co-operative woodland;<sup>1</sup> – international dollar conversion rate = €0.83/\$1.

	Quantity/ha yr <sup>-1</sup>	Value €/ha yr <sup>-1</sup>	Value \$/ha yr <sup>-1</sup>
<b>TFP</b>			
- Roundwood (m <sup>3</sup> )	2.74	222.02	267.49
- Wood-fuel (m <sup>3</sup> )	1.02	43.92	52.92
<b>NTFP</b>			
- Recreation			
- hunting	-	160.33	193.17
- Livestock			
- milk (ltrs)	0	0	0
- meat (carcass)	0	0	0
- honey (kgs)	0	0	0
- Mushroom, fruit, nuts	0	0	0
<b>Economic value</b>	<b>435.33</b>	<b>513.58</b>	

Observation and participant information identified that both roundwood and wood for fuel were produced. Roundwood produced from mature trees and thinning operations enters regional and national market places whereas wood for fuel supplies a local market (Figure 6.7). Local farmers harvest marked trees to produce a wood-fuel product, as part of thinning operations, for sale in and around the village locality (J. Loos pers. comm.).



**Figure 6.7** Wood-fuel and mechanised roundwood removals from the Co-operative forest study area; a) wood harvested, split and stacked to dry for the local fuel-wood market; b) thinning activities producing biomass material and small diameter poles.

**Table 6.7** Potential timber harvest volumes, roundwood and wood-fuel combined, data taken from European Commission (2014).

Forest area - available for wood supply (1000 ha)	Annual increment (1000 m <sup>3</sup> )	Fellings (% of annual increment)	Annual increment (m <sup>3</sup> ha <sup>-1</sup> )	Annual Fellings (m <sup>3</sup> ha <sup>-1</sup> )
3343	25136	71.69	7.52	5.39

National statistics identify values for potential harvested volumes using available forest area, annual increment, and annual felling statistics (European Commission, 2014) (Table 6.7). Total Austrian roundwood production, 2011, consisted of sawn logs, 55.5%, pulpwood, 17.4%, and wood-fuel, 27.1%, with an annual average price of sawn logs, €93.65, pulpwood, €40.53, and wood-fuel, €39.98 for softwood and €59.25 for hard wood, coniferous species

represented 84% of all harvested products (Forestry Department, Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2012). Based on these data estimated average market prices in Euros per cubic metre are calculated (Table 6.8).

However, due to specific management considerations in respect of the co-operative members, the volume of fellings as a percentage of annual increment is kept at 50% (J. Loos pers. comm.). Calculations combining felling volumes, product percentages, and market values generate an economic value from timber forest products, which for the Rechnitz co-operative study area is estimated as €265.94 ha<sup>-1</sup> (Table 6.9).

**Table 6.8** Average market prices for roundwood and wood-fuel produced from Austrian forests and woodland, data taken from European Commission (2014).

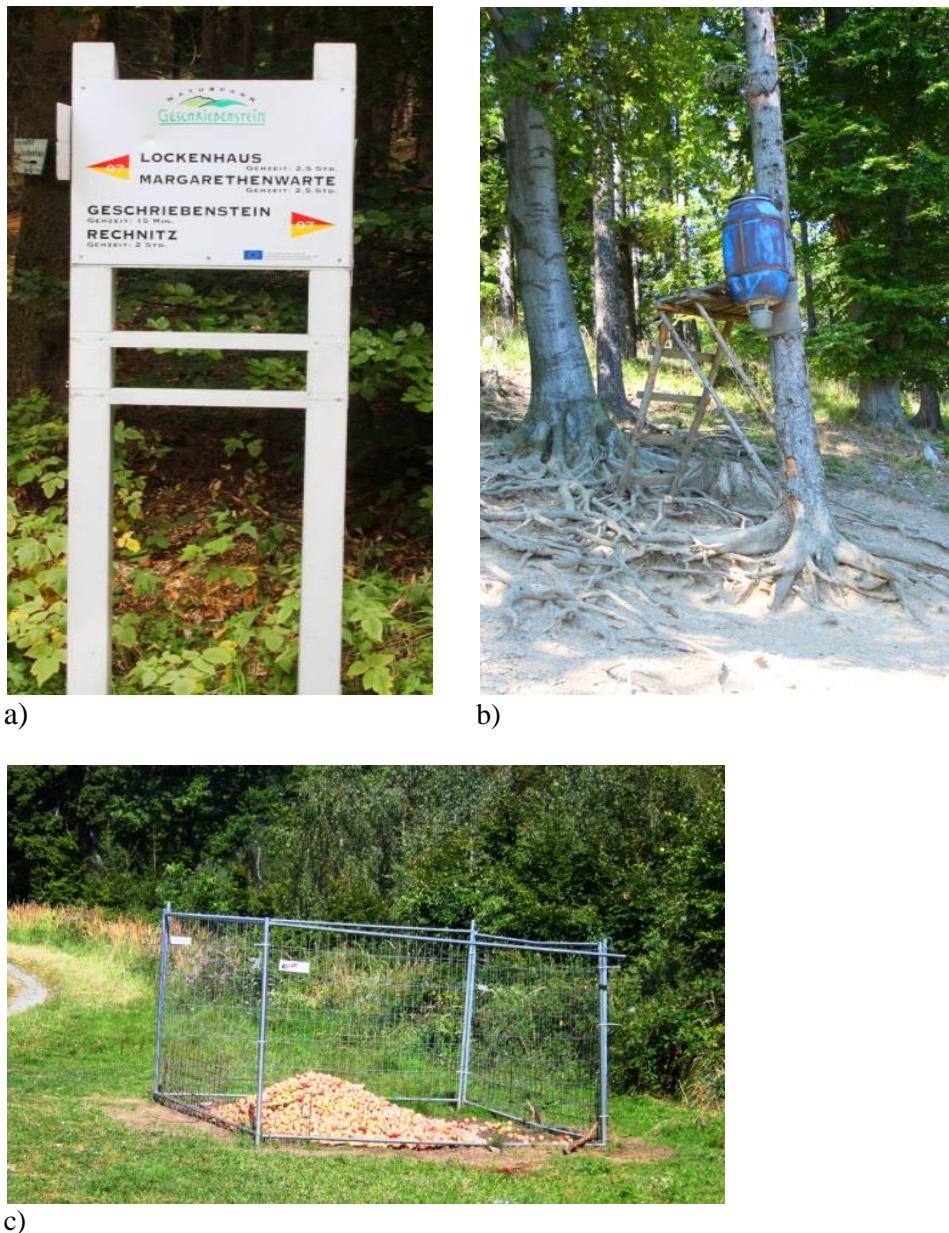
	Marketed quantity (%)	Market value (€ m <sup>3</sup> )	Average value (€ m <sup>3</sup> )
Sawn logs	55.5	93.65	
Pulpwood	17.4	40.53	
Roundwood			81.03
Wood-fuel	27.1		43.06
- coniferous	(84.0)	39.98	
- non-coniferous	(16.0)	59.25	

**Table 6.9** Calculation of the economic value generated from timber forest products, combining felling volumes, product percentages, and market values.

	Annual increment (m <sup>3</sup> ha <sup>-1</sup> )	Annual Fellings (m <sup>3</sup> ha <sup>-1</sup> )	Average value (€ m <sup>3</sup> )	Estimated value (€ ha <sup>-1</sup> )
Roundwood		2.74	81.03	222.02
Wood-fuel	7.52	1.02	43.06	43.92
				265.94

In keeping with an emphasis on the preservation of forest culture expressed within the Austrian Forest Act (Weiss, 2000) activities that present conflict with forestry focused management are not encouraged. Hunting, which has a long association with forest ownership and management, generates a valuable economic resource for forest and woodland owners in

Austria (Foglar-Deinhardstein et al., 2008). Despite the consequent cost of browsing damage, a good deer population will return valuable income from hunting rights sold by owners, and extensive management is undertaken to ensure numbers are maintained (Reimoser & Reimoser, 2010) (Fig 6.8). The high value of hunting rights in part provides compensation to the forest owners for browsing, fraying, or debarking damage associated with sustained high numbers of deer (Reimoser & Reimoser, 2010).



**Figure 6.8** Recreational signage and deer feeding stations within the co-operative forest study area; a) use of signage to direct recreational access; b) salt lick and feeder at height, bare ground and exposed roots indicate high levels of use, and c) bulk use of apples as foodstuff, fencing precludes access to less agile species.

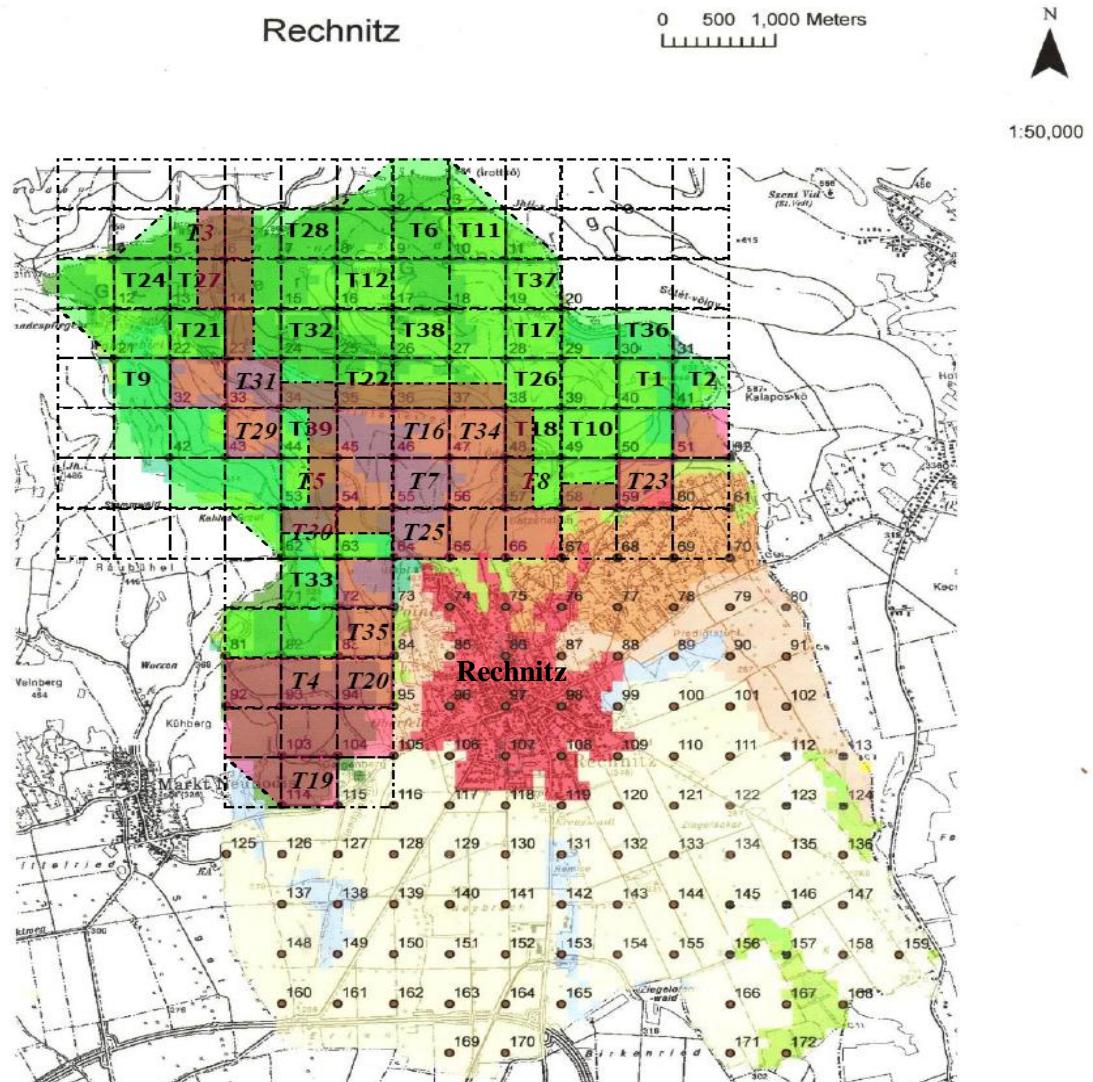
Whilst local conservation and touristic associations are developing recreational activities such as walking, mountain biking and horse riding, the Rechnitz forest co-operative organisation do not include these activities as part of their management remit. Forest access is permitted under Austrian law and management undertakes to reduce contact between forestry and hunting operations and forest visitors (A. Laschober pers. comm.).

Economic value generated from the leasing of hunting rights is calculated at €160.33 ha<sup>-1</sup>. Reimoser and Reimoser (2010) estimated the economic value of hunting in Austria as €536 million per year. Assuming an equal quality of hunting experience, across the woodland available for forestry (3343 ha), the calculated figure broadly accords with anecdotal information of circa 35% of the co-operative forest income derived from the leasing of hunting rights (A. Laschober & J. Loos pers. comm.) For the purpose of this study the estimation of direct-use economic value from hunting represents 37.6% of estimated economic value and may represent an overestimation.

#### **6.4.3 Privately owned sustainable forest, estate managed – Rechnitz, Austria**

The sampled area corresponds to that of the estate owned and managed woodland under daily use within the village administrative boundaries (Fig 6.9). Using the 500m x 500m grid square maps produced for ecological sampling the area under estate use, for the purpose of this study, was estimated as 1150 hectares.

Table 6.10 presents the economic value of direct-use goods for the estate management scenario, described by the Rechnitz study site, estimated as International \$652.59 ha<sup>-1</sup>. As with the co-operative management scenario, both timber and non-timber products were observed to generate tangible economic value; timber products, in the form of roundwood and wood for fuel (Fig 6.10), and non-timber products based on recreational activities in the form of hunting.



a)



b)

**Figure 6.9** a) Identified estate study area, Rechnitz, Austria, 500m x 500m squares highlighted in green; b) examples of the typical woodland found within the estate forest case study area.

**Table 6.10** Direct-use economic value of Rechnitz estate woodland; <sup>1</sup> – international dollar conversion rate = €0.83/\$1.

	Quantity/ha yr <sup>-1</sup>	Value €/ha yr <sup>-1</sup>	Value \$/ha yr <sup>-1</sup>
<b>TFP</b>			
- Roundwood (m <sup>3</sup> )	3.93	318.45	383.67
- Wood-fuel (m <sup>3</sup> )	1.46	62.87	75.75
<b>NTFP</b>			
- Recreation			
- hunting	-	160.33	193.17
- Livestock			
- milk (ltrs)	0	0	0
- meat (carcass)	0	0	0
- honey (kgs)	0	0	0
- Mushroom, fruit, nuts	0	0	0
<b>Economic value</b>		<b>541.65</b>	<b>652.59</b>



**Figure 6.10** Wood-fuel and roundwood removals from the estate forest study area; a) wood harvested, split and stacked to dry for the local fuel-wood market; b) clear cut harvested compartment, foreground, mature tree compartment, background; c) harvest and thinning activities produce biomass material.

Other recreational activities, such as walking, mountain biking, and horse riding, also produce a quantity of regional in-direct use value from tourism (Smith pers. obs). As with the co-operative scenario, these activities are characterised by a non-forest culture approach, in respect of forest management, and as such are not incorporated into defined management economic aims. However, in contrast to the co-operative management areas, a more formal approach is taken to the separation of hunting and forestry operations with recreational activities (Fig 6.11). Direct signage is used to moderate the behaviour of the recreational user; rights of access granted under the Austrian Forestry Act are expressly displayed. For example, under the Austrian Forestry Act, everybody is free to gather up to 2 kg of mushrooms per person and day, unless expressly prohibited by signs put up by the forest owner (Foglar-Deinhardstein et al., 2008).

Using data from national forestry statistics, as with the co-operative management scenario, direct-use value from timber forest products is calculated as €381.32ha<sup>-1</sup> (Table 6.11); fellings are assumed to follow the national forest industry level, 71.69% of the annual increment. In keeping with the economic timber production principles of the Austrian Forestry Act, other than hunting, recreational activities are not a component of the forestry management remit. Estimation of hunting revenues follows that previously described for the co-operative management scenario with a calculated value of €160.33 ha<sup>-1</sup>.

**Table 6.11** Calculation of the economic value generated from timber forest products, combining felling volumes, product percentages, and market values.

	<b>Annual increment (m<sup>3</sup> ha<sup>-1</sup>)</b>	<b>Fellings (m<sup>3</sup> ha<sup>-1</sup>)</b>	<b>Average value (€ m<sup>3</sup>)</b>	<b>Estimated value (€ ha<sup>-1</sup>)</b>
Roundwood		3.93	81.03	318.45
Wood-fuel	7.52	1.46	43.06	62.87
				381.32



**Figure 6.11**

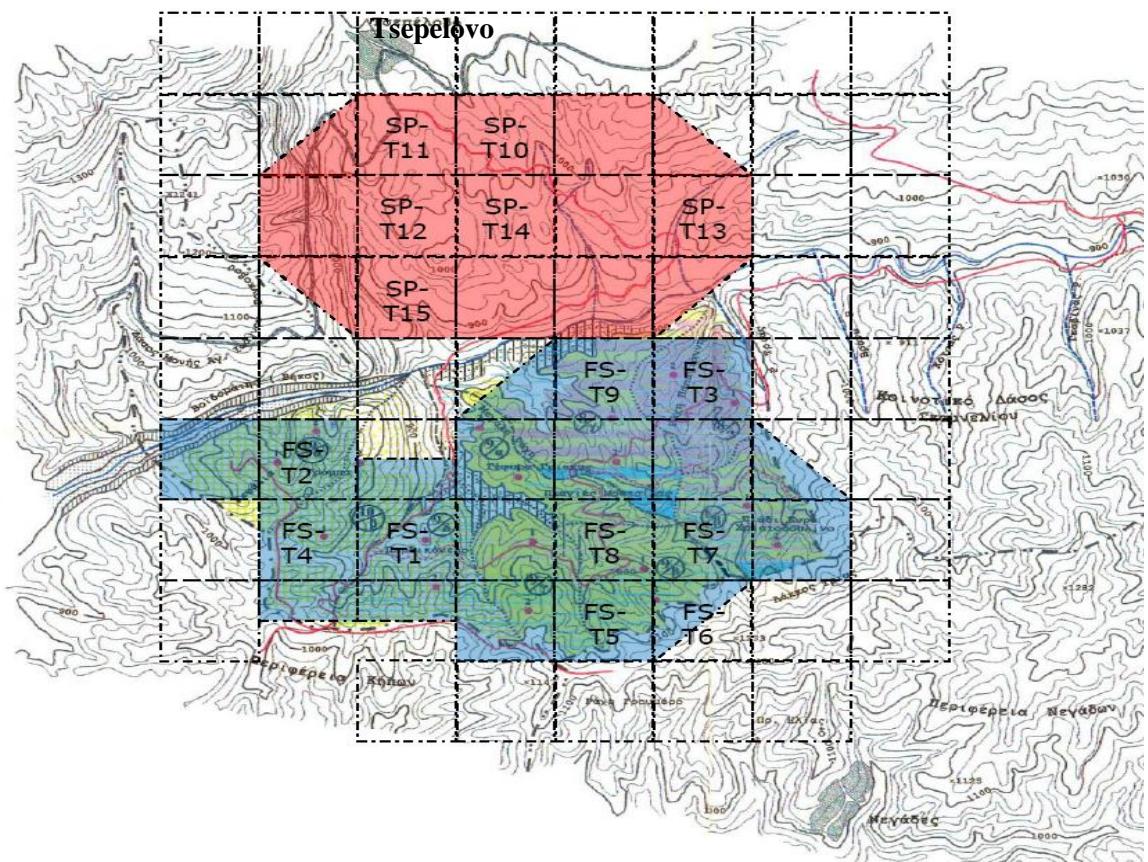
Examples of direct recreational signage used to reduce issues of conflict between hunting and forestry operations with a) mushroom collectors, b) & c) walkers, mountain bikers and horse riders. Informative signposts direct users through woodland routes.

#### 6.4.4 Publicly owned sustainable forest management – Tsepelovo, Greece

The sampled area corresponded to that of the Forest Service managed area within the village administrative boundaries (Fig 6.12). Using the 500m x 500m grid square maps produced for ecological sampling the area described as Forest Service managed, for the purpose of this study, was estimated as 450 hectares.

**ΔΙΑΧΕΙΡΙΣΤΙΚΟΣ ΧΑΡΤΗΣ  
ΚΟΙΝΟΤΙΚΟΥ ΔΑΣΟΥΣ  
ΤΣΕΠΕΛΟΒΟΥ**

Κλίμακα 1 : 20.000  
Ισοδιάσταση 20μ.



a)



b)

**Figure 6.12**

a) Identified Forest Service study area, Tsepelovo, Greece, 500m x 500m squares highlighted in blue; b) examples of the typical woodland found within the different forest compartments.

Table 6.12 presents the economic value of direct-use goods for the publicly owned and managed management scenario, estimated as International \$34.94 ha<sup>-1</sup>. Only timber forest products derived from roundwood and wood-fuel generate tangible economic value. Non-timber products in the form of mushrooms and herbs are taken for subsistence use. Recreational activities produce a quantity of regional in-direct use value in the form of local hospitality and accommodation from tourism, however, those involved in the management of the landscape do not receive any revenue from touristic activities (T. Kittas pers. comm.).

**Table 6.12** Direct-use economic value of Tsepelovo publicly owned woodland;<sup>1</sup> – international dollar conversion rate = €0.68/\$1.

	Quantity/ha yr <sup>-1</sup>	Value €/ha yr <sup>-1</sup>	Value \$/ha yr <sup>-1</sup>
<b>TFP</b>			
- Roundwood	0.24	18.72	27.53
- Wood-fuel	0.24	5.04	7.41
<b>NTFP</b>			
- Recreation	0	0	0
- Livestock			
- milk (ltrs)	0	0	0
- meat (carcass)	0	0	0
- honey (kgs)	0	0	0
- Mushroom, fruit, nuts	0	0	0
<b>Economic value</b>		<b>23.76</b>	<b>34.94</b>

In contrast to the Austrian approach to forest management the Greek Forest Service, in keeping with public ownership, pursue the interest of public goods in their management ethos. Sustainable management and timber removal are compliments to the conservation of natural resources and the provision of ecosystem goods and services (R. Tsakiris pers. comm.).

In keeping with Greek Forest Law a 10-year management plan describes forestry treatments to be applied and the expected timber volume to be cut by place and time. All logs produced are monitored, counted and marked by the Forest Service seal (Fig 6.13). The management plan (2001-2010) for all compartments identified as being harvested by the Tsepelovo village show volumes of 3330 m<sup>3</sup> for both roundwood and wood-fuel over the ten year period. Actual harvest volumes for compartments within the study area, calculated from Ioannina Forest

Service inventories, show 1100 m<sup>3</sup> of both roundwood and wood-fuel. This equates to volumes of 0.24 m<sup>3</sup> ha<sup>-1</sup> per year for roundwood and wood-fuel.

Making use of timber values described in Kazana and Kazaklis (2005) calculation towards a Total Economic Value for Greek forests, €78.00 m<sup>-3</sup> roundwood and €21.00 m<sup>-3</sup> wood-fuel, the value of TFP derived from the Tsepelovo publicly owned woodland is €23.76 ha<sup>-1</sup>. These figures for timber prices broadly accord with detail provided by Koutroumanidis et al. (2009) who identified 2006 market values of €65.29 and €19.80 for roundwood and wood-fuel respectively.

Support for the Tsepelovo per hectare economic value and productivity figures is provided using data from the Food and Agricultural Organisation of the United Nations Forestry Department Forest Resources Country Assessment (2010b) and Kazana and Kazaklis (2005). Using these data estimations for comparison of volume at 0.48 m<sup>3</sup> and value at €24.42 ha<sup>-1</sup> are calculated (Table 6.13).



**Figure 6.13** a) Representatives of Ioannina Forest Service complete harvest inventory and mark harvested logs, log end marked with blue dyed imprinted seal; b) Blue indelible ink identifies legally harvested timber. Logs without this seal cannot be sold through legal timber sales operations.

**Table 6.13** Supportive calculations of timber volume and value for Greek woodlands; source <sup>1</sup> Food and Agricultural Organisation of the United Nations Forestry Department, 2010b, <sup>2</sup> Kazana & Kazaklis, 2005.

	Production removals (1 000 m <sup>3</sup> )	Production area <sup>1</sup> (1000 ha)	Per hectare calculation (m <sup>3</sup> ha <sup>-1</sup> )
<b>Volume<sup>1</sup></b>			
- roundwood	948		0.26
- wood-fuel	795	3595	0.22
	1 743		0.48
<b>Value<sup>2</sup></b>			
Economic return	(1 000 €)		(€ ha <sup>-1</sup> )
	87 780	3595	24.42

## 6.5 Discussion

The intention of this component of the thesis was to quantify the monetary value associated with the four case study wood-fuel landscapes. Direct-use values are used to identify tangible economic revenue-based returns from actual market place transactions. The economic value of each study landscape is derived from the exchange of products for a market-based monetary consideration. In this context value is defined by a monetary unit, which excludes the accumulation of goods for subsistence-use as their value is in utility and exists outside of the monetary exchange process.

This approach acknowledges the combination of human skills and technology with natural resources in the generation of outputs to create an economic value. The aim was to illustrate the monetary value held in the economic relationship with the physical nature of the environment from a reflexive, purposeful, participative perspective, within the specific context of each woodland management scenario. Given that these regional economies are themselves embedded within wider regional, national and global economies, in this component of the thesis differences in landscape components and the associated structures, created by specific local management scenarios, produce different economic outcomes.

Landscapes are the result of this behavioural interaction, where the dynamic process of societal intervention directly links ecological systems with economic systems (Naveh, 1995).

Landscape management whose primary focus was the production of timber products, described in this chapter by the Austrian estate forest scenario, generated the largest per hectare monetary value. Management with a focus directed at the protection of ecosystem functions that results in high levels of public goods, described by the Greek public forest scenario, produced the lowest per hectare monetary value. The management decisions of both scenarios are grounded in a similar context, the sustainable use of natural resources to maintain ecological, economic and social functions for current and future generations (Weiss, 2000; Kazana & Kazaklis, 2005). However, these two positions reveal the tension between the creation of private and public goods; workers in the Tsepelovo forest co-operative, Greek public forest scenario, receive no specific compensation for costs or for any opportunity cost in terms of foregone revenue from wood production.

The estate forest, based on these observations, pursue services for which there are clear market values at the expense of those for which monetary return is not easily achieved. Emphasis is on sustainable and efficient production of a few wood supply related services for which there is payment. Whereas the Greek Forest Service pursues primarily ecological service-based goals for which monetisation can be calculated through in-direct techniques and hypothetical market value.

These two positions provide examples of how society's view on the use of natural resources, our cultural response, continues to change. Culture, in this context, establishes people's relationships with each other, the environment, and with the past and the future (Johann, 2007). The Austrian estate forest, with the presumption of active forest management engaged in economic timber production (Weiss, 2000), operates from a perspective connected to the nineteenth century economic and technical developmental roots of modern production forestry

and the maximisation of long-term economic return (Farrell et al., 2000). The Greek Forest Service emphasis on ecosystem function represents twentieth century cultural changes and a shift of emphasis for forestry away from a production lead ethos towards the maintenance of ecosystem services, from afforestation programs with single tree species to a balance of ecological land uses (Farrell et al., 2000; Johann, 2007).

Both landscapes illustrate how the provision of direct and indirect benefits to people from ecosystems can link ecology with economy and provide a framework for the transformation of environment into a set of marketable ecosystem goods and services commodities. More specifically, how economic valuation techniques can be used to assign a value to both ecosystem components as well as functions (Turner et al., 1994; Costanza et al., 1997; Chee, 2004; de Groot et al., 2010; Liu et al., 2010).

In contrast to the estate forest and Forest Service scenarios, economic outputs from the wood pasture and the co-operative forest landscapes demonstrate difference in outcome based on the local cultural context of the situation. Economic and ecosystem service based outputs are reduced to reflect local culture and livelihoods. Members of the co-operative forest group receive a reduced economic return to benefit the taxation position of individuals within the group. Whereas management of the wood pasture landscape acknowledges the relationship between the landscape and the local needs of the many generations of people who have and continue to live in it. Table 6.14 identifies the broad themes of economic difference between the study woodland landscape scenarios.

**Table 6.14** Difference between studied woodland landscape scenarios identified as based in either a production (estate forest and Forest Service) or cultural (co-operative forest and wood pasture) perspective.

Landscape	Production	Cultural
Service provision	Single / few	Multiple
Focus	Market	Subsistence
Scale	National / Global	Local / National
Output	Economic	Social-ecological

Market-led valuations that principally operate from an economic-based worldview may not fully encompass social perspectives, *cf* Weisbrod (1964) and Krutilla (1967). This development is contrary to the wishes of a society that expresses preference for the physical characteristics of a sense of connection to the surrounding landscape, for example a landscape that '*protects and provides long term stability*' in a manner '*that promotes physical and mental well-being*' (see chapters 3 and 4 of this thesis), where '*mixed landscapes*' promotes '*diversity and complexity*' and builds environments with '*integrity and resilience*' (see chapter 5 of this thesis). Cultural and traditional knowledge operates in a local context with multiple uses (Johann, 2007).

Sometimes, a focus on market values can obscure non-market values worth caring about. For example in the Zagori region of North West Greece, where Tsepelovo is located, landowners and farmers have taken up the opportunity of EU funded loans to exchange the life of livestock farming for that of a hotelier to benefit financially from an increase in tourism (V. Kati pers. comm.). Paradoxically this anticipated rise in tourism, and the associated investment in additional accommodation, has helped the decline of traditional activities responsible for much of the cultural and scenic beauty thought to attract potential visitors (Tzanopoulos et al., 2011).

Socio-economic change has altered the land-use pattern, land use systems that were once characterised by extensive hill grazing, forest exploitation and low intensity mixed farming are becoming replaced by land abandonment (Tzanopoulos et al., 2011). In a review of stakeholder views, residents of the Zagori region saw their cultural heritage best preserved with a system of active farming, in the sense of a production system based on economic outcomes from producing timber, food and fibre (Soliva et al., 2008).

Socio-economic impacts often determine the types of land use within a given region, with a consequent environmental influence (Naveh, 1995; Vos & Meekes, 1999; Wrbka et al., 2004; Kizos et al., 2011). Anthropol (2005) describes the division between more intensive and more extensive use of land as the main trend of actual landscape change. This difference between a cultural extensive approach and a more intensive economic productive attitude reveals the tension between connection to the land based in tradition on one hand and market pressure on the other (Kizos et al., 2011). The issue to be tackled here is the interdependent relationship between the economic issues of local economy (chapter 6) alongside the social (chapter 4) and ecological (chapter 5) integrity of landscape identity.

Value has a relationship that is dependent upon the physical, psychological, and social dimensions of the relationships that link the subject of value with the object of value (Mendes, 2007). Expressions of economic value need to consider the relationships between community, landscape and natural resources; they should reflect the attitudes that influence this relationship and interactions with landscape and natural resources (Tress and Tress, 2003). Value in complex social-ecological systems, where society is considered a participative actor in socio-cultural, ecological and economic value domains, can only be fully expressed through the multiple dimensions of cultural identity, beliefs and attitudes towards the landscapes that it creates (Farber et al. 2002; Sauer and Fischer, 2010).

## **6.6 Conclusion**

This component of the thesis, whilst employed in the calculation of monetary value for each of the study woodland landscape scenarios, reflects on the constituents of monetary value for natural resources. In the use of an economic valuation to reflect the value held by natural resources, the nature of the expression of value should represent understanding, truth and the appropriate nature of its component parts. The dimensions of value are multi-faceted and, whilst employed in the production of specific goods and services, should consider a broader set of goals. Value is a context specific mix of co-created social, ecological, and economic conditions.

The relationships between landscape patterns and the communities that create them integrates ecology and economy with people and place as components of a social-ecological-economic system. In this respect the dynamics of landscape both influences and are influenced by culture; landscape becomes a medium to express and evaluate value. Human perception, choice, and action drive political, economic, and cultural decisions that lead to or respond to change in ecological systems. This relationship is reciprocal; the physical nature of the environment will influence the socio-cultural interactions with it, but the nature of this interaction will influence the physical characteristics of the environment.

## **Chapter Seven<sup>4</sup>**

### **Fuzzy logic based evaluation across a range of wood-fuel landscapes**

#### **7.1 Summary**

Chapter 7 explores the use of fuzzy logic based reasoning in the landscape evaluation process.

Using data taken from previous chapters, socio-cultural (chapter 4), ecological (chapter 5) and economic (chapter 6) value, indices that describe a range of wood-fuel landscapes are brought together in a wood-fuel landscape evaluation model. This addresses aim 2, and objectives (a), (b), and (c), of this thesis' identified thematic narrative:

2) To develop a model for the calculation of a total landscape value across a range of wood-fuel woodland landscapes.

- a) Can socio-cultural, ecological, and economic values be combined to create a total landscape value?
- b) How do the relationships between the socio-cultural, ecological, and economic value domains, for each landscape, influence each other?
- c) Does this modelling technique provide a tool for landscape assessment which allows comparison between study sites?

As the preceding chapters have described, socio-cultural interaction with the natural world places structure and components in to the landscape in the pursuit of physical and mental well-being. The subsequent combination of structure and component is characterised by consequent ecological and economic conditions. Differences in these components and the associated structures that are created produce different value outcomes. These outcomes are captured and used to describe the multi-dimensional nature of the value relationship community holds with the surrounding landscape across a range of wood-fuel producing landscapes.

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<sup>4</sup> Findings and analysis from this chapter have been brought together in a conference oral presentation. The paper presented was: Smith, D., Kouloumpis, V., Ramsey, A & Convery, I. (2014) 'Can't see the wood for the trees: Renewable energy landscapes, assessment beyond monetary valuations' in, *Wellbeing and Equity Within Planetary Boundaries*, International Society for Ecological Economics, University of Iceland, Reykjavik

Landscape value is identified from a composition of these socio-cultural, ecological and economic value outcomes. Adopting an approach that accepts incommensurability, and rejects the permutability of all ‘values’, the informative nature inherent within the individual expressions of value is retained. Whilst employed in the calculation of a wood-fuel landscape index these data retain, within the constituent parts of each value expression, the distinct nature of the individual value expressions and the contrasting characteristics described within the preceding chapters. In this manner the studied range of wood-fuel producing landscapes are not simply characterised by a single indicator of overall landscape value, but by the varying degrees of contribution from the three primary value domains. Landscape takes on a focus that combines socio-cultural, ecological, and economic values in varied and complex ways. Approaching landscape evaluation from this perspective brings focus on management choice and questions of balance between natural capital and human capital across the social, ecological and economic value domains.

Across the four case study landscapes, ecological and economic values are not described by balance; higher levels of economic value appear to be generated at the expense of ecological value. Translation of data to a single metric for ease of use and communication, as seen in the employ of an accumulation ethic inherent in the use of monetary language and valuation techniques, obscures the expression of complimentarity and contrast between and within each value domain and the trade-offs revealed (McShane et al., 2011; Martín-López et al., 2014). Expressions of value used to support the institutional and political decision making process must reveal the true multi-dimensional nature of value.

## 7.2 Introduction

Increasingly total economic valuations have become the method of choice to measure the value associated with natural resources, for example see van Beukering et al. (2003); Jobstvogt et al. (2014); and Morri et al. (2014). The consumptive externally positioned relationship that society has developed with the natural world, when set against the complex

internal workings of ecological relationships, lends itself to the focus on economic valuation of the end-use benefits society derives from ecosystems (see chapter 2 of this thesis). In taking a monetary-based approach to articulate the value of natural resources, the components of nature change from being a physical reality to a system component of societal existence, from a context specific local occurrence to a global commodity that has value in use and exchange (Smith, 2007). Focus is given to market led properties not ecosystem properties, with value described from an accumulative approach that maximises net present value.

### **7.2.1 Socio-cultural, ecological and economic value as components of landscape evaluation**

The core idea of landscape valuation, when approached from an ecosystem service perspective, is that ecosystems contribute to human well-being. Where, biophysical components, structures, and processes become ecosystem services only if somebody uses, demands, or requires them either passively or actively (Costanza & Folke, 1997; Daily, 1997; de Groot et al., 2002; Luck et al., 2003; Boyd & Banzhaf, 2007; Wallace, 2007; de Groot et al., 2010). The importance of ecosystem services and the potential costs involved in their loss provides the basis for calculation of a monetary figure which reflects an economic valuation, for example see Costanza et al. (1997); Balmford et al. (2002); and Balmford et al. (2008).

Many authors promote the use of monetary valuation to highlight the critical role ecosystems and biodiversity perform in sustaining life, human well-being and providing long-term economic sustainability (Costanza & Folke, 1997; Balmford et al., 2008). As well as its use as a tool, framed using the conceptual metaphor of economic production, that has the capacity to bring environmental externalities in to the open with their value made an integral component of decision making processes (Daily, 1997; Daily et al., 2000; de Groot et al., 2002). Consequently, the expression of ecosystem service value in monetary, market-based terms is increasingly used to create economic incentives for conservation (Balmford et al., 2002).

As the preceding chapters (3, 4, 5 & 6) have demonstrated, value is normative, contains both objective and subjective components, and is a context dependent concept. Yet much of recent debate has become focused on the use of monetisation as the sole indicator of value. However, increased concern is now expressed for the use of monetisation in integrating sustainable use of natural resources in to the decision making process. For example;

1. issues regarding the specific nature of the values monetisation highlights or obscures (Plottu & Plottu, 2007; Peterson et al., 2009);
2. masking the importance of equity related to the unequal distribution of costs and benefits (Jax et al., 2013) which promotes an uneven accumulation of wealth and extends the reach of global capitalism (Matulis, 2014);
3. how the commoditisation of nature may change ones judgment from doing what is considered the ethical obligation or communal requirement to a purely economic self-interest (Gómez-Bagethun et al., 2010; Spangenberg & Settele, 2010);
4. the potential to reflect the limited extent of individual beneficiaries concerns with results biased towards information provided by markets at the expense of other value articulating institutions (Martín-López et al., 2014);
5. consideration of the difference between the spatial and temporal scales of economies and ecologies (de Groot et al., 2010);
6. the challenge of perspective, trade-offs, and the articulation of an informative truth through the monetised value of natural resources, in respect to the promotion of win-win solutions which seek to simultaneously generate substantial and sustainable socio-cultural, ecological and economic benefit (de Groot et al., 2010; McShane et al., 2011; Martín-López et al., 2014).

The monetisation of goods and services derived from ecosystems becomes informed through the anthropocentric and explicitly utilitarian dimensions of the interrelated social-ecological relationships (de Groot et al., 2002). In this context the danger is that ecosystem goods and services potentially only become necessary in as far as they support ideas of utility

maximisation and continued economic growth (Spash, 2009). Moreover, the monetary aggregation exercise endorses an accumulative approach to socio-cultural, ecological and economic value rather than that of a complex interdependent social-ecological system described by relationships of complimentarity and contrast.

This model of economic choice based on the standard assumptions of rationality and agency, glosses over the fundamental nature of the ecological limits to economic growth relationship (Daly, 1977; Spash & Aslaksen, 2012). Additionally, the economic conceptualisation of nature speaks to the continuation of a society-nature duality that the ecosystem goods and service model sought to eliminate. Money, when used to interpret the embedded qualities of the social-ecological relationship, fails to adequately account for the context specific, reflexive nature of human involvement and removes ideas of value pluralism (Spash, 2009). Landscape evaluation by society is realised through two basic components, 1) ecology - biophysical characteristics that are influenced by human activities assessed from an objective perspective, and 2) culture - the perception of value assigned to the environment by people, assessed from a subjective perspective (Petrosillo et al., 2007). Here society becomes more than just a consumer of landscape; people participate in ways that influence their understanding (Dakin, 2003).

If we accept that ecosystems provide multiple benefits across social, ecological and economic value domains, then we must make use of value articulating institutions and methods that better reflect value plurality (Martinez-Alier et al., 1998; Munda, 2004). In this sense articulation of a value position takes an embedded, plural and partial character informed by collective knowledge distributed across place and the people who occupy and interact with those places (Relph, 1976). Consequently, individuals will have only an incomplete understanding owing to their unique connection within the landscape. But, as Martinez-Alier et al. (1998) give emphasis to, incommensurability does not imply incomparability and should not be seen as weakness. The consideration of plurality and partiality can provide the basis for

a more culturally inclusive description, knowledge of difference can strengthen collective understanding (Martinez-Alier et al., 1998).

The contradictions, conflicts and plurality of values require institutions which allow them to be expressed. Recognising the need to integrate multiple expressions of value raises the question of how different value dimensions can be consistently aggregated or combined to reach sound conclusions (Martín-López et al., 2014). Whilst authors such as Munda et al. (1995) and Martinez-Alier et al. (1998) have proposed the use of multi-criteria evaluation techniques, which take into account conflicting, multi-dimensional, incommensurable and uncertain values, these approaches are still poorly represented in the ecosystem services literature.

However, an increasing number of publications now promote a move away from the narrow market-led monetary based view of value held in natural resources, to a position which [re]-establishes connections with biophysical and cultural values, for example see McCauley (2006); Norton & Noonan (2007); Kosoy & Corbera (2010) ; Spash & Aslaksen (2012); Jax et al. (2013). In contrast to the use of a '*monistic monetary measure of value*', see Norton & Noonan (2007), these publications advocate methodologies that accommodate multiple values without the necessity of reducing them to a single metric, and acknowledges incommensurability, interdisciplinarity, and empiricism using both qualitative and quantitative methods (Spash & Aslaksen, 2012).

This approach to the evaluation of change that occurs as a result of human activity uses value pluralism to enter in to a discourse which explicitly recognises the complexity of social-ecological systems (Spash & Aslaksen, 2012). A discourse that promotes the integration of social and ecological systems alongside economics, a pluralistic approach that Spash & Aslaksen (2012) describe as encompassing views from both the '*expert and lay person*', using '*multiple criteria*', taken from '*primary and secondary data*', incorporating a '*participatory*

*and deliberative process*', where contrast and complimentarity are described by '*value pluralism*', to achieve '*harmony with and a respect for Nature*' in '*sustainable systems*'.

### **7.2.2 Towards a fuzzy logic based landscape evaluation**

Value derived from these complex dynamic systems is characterised by both the objective quality of ecological resources and the subjective evaluation by society (Straton, 2006). Because their nature is one of 'a system of systems' each described by their own technical and methodological nature, the components of value resolve themselves to an irreducible and unsolvable epistemological nature, there is simply no one commensurable value (Stahel, 2005). Value becomes an emergent, relational property of each component that results from each system's own dialectics (Stahel, 2005). Where society, seen as a deliberative actor, connects the physical structure and functioning of the landscape with the values demanded through the intentional actions of its users (Antrop, 2005; Gobster et al., 2007).

Landscape evaluations, for the purpose of guiding decision making in the sustainable use of natural resources, need to consider a range of data from differing sources. Much of the data and knowledge considered concerns system aspects that combine issues of complexity alongside epistemic and linguistic uncertainty (Adriaenssens et al., 2004). Difficulty integrating the reflexive and subjective nature of these social-ecological systems is represented by the continued discourse between scientific, conservation, social, economic, and political concerns in the development of methods to assess the sustainable use of natural resources (Chiesura & de Groot, 2003; Balmford et al., 2008; de Groot et al., 2010; Spash & Aslaksen, 2012).

The combination of non-linear, uncertain, plural and partial nature of knowledge that is used to evaluate such systems aligns itself with the use of natural language, linguistic variables and values based on the fuzzy logic methodology. Fuzzy set theory, developed by Zadeh (1965), can take a form of approximate reasoning to replace the more traditional Boolean approach of

binary logic or crisp numbers (Zadeh, 1975). In this context fuzzy logic does not concern the likelihood of an outcome, but the degree to which the outcome itself occurred, in the sense that it cannot be described unambiguously (Zadeh, 1965). Phrasing the question changes from ‘what is the probability of sustainable use occurring?’ to ‘what degree of sustainable use is occurring?’

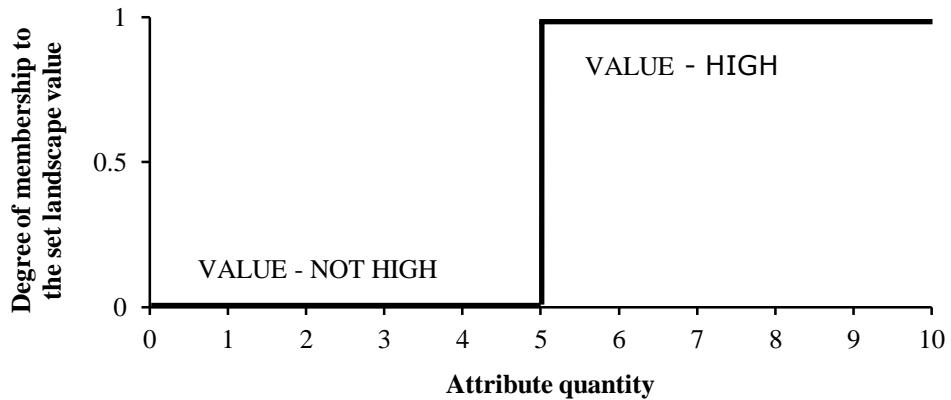
Fuzzy logic uses mathematical tools which handle ambiguous concepts and reasoning to give crisp number answers to problems populated with issues of uncertainty and partial knowledge (Cox et al., 1999). At its simplest, fuzzy logic is a generalisation of a standard logic proposition from two truth values, false and true, to the degree of truth membership between zero and one. Although fuzzy logic is not as widely used in environmental sciences as it is in engineering science, a number of studies have explored its use in providing reliable information to support the sustainable use of natural resources decision making process, for example see Silvert (2000); Adriaenssens et al. (2004); Özesmi & Özesmi (2004); Prato (2005); Kouloumpis et al. (2008); Phllis & Kouikoglou (2012).

### 7.2.3 Using fuzzy set theory

Consider the evaluation of a landscape based on three attributes of value; socio-culture (SC), ecology (Ecol) and economy (Econ). The determination of landscape value, in the case of using our three particular attributes, involves two decisions. Firstly, the empirical issue of measuring the attributes, which has been the focus of preceding data chapters, and secondly the conceptual issue of ‘do specific attribute values describe a landscape of high value?’, the question to which this chapter is focused on. Contemporary evaluations to address the second decision identify the high value landscape when  $SCt \geq SC^*$ ,  $Ecolt \geq Ecol^*$ , and  $Econt \geq Econ^*$  for all  $t$ , where  $SC^*$ ,  $Ecol^*$ , and  $Econ^*$  are threshold values and  $t$  refers to time periods.

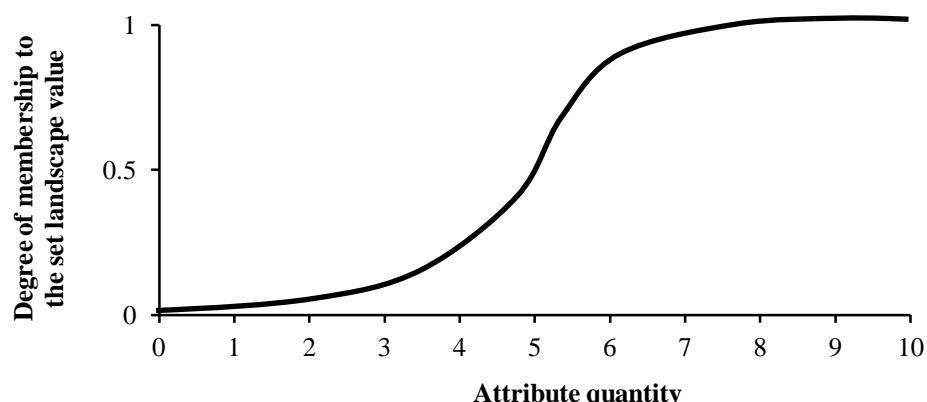
The identification of landscape value involves the assessment of crisp numbers, which imply the evaluation can make an unambiguous distinction between landscapes with value high and

value not high. Evaluations using crisp numbers involve a 1 or 0 conclusion in which attribute values slightly above the threshold defines high value (1), whereas values slightly below the threshold define the landscape as not highly valued (0) (Fig 7.1).



**Figure 7.1** A crisp set illustration of membership to the set of landscape value. All attribute quantity below a value of 5 are defined as not high, whereas 5 and above are identified as high.

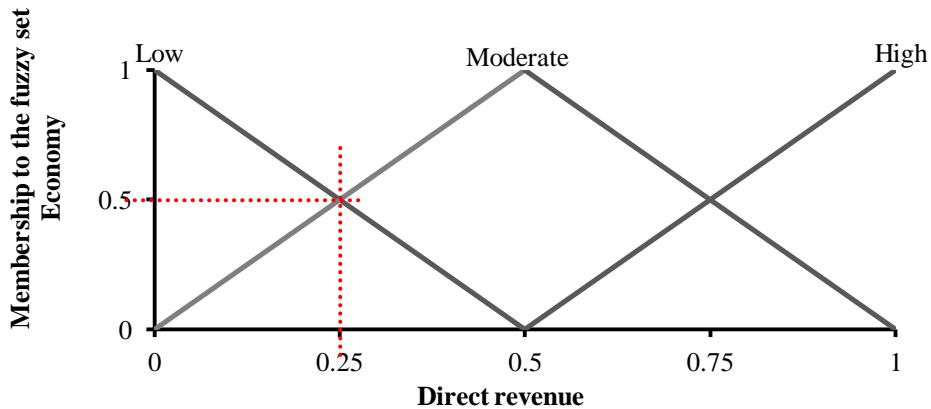
An approach based on crisp numbers for value attributes implies an ability to make clear, unambiguous distinctions between high value and not high value landscapes which runs counter to the uncertainties characterised by subjectivity, plurality and partial knowledge inherent in any complex system evaluation. In taking a fuzzy set approach, the fuzzy set is described as a set of objects with a continuum of grades of membership. Such sets are characterised by a membership function which assigns to each object a grade of membership ranging between zero and one (Zadeh, 1965) (Fig 7.2).



**Figure 7.2** A fuzzy set illustration of membership to the set of high landscape value. Attribute quantity is characterised by a membership function which assigns a membership grade between zero and one.

The boundary between highly valued and not highly valued is not only, not precise, but it is also not unique. As landscape value increases it enters a world where it contains properties of value ‘high’ and value ‘not high’ at the same time. Fuzzy logic models the extent to which the landscape’s measured attributes fulfil the criteria to be considered a member of the set *high landscape value*. In reality the boundary between landscape value ‘high’ and landscape value ‘not high’ is ambiguous and fuzzy, rather than sharp. Approximate reasoning using fuzzy logic provides a means to express this degree of ambiguity using linguistic concepts (Zadeh, 1975).

The term linguistic variable describes a variable whose values are words or sentences in either a natural or artificial language (Zadeh, 1975). Where, briefly, a linguistic variable is characterised by four components (1) the name of the variable, (2) its linguistic values, (3) the membership functions of the linguistic values, and (4) the physical domain from which the variable takes its quantitative or qualitative value (Cox et al., 1999).



**Figure 7.3** The fuzzy variable ‘Economy’ is associated with linguistic values ‘low’, ‘moderate’, and ‘high’, which are fuzzy subsets ( $u$ ) of the set ‘Economy’ (A). In which value is characterised by a membership function which represents the grade of membership of ( $u$ ) in (A). In this example the level of direct revenue value 0.25 is characterised with membership of (low) in (Economy) = 0.5 and of (moderate) in (Economy) = 0.5.

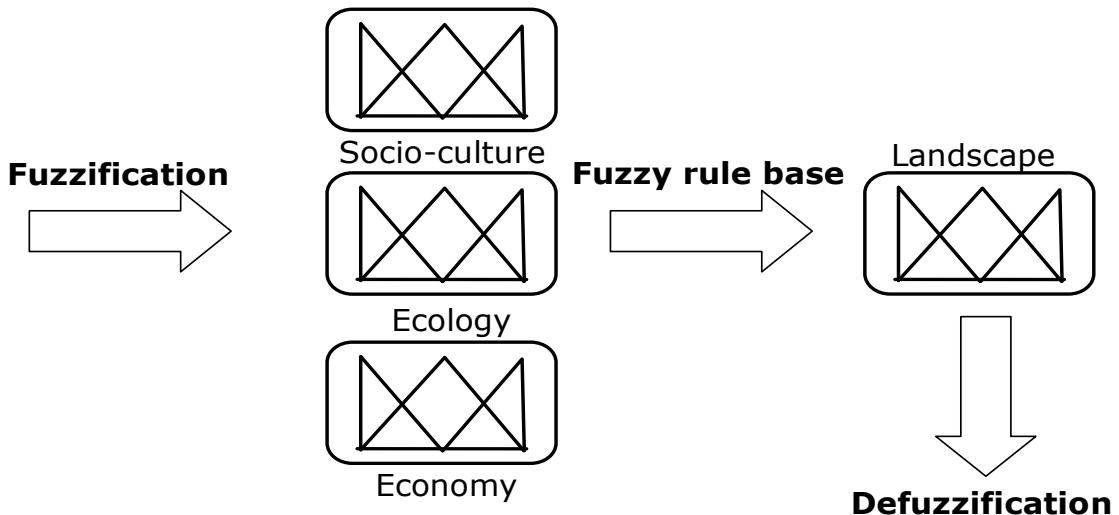
In the example above ‘economy’ is one linguistic variable of landscape value. ‘Economy’ could be comprised of three linguistic values, ‘low’, ‘moderate’, and ‘high’(Fig 7.3). The

membership functions of each linguistic value could be based on the amount of direct revenue generated per hectare of landscape, and the range of income represents the physical domain of the variable. Membership functions establish the degree of membership in the set and characterise the fuzziness in the fuzzy set. A triangular function is used here, where only one position has membership value of 1, the simplicity makes it a good choice when approximating unknown or poorly understood concepts (Ross, 2010). By calculating the degree of membership of a range of variables to a common linguistic concept, a diverse range of elements can become comparable (Kouloumpis et al., 2008; Weyland et al., 2012).

Fuzzy sets constructed in this manner allow for combination and modification using conventional set theoretic functions, following the fuzzy logic operations originally defined by Lofti Zadeh (1965). Basic fuzzy set operators in the form of the intersection ‘and’ operation, where  $A \cap B = \min(\mu_A[x], \mu_B[y])$ , and the union ‘or’ operation, where  $A \cup B = \max(\mu_A[x], \mu_B[y])$ , can then be applied through the use of a fuzzy inference rules based ‘IF-THEN’ system that connects the combined input variables to the output variable, for example see Phllis & Andriantsaholiniaina (2001); Adriaenssens et al. (2004); and Kouloumpis et al. (2008). In this way an aggregation of the values from the input variables, the degrees of membership to their specific fuzzy sets, are combined in accordance with the fuzzy propositions defined by the specific fuzzy inference rule base (Cox et al., 1999; Kouloumpis et al., 2008).

In the construction of a fuzzy inference rule base the degree of interdependence amongst the described variables can be expressed (Phllis & Andriantsaholiniaina, 2001). Fuzzy rules must cover all possible combinations of values for the input variables. The fuzzy output can then be defuzzified to produce a crisp number which can be used in further statistical analyses (Kouloumpis et al., 2008; Weyland et al., 2012). In consideration of the landscape value example, the composite linguistic variables ‘socio-culture’, ‘ecology’, and ‘economy’ can be

thought of as composed in a hierarchical sense where fuzzy reasoning applied in the form of ‘IF-THEN’ rules of inference provides an assessment of landscape value (Fig 7.4).



**Figure 7.4** A general scheme for a fuzzy model to evaluate the ‘value’ of landscape.

Each fuzzy inference rule base (or inference engine) is equipped with a collection of linguistic fuzzy ‘IF-THEN’ rules, for example see Table 7.1, using the Mamdani form. In this thesis, the fuzzy ‘IF-THEN’ linguistic rule bases are built upon the assumption that the individual components within socio-cultural, ecological and economic value variables be given as close an approximation to equal weighting as possible. Knowledge acquisition methodologies, such as interviews or questionnaires of lay and scientific expert, can also be used to build the rule base (Zadeh, 1973). The use of real data could also help in validating, modifying and improving the mathematical interpretations of the fuzzy operators or the linguistic rule base itself (Zimmerman, 1991).

‘Low’, ‘moderate’ and ‘high’ are linguistic values of the linguistic variables ‘socio-culture’, ‘ecology’ and ‘economy’; they correspond to the fuzzification of a measured amount of value of the respective variable. If we assume that the linguistic input value of ‘low’ is represented numerically by 1, ‘moderate’ by 2 and ‘high’ by 3, there are then only seven possible combinations of the aggregated numerical outcomes; 1x3 (low:low:low); 3x4, 6x5; 7x6, 6x7;

3x8; and 1x9 (high:high:high). Combinations to achieve a three linguistic value output from this three linguistic value input select the numeric output values of 3, 4 and 5 to describe ‘poor’, the numeric value 6 to describe ‘average’ and numeric values of 7, 8 and 9 to describe ‘good’. Thus ten rules describe the linguistic output ‘poor’, seven rules describe ‘average’, and ten rules describe the ‘good’ output. Defuzzification of the linguistic values ‘poor’, ‘average’, and ‘good’ provides a crisp measurement of value in ‘landscape’. In this example a complete rule base would contain  $3^3 = 27$  rules (all combinations of three linguistic values from three linguistic variables).

**Table 7.1** Fuzzy inference rule base for the ‘value’ of landscape example

Rule <i>R<sub>p</sub></i>	<i>If</i> Socio-culture <i>is</i>	<i>and</i> Ecological <i>is</i>	<i>and</i> Economic <i>is</i>	<i>then</i> Landscape <i>is</i>
<i>R<sub>1</sub></i>	low	low	low	poor
<i>R<sub>2</sub></i>	low	low	moderate	poor
<i>R<sub>3</sub></i>	low	low	high	poor
<i>R<sub>4</sub></i>	low	moderate	low	poor
<i>R<sub>5</sub></i>	low	moderate	moderate	poor
<i>R<sub>6</sub></i>	low	moderate	high	average
<i>R<sub>7</sub></i>	low	high	low	poor
<i>R<sub>8</sub></i>	low	high	moderate	average
<i>R<sub>9</sub></i>	low	high	high	good
<i>R<sub>10</sub></i>	moderate	low	low	poor
<i>R<sub>11</sub></i>	moderate	low	moderate	poor
<i>R<sub>12</sub></i>	moderate	low	high	average
<i>R<sub>13</sub></i>	moderate	moderate	low	poor
<i>R<sub>14</sub></i>	moderate	moderate	moderate	average
<i>R<sub>15</sub></i>	moderate	moderate	high	good
<i>R<sub>16</sub></i>	moderate	high	low	average
<i>R<sub>17</sub></i>	moderate	high	moderate	good
<i>R<sub>18</sub></i>	moderate	high	high	good
<i>R<sub>19</sub></i>	high	low	low	poor
<i>R<sub>20</sub></i>	high	low	moderate	average
<i>R<sub>21</sub></i>	high	low	high	good
<i>R<sub>22</sub></i>	high	moderate	low	average
<i>R<sub>23</sub></i>	high	moderate	moderate	good
<i>R<sub>24</sub></i>	high	moderate	high	good
<i>R<sub>25</sub></i>	high	high	low	good
<i>R<sub>26</sub></i>	high	high	moderate	good
<i>R<sub>27</sub></i>	high	high	high	good

In choosing socio-culture, ecology and economy as the principal factors of landscape value, the fuzzy rules might be;

- IF landscape is composed of ‘high’ socio-culture AND ‘high’ ecology AND ‘high’ economy  
THEN landscape is of ‘good’ value,
- IF landscape is composed of ‘moderate’ socio-culture AND ‘low’ ecology AND ‘high’  
economy THEN landscape is of ‘average’ value, and
- IF landscape is composed of ‘low’ socio-culture’ AND ‘low’ ecology AND ‘high’ economy  
THEN landscape is of ‘poor’ value.

This component of the thesis presents a pilot study which explores the use of a fuzzy logic rule based model to evaluate a range of wood-fuel producing landscapes. Here data that represents the variables selected in the preceding chapters, socio-culture (chapter 4), ecological (chapter 5), economic (chapter 6), are brought together within the framework of a fuzzy logic based evaluative model. Fuzzy sets provide the ability to integrate different kinds of observations in a manner that permits the inclusion of complimentarity and contrast found in the incommensurable influences of social, ecological, and economic value domains.

As Funtowicz & Ravetz (1994) propose, complexity and reflexivity are realised through the acceptance of facts beyond an objective, context free truth in a Kuhnian sense. This approach allows for what some would describe as ‘soft’, subjective, non-quantitative data to be handled alongside ‘hard’, scientific data. Enquiry of a ‘post-normal’ nature (Funtowicz & Ravetz, 1994; Funtowicz & Ravetz, 2003) generates knowledge produced by and for all stakeholders that is useful, operates in the context of application and is socially robust (Frame & Brown, 2008). In a ‘real world’ context the sustainable use of natural resources is not just the concern of science, the lives and livelihoods of all are dependent upon natural resources and all knowledge needs to be considered.

### 7.3 Method

#### 7.3.1 Study area

Case study sites were selected in the regions of Ioannina, NW Greece, and Südbergenland, SE Austria. The choice of study site reflects similarity in economic and demographic attributes, relative to national levels, and difference in institutional arrangements towards woodland use. Using the county of Cumbria, in the northwest of England, as a reference point, European case study sites are found where economic and demographic data identify similarities in ‘marginal’ status but also, importantly, where there is a sustained functional, economic, cultural or historic relationship with a woodland landscape. ‘Marginal’, in the context of this study is described by levels of rurality, standards of living and economic activity.

The regions of Ioannina, Greece, and Südbergenland, Austria provide areas with comparative economic and demographic data, whilst differences are identified across a variety of relationships, such as, land tenure, community institutions, local and national governance and cultural landscapes (Table 7.2). To avoid repetition a review of study site characteristics and rationale for study site choice has been completed elsewhere, see chapter three.

**Table 7.2** Overview of case study landscape characteristics

<b>Location</b>	<b>Landscape</b>
Tsepelovo, Greece	<b>Forest Service</b> An area of Natura 2000 large scale near to nature woodland under public ownership, with a national management ethos that reflects contemporary issues of conservation and ecosystem goods and services
Tsepelovo, Greece	<b>Wood pasture</b> A cultural landscape of small scale wood and pasture under local private ownership, with a traditional multi-functional utilitarian approach to use and management
Rechnitz, Austria	<b>Estate forestry</b> large national scale forestry operation under private ownership, by a single entity, managed with a sustainable forestry approach
Rechnitz, Austria	<b>Co-operative forestry</b> woodland with many small scale local private owners brought together under a co-operative management association with a sustainable forestry approach

### **7.3.2 Collection of data**

Data used in the construction of the fuzzy model are brought from the preceding data chapters.

Socio-cultural values relating to the attitudinal and normative behavioural responses from the communities of the studied landscapes are taken from findings in chapter 4. Ecological values relating to the wood biomass and herb biomass compartments of the studied landscapes are taken from findings in chapter 5. Economic values calculated from the direct revenue streams of the landscape users are taken from chapter 6. Data describes mean values for socio-cultural and ecological variables with absolute values for economic variables identified across the four study landscapes (Table 7.3).

**Table 7.3** Observed data and target values used in the normalisation of basic indicators prior to fuzzy landscape evaluation.

Value domain	Composite indicator	Basic indicator	metric	Target		Observed		Observed landscape values			Wood Pasture
				min	max	min	max	Co-operative	Estate	Forest Service	
Socio-culture	Attitudinal	Socio-cultural 1		0.80	1.00	0.20	1.00	0.95	0.95	0.96	0.96
		Socio-cultural 2		0.80	1.00	0.60	1.00	0.83	0.83	0.89	0.89
		Socio-cultural 3		0.80	1.00	0.20	1.00	0.86	0.86	0.75	0.75
	Normative behaviour	Ecological 1	Likert	0.80	1.00	0.60	1.00	0.92	0.92	0.91	0.91
		Ecological 2	scale	0.80	1.00	0.60	1.00	0.93	0.93	0.94	0.94
		Ecological 3	value	0.80	1.00	0.20	1.00	0.94	0.94	0.82	0.82
	Economic	Economic 1		0.80	1.00	0.20	1.00	0.86	0.86	0.79	0.79
		Economic 2		0.80	1.00	0.20	1.00	0.60	0.60	0.58	0.58
		Economic 3		0.80	1.00	0.20	1.00	0.68	0.68	0.72	0.72
Ecological	Wood biomass	Socio-cultural	Token	0.60	1.00	0.10	1.00	0.52	0.48	0.28	0.72
		Ecological	allocation	0.60	1.00	0.00	1.00	0.46	0.54	0.45	0.56
		Economic		0.60	1.00	0.00	1.00	0.56	0.44	0.29	0.71
	Herb biomass	0 - 0.5m		10.00	15.00	5.50	37.50	9.51	6.93	22.83	9.50
		0.6 - 2.0m	% cover	10.00	15.00	0.00	37.50	8.54	7.21	23.94	9.50
		>4.0m		15.00	20.00	0.00	87.50	61.08	70.48	76.67	20.50
	Timber forest products	0m		63.00	87.00	0.00	87.67	21.60	16.95	4.85	63.90
		0.2m	% cover	25.00	65.00	0.00	65.33	13.38	7.14	1.03	25.22
		forb		3.00	7.00	0.00	7.00	1.04	0.30	0.05	3.20
Economic	Non-timber forest products	herb diversity	$H'$	0.27	0.80	0.00	0.77	0.25	0.17	0.11	0.27
		herb height	cms	20.00	40.00	0.00	40.40	11.18	9.67	3.57	21.24
	Recreation	roundwood	Int \$ ha <sup>-1</sup>	350.00	400.00	0.00	383.67	267.49	383.67	27.53	0.00
		fuelwood		75.00	100.00	0.00	75.75	52.92	75.75	7.41	0.00
	Livestock	recreation	Int \$ ha <sup>-1</sup>	190.00	250.00	0.00	193.17	193.17	193.17	0.00	0.00
		livestock		200.00	250.00	0.00	221.61	0.00	0.00	0.00	221.61

## **7.4 Analyses and results**

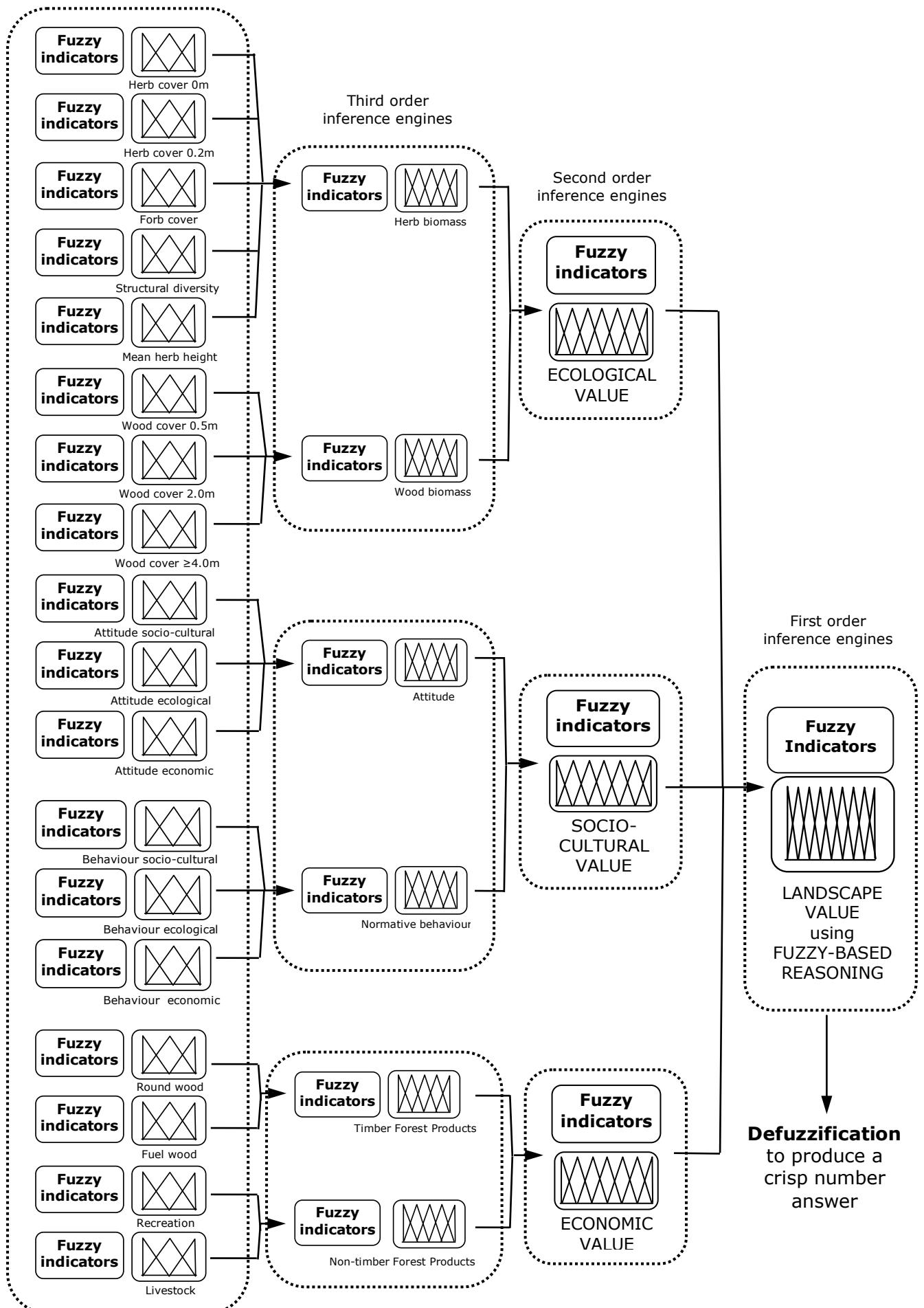
### **7.4.1 Analyses**

All fuzzy based functions, calculations and building of fuzzy inference systems were generated using The MathWorks Fuzzy Logic Toolbox. The following fuzzy model related detail presents the underlying methodologies upon which the Fuzzy Logic Toolbox are built.

#### **7.4.1.1 The fuzzy model; an evaluation of wood-fuel landscape values**

Schematically the landscape evaluation model is shown in figure 7.5. The landscape value of each wood-fuel producing woodland scenario is produced as a composite measure of the indicators described in the preceding data chapters. Thus, landscape value is comprised of three primary components; socio-culture, ecological, and economic value. Each of these primary value components are further comprised of two secondary components; socio-cultural value described by attitude and normative behaviour, ecological value described by herb biomass and wood biomass, and economic value described by timber forest products and non-timber forest products.

Each secondary component is assessed using a range of tertiary indicators, for example herb biomass comprises five basic indicators that characterise the herb layer compartment of each of the studied landscapes; % of herb cover at 0m and 0.2m, the % of forb cover, level of vegetation structural diversity, and the mean herb height. These basic indicators are described and measured by a variety of units over a wide range of scales which requires a normalisation procedure before being entered in to the fuzzy model.



**Figure 7.5**

Schematic of the hierarchical fuzzy model for landscape evaluation across a range of wood fuel producing woodland scenarios.

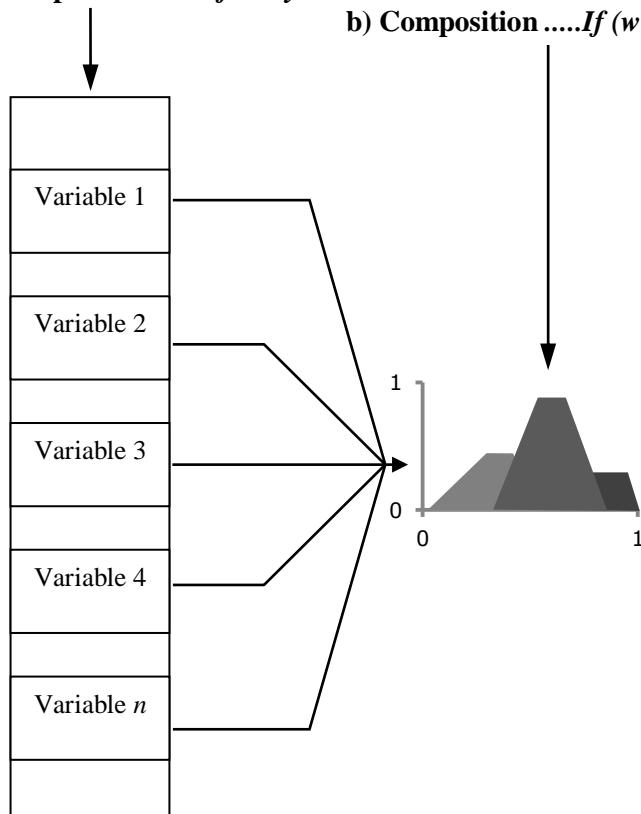
Normalised values on the scale [0,1] are obtained by linear interpolation between the most desirable and the least desirable value states described for each tertiary indicator within each of the preceding chapters. Specifically, for each basic indicator,  $c$ , a target minimum and maximum value is assigned, values are based on interpretation of observations in the preceding data chapters (chapter 4 – 6) (Table 7.1). In this manner evaluation takes the form of an inward focussed ranking exercise across the range of studied wood fuel producing woodland landscapes.

The desirable range for this normalisation process can be any interval on the real line of the form  $[T_c, \bar{T}_c]$  representing minimum and maximum target values for each indicator. For example, wood biomass  $\geq 4.0\text{m}$  is defined by a desirable range of 15-20%, normalised values outside this range will be  $<1$ . The maximum and minimum values,  $\bar{c}$  and  $\underline{c}$ , are taken over the set of all observed measurements for each indicator across the studied landscapes. If  $z_c$  is the indicator value for the system whose landscape value is to be assessed, then the normalised value  $x_c$  is calculated as follows (step 1 Fig 7.6);

$$x_c = \begin{cases} \frac{z_c - \underline{c}}{\bar{T}_c - \underline{c}} , & \underline{c} \leq z_c < T_c \\ 1 , & T_c \leq z_c \leq \bar{T}_c \\ \frac{\bar{c} - z_c}{\bar{c} - T_c} , & T_c < z_c \leq \bar{c} \end{cases}$$

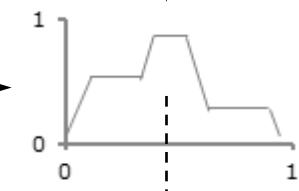
### Step 3 FUZZY INFERENCE ENGINE

a) Propositions .....If  $x$  is  $y$

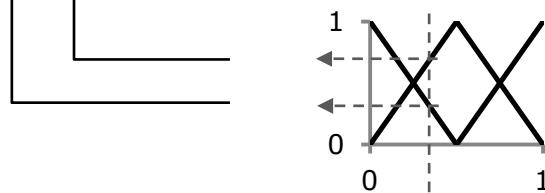


b) Composition .....If ( $w$  is  $Z$ ) and ( $y$  is  $W$ ) and ....( $u$  is  $S$ ) then  $x$  is  $y$

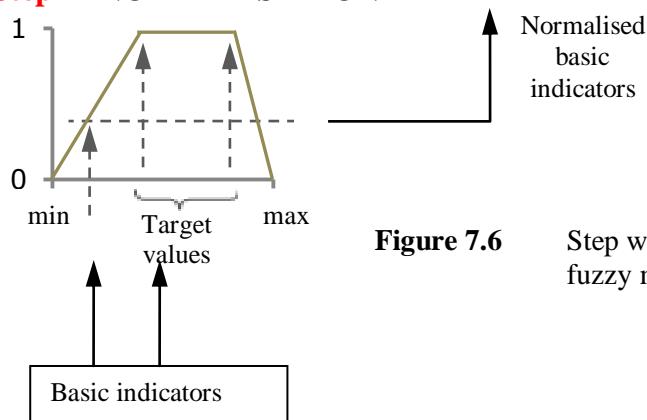
### Step 4 DECOMPOSITION (de-fuzzification)



### Step 2 FUZZIFICATION

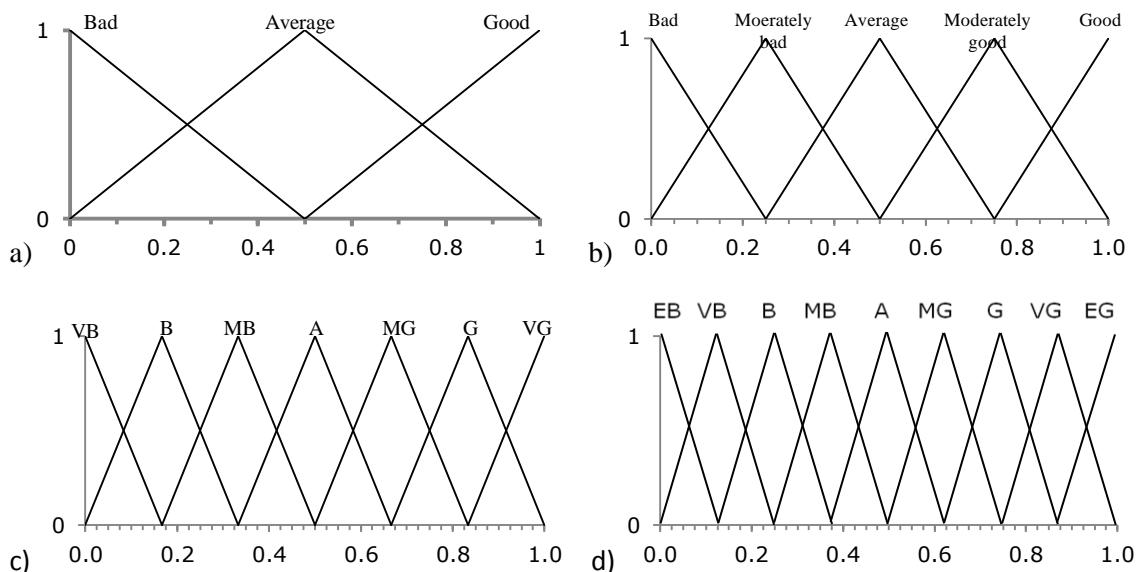


### Step 1 NORMALISATION



**Figure 7.6** Step wise operational outline to describe the fuzzy model evaluation process.

Normalised indicators are then fuzzified using three fuzzy sets with linguistic values ‘bad’ (B), ‘average’ (A), and ‘good’ (G), whose membership functions are shown in Fig. 7.7(a). Taking an approach to fuzzification that reflects a starting position of uncertainty, linguistic values of the tertiary basic indicators are set at their fuzziest, characterised by a triangular membership function (step 2 Fig 7.6). In this manner precision, and therefore complexity, is allowed to build within the model in a manner that moderates the need for a consequent increase in computational effort. The linguistic values of the fuzzy set (B) are low to mid values [0, 0.5], set (A) cover low to high values [0, 1], whilst set (G) covers mid to high values [0.5, 1] of the normalised indicators. Use of this as a starting position agrees with widely accepted assessment practices, see Kouloumpis et al. (2008); Ross (2010).



**Figure 7.7** Membership functions used to describe linguistic values in the fuzzy landscape evaluation model; a) basic indicators, b) secondary composite component, c) primary composite component, and d) landscape value.

To increase levels of precision and reduce information loss across the fuzzy model, fuzziness is reduced by the introduction of greater numbers of linguistic values used at each fuzzy rule base inference engine. Hence, secondary components are described by five linguistic values, primary components by seven, and the final landscape value by nine (Fig 7.7 b, c, d). At the landscape value level linguistic values are; extremely bad (EB), very bad (VB), bad (B),

moderately bad (MB), average (A), moderately good (MG), good (G), very good (VG), and extremely good (EG).

Each inference engine is equipped with a collection of ‘IF-THEN’ linguistic rules that function to reflect the truth that  $x_n$  is a member of fuzzy set  $L$ . The ‘IF’ component of the fuzzy rule rule base comprises the antecedent assertions of the rule, all fuzzy rules are assessed with the truth function, or degree of membership, determined using the intersection ‘AND’ operator. The resultant fuzzy space is found by taking the minimum of the truth functions found across the respective indicators for each rule. The consequent, ‘THEN’ component, updates the solution variable combining the antecedent propositions to produce a composite truth, an overall membership grade. This fuzzy space is described by taking the maximum of the individual truth functions derived from the firing of each rule in the ‘AND’ string.

This approach follows Zadeh’s min-max rule of implication using the Mamdani fuzzy inference method, and the most commonly used defuzzification technique which determines the centre of the area of the combined membership functions (Ross, 2010). In which output membership functions are fuzzy sets, and where, after aggregation, there is a fuzzy set for each output variable that needs defuzzification (Ross, 2010).

To understand the operation at each inference engine stage of the evaluative model consider the following (step 3 Fig 7.6 – proposition and composition). The inference engine combines  $n$  fuzzy inputs  $x_i$ , where  $x = 1.....n$ , to compute the composite variable  $x_{n+1}$ , based on a rule  $R_p$  which has the form;

$$R_p : \text{IF } (x_1 \text{ is } L_{1,p}) \text{ AND}.....\text{AND } (x_n \text{ is } L_{n,p}), \text{ THEN } (x_{n+1} \text{ is } L_{n+1,p})$$

where  $L_{i,p}$  is the fuzzy set which  $x_i$  belongs with grade  $\mu_{i,p}(x_i)$ . Thus, the overall degree to which  $R_p$  is applicable, the strength of each rule, is represented by the minimum of the individual truth functions;

$$\mu_{n+1,p}(x_{n+1}) = \min \{ \mu_{1,p}(x_1), \dots, \mu_{n,p}(x_n) \}.$$

Updating the solution variable to produce an overall membership grade of  $\mu_L(x_{n+1})$  of  $x_{n+1}$  to  $L$ , rules are aggregated by the union ‘OR’ operator, which is represented by the maximum of the individual truth functions determined for each rule. Membership of  $x_{n+1}$  to the fuzzy set  $L$  is;

$$\mu_L(x_{n+1}) = \max_{p:L_{n+1,p}=L} \{ \mu_{n+1,p}(x_{n+1}) \}.$$

Where ‘ $p:L_{n+1,p}=L$ ’ is an abbreviation for all rules  $R_p$  such that their consequences assign the linguistic value  $L$  to  $x_{n+1}$ .

Finally, a crisp value for the output is computed via the centroid, centre of gravity, method of defuzzification, where the expected value for a consequent variable is produced by finding the centre of gravity of the fuzzy region (step 4 Fig 7.6 – decomposition);

$$X_{n+1} = \frac{\int \mu_A(d_i) \cdot d_i}{\int \mu_A(d_i)}$$

where  $d_i$  is the  $i$ 'th domain value,  $\mu(d)$  is the truth membership value for that domain point, and  $\int$  denotes an algebraic integration.

This value is described on a scale of zero to one that illustrates the extent by which the modelled fuzzy solution space exhibits the described qualities of ‘high’ socio-cultural,

ecological, economic value. The fuzzy output that describes an aggregated landscape value, as described by the chosen basic indicators, presents a numerical value for this final fuzzy solution space; where zero is equivalent to a measure of no ‘high’ value and one complete alignment with ‘high’ value.

#### **7.4.1.2 Sensitivity analysis and a ranking of basic indicators**

A simple one-way sensitivity analysis demonstrates the impact of varying one parameter in the model. This first order sensitivity analysis of the fuzzy landscape evaluation examines the impact on the models results by an artificial introduction of perturbation to each of the basic indicators. This approach both provides for an assessment of stability across the calculated landscape values plus gives an indication to those basic variables with the potential to influence overall landscape values.

The sensitivity analysis is conducted as follows;

- 1) Calculate a crisp number value, for each of the studied landscapes, from the fuzzy landscape value output, where  $x \in [0,1]$ .
- 2) Introduce a predetermined level of perturbation to each basic indicator ( $x$ ), for this exercise an increase of the normalised values by 10% ( $\delta$ ) is used. The resultant normalised values  $(x + \delta)$  are held to a maximum of 1 to avoid values falling outside of the permitted range,  $[0,1]$ .
- 3) Assess sensitivity using steps 1 and 2 for each basic indicator at  $x_c + \delta$  to calculate a landscape value  $(x_c + \delta)$ . The sensitivity of landscape value with respect to  $x_c$  is defined by;

$$D_x = (1-x_c) \Delta_c$$

where  $x_c$  is the normalised value of indicator  $c$ ,  $1 - x_c$  represents distance from the optimal value, and  $\Delta_c = \text{landscape value } (x_c + \delta) - \text{landscape value } (x_c)$ .

Thus, issues that relate towards difference in influence from indicators of large and small composite components are resolved, see Kouloumpis et al. (2008). For example, the composite secondary component herb biomass depends upon five basic indicators, an increase in one of these basic indicators will have a moderate influence on the value of herb biomass. Whereas, the secondary component timber forest product is dependent on just two basic indicators, a similar increase in one of these basic indicators will potentially have a larger influence.

#### **7.4.1.3 Relationships between and within socio-cultural, ecological and economic value domains**

In order to characterise the contribution of observed data to the final assessment of a fuzzified landscape value, relationships between basic indicators, secondary and primary composite variables are explored. Comparison of the relationships described by the observed data and defuzzified crisp number values, across the range of wood fuel producing woodlands, identifies the ability of the fuzzy evaluative model to translate data and retain the inherent nature of original relationships. As well as the consideration of primary relationships this approach highlights potential for trade-offs between and within the three value-domains. Trade-offs can arise when management choices result in the maximisation of a single or a few specific aspects of society's relationship with natural resources, where preferential use in one value domain of the landscape leads to reduction or deterioration in others (Martín-López et al., 2014).

Descriptors of the relationships between basic indicator values are taken from analyses of observed data in the preceding data chapters. Where socio-cultural values are represented as proportional data (chapter 4), ecological values are described using proportional coverage, diversity indices, and height metrics (chapter 5), and economic value is derived from the absolute values of direct revenue streams (chapter 6). Defuzzified crisp number values are taken from the outputs at each hierarchical stage during the fuzzy evaluative process.

Principal component analyses (PCA) were applied, which reduces the multi-dimensional nature of the value space to characterise the relationships between the components of both primary and secondary composite variables presented in a two dimensional space. The Kaiser criterion, selection based on eigenvalues  $\geq 1$ , was used to select principal components that contribute most of the variance across the different observed value domain measures (Kaiser, 1960).

Characterisation of the relationships evident between the observed basic indicator variables are compared with those expressed by the defuzzified crisp number values of primary and secondary composite variables. Through the process of data translation and transformation the nature of any inherent relationship expressed within the observed data should not be lost.

## 7.4.2 Results

### 7.4.2.1 Fuzzy evaluation; a ranking of landscape values

The model output calculates a fuzzy landscape solution value which is used for a ranking of studied wood-fuel landscapes. In this application the estate forest landscape is described by the highest level of value, 0.875, the co-operative forest is ranked second, 0.844, wood pasture third, 0.826, with Forest Service ranked lowest, 0.243 (Table 7.4). Additionally, a defuzzified crisp number value for primary and secondary composite variables provides data for further ranking, statistical analyses, and interpretation. A pattern of directed contribution from specific value domains is also observed for the secondary value variables, where broad similarity and difference can be described across the four studied landscapes and between variables within each landscape.

**Table 7.4** Defuzzified crisp number values, calculated from the fuzzy evaluation model, across the studied range of wood-fuel producing landscapes.

		Fuzzy Value			
	Value domain	Estate	Co-operative	Wood pasture	Forest Service
	Landscape value	0.875	0.844	0.826	0.243
Primary composite variables	Socio-cultural	0.834	0.857	0.873	0.773
	Ecological	0.396	0.634	0.938	0.263
	Economic	0.833	0.597	0.167	0.058
Secondary composite variables	Normative behaviour	0.914	0.914	0.912	0.912
	Attitudinal behaviour	0.718	0.738	0.918	0.537
	Wood biomass	0.474	0.626	0.869	0.448
	Herb biomass	0.385	0.560	1.000	0.160
	Timber Forest Products	1.000	0.650	0.000	0.085
	Non-Timber Forest Products	0.500	0.500	0.500	0.000

#### **7.4.2.2 Sensitivity analysis and a ranking of value indicators**

The robustness of the fuzzy landscape evaluative model is investigated through a simple one-way sensitivity analysis by artificial perturbation of the basic indicators. Such an approach provides for a preliminary assessment of the model's stability across the calculated landscape values plus gives an indication of those basic variables with the potential to influence overall landscape values. Perturbation of the normalised figures for all basic indicators of value, by a level of 0.1 (10%), did not result in changes to ranking of overall landscape value, nor those values at the level of primary and secondary composite variables.

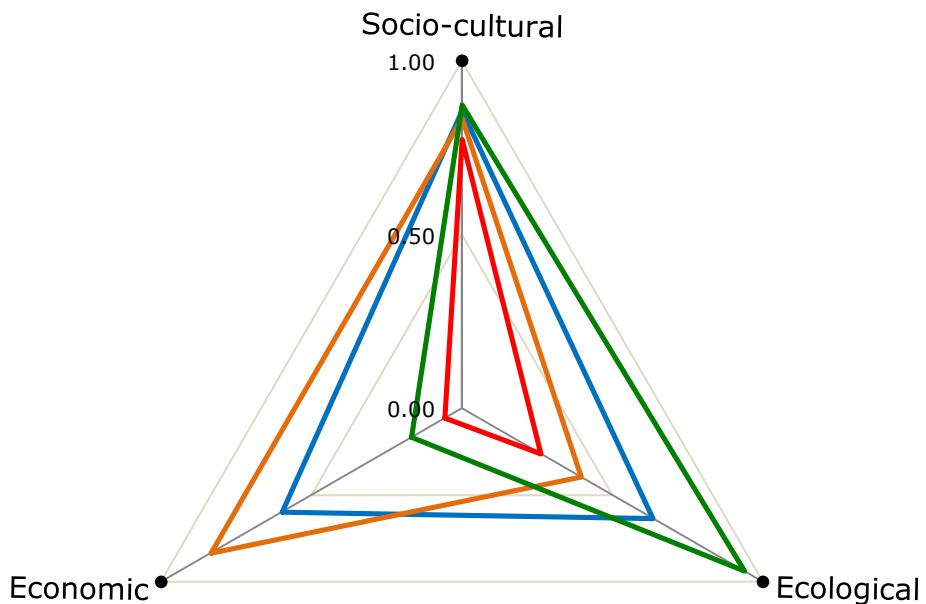
Table 7.5 shows values obtained from the sensitivity analysis of basic value indicators for each of the studied landscapes. The basic indicators of ecological value wood biomass cover at  $\geq 4.0\text{m}$ , herb biomass cover at 0m and forb cover are identified as the more sensitive to change for the co-operative forest landscape. The socio-cultural value indicator of normative ecological behaviour is the standout indicator for the estate forest landscape, and the economic value indicators of roundwood and wood-fuel, and recreation and livestock are the more sensitive for the wood pasture and Forest Service landscapes respectively. However, the levels of sensitivity to change are relatively low across the four landscapes and further demonstrate the robust nature of this fuzzy evaluative model.

**Table 7.5** Sensitivity of basic indicator values to a 10% increase in normalised value. Bold values denote basic indicators that exhibit higher levels of sensitivity to change within each studied landscape.

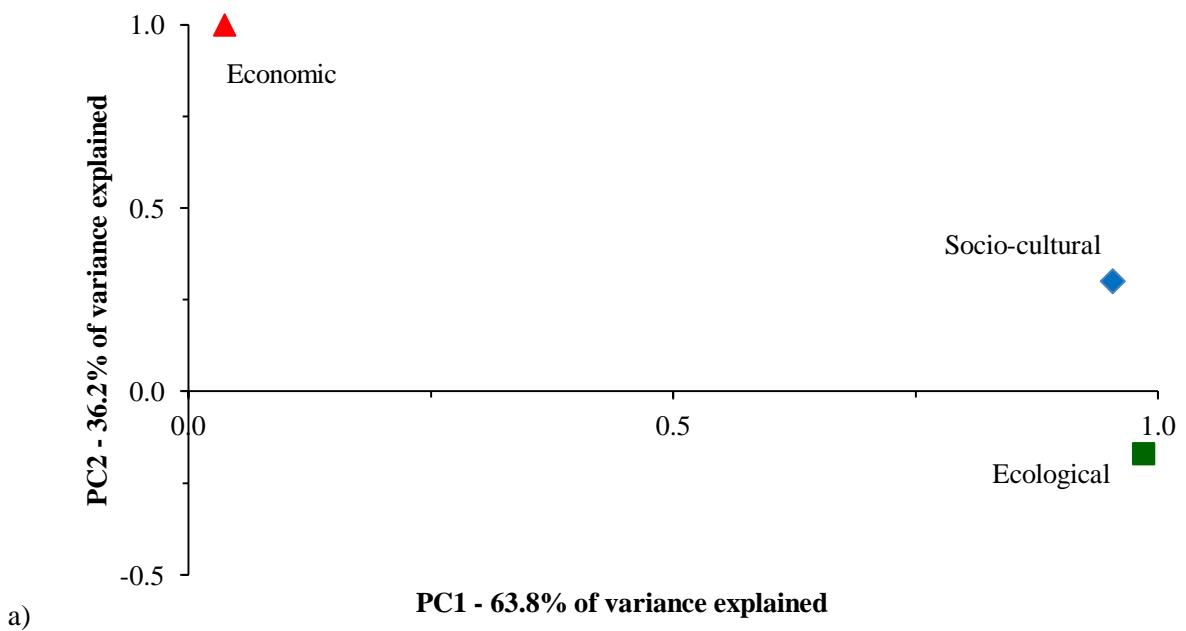
Composite indicators			Landscape			
Primary	Secondary	Basic indicator	Co-operative	Estate	Wood Pasture	Forest Service
Socio-cultural	Normative behaviour	Socio-cultural	0.0000	0.0000	0.0000	0.0000
		Ecological	0.0000	0.0000	0.0000	0.0000
		Economic	0.0000	0.0000	0.0000	0.0000
	Attitudinal behaviour	Socio-cultural	0.0005	0.0000	0.0000	0.0000
		Ecological	0.0007	<b>0.0005</b>	0.0001	0.0000
		Economic	0.0002	0.0003	0.0000	0.0000
Ecological	Wood biomass	0 - 0.5m	0.0037	0.0000	0.0002	0.0008
		0.6 - 2.0m	0.0041	0.0000	0.0001	0.0007
		≥ 4.0m	<b>0.0203</b>	0.0000	0.0000	0.0018
		0m	<b>0.0159</b>	0.0000	0.0000	0.0000
	Herb biomass	0.2m	0.0020	0.0000	0.0000	0.0048
		forb cover	<b>0.0155</b>	0.0000	0.0000	0.0049
		Herb diversity	0.0002	0.0000	0.0000	0.0030
		Mean herb height	0.0027	0.0000	0.0000	0.0017
Economic	Timber Forest Products	Roundwood	0.0025	0.0000	<b>0.0050</b>	0.0006
		Wood-fuel	0.0007	0.0000	<b>0.0050</b>	0.0013
	Non-Timber Forest Products	Recreation	0.0000	0.0000	0.0000	<b>0.0239</b>
		Livestock	0.0000	0.0000	0.0000	<b>0.0239</b>

#### 7.4.2.3 Relationships between and within socio-cultural, ecological and economic value domains

Assessment of the contributions made by the three value domains to the overall landscape value suggests that the socio-cultural, ecological and economic dimensions of landscape value generate different information. Difference across value domains is suggested in Figure 7.8, whilst high socio-cultural values were observed across the four studied landscapes an inverse relationship between ecology and economy is shown, where reductions in ecological value appear connected to a consequent increase in economic value.



**Figure 7.8** Defuzzified crisp number values of socio-cultural, ecological and economic composite indicators derived from different basic information sources; socio-cultural, biophysical and monetary valuation. Colours denote landscape type; — co-operative forest, — estate forest, — wood pasture, — Forest Service, • maximal value (1.0).



Variables	Factor loadings		Square cosines	
	F1	F2	F1	F2
Socio-cultural value	0.954	0.301	<b>0.909</b>	0.090
Ecological value	0.985	-0.170	<b>0.971</b>	0.029
Economic value	0.037	0.999	0.001	<b>0.999</b>
Eigenvalue	1.913	1.087		
% of variance explained	63.764	36.225		
% of cumulative variance	63.764	99.989		

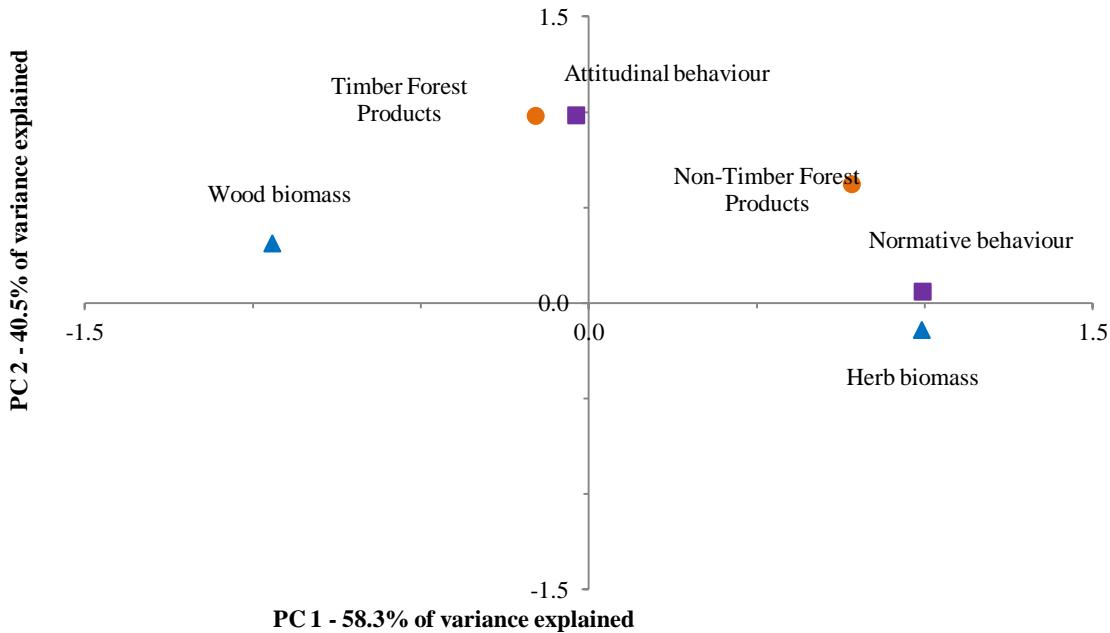
b)

**Figure 7.9** Contrast between value characteristics of primary composite variables; a) graphical representation of factor loadings, b) factor loadings and squared cosines derived from the principal component analysis. Yellow highlights indicate difference in information across the two axis; bold squared cosines denote most influential variables.

A principal components analysis reduces the three-dimensional primary value space to two dimensions, where the selected factors (F1 and F2) have eigenvalues  $\geq 1$  and account for 99.99% of the total variance. Figure 7.9 summarises the results. The first factor (F1), which accounts for 64.8% of total variance, shows that the information obtained from socio-cultural and ecological values is different from the economic value information. On the other hand, the second factor (F2), which accounts for 34.7% of total variance, shows that different information was obtained from the ecological and socio-cultural indicators, where ecological

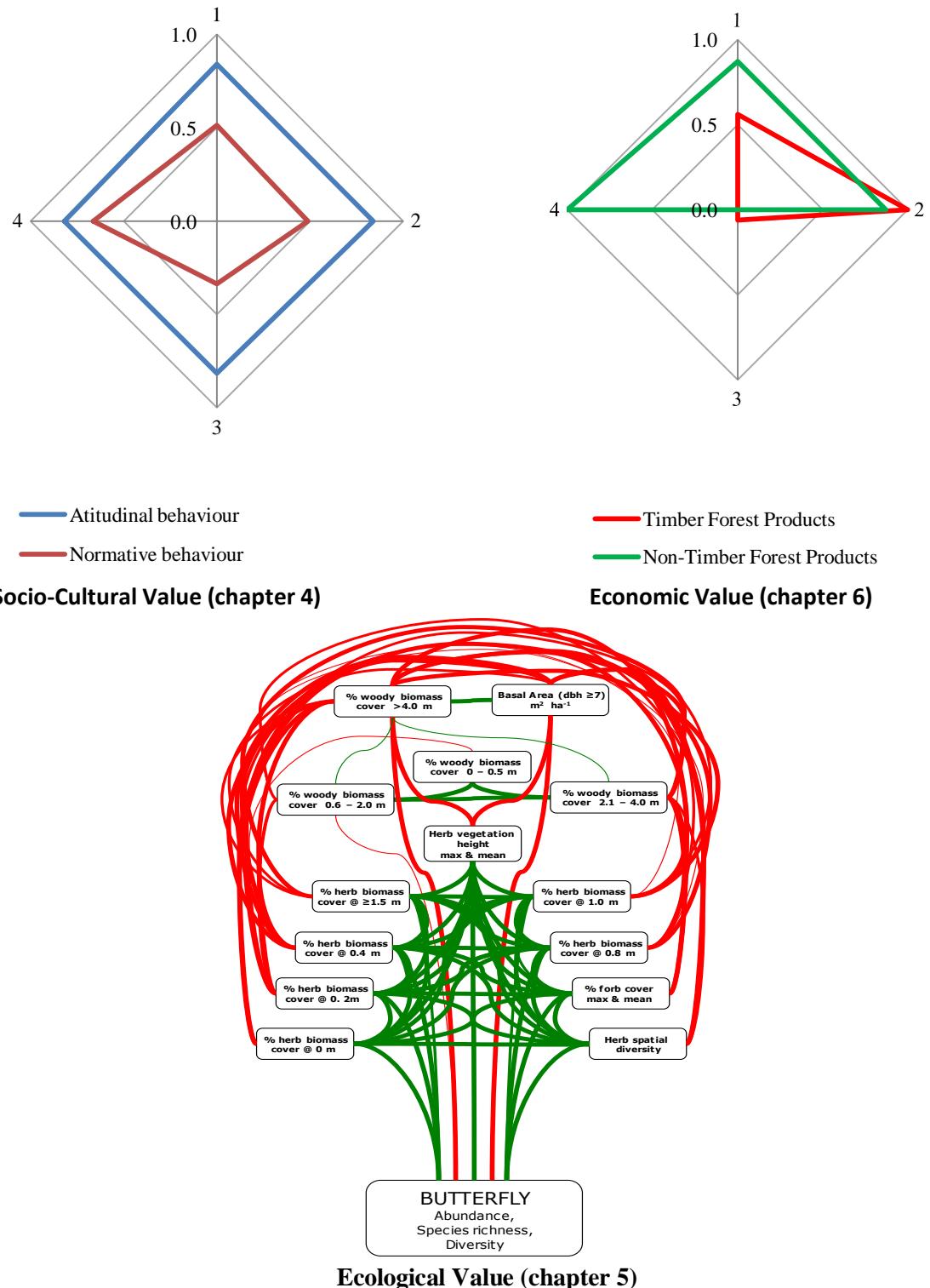
values describe negative contributions to F2, and socio-cultural values positive contributions to F2.

A second principal component analysis, on the secondary value components, reduces the six-dimensional value space to two dimensions, where the selected factors (F1 and F2) have eigenvalues  $\geq 1$  and account for 98.85% of the total variance (Fig 7.10). The first factor (F1), which accounts for 58.3% of total variance, shows that the information obtained from attitudinal behaviour, timber forest products, and wood biomass composite indicators is different from the value information of normative behaviour, non-timber forest products, and herb biomass. The former being described by negative contributions to F1, the latter described by positive contributions to the F1 axis. The relationships of complimentarity and contrast described between the components of basic value indicators, displayed by the observed data, are retained in both the secondary and primary levels of the fuzzy composite values.



Variables	Factor loadings		Square cosines	
	F1	F2	F1	F2
Attitude behaviour	-.039	.984	0.001	<b>0.968</b>
Normative behaviour	.992	.060	<b>0.985</b>	0.004
Timber Forest Products	-.159	.981	0.025	<b>0.962</b>
Non-Timber Forest Products	.782	.623	<b>0.611</b>	0.388
Wood biomass	-.943	.313	<b>0.889</b>	0.098
Herb biomass	.990	-.140	<b>0.980</b>	0.020
Eigenvalue	3.499	2.432		
% of variance explained	58.316	40.535		
% of cumulative variance	58.316	98.851		

**Figure 7.10** The relationships of complementarity and contrast between secondary composite variables and basic indicator variables; a) a principal component analysis using defuzzified secondary composite values; yellow highlights indicate difference in information across the two axis; bold squared cosines denote most influential variables.



**Figure 7.10** The relationships of complimentarity and contrast between secondary composite variables and basic indicator variables; b) relationships between basic indicator variables characterised using observed values; socio-cultural data displayed using proportional values (chapter 4), ecological values described by the output of a Spearman's rank correlation (chapter 5), and economic data taken from direct revenue streams using proportional international dollar values (chapter 6). Numbers denote landscape; 1) co-operative forest, 2) estate forest, 3) Forest Service, 4) wood pasture.

## **7.5 Discussion**

In this element of the study, use of fuzzy logic based approximate reasoning explores a landscape evaluation technique with the ability to communicate reliable information that can support the institutional and political decision making process. This approach sees natural resources as a system component of societal existence where, the interaction of society creates structures in landscape that are themselves described by a consequent socio-cultural, ecological and economic value. Landscape and its structure, in this sense, becomes a value articulating institution, which is characterised by purposefulness, awareness, reflexivity, and is context specific.

In the combination of multiple metrics to describe landscape value, the aim was to retain information that faithfully characterises the basic relationships held between each value domain and their constituent parts. Expressions of value should communicate information about the nature of things based on understanding, truth, and the appropriateness of its components, which in turn are dependent upon the psychological, physical, and social dimensions of the relationships that link the subject of value with the object of value (Mendes, 2007).

Importantly, the fuzzy evaluative process, used in this thesis, produces a model that allows for a ranking across the studied wood-fuel producing landscape scenarios (Table 7.2), and does so in a stable manner (Table 7.3). Although, further multi-way sensitivity analysis involving the increase and decrease of two or more different parameters, changing simultaneously, will provide additional support to the identification of key variables within each value domain. Notwithstanding this caveat, these results demonstrate that the fuzzy model retains information of complimentarity and contrast described by the basic indicators observed values. The consequent nature of these relationships can be seen across the primary value domains (Fig 7.9), and the secondary composite value variables (Fig 7.10).

Using the fuzzy evaluative model to rank the differing wood-fuel producing landscape scenarios based on a simplistic aggregated value describes, from high to low value, 1 – estate forest, 2 – co-operative forest, 3 – wood pasture, and 4 – Greek Forest Service. However, equally as important is the extent to which data from the primary value domains contribute to these landscape values. Here broad difference is expressed in the degree of contribution from each value domain to calculated landscape values. Value in the estate forest landscape is primarily described by social-economic characteristics. In contrast co-operative forest and wood pasture landscapes have a value primarily comprised of social-ecological characteristics, whilst value for the Forest Service landscape comes primarily from the socio-cultural domain.

Additionally, difference between the co-operative and wood pasture scenarios is observed in the amount of contribution to the primary value domains of economy and ecology. Co-operative forest, when compared with wood pasture, is described by a higher economic value input, 0.597 vs. 0.167, and a lower ecological input, 0.634 vs. 0.938. Defuzzified crisp number values highlight the strength of contribution from each of the composite value variables to the calculated overall landscape value. This pattern of a directed contribution from specific value domains can also be observed in the secondary value variables, where broad similarity and difference can be described across the four studied landscapes and between variables within each landscape.

The visible nature of value relationships between the components of an overall landscape value, as described across the four studied landscapes, implies that in the acceptance of an accumulative approach to the evaluation process there is an implicit acceptance of the inherent relationships between value domains that generate the overall value figures. In the acceptance of high value, as described across the four case study landscapes, primacy would be given to social-economic characteristics in a manner that suggests trade-offs by management choices against ecological value. Thus, in the assessment of a calculated landscape value, the

components of value and their contribution to a final value are made apparent. The comparable quality of these data reveals a truth in value based on the nature of observed relationships, with the possibility to illustrate potential trade-offs across value domains (Fig. 7.8). Thereby facilitating the acknowledgement of the true nature of value in the decision making process.

Choice of a preferential landscape approach to the provision of wood-fuel, based on these data, would need to accept the estate forest landscape as providing socio-cultural and economic value over ecological value. Alternatively, wood pasture is characterised by predominately socio-cultural and ecological value with a small contribution from economic value, whilst the Forest Service landscape is primarily described by socio-cultural value with little ecological and economic value. However, the co-operative forest landscape represents an equitable landscape approach based on moderate contributions across all three value domains. Although selection of this scenario accepts a lower economic value than the estate forest and also a lower ecological value contribution than wood pasture.

In the use of values taken from studied landscape scenarios to define the desirable range of basic value indicators, on which normalisation is based, a limited inward facing evaluation exercise is completed. This enables a basic comparison and ranking between the studied landscapes. However, the use of expert opinion would better determine a desirable basic indicator range, and work towards an outward facing evaluation. Unfortunately academics and forestry professionals approached by the researcher felt unable to adequately identify desirable values for those basic indicators identified in this study.

The issue here appears to be one grounded in a multi-use versus single-use dichotomy, despite much of the economic value literature describing multi-functional sustainable use as economically more beneficial than single function use (Balmford et al., 2002; de Groot et al., 2010). The complexity of interaction and interdependency in a truly multi-use value space

proves difficult to address, whereas, management for single-use functions is an approach that has long been taken by many who use and create structure in landscape to meet clearly defined goals.

A functional production space use of landscape can remove thoughts of society and position distance between people and place (Antrop, 2005). Landscape describes both place and the consequences of human influence, a multi-use choice space made of many parts which are at the same time both different and complimentary. Landscapes make visible the dynamic interaction between environmental processes and society in the conscious, intentional, and repeated reorganisation of land to adapt its use and structure to better meet changing societal demands (Antrop, 2005; Gobster et al., 2007).

Acceptance of human systems as a component of ecosystems not only removes the dualistic thoughts of the human world-natural world dichotomy, but also thoughts of simplicity. Society becomes an embedded component of a complex and dynamic social-ecological system described by the context specific, subjective, and reflexive quality of human involvement alongside the objective nature of ecological resources (Spash, 2009). The dynamic nature of change, common to all systems, occurs continuously both in space and time in the [re]creation of an ordered structure (Stahel, 2005). Thus, value, in the sense of the system, is an emergent, novel, and relational property that results from the unique context specific composition of its constituent parts, connective structure and the functions it performs (Stahel, 2005).

In the acceptance of a systems complexity, where problems cannot be captured using a single perspective, expressions of value need to reflect the multi-dimensional nature of complexity (Martinez-Alier et al., 1998; Munda, 2004). The use of monetary valuations, to describe value for natural resources, sidesteps issues of the irreducible value conflict by translation to a common comparative term (Martinez-Alier et al., 1998; Munda, 2004). As Martinez-Alier et

al. (1998) advocate, absence of a common unit of measurement across plural values should not result in a value reductionism. Incommensurability does not imply incomparability. Different values are weakly comparable, in that they are comparable without recourse to a single type of value (Martinez-Alier et al., 1998; Munda, 2004). Viewed from a methodological perspective, the issue of incommensurability needs to address the representation of multiple value identities in evaluative models. This represents the best approach from a holistic position, rather than commodification and monetisation, since it does not seem reasonable that a complex, multidimensional space should be represented by a single number.

Thus, the evaluative process needs to adopt a pluralistic approach, one which can accommodate plural values, partial knowledge, and uncertainty used to describe both subjective, qualitative ‘soft’ science and objective, quantitative ‘hard’ science (Norton & Noonan, 2007; Spash & Aslaksen, 2012). Fuzzy logic-based modelling not only allows for the integration of both data sources, structured by means of linguistic expressions (Adriaenssens et al., 2004), but can also accommodate knowledge based on a deliberative discourse (Özesmi & Özesmi, 2004). The semantic expression of the value discourse allows for the inclusion of knowledge from scientific expert and local expert alike. And, notwithstanding the underlying mathematics, provides an intuitive and transparent way to parameterise model construction (Adriaenssens et al., 2004). In this manner societal experience helps build a foundation for model rules that comprise its functional logic such that a fuzzy model represents the synthesis of expert knowledge in the form of rules and fuzzy sets. This process presents an iterative knowledge acquisition methodology that is built upon the expert’s narrative.

Evaluative models should calculate values that reflect the true nature of the interconnected relationships that describe complex social-ecological systems. These expressions of value will themselves be multi-faceted and context specific. Value in complex social-ecological systems, where society takes a participative role in socio-cultural, ecological and economic

value domains, can only be fully expressed through the multiple dimensions of cultural identity, beliefs and attitudes towards the landscapes that it creates (Farber et al. 2002; Sauer and Fischer, 2010). Expressions of value that support the sustainable use of natural resources decision making process should provide knowledge that communicates understanding and truth constructed from an appropriate framework of apposite descriptors.

## **7.6 Conclusion**

The approach of conceptualising biodiversity and ecosystems as a supply of goods and services, whose value lies in a monetary measure, has become a generally accepted medium of communication for economists and many ecologists used to inform the institutional and political decision making process. Taking a pragmatic move towards the expression of value for biophysical components, structures, and processes, the current trend characterises specific aspects of ecosystems and biodiversity which are then expressed as a monetary-based numbers equivalent to a financial value. This financialisation of nature represents a direct conflict with the accepted understanding that the biophysical components, structures, and processes of social-ecological systems have multiple incommensurable values.

If concepts of value are to have use in providing information that supports an effective decision making process there is a recognisable need to look beyond current acceptance of an economically informed discourse. A new deliberative discourse is required that goes beyond the purely utilitarian ethic which only continues to provide an effective illustration of the dominant and destructive separation between society and nature. The focus on consumption and accumulation conceals the complex and proximate connections of people's daily lives to the environment in which they live, and suggests that solutions can be found in the creation of disembedded markets and further consumption.

In this work, the presentation of a fuzzy logic based evaluative model argues that more can be done to support effective decision making than describing pseudo-economic values based

upon techniques that do not adequately reflect the complex, multi-faceted nature of interrelated social-ecological systems. Value, as a concept that gives voice to the interdependent relationship between society and nature, should not be focussed on the end point of an accumulative process.

Alternative approaches to evaluation must accommodate the plural values, partial knowledge, uncertainty, and reflexivity inherent in complex social-ecological relationships. In the accommodation of multiple value dimensions the contribution and relationships between and within each value component should remain visible. In this way emphasis can be placed on value in composition and balance, complimentarity and conflict, benefit and consequence, not simply value by accumulation.

Fuzzy values, used in the context of this thesis, do not consider a monetary amount of landscape value accrued, which in the process removes information describing original relationships, but considers to what degree of membership truth the concept of [high] landscape value has occurred. In doing so information that describes the fundamental relationships between and within value components, and their contribution to the overall degree of membership truth is retained and made visible. This fuzzy logic application presents an alternative that enables the development of propositions which can provide reliable information for decision makers to judge the effects of landscape management options.

## **Chapter Eight**

### **Objectives, thoughts and findings: a general summation**

#### **8.1 Summary**

In using the provision of wood for fuel, a renewable energy source, this thesis has taken an interdisciplinary approach to illustrate the utilitarian relationship that society has, and continues to build, with the natural world. Socio-cultural, ecological and economic data have been used to explore a value-based approach to landscape evaluation designed to provide information that supports deliberative discourse on sustainable landscape management. Taking a value-based view different landscape management options that provide wood-fuel have been assessed.

Qualitative and quantitative description of socio-cultural, ecological, and economic values have been used to characterise the relationships between society, land-use and landscape. This approach, by necessity, involves taking an interdisciplinary approach to the discourse around landscape management and the use of wood for fuel. This thesis is based on a conceptual framework that emphasises the connections between social and ecological system components (Folke, 2006). ‘Value’, in this context, is generated through the normative and attitudinal frameworks a society develops with the landscape that it creates and surrounds itself with (Farber et al., 2002). Adopting a ‘living-in-place’ approach, a sustainable sense of place is built upon local knowledge and the connections people develop with landscape (Borgstrom Hansson & Wackernagel, 1999).

Society, when viewed as a purposeful and reflexive component, places structure and components into the landscape in pursuit of physical and mental well-being. Differences in the structures and components of these created landscapes lead to different value outcomes. These value outcomes are described and used to express the multi-dimensional nature of the value relationships society holds with the surrounding landscape. The intention being to

describe socio-cultural, ecological, and economic values in a manner that facilitates use of the inherent relationships between society, land-use and landscape, supports deliberative discourse and informs both the institutional and political decision-making process.

Analysis, at the landscape scale, allows for the interactions between socio-cultural, ecological, and economic value to develop a framework that respects the relationships between and within each value domain. In this manner the characteristics of complementarity, contrast and trade-off, inherent in systems described by finitude, become apparent. Such approaches are urgently needed if society is to move away from a wholly utilitarian framework, based on value-in-exchange, to address the sustainable use of natural resources in a manner that fully considers future generations.

Thoughts developed from the literature review (chapter 2) outline the socio-cultural context of society's changing relationship with nature. A change that, in reconciling the society-nature dichotomy, now sets the context and provides support for the adoption of a multi-dimensional value-based approach to the sustainable use of natural resources. Observations and findings from the preceding data chapters (chapters 3, 4, 5, 6 and 7) are linked with research aims, which as stated in Chapter one were;

- 1) To calculate a socio-cultural, ecological, and economic value for case study landscapes, in which land-use includes the provision of wood-fuel.
- 2) To develop a model for the calculation of a total landscape value across a range of wood-fuel woodland landscapes.

Thoughts for additional work to further develop and broaden the scope of this values-based approach are presented within each data chapter summary.

Chapters four (socio-cultural value), five (ecological value), six (economic value) and seven (a fuzzy logic-based evaluation) provide data that populates and develops a values-based model. Outputs from the fuzzy logic evaluation process provide information to support a

deliberative discourse on the sustainable use of natural resources, in sustainable renewable fuel future. Following this review of thoughts and findings, (chapter 8) data derived from the fuzzy modelling component (chapter 7) is used to address the primary research question, aim 3 of this thesis, in chapter 9;

- 3) Apply the modelling technique developed to address the proposition of '*A values-based wood-fuel landscape evaluation: building a fuzzy logic framework to integrate socio-cultural, ecological, and economic values.*'

## **8.2 Thoughts regarding the cultural context of society's changing relationship with natural resources**

This review of society's relationship with the natural world is approached through a conceptual organisation, which takes a linear, temporal and comparable view of the prevailing paradigms experienced over time. Society's relationship with the natural world is illustrated as a move from an Aristotelian teleological position of the medieval ages, where religious thought viewed society as external to a non-human natural world (Hamilton, 2002; Heller, 2011), to the placing of society as an integral component of a social-ecological system (Pickett et al., 2005). A perspective that begins to [re]-embed society within a natural world, set in the context of a growing recognition of knowing the world and being in the world (Haila, 1999). Society moves towards thinking about landscape as the result of interaction between human intervention and natural process, operating at a range of spatial and temporal scales, described by plurality, partiality and reflexivity.

Where natural capital was once realised by an agrarian society in which successive generations shared productive resources to sustain life and livelihoods (Lowry, 2004). Social change, brought about by the rise of the individual, urbanisation, global trade, the capitalist, the consumer, and technological advancement transforms the relationship between community and the natural world (Allen, 1998; Argemí, 2002; Bryer, 2006; Allen, 2011). Human capital

became synonymous with natural capital described by a monetary market-based value; wealth was measured in financial terms (Bryer, 2000b; Wrigley, 2006; Allen, 2011).

Continued conversion of natural capital to human capital fuelled the emergence of a commodity culture, the rise of consumption and consumerism (Richards, 1990; Hilton, 2004). Consumption became the means by which government shaped policies and interventions (Hilton, 2003). Thus the politics of consumerism shaped ideas of an increasing consumption building a strong economy (Maniates, 2001; Hilton, 2003). An attitude that still holds true today in many sections of the political economy. The monetary, market-based value of the flow of final goods and services, described as Gross Domestic Product (GDP), is considered synonymous with social well-being and standard of living (Daly, 1991). However, in constructing a measure of GDP only the value of benefits and costs are brought together, which fails to take account of changing levels of [natural] stocks. At a basic level, neglecting the influence of depleting stocks of natural capital, to produce human capital, makes society feel richer than it really is and encourages the replacement of a natural economy with a market [human] economy (Daly, 1991).

Ecologically speaking, society's place in the natural world should be considered from a [eco]-systems perspective. A system described by the fundamental unit of interaction between organism and environment (Tansley, 1935; Odum, 1971). Interaction occurs from the level of the gene, through cell to individual, population, community, ecosystem, up to those of the biosphere (Odum, 1971). When viewed as a system of hierarchical interacting components and elements, where at any given level of resolution, an element at one level contains both elements in the level below and is itself a constituent of the level above (O'Neill et al., 1989). Component interaction at lower hierarchy levels creates endogenous structure which forms patterns that emerge at higher levels (Levin, 1998). With the multiplicity of interconnected relationships and levels in mind [eco]-system definition encompasses a range of attributes;

composition, structure and function, over differing dimensional scales; spatial, organisational and temporal (Tansley, 1935; Odum, 1971; Levin, 1998).

Placing society within the context of a social-ecological system will logically extend to including humans, we simultaneously influence and depend upon ecosystems. Strong economic growth based on unabated consumption has led to many of the world's ecosystems becoming dominated by humans (Vitousek et al., 1997). As a result the current activities of society have influenced the ability of ecological systems to respond to disturbance, changing the ability of natural systems to sustain the flow of ecosystem goods and services which society has become reliant upon (Ehrlich & Holdren, 1971; Vitousek et al., 1997; Dullinger et al., 2013).

In the realisation of society as a component of a wider, complex, dynamic social-ecological system, fundamentally described by finitude, the natural world-human world dichotomy becomes reconciled. Ecological value as natural capital can not be replaced by human capital in a sustainable world view. However, the dominant nature of a consumer-based world view of society's relationship with natural resources sees concern for continued unsustainable use of natural resources described using an economic language.

A contemporary, neo-classical, economic world view illustrates the value of natural resources to society as a value in exchange (Gómez-Baggethun et al., 2010). The core idea of the valuation process, approached from an ecosystem goods and services perspective, is that ecosystems contribute to human well-being. Consequentially, the commodification and monetisation of goods and services derived from ecosystems becomes informed through an explicitly utilitarian characterisation of the interrelated and interdependent social and ecological relationships (de Groot et al., 2002). In this manner an economic valuation of the costs and benefits associated with ecosystem goods and services informs communication using a familiar metric presented in a common language. However, in this context, the danger

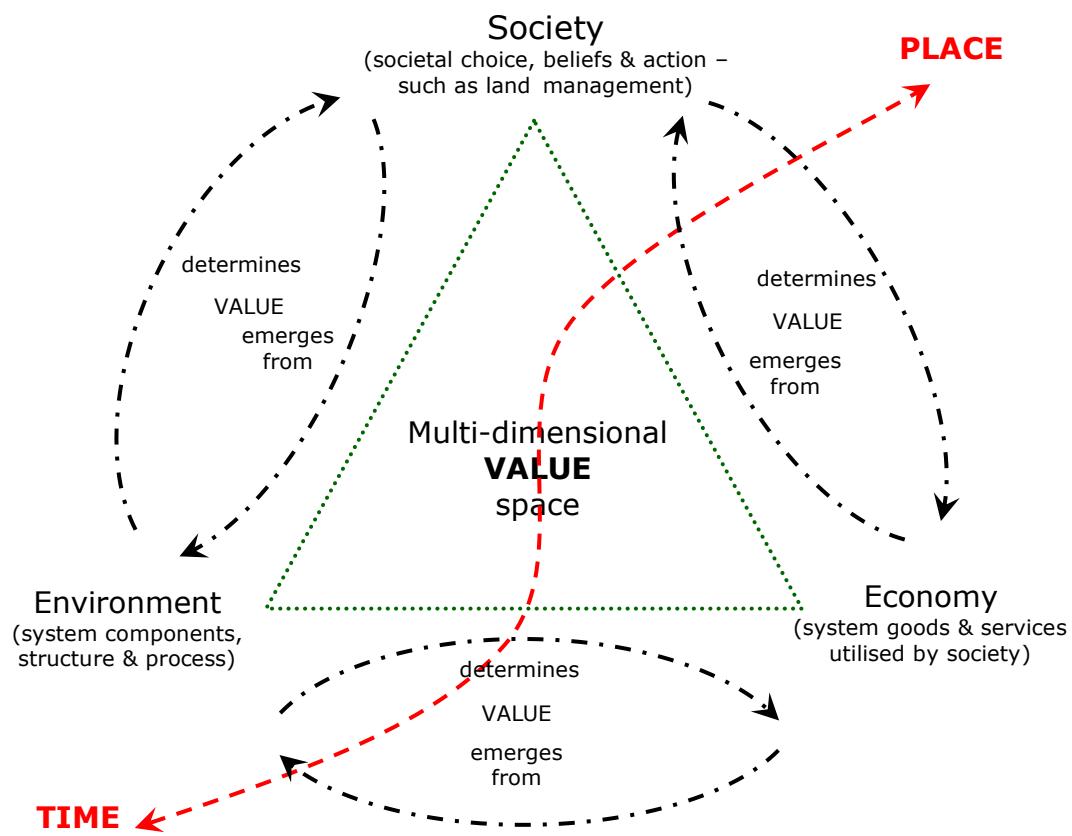
is that ecosystem goods and services only become necessary in as far as they support ideas of utility maximisation and continued economic growth (Spash, 2009). Additionally, the economic conceptualisation of nature promotes a continued society-nature dichotomy.

Conversely, if we accept that ecosystems provide multiple benefits across multiple value domains, then we must advance the use of value articulating institutions and methods that better reflect value plurality (Martinez-Alier et al., 1998; Munda, 2004). This thesis takes the view that value in complex social-ecological systems can only be fully expressed using multiple value dimensions. Evaluative models should reflect the true nature of these interconnected relationships that describe complex social-ecological systems. A multidisciplinary perspective seeks to incorporate knowledge informed by multiple non-equivalent observers and observations, where ecological and economic values are seen through the lens of socio-cultural value, developed using quantitative and qualitative data (Munda et al., 1995; Martinez-Alier et al., 1998).

### **8.3 Observations, thoughts and findings regarding the development of a fuzzy logic values-based landscape evaluative model**

Observations collected across the four case study wood-fuel landscape scenarios are considered below in relation to the first of the three main research objectives of this thesis. Namely, *to calculate a socio-cultural, ecological, and economic value across a range of landscapes in which land-use includes the provision of wood-fuel*. The main focus of these data chapters was to establish suitable basic value indicators for inclusion into a fuzzy evaluative model, primarily based upon an ability to describe relationships and differences across a range of case study landscapes. In the following synthesis, in addition to the presentation of observations, thoughts and findings, a wider, further work-based perspective is also taken.

Three empirical value chapters (chapter 4 socio-cultural value, chapter 5 ecological value and chapter 6 economic value) describe the components of each primary value domain and the nature of relationships between and within secondary value components and their basic value indicators. Relationships between basic value indicators and their secondary composite value variables are fundamentally characterised by complimentarity and contrast. Taken together these data represent a multi-dimensional value space in which the relationships and connections between society, environment and economy describe a complex social-ecological system (Fig 8.1). Interactions between living elements and the environment describe the emergent nature of value within the concept of an eco-system, a system which encompasses the direct and indirect influence of society as an integral component.



**Figure 8.1** A social-ecological multi-dimensional value space

### **8.3.1 Context for observations**

Chapter 3 contributes to this thesis from the perspective of context. The intention here was to recognise that the scale of observation, for these studies, must be described at the outset.

Boundaries for the case study landscapes are described by the extent of direct influence that community exerts over its surrounding landscape. In this respect observations determined that local socio-cultural, ecological and economic interactions take place within a conceptual space defined by the municipal boundary.

Thematic grouping of landscape components and connections identified interaction between community, landscape and land-use. These interacting pathways illustrate linkage between components that define a conceptualised structure used to describe the interaction of community with the surrounding landscape. This approach positions the influence of community on local landscape as a determinative element in the community-land-use relationship, where landscape and the natural resources therein are managed to produce goods and services for society.

Described in a geographical context, community (see chapter 3) can be thought of as an area in which social and economic structures interact with ecological systems to meet the daily needs of its inhabitants (Tuan, 1975; Relph, 1976; Williams & Stewart, 1998; Brown et al., 2002; Stedman, 2003). Accordingly communities occupy a distinct spatial area that reflects local values, attitudes and lifestyles. Thus community presents a way to integrate the biophysical and ecological attributes of place with cultural meaning and the socio-political process. Description of the relationships between community, land-use, and landscape provides a powerful medium to express place-based values in a manner that embeds society and natural resources into a social-ecological system of which they are a part (Williams & Patterson, 1996; Cheng et al., 2003; Folke, 2006).

In this thesis, interaction with the local ecosystem provides a familiar institutional context, within which respondents can feel comfortable enough to express importance in a manner that reflects their preferred behaviour (Borgstrom Hansson & Wackernagel, 1999; Meinard & Grill, 2011). Here expressions of value aim to capture local distinctiveness and incorporate multiple stakeholder views (de Chazal et al., 2008). Society and the values it holds are an integral component of a wider socio-ecological system, a system in which nature is not viewed as external to the expression of socio-cultural values (Adger, 2000; Chiesura & de Groot, 2003; Folke, 2006). In this way the influence of society on landscape is seen as a fundamental component in the interactions between the socio-cultural, ecological, and economic value domains. Landscape value as meaning requires a physical space defined by experiential knowledge, gathered through the process of living in it, to be fully expressed (Stedman, 2003).

### **8.3.2 A socio-cultural value**

Chapter 4 approached the concept of a socio-cultural value through Ajzen's theory of planned behaviour (Ajzen, 1991). Expressions of preference provide a measure of socio-cultural value for each of the wood-fuel landscapes. Individual assessments of attitudinal and normative-based socio-cultural value statements describe the socio-cultural, ecological and economic dimensions of the value relationships community holds with its surrounding landscape.

Chapter 4, and the pilot case study in chapter 3, demonstrated a shared normative behaviour towards a community's relationship with natural resources when expressed through the lens of the surrounding landscape. Significantly, a shared agreement for strength of preference over the three value domains extends across the different cultural focus of study communities in three countries. The nature of shared norms accords with Nassauer (1995) who suggests that both a temporal and spatial component describe society's perception of place. In this thesis, the broad nature of shared attitudes across countries suggests a common time to which

communities belong. Whereas the subtle differences between the components of socio-cultural and ecological attitudes identifies a more geographic, spatially specific space.

Normative-based value statements that promote socio-cultural and ecological value considerations to their surrounding landscape are described by strong agreement across case study communities. Contrastingly the position taken by participants with regard to economic considerations is one informed by neutrality and disagreement. Preference, by agreement, with socio-cultural and ecological statements is expressed through a sense of connection to the physical characteristics of landscape. Where, paraphrasing the original value statements, '*mixed landscapes*' described by '*diversity and complexity*' build environments with '*integrity and resilience*' to '*protect and provide long term stability*' in a manner '*that promotes physical and mental well-being*'.

Participant disagreement with the economic value statements, across the three communities, is expressed by values that communicate overt transactional characteristics. More specifically, voiced through those statements characterised by ideas of efficiency, maximisation and the conversion of natural capital to human capital. Here natural '*resources are produced efficiently and in large quantity*' and natural '*resources can be exchanged for monetary value*'. Thus, a consensus in normative behaviour is observed around agreement for a physical, experiential grounding to society's relationship with natural resources, set against a market-based transactional relationship.

Whilst community norms across the studied landscapes broadly demonstrated similarity, the attitudinal assessment expressed differences between landscapes from a local, community based perspective. Interestingly, in respect to placing high value on landscapes fundamentally characterised by socio-cultural and ecological descriptors (wood pasture and co-operative forest see chapters 4 and 5), the discriminative ability of the attitudinal-based token allocation duplicates that of the normative-based value statements. However, none of the studied

landscapes completely displayed the preferred combination of characteristics, as identified by the normative preference exercise.

This finding has implications around the perception of control component of Ajzen's (1991) theory of planned behaviour. Differences between community attitudes and norms towards the relationships between community, landscape and natural resources identifies an attitude-norms mismatch. This lack of attitude-norm unity is suggestive of a perception gap which may be reflective of the degree to which people characterise themselves as a part of nature. That is nature defined by the landscape that surrounds them, the physical and emotional distance they feel separates them from the landscape and the level of individual and community control over the surrounding landscape. A mismatch between attitude and norms identifies perceptual difference, described by distance between the realised and idealised landscape. This distance reflects the degree to which society expresses its embeddedness in the landscape that surrounds it. A measure, which in this thesis, can be expressed as the distance (difference) between the attitudinal and normative values expressed in the fuzzy model (chapter 7).

Expressions of a behavioural intention toward landscape by society give voice to cultural and personal choice. A purposeful and reflexive 'choice space' is created where awareness of preference constructs value, the geographic location of which is 'place' (Relph, 1976; Brown, 1984; Cheng et al., 2003). From a general perspective difference and similarity between and within the attitudinal and normative-based socio-cultural value assessments suggests a discriminative appraisal in participant responses. The discriminative nature of both attitudinal and normative-based behavioural preference statements, across the studied range of wood-fuel landscapes, supports use of these values in the final wood-fuel landscape evaluative model. Attitudes toward the behaviour, subjective norms with respect to the behaviour, and perceived control over the behaviour have been found to predict behavioural intentions with a high degree of accuracy (Ajzen, 1991; Kaiser et al., 2005).

Ajzen's (1991) theory of planned behaviour is grounded in rational choice deliberations (Kaiser et al., 2005). Behaviours are informed by intentions which themselves are a function of the individuals' perceived control, attitudes towards the behaviour, and subjective norms (Ajzen, 1991). Attitude is a rational choice based evaluation of a behaviour's subjective utility and an estimation of the likelihood of its outcome. Norms characterise the strength of normative belief described by socially accepted standards as conveyed by peers, family, community or society (Ajzen, 1991). The perception of control refers to the ease or difficulty in performing the behaviour, and as such is context specific (Ajzen, 1991). Which in this thesis can be described through the differing responses and relationships attached to the small scale community-based ownership and large scale public ownership properties of the studied landscapes (chapter 4).

Community-based descriptors were presented to identify socio-cultural value embedded in the local landscape by community. An individual's interaction with local landscape introduces a familiar setting where the relationships between attitude, norms and perception of control should be closest and felt at their strongest. Landscape as a concept simultaneously describes place and the consequence of the human influence on place (Nassauer, 2012). Connected with ideas of sense-of-place, place-attachment, place-identity and place-dependence landscape resolves the nature-culture duality (Naveh, 1995; Manzo, 2003).

When viewed from an experiential position the subject-object, human world-natural world dichotomy is left behind; the community-landscape-natural resources value relationships are seen from a holistic perspective. The aim here was to utilise the socio-cultural relationship with the physical nature of the environment to illustrate the nature of value from a reflexive, purposeful, participative perspective, within the specific context of each landscape scenario. Landscapes are the outward expression of this behavioural interaction, the dynamic process of societal intervention directly links social systems with ecological systems (Antrop, 2005).

This area of the thesis could be expanded by further work around the concept of embeddedness and the nature of community's relationship with the landscape that surrounds it. How issues of governance and the process whereby communities effect local landscape change can move society towards or away from the idealised landscape. Recognition of distance between society and landscape describes the process of cultural landscape change, where culture structures landscapes and culture becomes embedded in landscape. This approach retains a place for society as a participative actor in landscape which, through the multiple dimensions of cultural identity, beliefs and attitudes towards the landscapes that it creates, fully reflects the development and advancement of socio-cultural value derived from a behavioural context.

### **8.3.3 An ecological value**

Chapter 5 presents an ecological value from the perspective of relationships between physical structures and biodiversity created by land management. Different land-use approaches to the provision of wood-fuel describe the influence of the human-landscape interaction on levels of biodiversity through structure. A suite of structural indicators were established that represent an ecological value identified with each case study landscape. These ecological value components reflect the ecological consequence of socio-cultural interaction on the physical nature of the environment. Consequently landscape management builds connectivity between society and the biotic components in the landscape through the structures it creates (Laland & Boogert, 2010).

Initially evidence of differences across measures of biodiversity for a faunal indicator group, over the four studied landscapes, was established. The assumption being that these differences can be attributed to landscape structure. Using butterflies as the indicator group, a gradient of difference in abundance, species richness, diversity, and evenness was demonstrated. Ranking the studied landscapes, from high to low for measures of abundance, species richness,

diversity and evenness describes this gradient as; 1-wood pasture, 2- co-operative forest, 3-estate forest, and 4-Forest Service.

The next step tested the assumption for a relationship between fauna and landscape structure and clearly identified correlations between measures of faunal diversity and the observed structural landscape components. Observations across the four studied landscapes described significant positive and negative relationships between the woody biomass, herb biomass, and butterfly components.

Butterflies have variously been shown to be good candidates as biodiversity indicators (Pollard, 1977; Kremen, 1992; Pollard & Yates, 1993; Ehrlich & Hanski, 2004; Thomas et al., 2004; Thomas, 2005; van Swaay et al., 2006; Settele et al., 2008; Brereton et al., 2011), with many studies describing correlations between butterflies and other taxonomic groups (Fleishman et al., 2005; Maes et al., 2005; Thomas, 2005). Evidence from the literature supports the idea of a structural influence on butterfly communities (van Swaay et al., 2006; Smith et al., 2007; Nilsson et al., 2008; Fartmann et al., 2013;). Moreover changes in management ethos resulting in structural simplification have been shown to lower diversity in both flora and fauna (van Swaay et al., 2006; Fartmann et al., 2013; Zakkak et al., 2014). A similar influence on levels of bio-diversity has also been attributed to reductions in woodland structural complexity through the effects of herbivorous under and over grazing (Feber et al., 2001; Stewart, 2001).

Having established a relationship between structure and faunal diversity, a principal components analysis generated a reduced set of environmental variables extracting the most important information from the data set, whilst reducing its size. This step sought to simplify the scope of the data set, keeping only important information, and allowing for subsequent analysis of the structure of retained observations (Abdi & Williams, 2010). Through the process of data consolidation focus is concentrated on a set of three wood biomass and five

herb biomass structural variables. These structural variables describe a reduced dimensional space, where the largest measure of variability is explained by a reduced number of descriptors with low information loss (King & Jackson, 1999; Joliffe, 2002; Legendre & Legendre, 2012).

By way of testing the validity of this reduced set of structural variables, using the constrained multivariate space as an *a priori* described environmental gradient, a canonical correspondence analysis provides support for the idea that the reduced indicator set adequately describes faunal distribution along the wood biomass - herb biomass gradient. Butterfly observations, plotted in ordination space, occupy positions along the environmental gradient consistent with the behavioural literature.

Separation of the selected variables into two landscape compartments, wood biomass and herb biomass, identifies a relationship characterised by conflict. Increases in the wood biomass compartment result in consequent reductions in herb biomass and butterfly abundance, species richness, and diversity. Conversely reductions in the wood biomass compartment encourage increased herb biomass and butterfly abundance, species richness, and diversity. Relationships between butterfly diversity and structure reveal themselves through two distinct pathways, each directly connected to the main protagonist of this thesis, wood and wood-fuel (see chapter 5, Fig 5.17).

These observations suggest a trade-off situation between timber forest products and biodiversity. In this context land-use decisions that primarily focus on the wood biomass component will have a negative influence on the herb biomass component, with the potential to effect woodland simplification. Viewed from a timber forest products and wood-fuel production perspective landscape management potentially comes with a consequent reduction in butterfly abundance and diversity. Contemporary economic land-use decisions that focus on increased use of fewer resources through simplified techniques create large scale,

homogenous areas informed by large scale economies (Farina, 2000). On the other hand, traditional management creates aggregations of hierarchical arranged heterogeneous cultural landscape units informed by local needs in which biodiversity is often higher (Bugalho et al., 2011; Middleton, 2013).

Construction of an ecological component of landscape value where knowledge is gathered through the structures created in the course of living in it places society as an actor shaping landscape structure and driving landscape level processes (Farina, 2000). With bio-diversity in mind, human landscape management over time places society in the role of '*niche constructors*' (Laland & Boogert, 2010). This relationship is reciprocal; not only will socio-cultural interactions influence the physical nature of the environment, but the physical characteristics of the environment will influence the nature of socio-cultural interactions with it (Cheng et al., 2003). Society must be viewed as a fundamental component of ecology; society is inextricably tied to the ecological systems that sustain their lives and livelihoods.

With hindsight this element of the thesis would benefit from a broadening of the faunal scope used to identify biodiversity associated with the studied landscapes. Accordingly this addition would necessitate a revision of the structural indicators incorporated in to the analyses.

Despite many authors describing the use of butterflies as surrogate indicators of biodiversity, the use of a single taxonomic group to demonstrate congruent associations in species richness patterns and common responses to local environmental factors is much questioned, for example see Perfecto et al. (2003); Kati et al. (2004); and Kati et al. (2009). Findings from other studies suggest that selection of a complementary network of indicator taxa to form a broad ecological gradient should be considered (Kati et al., 2004; Lovell et al., 2007; de Andrade et al., 2014).

The use of additional taxa would broaden the functional and spatial aspects of the species richness-environment structure relationship that supports the expression of ecological value in

this thesis. In keeping with the representation of a complex system view, this approach introduces additional observations, and generates additional information from the perspective of multiple, non-human, non-equivalent observers. The inclusion of additional taxa, upon which a more comprehensive suite of structural indicators can be built, adds significance to the expression of ecological value approached from the appropriate nature of its components informing understanding and truth.

#### **8.3.4 An economic value**

Chapter 6 calculated economic value as income received from real markets for each of the studied landscapes. Landscape management, from this perspective, sees society place structure and components into landscape in the pursuit of economic well-being. Differences in the components and associated structures across the range of studied landscapes produce different economic outcomes. These outcomes are captured to describe the economic dimensions of the value relationship that community holds with the surrounding landscape across a range of wood-fuel producing landscape scenarios. Economic value in this thesis represents an aggregated sum of economic return generated from the products of multiple revenue seeking landscape management decisions.

These data described contrasting approaches to the provision of financial incomes across the studied landscape range. The principal difference was observed through management focused on either timber forest products or non-timber forest products. Differences are also described through woodland type, ownership, designation, and management ethos (chapters 3 and 6). Difference, across the range of studied landscapes, provides data for inclusion in to the wood-fuel landscape evaluative model.

In summary the Austrian estate forest landscape is characterised by production of predominantly timber and timber related products in a manner that preserves forest productivity and functions, consistent with national legislation in the form of the Austrian

Forest Act. The financial returns of which benefit a single owner. Austrian co-operative forest is managed similarly in terms of products and adherence with the principals of the Austrian Forest Act. However the financial benefits are shared between multiple owners who live locally. The Greek wood pasture landscape is managed by multiple local owners for multiple uses, the financial benefits of which are derived from non-timber forest products. Although timber and timber forest products provide for subsistence benefits accrued by owners. The Greek Forest Service landscape is publicly owned and managed for society, the main focus of which is the protection of ecosystem functions. Management also allows for local village based co-operatives to generate a small amount of income from timber under control of the Greek Forest Service.

This thesis has demonstrated that the largest per hectare monetary value is generated from landscape management whose primary focus is the production of a high volume of specific timber and related timber forest products, described by the Austrian estate forest landscape. Management focused on the protection of ecosystem functions producing high levels of public good, described by the Greek Forest Service landscape, produced the lowest per hectare monetary value. Management of the estate forest, based on these observations, pursues objectives with clear market values. Emphasis is on sustainable and efficient production of a few wood supply related services for which there is payment. On the other hand the Greek Forest Service management pursues primarily ecological service-based goals for which a surrogate monetary value can be calculated through in-direct techniques and hypothetical market value.

These two landscapes capture the broad nature of society's changing view on the use of natural resources, characterised by the utilitarian-sustainable, society-nature dichotomy. The Austrian estate forest approach to active forest management engaged in sustainable economic timber production (Weiss, 2000), operates from a perspective connected to the nineteenth century developmental roots of modern production forestry and the maximisation of long-term

economic return (Farrell et al., 2000). The Greek Forest Service emphasis on ecosystem function expresses a twentieth century cultural shift of emphasis for forestry away from a production led ethos towards the maintenance of ecosystem services with a balance of ecological land uses (Farrell et al., 2000; Johann, 2007).

In contrast, monetary income observations from the wood pasture and the co-operative forest landscapes demonstrate management difference informed by a local cultural context. Market-based income is forgone to reflect local needs, culture and livelihoods. Land-use and management decisions acknowledge the embedded nature of the relationship between landscape and local needs of the community who have and continue to live in it. However, reduced monetary incomes do not result in a lower perception of socio-cultural value, by comparison across the four studied landscapes (chapters 4 and 7). Socio-cultural values expressed for wood pasture and co-operative forest landscapes suggest the non-monetary benefit received by community is actively considered.

In this context, the relationships between community, landscape, and natural resources need not depend upon a solely economic based value to be expressed. Reference to a broader value basis provides scope to incorporate a range of factors that influence society's relationship and interaction with landscape and natural resources (Tress and Tress, 2003). Value, where society is considered a participative actor across socio-cultural, ecological and economic value domains, is better expressed through the multiple dimensions of cultural identity, beliefs and attitudes towards the landscapes that society creates (Farber et al. 2002; Sauer and Fischer, 2010).

Signals for economic change to landscape and land-use patterns, based on market-led expectations generated from the products of natural resources, may not fully encompass local needs and culture. Sometimes, a focus on market values can obscure intrinsic non-market values worth caring about, *cf* Weisbrod (1964) and Krutilla (1967). Reference to the

relationship between society and natural resources from a wholly economic perspective appears contrary to the attitude of a society that expresses preference for the physical characteristics of a sense of connection to the surrounding landscape (chapters 3 and 4). For example, a landscape that '*protects and provides long term stability*' in a manner '*that promotes physical and mental well-being*', where '*mixed landscapes*' promote '*diversity and complexity*' and builds environments with '*integrity and resilience*'.

Further work focussed on the economic component of the value triptych would investigate whether local needs can be fully recognised by market-led expectations in a global market place. This would, by necessity, involve the addition of further study landscapes representing a wider range of community-land-use-management approaches. Traditional management, represented by wood pasture in this thesis, operates via short feedback signals which communicate at a local level supplying goods to satisfy local market needs. Whereas modern economic landscapes, similar in approach to the estate forest landscape, operate via long diffuse feedback signals supplying global market needs (Farina, 2000).

In this context large scale global systems are seen to operate with a spatial and temporal independence aimed at overcoming local biophysical constraints; place becomes '*empty space*' that is independent of any particular village, town or region, and time becomes '*empty time*' independent of ecological time demands (O'Hara & Stagl, 2001). Values become generic rather than specific, and community becomes disembedded. The disembedded market filters out signals from local markets and as a result the global economy removes society and fails to support local social-ecological systems (O'Hara & Stagl, 2001).

#### **8.4 A fuzzy landscape value**

In chapter 7 a fuzzy logic based approach was taken to construct a model that incorporates the socio-cultural, ecological, and economic values, generated by the studied landscapes, to calculate a total landscape value. This chapter addressed the second of the three main aims of

this thesis, '*to develop a model for the calculation of a total landscape value across a range of wood-fuel woodland landscapes*'.

Contemporary approaches used to convey information to decision makers, regarding the sustainable use of natural resources, have centred on total economic valuations as the method of choice, for example see van Beukering et al. (2003); Jobstvogt et al. (2014); and Morri et al. (2014). The use of monetary valuation seeks to highlight the critical role ecosystems and biodiversity perform in sustaining life, enhancing human well-being and providing long-term economic sustainability (Costanza & Folke, 1997; Balmford et al., 2008). Consequently, the expression of ecosystem service value in monetary, market-based terms is increasingly used to create economic incentives for conservation (Balmford et al., 2002).

However, an increasing number of publications now promote a move away from a solely market-led monetary based view of the value held by natural resources, for example see Spash & Aslaksen (2012) and Kallis et al. (2013). As the preceding chapters (3, 4, 5 & 6) have demonstrated, value is a normative, context dependent concept described by objective and subjective components. Ecosystems provide multiple benefits across multiple value domains; socio-culture, ecology and economy. In this sense value takes an embedded, plural and partial character informed by collective knowledge distributed across place and the people who occupy and interact with those places (Relph, 1976; Brown et al., 2002).

In the acknowledgment that ecosystems provide multiple benefits across social, ecological and economic value domains, we become obligated to make use of value articulating institutions and methods that better reflect this value plurality (Martinez-Alier et al., 1998; Munda, 2004). Recognising the need to integrate these multiple expressions of value also raises the question of how different value dimensions can consistently be aggregated or combined in a manner that informs sound decision making (Martín-López et al., 2014). The difficulty in integrating the reflexive and subjective nature of these social-ecological systems

informs a continued discourse between scientific, conservation, social, economic, and political commentators regarding the development of methods to assess the sustainable use of natural resources (Chiesura & de Groot, 2003; Balmford et al., 2008; de Groot et al., 2010; Spash & Aslaksen, 2012). The combination of an uncertain, plural and partial nature of knowledge, that is used to evaluate such systems, aligns itself with the use of natural language and linguistic values based on the fuzzy logic methodology (Zadeh, 1965). The use of fuzzy approximate reasoning, in this thesis, to develop a fuzzy landscape value contributes to this continued multi-disciplinary discourse.

In building the fuzzy landscape value model each wood-fuel producing woodland landscape is constructed as a composite measure of the value indicators described in the preceding data chapters. Thus, landscape value is comprised of three primary components; socio-cultural, ecological, and economic value. Each of these primary value domains consists of two secondary components, each of which are further described using a range of tertiary indicators. Combining this hierarchical value structure through a series of fuzzy ‘IF-THEN’ rule based inference engines describes a measure of landscape value for each studied wood-fuel producing woodland landscape (see chapter 7, Fig 7.5).

At a basic level the fuzzy model calculates a crisp number value which allows for a ranking exercise across the studied landscapes. This approach describes a high to low value range; 1 – estate forest, 2 – co-operative forest, 3 – wood pasture, 4 – Forest Service. But also, and equally as important, these results demonstrate that the fuzzy model retains information of complimentarity and contrast described by the basic indicators observed values. The consequent nature of these relationships and their subsequent value contributions can be seen across the primary value domains and the secondary composite value variables. Thus, in the assessment of a calculated fuzzy model based landscape value, all the described components of value and their contributions to a final value are made apparent.

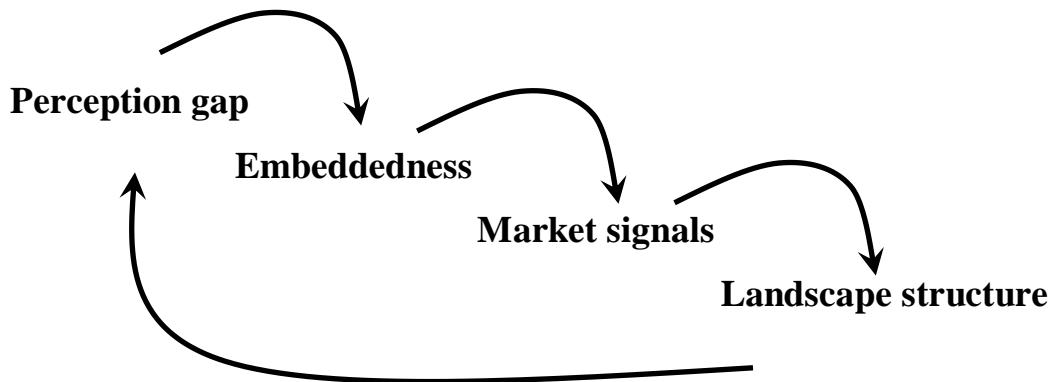
Value in complex social-ecological systems, where society takes a participative role in socio-cultural, ecological and economic value domains, can only be fully expressed through the relationships of multiple value dimensions of the landscapes that society creates (Farber et al. 2002; Sauer and Fischer, 2010). The fuzzy logic based evaluative model presented here accommodates the multi-dimensional nature of value, as described by this thesis, supporting the development of propositions which can reliably inform an effective, deliberative decision making process.

As with other areas of this thesis possibilities for additional study present themselves in the completion of this research. The addition of extra case study landscapes would provide data to complete a comprehensive comparative assessment across landscapes and the relationships between and within value components. The inclusion of expert opinion, both scientific and local, as a function of the model construction represents an opportunity to add dialogic potential, where knowledge drawn from a range of stakeholder groups informs the analytical perspective of the fuzzy evaluative process. This addition makes use of a fundamental characteristic of the fuzzy approximate reasoning process. Semantics are used to build a narrative-based conceptual framework which informs the construction of a series of fuzzy sets that represent the expert opinion and judgement protocol. Drawing together knowledge from multiple stakeholders helps develop the associated rule base to more faithfully simulate a given systems actual behaviour (Ross, 2010).

Taking on the follow up work themes presented in the chapter summaries above, a fuzzy-based value approach could be used to investigate the role of scale, governance and the societal cues that shape landscape. As a concept this envisages a '*value cascade*' along the lines described in figure 8.2, where culture changes economy, changes ecology, changes culture. An increased cultural distance from the surrounding landscape initiates a chain of change. A widened perceptual gap, between attitude and norms, alters society's feeling of

connection to the landscape that surrounds it, leading to a different interpretation of market signals which results in changes to landscape.

Embodied within the concept of a ‘value cascade’ lies the complexity of scale, both spatial and temporal, that simplification through large scale landscape management, commodification and monetisation has failed to address. The fuzzy logic based approach developed in this thesis models a complex system where categories are organised in to layers of hierarchy that can be linked together in a functional way but still operate to their own set of goals and rules. This approach gives voice to individual components as well as the whole. We are able to see both the trees and the wood at work. In developing this model further the influence of society on the natural world can be considered in a fully participatory context as individuals, communities, regions, and nations become levels of hierarchy within a larger fuzzy model, rather than a market based agent within an economic valuation. Such hierarchical models can be used to consider the local effects of global market forces, under the influence of regional and national policies, on sustainable landscape management.



**Figure 8.2** A conceptual value cascade

## **Chapter Nine**

# **A values-based wood-fuel landscape evaluation: building a fuzzy logic framework to integrate socio-cultural, ecological, and economic values**

### **9.1 Summary**

The overarching focus of this research was to explore the creation of a values-based approach towards landscape evaluation. In this manner, expressions of value provide information that supports and facilitates deliberative discourse in the sustainable landscape management decision making process. Moving beyond a purely monetary based valuation, this research has presented a new and novel method of landscape evaluation. In the construction of a hierarchical model, value descriptors are combined in a manner that gives emphasis to relationships and contributions between and within indicators and each value domain. Differences are observed, across the four case study wood-fuel landscape scenarios, between and within value domains and value components. These differences illustrate a tension that exists between sustainability and society's continued use of natural resources.

The comparable quality of these data reveals an emergent property of value. A characteristic that becomes perceptible through the description of observed relationships. Where the possibility to describe influence, between and within value domains, provides the capacity to highlight trade-offs across value domains. Consequentially, a values-based information approach has the capability to engage in discussions around themes that extend past a focus on consumption and accumulation, such as; 1 - the extent to which data from the primary value domains contribute to overall landscape values, 2 - the relationships between and within value domains, and 3 – a deeper comparison between the studied landscapes based on relationships and influence. Thereby facilitating the acknowledgement of the true nature of value within the decision making process.

## **9.2 Introduction**

Socio-cultural interaction with the natural world places structure and components into the landscape, the subsequent combination of which is characterised by consequent ecological and economic conditions. Compositional, structural, spatial and temporal differences produce different value outcomes. In the completion of this research, value outcomes have been captured and used to describe the multi-dimensional nature of the relationships that society experience with their surrounding landscape, across a range of case study wood-fuel producing scenarios. Understanding the complex nature of these interrelated and interdependent relationships can inform the political and institutional decision making process. In this manner knowledge of interaction, interdependence and the potential for trade-offs, consistent with systems described by finitude, can support deliberative discourse in the creation of new wood-fuel woodlands, in a sustainable, renewable fuel future.

The existence of different levels and scales at which complex and dynamic social-ecological systems can be analysed implies the unavoidable existence of non-equivalent descriptions. Multiple identities in complex systems result in non-equivalent observers, epistemological plurality, non-equivalent observations and ontological characteristics; irreducible value conflict is therefore unavoidable (Martinez-Alier et al., 1998; Munda, 2004). Indeed, in real world situations, solutions that seek to maximise multiple value based objectives at the same time are impossible (Munda et al., 1995; Martinez-Alier et al., 1998; Munda, 2004).

However, this does not imply that issues of weak comparability and incommensurability are problems to solve, only that they should be accommodated within any evaluation exercise. Such an approach should reflect not only one value held by landscape but seek to express the contributions from multiple value components in any complete appreciation of the one value. Value in this sense has an emergent, relational, embedded quality grounded in a specific compositional-spatial-temporal context (Stahel, 2005).

In the presentation of a value-based model set across multiple value domains the fundamental issues of weak comparability and incommensurability are accepted at the outset. This is an important caveat in the adoption of a mature post-normal approach to the [sustainable] use of natural resources, where socio-cultural, ecological and economic relationships come together in a whole world view. When experienced from a complex system perspective, where, within a functional connected system of systems, action taken in one value domain will influence value in the other domains. In this manner value emerges from an understanding of the connected and embedded nature of society's relationship with natural resources. Thus meaning for any value proposition becomes apparent through comparison and not accumulation.

Decision making for sustainable land-use solutions, informed by value, should be communicated and supported by a language of value that expresses the true nature of things based on three elements; an understanding built upon truth described by correct and appropriate components (Mendes, 2007). Value becomes characterised by the nature of relationships between and within multiple value components, not by a simple accumulation of commensurable value. In a world described by finitude, preference is characterised by competing socio-cultural, ecological, economic objectives where trade-offs are the norm (Plottu & Plottu, 2007; Peterson et al., 2009; Gómez-Bagethun et al., 2010; de Groot et al., 2010; Spangenberg & Settele, 2010; McShane et al., 2011; Jax et al., 2013; Martín-López et al., 2014; Matulis, 2014). Even modest improvements at one point are often only achieved at the expense of other value components, either because they are directly in conflict or because preferential action redirects interaction.

### **9.3 A values-based wood-fuel landscape evaluation: building a fuzzy logic framework to integrate socio-cultural, ecological, and economic values**

Bringing socio-cultural, ecological, and economic value components together within the fuzzy modelling environment generates information which supports a deliberative discourse to address this third and last thesis aim:

- 3) Apply the modelling technique developed to address the proposition of '*A values-based wood-fuel landscape evaluation: building a fuzzy logic framework to integrate socio-cultural, ecological, and economic values.*'

Addressed from a perspective of accumulation, where value accrued by each of the three value domains is aggregated, an estate forest landscape generates the highest value. Taking this approach, value created within each of the three separate domains, socio-culture, ecology, and economy, is considered equivalent, and therefore having the capacity for accumulation.

Viewed from the perspective of equivalence parallels can be drawn with the approach of conceptualising natural resources, and society's relationship with them, in economic terms of commodification and financialisation represented by monetary values. Landscape value becomes represented by a capital accumulation exercise, whatever the specific socio-cultural, ecological, or economic characteristics and the consequences of actions between the value articulating domains.

Accumulation of this general purpose value removes thoughts of the interconnected and interdependent nature of relationships between components in a system fundamentally described by finitude. Adoption of an evaluation process that includes thoughts of interaction, proportion, dominance and balance, alongside amount, across the three composite value indicators, alters interpretation. Acceptance of a preferred landscape now involves a consideration of goal setting and the associated trade-offs encountered in a finite world; landscape becomes described in terms of compromise. In this manner management systems become adaptive, reflexive and sensitive to local situations, where the experience of natural resource use institutions are used to inform and shape future actions (Haila, 1999). Society

becomes [re]-embedded in the natural world from a ‘living-in-place’ perspective (Borgstrom Hansson & Wackernagel, 1999). This position reflects a respect for the capacity of nature to reproduce the earth’s life support systems, which is internalised in to all types of human activity (Haila, 1999).

The phrasing of this thesis’ main research aim recognises a role for the contribution from each value domain to be actively articulated and considered in the course of understanding the true nature of the value expressed for each of the studied landscapes. In the acceptance of landscape value as a multi-dimensional concept the context specific nature of each value expression becomes apparent. Thus, landscape value becomes the consequent expression of a specific compositional-spatial-temporal context. Where all societal activities are played out in the same material processes as the activities of all other organisms (Haila, 1999).

Despite a historical relationship grounded in consumption, albeit driven by a political economy, society has continued to acknowledge and express a connected view of its relationship with nature (chapter 2). This relationship is clearly evidenced in chapters three and four. Tangible socio-cultural and ecological interactions and connections with landscape hold a significantly higher recognition of value than those of an economic nature. Interactions between value components, described by data collected in chapters four – six, and further defined through building the fuzzy logic landscape evaluative model in chapter seven, reveal internal tensions. Characteristics of contrast are presented for all paired secondary composite variables; herb biomass – wood biomass, timber forest products – non-timber forest products, and attitudes – norms. This pattern is repeated for the primary composite value domains, and reflects the societal normative view expressed in chapters three and four, where the expressions of socio-cultural and ecological values differ from that of economic value.

Interpretation of these findings, with respect to suggestions for creating a wood-fuel producing landscape, should take a societal perspective which reflects the necessity of healthy

socio-cultural and ecological systems to support a healthy economic system. In this respect a multi-functional approach embodied with local cultural values and complex biophysical landscape structures should be promoted. A narrow primarily economic focus has the potential to build simplistic landscape structure with little direct reference to local culture and needs. In reconciling the behaviour of past generations, in the actions of the current generation, for the benefit of future generations, decision making should move away from an individual, consumption based relationship toward a more societal, co-operative and sustainable relationship with natural resources. In this manner decisions are made that fully acknowledge the influence of society. Thus, society becomes an aware, reflexive, purposeful component of a complex system of systems, creating an environment in which culture and nature occupy the same space.

Alternatives to narrow [monetary] definitions of value need to consider scale, context, plurality, and complexity as part of a wider values-based discourse (McShane et al., 2011). A more explicit acknowledgement of this multi-dimensional interdependent relationship will provide meaningful concepts in order to transform the increasingly destructive relationship that a society separated from nature continues to build. Where incommensurable values are in conflict single numbers are not helpful in addressing complex problems, however pragmatic the approach (Spash & Aslaksen, 2012). Translation of multiple values to a common language obscures information regarding the embodied characteristics and consequences of interaction; in simplification understanding and truths can become hidden. The placing of economy as a sub-system of a wider social-ecological system, upon which it is dependent (Daly, 1977), gives primacy to and requires a healthy socio-cultural and ecological value base for a long term sustainable future. In the recognition of trade-offs, making difficult choices may result in more resilient and sustainable landscape outcomes (McShane et al., 2011). This approach calls for clarity and a sense of purpose regarding those things that should absolutely not be traded off, such as ecological value.

An answer to the main objective of this thesis now rests upon a setting of value-based goals within a deliberative sustainable use of natural resources discourse. So, replacing the economic hegemony of valuation, perhaps the overarching aim of landscape evaluation should be rephrased to one of '*what degree of socio-cultural, ecological, and economic good*'.

A fuzzy-logic based approach allows society to assess observation of the relationships based on the idea of membership to a concept of 'good', expressed within and between all components of a hierarchical system of systems model. Description changes from 'how much' best reflects the system under observation to how do the system components reflect a pre-determined system state of 'good'. In which 'good' is a measure of specific compositional, structural, spatial and temporal conditions, not an abstract monetary based measure of goodness. In this manner the assessment of society's [sustainable] relationship with natural resource can be thought of as maintaining a system 'good' and not an accumulation of monetary value. Accordingly a sustainable approach to being in the world becomes a measure of the conservation of natural capital not its conversion to human capital.

#### **9.4 Conclusion**

This thesis has constructed a novel fuzzy logic modelling approach to building a values-based evaluation of landscape. The purpose of this model is to describe landscape in a manner that informs and supports a deliberative land-use decision making discourse. This use of a fuzzy model marks an increasing awareness of the need to explore the use of alternative landscape assessments that explicitly acknowledge the multi-dimensional, interconnected and interdependent nature of society's relationship with nature.

Contemporary value-based studies rely upon a process of translation where socio-cultural and ecological values are communicated by a monetary equivalence. Landscape as a social-ecological system is a complex, reflexive, and dynamic system. A process of monetisation obscures the nature of relationships between and within the system components. The use of fuzzy logic here attempts to make visible the consequences of land-use choices and the

associated changes across socio-cultural, ecological and economic value domains. In a system fundamentally defined by finitude making the reality of trade-offs between value domains visible will support responsible institutional and political decision making for a sustainable future.

This thesis has demonstrated a novel approach to valuation, with the potential to provide an effective and viable alternative to contemporary valuation studies. Taking an interdisciplinary approach, landscape value, across the four studied wood-fuel producing woodland landscapes, is presented in a manner that retains the primary characteristics of complementarity and contrast. Comparison across the value domains and their components facilitates discourse based upon understanding. Where the true nature of value is considered an emergent, embodied property expressed through an appreciation of the value components and the outcomes of their relationships. Thus, value is fundamentally a comparative property, and not the outcome of an accumulative argument, and should be considered as such in the institutional and political decision making and policy setting process regarding the sustainable use of natural resources.

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## Appendix 1: Socio-cultural value questionnaire



Hello,

- **Introduction**

I am a PhD research student from the United Kingdom, I work for the University of Cumbria in the National School of Forestry, and my name is Darrell Smith. As part of our efforts to reduce the use of fossil fuels in the UK we are looking into the potential for planting new woodlands. This will help us increase the availability of wood which can be used as an energy source, reducing carbon dioxide emissions and the dependence upon a fossil fuel energy supply.

- **Background**

Throughout Europe examples of different woodland management traditions exist, many of these link woodlands with sustainable energy provision. These woodlands incorporate traditional knowledge and practices developed by local culture. The different approaches taken provide standards for sustainable woodland management which can be used as models for research.

- **My work**

To help provide information about woodlands that would best suit the needs of the UK I am researching different woodland areas in Europe from which we can learn. My work seeks to understand how different approaches to woodland provision and management can influence the social and cultural, ecological and economic value of the landscapes in which we all live. My chosen areas for this work are the Municipality of Zagori, Greece, and the Municipality of Rechnitz, in Austria. We also hope this work will further the links between the University of Cumbria and the University of Ioannina, the Municipality of Zagori, and the Pindos National Park.

- **Summary**

So, I am here as a representative from the University of Cumbria to learn and gain information from the village of Tsepelovo. I would be most grateful if you could help me by completing the attached questionnaire. Once you have completed the questionnaire please return all pages of the completed form using the enclosed addressed and stamped envelope. All responses will be anonymous with any information used presented in a manner that hides individual views.

**Please return completed questionnaires before 31<sup>st</sup> August 2012.**

**Thank you very much for your participation.**

**Darrell Smith**

- **This questionnaire**

This questionnaire will collect views regarding your relationships with the landscape around the village of Tsepelovo, its management and uses. Your opinion will establish the important aspects of the surrounding landscape and help identify areas where you place high social and cultural, ecological and economic value.

- **What do you do next?**

On the enclosed map two areas of woodland have been identified, 1) red boundary from the river to the village, which includes 5-Ράτζα, 6-Καστανιές, 7-Ράχη Ζαφείρη, and 2) blue boundary across the river, which includes 1-Κεφάλια, 2-Γκρούμερο, 3-Μιτσίλα, 4-Troia. Ask yourself which characteristics of these woodlands, the areas within them, the products or the facilities they provide you feel contribute most to the three following categories:

- **your sense of belonging to a community**
- **your local natural environment**
- **your livelihoods and business activities**

Now, with thoughts of your chosen characteristics in mind, I would like to collect information to help me understand the qualities held by your chosen characteristics. In the next three tables I suggest different phrases that describe qualities within each category. Please rate how closely each of the suggestions agree with your views.

For each of the following please state, by ticking the appropriate box, whether you:

**1** - Agree strongly, **2** - Agree, **3** – Feel neutral, **4** - Disagree or **5** - Disagree strongly.

Your sense of belonging to a community						
Qualities that are important for you		Agree.....	Neutral.....	Disagree		
		1	2	3	4	5
<b>1</b>	<b>A landscape that promotes vitality, physical and mental well-being</b>					
<b>2</b>	<b>A landscape that maintains local arts, customs, institutions and characteristics</b>					
<b>3</b>	<b>Fair and equal access to all aspects of the surrounding landscape</b>					
Which one of the above three qualities best expresses the social and cultural value you place in the surrounding landscape?		<b>1</b>	<b>2</b>	<b>3</b>		
		(circle the appropriate number)				

Your local natural environment						
Qualities that are important for you		Agree.....	Neutral.....	Disagree		
		1	2	3	4	5
<b>1</b>	<b>A landscape in which scarce and rare elements exist, now and in the future</b>					
<b>2</b>	<b>A mixed landscape of meadow, mountain, woodland, river and farmland</b>					
<b>3</b>	<b>A landscape that protects and provides long term stability of the environment</b>					
Which one of the above three qualities best expresses the ecological value you place in the surrounding landscape?		<b>1</b>	<b>2</b>	<b>3</b>		
		(circle the appropriate number)				

Your livelihoods and business activities						
Qualities that are important for you		Agree.....	Neutral.....	Disagree		
		1	2	3	4	5
<b>1</b>	<b>A landscape that provides resources for consumption, now and in the future</b>					
<b>2</b>	<b>A landscape in which resources are produced efficiently and in large quantity</b>					
<b>3</b>	<b>Landscape that provides resource which can be exchanged for monetary value</b>					
Which one of the above three qualities best expresses the economic value you place in the surrounding landscape?		<b>1</b>	<b>2</b>	<b>3</b>		
		(circle the appropriate number)				

Now, keeping in mind the importance you place on the significant characteristics within each of the two woodland areas, I would like you to give a value to each of the three categories. Using twenty tokens of value for each category, divide the tokens between each area, 1) red and 2) blue, according to the value that best describes the importance of the contribution you feel each woodland area provides.

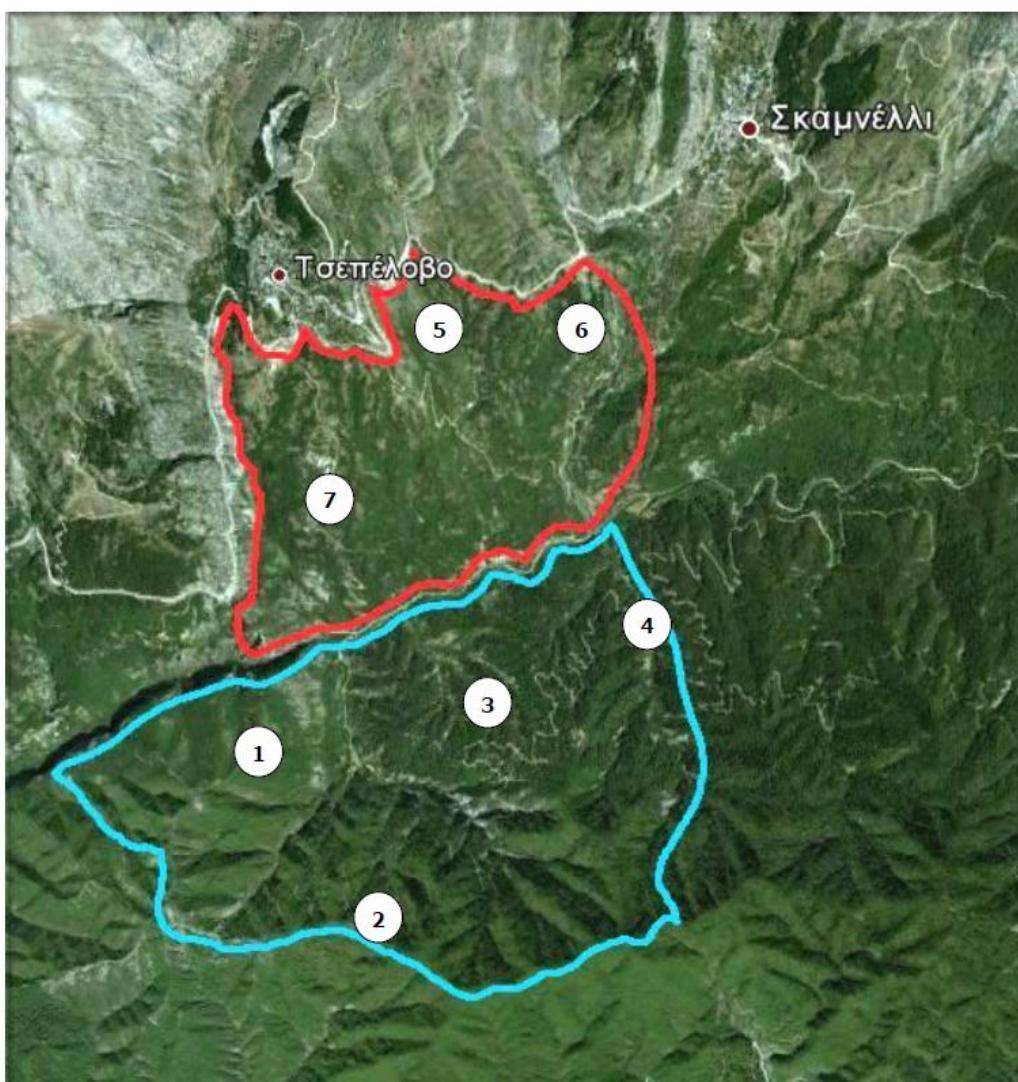
Please use the table below to record your choices.

Category	For Example			Your tokens		
	Red	Blue	Total	Red	Blue	Total
your sense of belonging to a community	17	3	20			20
your local natural environment	10	10	20			20
your livelihood and business activities	1	19	20			20

**Τσεπέλοβο**

Please consider the two woodland areas, identified by: 1) red boundary from the river to the village, which includes 5-Ράτζα, 6-Καστανιές, 7-Ράχη Ζαφείρη, and 2) blue boundary across the river, which includes 1-Κεφάλια, 2-Γκρούμερο, 3-Μιτσίλα, 4-Τροιά, and ask yourself which characteristics of these woodlands, the areas within them, the products and the facilities they provide contribute most to the three following categories:

- **your sense of belonging to a community**
- **your local natural environment**
- **your livelihoods and business activities**



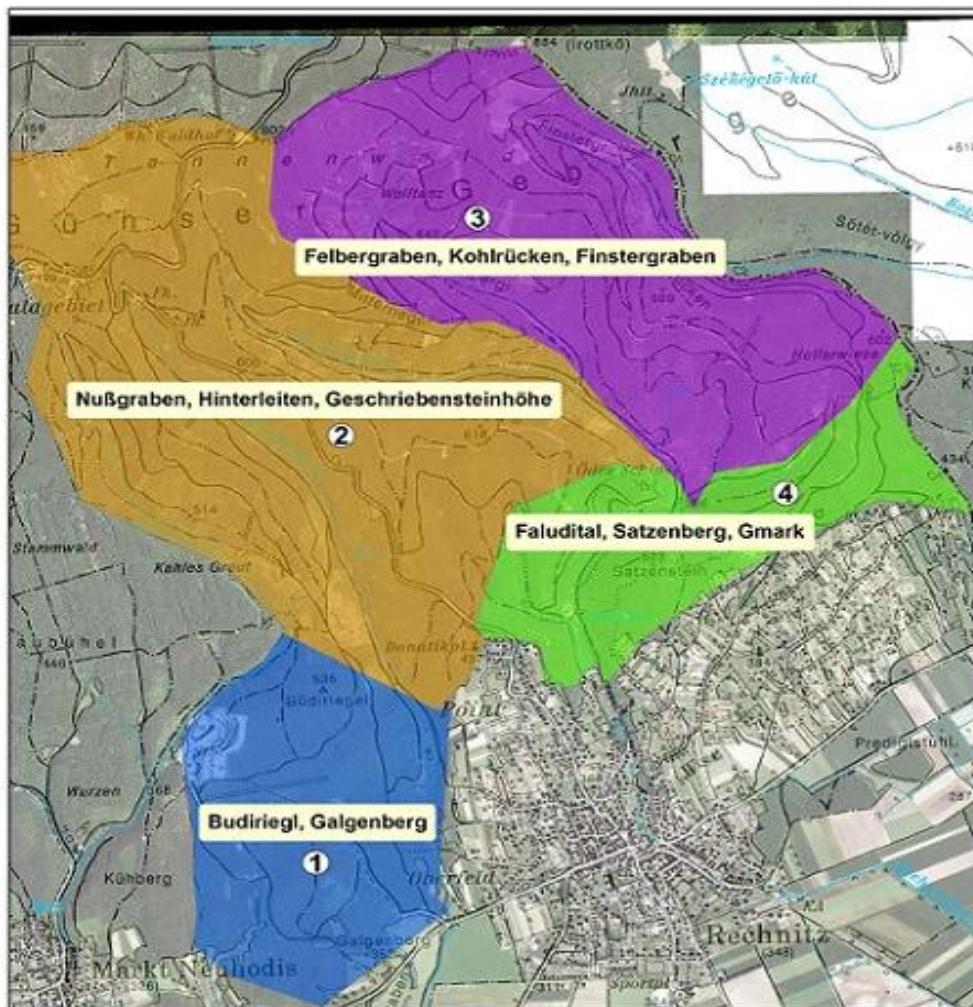
## RECHNITZ

Auf den folgenden 3 Seiten werden Sie ersucht, jeweils 20 Punkte für die Kategorien "SOZIAL" / "ÖKOLOGIE" / "WIRTSCHAFT" auf diese 4 Gebiete aufzuteilen..

In der Studie werden die Antworten dann mit Informationen aus anderen Quellen (Feldaufnahmen, Begehungen, Luft- und Satellitenbildern) verglichen. Die Auswertung soll dann zeigen, inwieweit diese verschiedenen Indikatoren übereinstimmen oder divergieren.

Es geht dabei nicht um einen "Wettbewerb" zwischen den 4 Gebieten sondern um den Vergleich naturwissenschaftlich-technischer Indikatoren mit der Bevölkerungsmeinung.

### Waldgebiete in Rechnitz - Geschriebenstein



**Appendix 2:**

**Observations of Lepidoptera by species and landscape study site.** Figures denote aggregated individuals per kilometre within each landscape type; WP – 322 individuals, 29 species, 6 transects; CF - 118 individuals, 19 species, 15 transects; EF – 64 individuals, 12 species, 21 transects; FS – 14 individuals, 8 species, 9 transects.

Family	Species	WP	CF	EF	FS
Hesperiidae	<i>Heteropterus Morpheus</i>		5.65		
	<i>Ochlodes sylvanus</i>	40.34			
Lycaenidae	<i>Celastrina argiolus</i>	4.65			
	<i>Cupido minimus</i>	4.98			
	<i>Everes argiades</i>		9.58		
	<i>Plebejus argus</i>	32.52			
	<i>Plebejus argyrogynomon</i>	14.93			
	<i>Polyommatus amandus</i>	19.9			
	<i>Polyommatus icarus</i>	58.41	9.58		
	<i>Satyrium ilicis</i>	27.39			
Nymphalidae	<i>Ultraaricia anteros</i>	29.42			
	<i>Argynnис aglaja</i>	21.58	9.95		
	<i>Argynnис paphia</i>	29.2	47.95	34.42	4.79
	<i>Inachis io</i>			4.94	5.81
	<i>Issoria lathonia</i>			9.52	
	<i>Limenitis reducta</i>	4.76			
	<i>Melitaea didyma</i>	136.6			
	<i>Neptis Sappho</i>		10.42		
	<i>Polygonia c-album</i>	4.98	15.47	14.28	5.08
Papilionidae	<i>Vanessa atalanta</i>	4.98		4.94	
	<i>Iphiclides podalirius</i>	5.03			
	<i>Papilio machaon</i>		5.16		
Pieridae	<i>Aporia crataegi</i>	131.9			20.31
	<i>Colias alfacariensis</i>	4.65			
	<i>Colias crocea</i>	187.3	19.16		
	<i>Gonepteryx rhamni</i>	137.7		9.89	
	<i>Leptidea sinapis</i>	13.95	11.84	9.7	5.81
	<i>Pieris napi</i>		71.23	44.26	
	<i>Pieris rapae</i>	4.98	30.91		
	<i>Pontia edusa</i>	42.86			
Satyridae	<i>Aphantopus hyperantus</i>		28.25		
	<i>Brintesia circe</i>	49.25	4.43		
	<i>Coenonympha arcania</i>	17.44			14.35
	<i>Coenonympha pamphilus</i>		4.79		
	<i>Coenonympha rhodopensis</i>	5.03			
	<i>Hipparchia fagi</i>		19.53	13.65	5.81
	<i>Lasiommata megera</i>	4.98			
	<i>Maniola jurtina</i>	157.7	130.2	43.09	
	<i>Melanargia galathea</i>	422.3			9.57
	<i>Minois dryas</i>		168.2	29.48	
	<i>Pararge aegeria</i>		107.5	86.93	