A Soft Systems Methodology Approach to Multifunctional Landscapes:
understanding interactivity and engaging stakeholders

by

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Abstract

Landscapes are intrinsically multifunctional. However, only some landscapes display synergistic dynamism between 'natural' and 'cultural' landscape functions. Positive dynamism between landscape functions is a property that has usually emerged fortuitously and over a long period of time. The literature suggests that the promotion of landscape multifunctionality through purposive landscape interventions can set appropriate 'initial conditions' to speed up the emergence of multifunctional, resilient and distinctive landscapes. The challenges for landscape practitioners are to understand complex relationships between landscape functions and to include people as an integral part of the landscape.

This research studies multifunctional landscapes as social-ecological systems, and its methodology is applied to the area covered by the National Forest Company (NFC), in England. After reviewing literature on landscape functions as systems, three GIS-based systems are used to explore and compare approaches to mapping landscape functions. This provides a basis to apply a Soft Systems Methodology (SSM) approach to the interpretation of landscape function interactions. Eight landscape function system conceptual models were developed, which were evaluated through workshops with NFC and their stakeholders.

The initial literature review and GIS exercises broadly confirmed that, due to the limitations of available existing spatial data, mapping exercises could only be a complement to landscape multifunctionality assessments. However, an approach based on SSM, by placing stakeholder participation at the centre of its structured thinking process, advances on previous approaches. Not only did the models successfully depict interactions between landscape functions, but also they were evaluated as a useful approach to support knowledge generation and decision-making. SSM proved to be a qualitative approach that gave structure to multifunctionality complexity. This thesis proposes SSM as a methodology to support policy development on landscape function systems dynamics through the use of qualitative models and stakeholder participation.

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Chapter 1 | I n t r o d u c t i o n

Landscapes are no longer identified just by the presence or absence of scenic qualities of rural or urban units of land. Now, landscapes are recognised as systems underlain by complex relationships between people and natural processes, which operate "beyond the view" (Natural England, 2006; Jorgensen, 2011; Selman, 2009, 2012). Increasingly in the literature, landscapes are described and studied as social-ecological systems (SES). In turn, SES studies aim to identify and understand the dynamics which occur in landscapes between people and nature. Emphasis is increasingly placed on systemic emergent properties – such as resilience, distinctiveness and multifunctionality – in order to encourage desirable landscape change and to support ecosystem service delivery (Folke et al., 2010; Moore et al., 2014).

Furthermore, in landscape practice, the recognition of the interconnected relationships between people and nature requires that landscape practitioners, managers and policy makers address a wider range of social and ecological objectives. In the UK, biodiversity and conservation policies, such as Natural Improvement Areas (NIAs) and the UK National Ecosystem Assessment (NEA), look at the provision of a resilient environment aiming to stop biodiversity loss and restore ecosystem services. Furthermore, these policies are currently placing people at the centre of implementation, by acknowledging both how biodiversity and people influence each other, and how the active engagement of local communities can assist biodiversity protection objectives and implementation practices (Collingwood Environmental Planning Limited and Defra, 2013; 2014a; 2014b; Defra, 2011b; UK National Ecosystem Assessment, 2014). Landscape multifunctionality principles and qualities are also being promoted through high-level policy and planning frameworks, notably The European Landscape Convention (continental scale) (Council of Europe, 2000) and the National Planning framework (national scale) (Department for Communities and Local Government, 2012). These, too, recognise the impact and complexity of the relationships between natural and social processes, and promote objectives which go beyond traditional biodiversity conservation and protection, such as re-connecting fragmented landscapes, encouraging the emergence of self-organised and resilient landscapes, contributing beneficially to climate change adaptation and mitigation, and supporting social well-being, community empowerment and economic recovery (Landscape Institute, 2009; 2013; Lovell and Johnson, 2009).

Beyond the establishment of wide-ranging social and ecological objectives, current discussions within landscape research and practice also focus on how to assess, direct, approach, implement, inform and monitor the impact and resonance of actions, policies and outputs directed at landscape re-generation (Selman, 2002; Lovell and Taylor, 2013; Fish and Saratsi, 2015). Within the literature, two key aspects persistently emerge as critical to the study of multifunctional landscapes (Potschin and Haines-Young, 2013). First, is the recognition and study of complex and interconnected social and ecological dynamics through innovative, holistic and integrated approaches. Second, is the desirability of adopting an inter-disciplinary and plural approach centred on people via an active dialogue amongst the wider landscape community (public, scientists, practitioners and policy makers); this aims to understand their issues, concerns and aspirations, and also to achieve co-production of knowledge and information.

Over about the last two decades, landscape researchers, practitioners and government agencies have been paying attention to the multifunctional properties of landscapes (Council of Europe, 2000; Crossman and Bryan, 2009; Willemen et al., 2010; Selman, 2012; Lovell and Taylor, 2013). The exploration of landscape multifunctionality as an approach continues to develop in accordance with the issues explored above – namely complexity, active engagement and co-production.

An understanding of landscape multifunctionality can help practitioners to create good quality new or regenerated landscapes by understanding and supporting ecological and cultural dynamics, which in turn can assist the emergence of landscape character, distinctiveness, time-depth, place and resilience (Selman, 2009). Approaches based on landscape multifunctionality analyse landscape dynamics through four key lenses. First, landscape multifunctionality entails continuous interactions, relationships and exchanges between landscape functions (Naveh, 2001; Wood and Handley, 2001; Ling et al*., 2007;* Lovell and Johnston, 2009; Selman, 2009; 2012; Lovell and Taylor, 2013), whose interconnected elements have particular directions and strengths (Folke, 2006). Second, landscape multifunctionality occurs and crosses multiple spatial, temporal and organisational scales (Cash et al., 2006; Selman, 2009; Folke et al., 2010; Lovell and Taylor, 2013; Mastrangelo et al., 2014). Third, landscape multifunctionality recognises landscape users and landowners as fundamental parts of the system (Council of Europe, 2000; Sevenant and Antrop, 2010; Lovell and Johnston, 2009). The fourth characteristic is that landscape multifunctionality requires to be understood through an inter and trans-disciplinary approach (Fry, 2001; Selman; 2009; Bollinger et al., 2011; Haines-Young, 2011).

1.1 Landscape Multifunctionality: *current research and practice*

Landscape dynamics emerge from a landscape's capacity to support manifold functions simultaneously (Meyer and Grabaum, 2008; Willemen et al., 2010; Selman, 2009; 2012; Bollinger et al., 2011). Landscape functions are responsible for the regulation of natural processes, affording spatial frameworks for social and economic processes to occur, and providing natural resources essential for humans. Individual landscape functions are also systems, characterised by the dynamism generated through landscape components, such as ecological and biophysical processes and cultural associations. Thus, landscapes are part of a wider system and are formed by systems. Existing valued and mature landscapes are characterised by a positive dynamism between landscape functions, which have emerged *"fortuitously"* and *"serendipitously"* over a long period of time (Selman, 2009). The literature suggests that, in order to increase the likely occurrence of positive dynamism, the dynamics of a landscape system can be inflected towards synergetic pathways and feedbacks between its individual functions (Moore et al., 2014).

These elements make landscape multifunctionality different from other landscape approaches and concepts of a similar nature, such as those based on co-location of multiple land uses, and quantification and economic valuation of ecosystem services. The principal difference is that these approaches only consider individual flows of benefits from the landscape, and do not necessarily consider how a whole landscape evolves in association with its underlying biophysical processes, components and local land managers and communities. For example, Fish and Saratsi (2015), through public participation, evaluated the National Ecosystem Assessment as a framework applied to monetary and non-monetary valuation assessments. However, their findings suggest that, although the framework and assessments are positively accepted for acknowledging complexity and communicating values, the participants identified a potential "consumerist" and "political" dimension that could lead to people paying for currently free and accessible ecosystem services, or focusing on what to 'get' from the environment instead of how to return key qualities and functions to it.

Multifunctional landscapes are currently explored in scientific, policy and practice debates through two different approaches. In one, multifunctionality is applied within an agricultural context (Brandt and Vejre, 2004; Wiggering et al., 2006; Renting et al., 2009; Carey et al., 2003; Gimona and van der Horst, 2007); in the other, multifunctionality is applied within cultural landscapes at urban and peri-urban scales (Selman, 2006; Selman, 2012; Selman and Knight, 2006b; Ling et al. 2007; Lovell and Taylor, 2013).

The main objective of agricultural multifunctionality is to efficiently provide two or more ecosystem services on specific land units, including tangible services or commodities such as food and raw materials, and cultural services or non-commodities such as biodiversity conservation and recreational opportunities (Wiggering et al., 2006; Renting et al., 2009; Lovell et al., 2010). Agricultural Multifunctionality is primarily promoted through governmental schemes (Carey et al., 2003; Wiggering et al., 2006; Gimona and van der Horst, 2007), which reward agricultural and farming practices that integrate a range of economic, social, cultural and environmental functions (Crossman and Bryan, 2009), for example Environmental Stewardship in England.

Multifunctionality in the urban and peri-urban context is referred to as landscape multifunctionality, and is the focus of this research study. Over the last decade, landscape multifunctionality has been promoted mainly through landscape planning and policy approaches to biodiversity conservation, Green Infrastructure and housing development (CABE, 2006, 2009; Natural England, 2009a; Collingwood Environmental Planning and Defra, 2013; 2014a; 2014b; Defra, 2011b; UK National Ecosystem Assessment, 2014; Landscape Institute, 2009, 2010).

Overall, landscape multifunctionality assessments aim to generate knowledge and insights to inform decisions and approaches for spatial planning, landscape management and policy making. The approaches to these assessments come from different perspectives and theoretical frameworks (Mastrangelo et al., 2014). There are different key frameworks from which landscape multifunctionality is assessed: for instance, assessments focused on ecosystem services delivery and economic values, quantification of ecosystems services stocks at different scales (local, national, continental and global scales), and spatial assessments (mapping) of ecosystems services stocks.

Another landscape multifunctionality framework aims to look at the underlying dynamics between social and ecological processes and components through the concept of landscape functions (de Groot, 2006) rather than through ecosystem services. Haines-Young and Potschin (2010) describe landscape functions as the processes that perform and interact with other social and ecological systems; furthermore, they show that landscape functions deliver ecosystems services, and - as is widely explored within the literature-ecosystem services are the tangible and non-tangible manifestations of interactions between functions. These, in turn, are considered beneficial to people, and so can have a value placed in them. An early exploration and analysis of literature identified a total of 37 landscape functions. Research studies by de Groot et al. (2002), de Groot (2006), de Groot et al. (2010), Constanza et al. (1997), Daily et al. (1997) and the Millennium Ecosystems Assessment (MEA) (2005) have mainly influenced the identification and classification of landscape functions. Generally, landscape functions are classified in five categories: i) regulation, ii) habitat, iii) production, iv) information and v) carrier. Although the approach of Haines-Young and Potschin (2010) to distinguish landscape functions from ecosystem services is widely adopted by research studies, to date the identification and classification of landscape functions remains inconsistent (Hermann et al., 2011; Křováková et al., 2015).

Finally, another important component of landscape multifunctionality assessment is landscape function mapping, which aims to spatially represent landscape functions and to illustrate the spatial distribution and capacity of potential landscape functions to provide ecosystem services at a landscape scale. There are two important elements of landscape function mapping. One entails conducting a spatial analysis to support the identification of areas of opportunity for intervention; the second uses the output maps for supporting communication between stakeholders. However, to date, landscape multifunctionality assessments together with landscape function and services mapping approaches, are constrained by the quality and capacity of existing data (indicators, proxies, census data and spatial data) to deal with the complexity of relationships and exchanges between social and ecological processes.

1.2 Landscape multifunctionality: *as a system*

Landscape multifunctionality has been represented in terms of social-ecological systems, providing the opportunity to assess complexity through process-based and systems theory approaches (Selman and Knight, 2006a; Haines-Young, 2011; Potschin and Haines-Young, 2013). Systems are inter-connected and organised elements with a purpose; within a system it is important to understand how its components affect the "whole", contrary to looking solely at individual components' behaviour, although these components can be regarded systems in their own right (The Open University, 2013). Understanding a landscape's multifunctionality from its intrinsic definition as social-ecological system requires recognition of its main properties: dynamism, multiple-scale occurrence, participation and trans-disciplinarity.

Within systems theory there are quantitative and qualitative approaches. Existing quantitative assessments aim to simulate and predict a particular system by segmenting and modelling its subsystems and components; these are described as "hard systems". These approaches have the tendency to model systems through mathematical, statistical and computer simulations. Although hard systems analysis is characterised by its scientific rigour and validity, there are certain limitations to its application, especially when dealing with the complexities generated by integrating people in a system (Oreszczyn, 2000), for example when inspecting and modelling social processes (Cundill et al., 2012).

Conversely "systems thinking" entails qualitative approaches aimed at studying a system as a *whole* that is part of larger relationships with other systems, whose interconnections give the 'system of interest' both context and significance (Oreszczyn, 2000; Bosch et al., 2007; Cabrera et al., 2008; Open University, 2013). In contrast with hard systems, 'systems thinking' puts special emphasis on the enquiry and learning processes rather the procedures *per se* (Cundill et al., 2012). Furthermore, systems thinking is characterised as a participative and action research approach (Oreszczyn, 2000). In this respect, the present research study approaches landscape multifunctionality through a 'systems thinking' approach, in the search for a method that could support landscape practitioners. Potentially, it could help us to understand the relationships between landscape functions, in order to identify how to intervene purposefully to change and transform the direction and dynamics of a system to create new or to regenerate damaged landscapes (Pickett et al., 2004; Matthews and Selman, 2006).

Within systems thinking, Soft Systems Methodology (SSM) has been selected as a particular approach to be explored in this research study. Peter Checkland from Lancaster University has developed this methodology since early 1980's in response to a need to study systems that include social processes where people have different points of view and have the tendency of acting purposefully towards a situation. There are relevant examples of SSM looking at environmental management issues and social-ecological systems. For instance, Bunch (2003) applied SSM to explore and re-define the Cooum River in southern India as a social-ecological system; Bowler (2006) explored the Irish Sea as a social-ecological system and used SSM to collect and analyse data from different resources; Mendoza and Prabhu (2006) explored SSM and different conceptual models methods to assess sustainable forest management; and more recently, Watkin et al. (2012) applied SSM to explore the problems related to the development of a micro-hydropower source.

1.3 Research Aim and Objectives

As mentioned previously, landscape multifunctionality aims to provide a framework for landscape practitioners to set appropriate initial conditions to speed up the emergence of valued landscapes. However, it requires identifying and understanding the underlying processes and dynamics occurring between social and ecological landscape functions. Yet, landscape multifunctionality evaluation and promotion is still a challenge for planning agencies and landscape practitioners. This is because we still lack definitions, data and methods to look comprehensively at landscape multifunctionality as something which is interactive, crosses multiple-scales, and incorporates participation and trans-disciplinarity. Nevertheless, through its approach based on describing landscapes as systems, in particular as social-ecological systems, this thesis seeks a way of exploring landscape function dynamics through a qualitative approach based on 'systems thinking'.

In the light of this introductory discussion, the thesis aims: *to explore and to apply a systems thinking approach to support and to provide a comprehensive illustration of landscape function dynamics and landscape multifunctionality properties*. This overarching aim has led to the development of research study objectives, namely:

1. To critically disambiguate and establish the current state of knowledge and theory with regard to the range and nature of landscape functions as landscape systems.

2. To develop an approach to landscape function mapping in order to spatially identify and reflect the extent and direction of landscape systems.

3. To explore Soft Systems Methodology as a *Systems Thinking* approach to understand and address landscape multifunctionality properties in order to inform potential applications of this framework in landscape practice in future.

1.4 Definition of terms

There are a number of terms that are used extensively throughout this thesis and it is useful to define them briefly in this introductory chapter.

Landscape function systems comprise the processes and components that perform and interact with other social and ecological systems and have the capacity to deliver ecosystem services (Haines-Young and Potschin, 2010).

Landscape function processes refer to the physical, chemical, biological and social transformations and responses occurring within the system (Millennium Ecosystem Assessment, 2005).

Landscape function components comprise all the social, physical and biological elements that form a landscape function system.

Landscape function dynamics relates to the relationships, interactions and feedbacks between landscape function systems.

Systemic thinking refers to thinking processes that look at the connected wholes, and contrast with systematic or reductionist thinking (linear procedures and their cause and effect relationships) (Open University, 2013).

A “problematic situation” is a term used in SSM to support learning about something requiring intervention, as opposed to the term *problem* which tends to lead us to think about solutions (Checkland and Poulter, 2010).

1.5 Thesis structure

The academic context, methods, findings and concluding remarks of this thesis are presented through nine chapters. The structure of the thesis presents the overall order in which my exploration of landscape multifunctionality proceeded. This introductory chapter presents the contextual background, research gaps and opportunities for study, and defines the research aim and objectives.

Chapter 2 comprises a literature review of key concepts related to landscape's multifunctional properties. In particular, it explores landscapes as social-ecological systems, and highlights and distinguishes differences between landscape functions and ecosystems services. It reviews existing approaches to landscape multifunctionality and examines systems thinking theory as a qualitative approach to learn about complex relationships in multifunctional landscapes and between landscape functions.

Chapter 3 explores the methodological framework, which is underpinned by systems thinking theory. Also, this chapter outlines and discusses the range of and justification for methods used in this thesis. In addition, the thesis methodology is applied to a single case study, The National Forest (NF), which is described in detail in this chapter.

Chapter 4 presents findings from a comprehensive literature review on each identified landscape function systems, aiming to critically analyse and describe the nature and range of landscape functions, from a process-oriented point of view. In particular, this literature review aims to enhance landscape research understanding of landscape functions' components. This chapter is relevant to meeting research objective number one.

Chapter 5 examines three different approaches to landscape function mapping relevant to landscape multifunctionality through three exploratory exercises applied to the National Forest project area using Geographical Information Systems. The first two approaches relate to two different published approaches, one by The Mersey Forest (2009, 2013) and the second by Louise Willemen and others (2008). The third exploratory exercise draws upon the two previous studies which conducted spatial explorations of landscape functions as social and ecological systems, as a way of advancing upon assessments of ecosystems services delivery. This chapter relates to achieving thesis objective number two.

Chapter 6 explores Soft Systems Methodology (SSM) as a systems thinking approach to landscape multifunctionality. This approach is applied to the National Forest project area. SSM comprises four stages that structure different thinking processes and exercises. These in turn aim: to build a comprehensive picture of the problematic situation; to identify and define relevant systems; to construct conceptual models of the previously identified systems; and finally, to use the conceptual models to organise and structure a discussion between stakeholders, so they explore landscape multifunctionality dynamics and complexity. This discussion took place through two workshops with National Forest stakeholders. In addition, this chapter describes the methods used to analyse the qualitative data collected from the workshops. This chapter is relevant to meeting research objective number three.

Chapter 7 explores the results from the two workshops undertaken as part of SSM. The workshops comprised two sections. In first section, the National Forest's stakeholders explored the landscape function conceptual models and evaluated whether they successfully depicted components, interactions and points of intervention in the landscape functions system. In the second part, workshop participants discussed the utility, credibility, feasibility and relevance of the conceptual models for understanding relationships between landscape functions and identifying points of intervention.

Chapter 8 discusses the key findings in relation to the thesis aim and objectives. These are organised in terms of: description and nature of landscape function systems; mapping approaches to landscape function systems; and evaluation of Soft Systems Methodology to support participation and to learn about complex relationships between landscape functions.

Finally, Chapter 9 presents a synthesis of findings and concludes by outlining the study's contributions and limitations, and its implications for future practice and research.

Chapter 2| Literature Review

2.1 Introduction

This chapter presents a review of literature concerning concepts related to landscape multifunctionality and its use as a framework for participatory planning. Subsequently, Chapter four drills down into the literature associated with specific landscape functions. The present chapter aims to contextualise this thesis in relation to landscape multifunctionality as a framework for identifying purposive planning interventions that can set appropriate "initial conditions" to speed up the emergence of valued landscapes. Section 2.2 explores the landscape as a social-ecological system and defines landscape's emergent properties. Section 2.3 explores and defines landscape multifunctionality as a quality emerging from the underlying dynamics between landscape functions. Section 2.4 describes the attributes of landscape multifunctionality: complexity and interactivity, multiple-scale awareness, participation and trans-disciplinarity. Section 2.5 defines and identifies landscape functions. Section 2.6 explores current approaches to landscape planning and includes an analysis of stakeholder participation strategies. Finally, section 2.7 discusses systems thinking as a qualitative approach to support the understanding of complex dynamics between systems components.

2.2 Landscapes as social-ecological systems

Social-ecological systems (SES) (Folke et al., 2010; Moore et al., 2014), sometimes referred to as coupled human and natural systems (Liu et al., 2007; Milne et al., 2009), provide an approach to studying the dynamic and systemic properties of the landscape. Landscape dynamics are the interactions and relationships between processes, patterns, structures and functions through space and time, and the results from such interactions are expressed through the character, condition and properties of the landscape (Wood and Handley, 2001). SES characterises the landscape as a complex system. Looking at landscapes through a systems lens enables study of the dynamics occurring between social and ecological systems that at the same time are part of a wider system (Wood and Handley, 2001; Naveh, 2001). An understanding of dynamics and systemic emergent properties supports the identification of drivers of change and points of interventions that could encourage desirable landscape change, primarily to enhance, restore and protect landscapes and to support a desirable state of the landscape and its provision of ecosystem services (Wood and Handley, 2001). The following paragraphs will explore SES dynamics and emergent properties.

In principle, throughout the complex theory lens, an SES will not reach a static equilibrium state. Contrary to sustainable development aims, an SES will always continue to change. However, if the system is resilient it will promote stable and optimum states that will allow the systems to self-organise and retain structure, function and identity when they encounter pressures, disturbance or non-desirable changes (Kay et al., 1999; Moore et al., 2014). Resilience is an emergent landscape property. Understanding SES dynamics can enable purposeful and desirable change by directing a system's dynamics towards synergetic paths through feedbacks between processes, functions and services (Moore et al., 2014).

Kay et al. (1999) describe the properties of complex systems. They describe an SES as a non-linear system that is not possible to analyse by breaking it down; it requires to be analysed as a whole. An SES is part of a wider system and consists of several systems. SES dynamics are not mechanical and an SES has the capacity to self-organise. Thus, an SES will not reach an equilibrium point, but will self-organise to reach an optimum state; however, there might be different desirable system states accordingly to the situation, for example mono-functional versus multifunctional objectives. Furthermore, an SES has a *chaotic behaviour* making it difficult to predict and estimate system behaviour (Moore et al., 2014). SESs are complex systems with open boundaries (Paavola and Hubacek, 2013) where there is a continuous exchange of material and energy between the systems (Kay et al., 1999).

SES dynamics take place at multiple spatial and temporal scales (Kay et al., 1999; Wood and Handley, 2001). The effects of change in an SES will also resonate at multiple scales. Folke et al. (2010) and Moore et al. (2014) show that any transformation in a small or single SES element will encourage change to different systems components and will have effects on larger SESs. Conversely resilience and change at larger SES scales will affect smaller SESs, for instance the contribution of a woodland patch to CO_2 absorption will contribute to the resilience to climate change at an earth system scale.

Ultimately, the aim of understanding and unpacking SES complexity is for researchers and practitioners to identify feedbacks, thresholds and points of interventions (Moore et al., 2014). Potentially, this will allow the system either to adjust and respond to external and internal pressures, then continue on the current and desirable trajectory, or else to transform the existing dynamic towards new trajectories. These SES qualities are called adaptability and transformability; both are elements of resilience and systemic properties (Folke, 2006; Folke et al., 2010; Moore et al., 2014).

Within SESs transformation occurs purposefully and intentionally, whilst adaptability and resilience are emergent properties. Intentional change to key components of the social or ecological systems will prompt a transformation, which will have effects across multiple scales. The aim is that the transformation will change current system feedbacks toward synergies and positive dynamics leading to desirable emergent properties (resilience, character and distinctiveness). Table 2.1 illustrates specific components of the social and ecological systems where, potentially, change can take place. In ecological systems change can take place in processes, species configurations and ecosystems services. Within social systems, change can occur in existing norms, values, beliefs, needs, distribution of power, rules and practices.

Table 2.1. Systems components susceptible to change in a given transformation (based on Moore et al., 2014).

System	Systems components
Ecological	Natural capital Processes Species configurations Physical environmental and ecological functions (Selman and Knight, 2006)
Social	Norms Values Beliefs Rules and practices (law, procedures and customs) Distribution of power, authority and resources Community needs (Paavola and Hubacek, 2013)

This thesis seeks to explore landscape multifunctionality as SESs, to enable looking into landscape dynamics as a basis to encourage the emergence of resilience, landscape character and multifunctionality. In SES terms, landscape multifunctionality as an approach will aid the transformation of certain landscapes system's components by identifying purposive planning and management interventions, that can set appropriate "initial conditions" to speed up the emergence of valued landscapes.

2.3 Landscape multifunctionality

As discussed above, landscapes are no longer acknowledged just by their scenic qualities. Now, landscapes are recognised as complex systems that operate *"beyond the view"* (Natural England, 2006; Jorgensen, 2011; Selman, 2009, 2012). In this thesis landscapes are underpinned as social-ecological systems. Furthermore, landscapes are acknowledged for their intrinsic capacity to support continuously and simultaneously several natural and social processes that provide a wide number of ecosystems services; this capacity is referred to as multifunctionality (de Groot, 2006; Selman, 2009; 2012; Termorshuizen and Opdam, 2009; Bollinger et al., 2011; Wolf and Meyer, 2010; Lovell and Taylor, 2013).

The social and natural processes that have the capacity to support and provide ecosystem services are described as landscape functions. Nevertheless, the literature shows a fluid use of terms such as functions, landscape services, ecosystem functions or ecosystem services (Wallace, 2007; Krováková et al., 2015). Within the literature there is an inclination to refer to landscape functions when looking at a wider set of social and ecological objectives at a landscape scale (Hermann et al., 2011). Contrary to ecosystem services approaches that aim to quantify and give a value (human or monetary) to services with the purpose of informing the importance of nature in policy making (Antrop, 2006; Villa et al., 2014; Silvertown, 2015), this research study focuses on landscape functions as a term aiming to reflect the underlying processes where practitioners could intervene to influence feedbacks and dynamics to encourage desirable change, resilience, character and multifunctionality (Moore et al., 2014). In section 2.5 this study explores the specific definition and account of landscape functions.

In this context, a landscape's functional capacity to support processes is determined by the dynamism generated between its components (Council of Europe, 2000; Naveh, 2001; Wood and Handley, 2001; Antrop, 2006; Willemen et al, 2010; Albon et al., 2011; Selman, 2012). As explored in the SES section, these interactions are the underlying landscape dynamics that trigger emergent landscape properties - multifunctionality, landscape character and resilience (Oreszczyn, 2000; Wood and Handley, 2001; Selman 2009; 2012) - and produce ecosystem services highly valued for human well-being. In addition to multifunctionality being an emergent attribute, landscape research and practice uses landscape multifunctionality as a concept that supports thinking holistically about the underlying dynamics of landscapes. The literature suggests (Wood and Handley, 2001) that by understanding the dynamics occurring within landscapes, it is possible to know how to intervene to increase the likelihood of positive interactions between landscape functions, aiming to speed up the emergence of multifunctional, distinctive and resilient landscapes.

The understanding of landscape multifunctionality in landscape research has been dynamic. The definition and description of landscape multifunctionality has changed from the juxtaposition of complementary multiple land uses, to the capacity of multiple provisions of ecosystems services, and then to the study of underlying dynamics between processes and structures and of the landscape (Pickett et al., 2004; Wood and Handley, 2001; Selman, 2009).

Early concepts of multifunctionality were incorporated in Ian McHarg's approach to urban planning; in his approach "Design with Nature" (1971) he explains the importance of the integration and understanding of natural, social and cultural processes (Yang et al., 2013). McHarg proposed to identify and juxtapose natural and cultural process and then to analyse the current state of environment as a basis for design and planning approaches. However, Pickett et al. (2004) argue that because of the limitations of technology and data, McHarg's approach nowadays is characterised as a static examination of current processes. Concepts underpinning landscape multifunctionality continued to develop in the 1980's through the emergence of landscape ecology as a discipline, where paradigms looking at patterns, processes and dynamics started discussing the role of people affecting landscapes processes, and for example, looking at the relationship between science and landscape design (Musacchio, 2009). Then Ahern (1995) explored how spatial connectivity based on Forman and Godron (1986) *"patch and corridor"* approach and land use pressures could be incorporated through the concept of "Greenways". Greenways were characterised as multifunctional landscapes, because these sought *positive* and *synergetic* combinations of compatible and multiple land use to support spatial connectivity for biodiversity and the inclusion of public participation.

In the past twenty years, throughout the exploration of ecosystem services, multifunctionality has gained momentum as a landscape property able to provide multiple benefits for humans. The ecosystem service approach initially explored by de Groot (1992), Daily et al. (1997) and the Millennium Ecosystem Services Assessment (2005) aims to demonstrate and justify the *"importance of ecosystems and biodiversity for human well-being"* (Willemen et al., 2010). These demonstrations have centred on finding ways of valuing ecosystems services from both economic and social perspectives.

However, landscape multifunctionality, as a desirable property for protecting, planning and management of new and highly damaged landscapes has been promoted by the European Landscape Convention (Council of Europe, 2000), and has steadily expanded to other global regions (Selman, 2009; Lovell and Taylor, 2013). Landscape multifunctionality in the planning context centres its discussion on landscape as a system and its potential emergent properties of resilience, distinctiveness and character generated throughout synergetic dynamics between landscape functions (Selman, 2009; Lovell and Taylor, 2013).

It is important to clarify that landscape multifunctionality is linked to but different from "agricultural multifunctionality" and "ecosystems services" approaches. Agricultural multifunctionality is specifically applied to the efficient co-production of two or more ecosystem services in a rural and agricultural context (Wiggering et al., 2006; Renting et al., 2009; Selman, 2009). Governmental schemes promote agricultural multifunctionality through encouraging other land covers and land uses apart from intensive agriculture, such as forestry or recreational uses, primarily to obtain more ecosystems services than only the production and provision of food and fibre (Selman, 2009; Lovell et al., 2010).

Two characteristics make a clear distinction between ecosystem services and landscape multifunctionality. First, ecosystem services are the surface (tangible or intangible) manifestation of the underlying dynamics occurring on the landscape; whereas landscape multifunctionality and landscape functions refer to the processes, components and dynamics between systems. Secondly, Ecosystem Services are primarily anthropocentric (de Groot et al., 2002; Agbenyega et al., 2009), *i.e.* they exist because people value them as essential for human well-being (Termorshuizen and Opdam, 2009; Silvertown, 2015). By contrast, landscape multifunctionality focuses on how earth systems function, and is relatively eco-centric (Selman, 2009), *i.e*. landscape functions continue to exist without people (Termorshuizen and Opdam, 2009), even if people are integral to its dynamics and generate cultural services (Selman, 2009). The confusion is generated because both approaches require studying the dynamics of the underlying processes occurring at the landscape scale (Fagerholm et al., 2012; Villa et al., 2014). This literature review will further distinguish landscape multifunctionality from other approaches by exploring four key attributes.

2.4 Landscape multifunctionality properties

This literature review aims to identify and describe landscape multifunctionality (LM) as an emergent quality of landscapes, as well as the application of this approach in landscape planning and management. In both cases, landscape multifunctionality has four key properties that are fundamental for understanding its context and rationale. These attributes are: interactivity, multiple-scale organisation, stakeholder participation and trans-disciplinarity. The following sections will explore these in greater detail.

2.4.1 LM: *is interactive*

Emergent properties of landscapes are the manifestation of continuous interactions, connections and exchanges between landscape functions components (Naveh, 2001; Wood and Handley, 2001; Selman, 2012); these interconnected elements have particular directions and strengths (Folke et al., 2010). These interactions are described as landscape dynamics, and landscape multifunctionality aims to look at the ways these landscape functions interact. The literature suggests that by encouraging and increasing positive interactions between landscape functions there is the likelihood of speeding up the emergence of resilient and distinctive landscapes (Wood and Handley, 2001; Selman, 2009). Furthermore, interactivity between landscape functions determines the capacity of the landscape to provide ecosystems services (Willemen et al., 2010; Mastrangelo et al., 2014).

The study of the conditions that drive or influence the dynamics between landscape functions are the challenge that researchers, planners and managers are concerned about (Naveh, 2001; Fry, 2001; de Groot et al., 2010; Willemen et al., 2010; Hermann et al., 2011; Potschin and Haines-Young, 2013). Naveh (2001) argues that landscape dynamics require to be approached as a 'whole', contrary to the study of fragmented and mechanised linear process. In other words, they require integral and synthetic analyses.

Studies by Selman and Knight (2006a) and Willemen et al. (2010) look specifically at landscape function interactions. Selman and Knight (2006a) explored interactivity from a systems perspective. They proposed that according to occurring feedback loops between systems components two types of interactions emerge. First, "virtuous circles" promoted regenerative properties through positive feedbacks between landscape quality and its positive influence on social processes and well-being. On the other hand, "vicious circles" emerge from negative feedback loops through land degradation and social processes, limiting landscape properties for regeneration.

From an ecosystem service perspective, Willemen et al. (2010) aimed to study landscape function interactions to determine how spatial and landscape elements influence the capacity of the landscape to deliver ecosystem services. They classified landscape function interactions according to three types. First, conflicting interactions are landscape function combinations that hinder other functions' capacity to produce ecosystem services. Second, synergetic interactions are landscape function combinations that enhance other functions' capacity to deliver ecosystem services. Finally, compatible interactions are landscape function combinations that co-exist, where interactions neither hinder nor enhance other functions' capacities.

2.4.2 LM: *crosses multiple scales*

Landscape multifunctionality, through landscape function dynamics, is a property that takes place and has effects at multiple spatial, temporal and organisational scales simultaneously (Cash et al., 2006; Selman, 2009; Folke et al., 2010; Lovell and Taylor, 2013; Mastrangelo et al., 2014). Landscape processes will, for example, occur at a landscape scale (e.g. catchment area), whilst ecosystem services yield and trade-offs will have an impact at a local scale. Equally, large scale processes such as global warming will impact local scale process (for example, microclimate), and consequently this local scale process will feed back into the larger processes again (Willemen et al., 2012). This cross-scale effect can be explored throughout its role on SES dynamics and resilience: change at small scales facilitates resilience at larger scales, whilst the ability of a process to change at a small scale relies on the resilience of larger scale systems (Folke, et al. 2010).

Changes and processes of landscape functions occur and affect other processes at different time-frames. These time-frames could be seasonal, time-depth (past, present and future) and frequency (Cash et al., 2006). Understanding changes occurring at different time-frames will support comprehension of impacts and trajectories of changes and dynamics on particular natural or social processes (Brace and Geoghegan, 2011). Organisational cross-scale aspects relate to natural and cultural process taking place across political boundaries, institutional arrangements, management regimens and disciplines (Cash et al., 2006). Figure 2.1 illustrates an example given by Cash et al. (2006) positioning a natural process within multiple scale influences.

2.4.3 LM: *is participatory*

Landscape multifunctionality requires recognising landscape users and landowners as a fundamental part of the system (Council of Europe, 2000; Sevenant and Antrop, 2010; Lovell and Johnston, 2009). Landscapes emerge from the integration of natural and cultural processes, but also landscapes contribute to people's quality of life and conversely people contribute to the quality of landscapes (Jones, 2007). Potentially the systems (natural and social) reinforce each other.

Therefore, landscape multifunctionality is participative because it requires substantial input from key people that influence or are being influenced by the landscape, through living, working or being responsible for it (Termorshuizen and Opdam, 2009). Participation of local communities and stakeholders provides local-place knowledge essential for the understating and reconnection of current landscape dynamics between natural and social processes (Lovell and Taylor, 2013). However, stakeholders are characterised by their multiple and conflicting preferences, needs and objectives (Selman, 2004; van Berkel and Verburg, 2012; Harden et al., 2013); in this context the role of the participation process is to contribute to the collection, account and analysis of multiple social-ecological aims from a wide range of stakeholders.

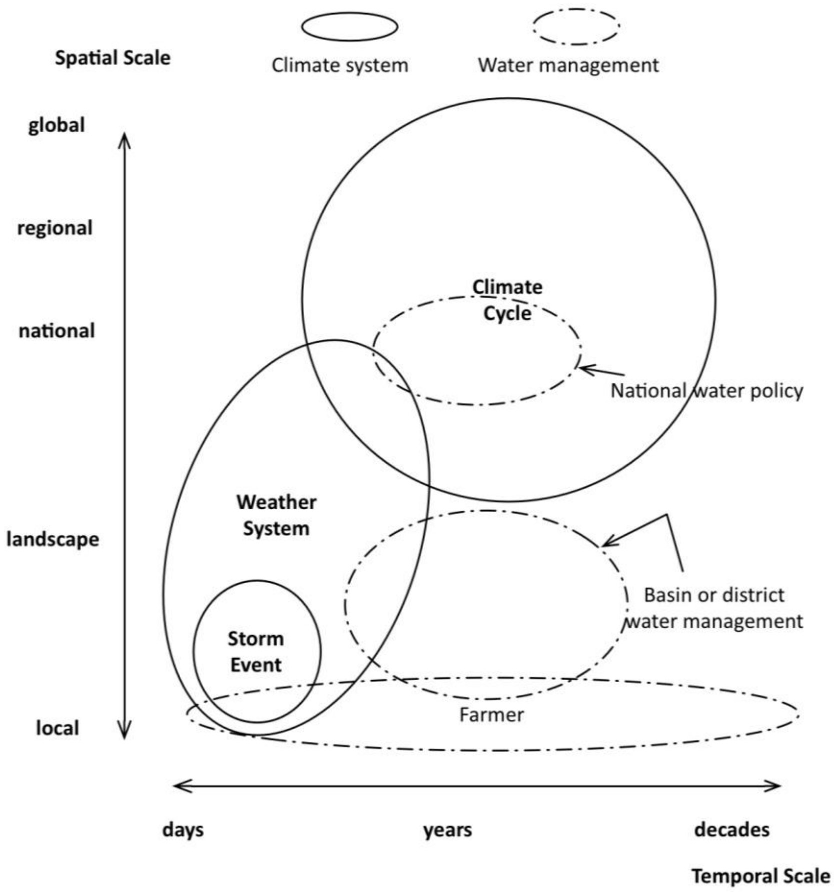


Figure 2.1 Schematic example of natural processes and multiple scale interaction, based on Cash et al. (2006).

2.4.4 LM: *is trans-disciplinary*

The final attribute to explore is that landscape multifunctionality requires to be understood through a trans-disciplinary approach (Tress and Tress, 2001; Fry, 2001; Selman; 2009; O' Farrell and Anderson, 2010; Bollinger et al., 2011). Trans-disciplinarity is the approach required to embrace LM's previously discussed properties: interactivity, participation and cross-scale. Those properties are primarily concerned with the interconnected relationships between different disciplines but, moreover, relationships between specialist knowledge and people's needs, beliefs, experiences and observations. Trans-disciplinarity is an approach that aims to integrate knowledge and expertise from different disciplines with knowledge and perspectives from non-professionals, non-academics or non-specialists. Integration results in the creation of new knowledge and understanding (Tress, et al., 2006a), particularly relevant and applicable to the local community involved (Beunen and

Opdam, 2011). Trans-disciplinarity itself is a participatory approach; this is what distinguishes it from multi- and inter-disciplinary approaches, as illustrated in Fig 2.2.

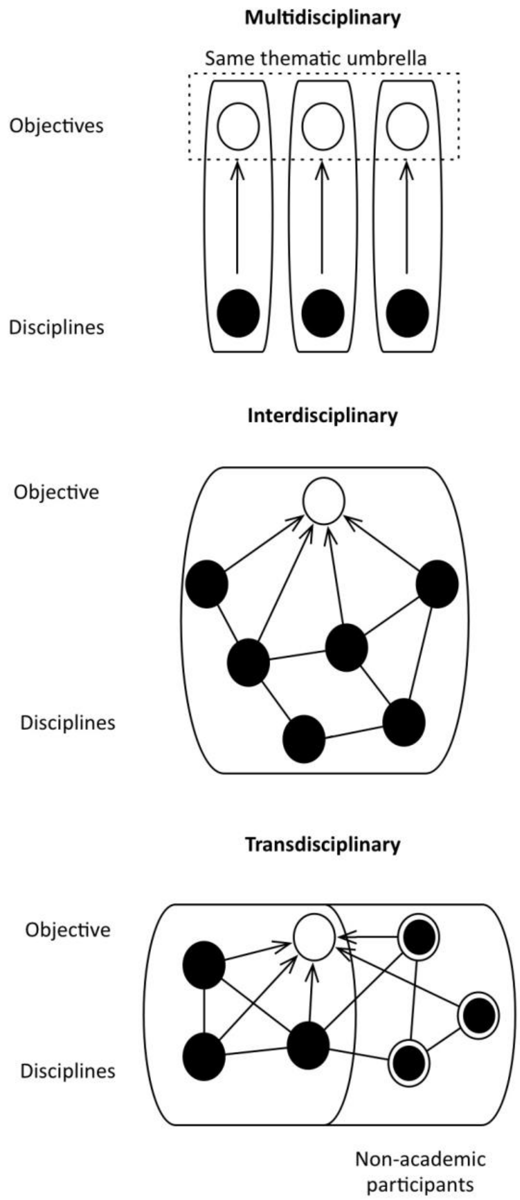


Figure 2.2 Differences between collaboration approaches, based on Tress et al., 2006a.

2.5 Landscape functions

Section 2.3 of this literature review defined landscape multifunctionality and emphasised the focus of this thesis on landscape functions. This thesis specifically refers to de Groot's (2006) emphasis on landscape's complex ecological structures, components and processes throughout a defined list of landscape functions. However, as previously explored, ambiguity between, and interchangeable use of, terms generates important discussions in multifunctionality and ecosystem service studies (Selman, 2009; Hermann et al., 2011; Bastian and Grunewald, 2012). Research by Daily et al. (1997), Costanza et al. (1997), de Groot et al. (2002) and de Groot (2006), Boyd and Banzhaf (2007), Millennium Ecosystem Assessment (MEA) (2005) and UK NEA (Albon et al., 2011) has explored and proposed alternative definitions, typologies and classifications of such terms. However, discussions regarding the need for standardised definitions have two points of view. One regards the need for coherent definitions to be used between studies in order to carry out comparisons of results within different regions and times. This type of discussion usually centres on economic and ecological studies, such as Boyd and Banzhaf (2007) and Wallace (2007). The second point of view regards the sense and scope that those particular terms provide to the research. These studies tend to focus on the qualities and properties of social-ecological systems to be assessed (Hermann et al., 2011), for example potential management options to increase ecosystems services (Kienast et al., 2009; Fagerholm et al., 2012).

To date, discussion on definitions and classification of landscape functions and ecosystems services terms continues (Hermann et al., 2011; Krováková et al., 2015). This literature analysis aims to build on existing research definitions of *landscape functions* and to identify an appropriate classification to explore the character and components of each identified system; and secondly to disambiguate the term from ecosystems services, benefits and values.

Haines-Young and Potschin (2010) analyse the relationships and distinctions between functions-services-benefits throughout a *"cascade model"* (Figure 2.3) that has been discussed and applied in several landscape studies (Selman, 2009, 2012; de Groot et al., 2010; Hermann et al 2011; Kienast et al., 2009). The model describes *functions* as the *processes* that perform and interact within particular *social and ecological systems;* then *functions* deliver *services*, which are tangible and non-tangible manifestations of interactions between functions; these, in turn, relate *benefits* to people, who place *value* on them.

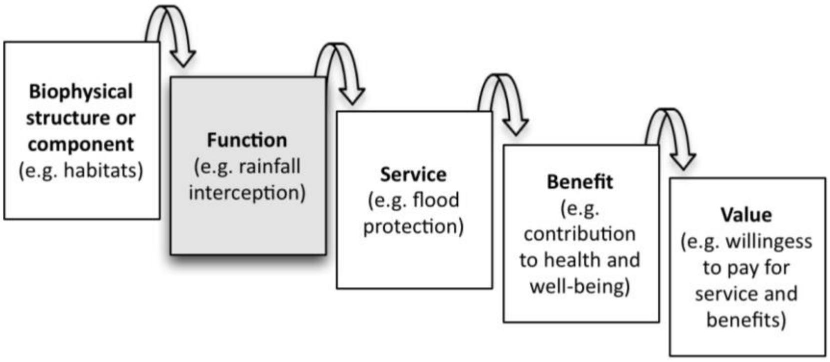


Fig 2.3. Haines-Young and Potschin (2010) *"cascade model"* differentiating functions and processes.

Another distinction between landscape function and ecosystem services is that their focus is eco-centric or anthropocentric respectively (Selman, 2009; Krováková et al., 2015). Landscape functions support the natural processes that are fundamental for ecosystems (Forman and Godron, 1986), these will continuously occur without a positive or negative human valuation (Selman, 2009; de Groot et al., 2002; Willemen et al., 2008; Kienast et al., 2009). Ecosystem services have an anthropocentric focus and they prevail because they are used and valued by people; ecosystem services, benefits and values are related to the fulfilment of people's well-being (Selman, 2009; Termorshuizen and Opdam, 2009).

In addition, landscape studies examine the particular use of the term *landscape* [function] instead of ecosystem function, referring particularly to the intrinsic capacity of landscapes to be multifunctional, in terms of the dynamics between underlying ecological and social processes (social-ecological systems) (Kienast et al., 2009; Selman, 2012; Willemen et al., 2008). Other ecosystem services studies emphasis how the term *landscape* is related to the relationships between spatial patterns and processes, and the association of landscape to the quality of place and local context (Termorshuizen and Opdam, 2009; Fagerholm et al. 2012).

Thus, this study uses and defines *landscape functions* as sub-systems that have the ***capacity*** to regulate and support natural and social processes. de Groot (2006) describes five landscape function categories as follows: *Regulation functions* are the capacity to regulate ecological processes and life support systems, thus functions within this category establish the pre-conditions for other functions to happen; *Habitat functions* are the capacity to support habitats for wildlife; *Production functions* are the capacity of a landscape to provide natural products; *Information functions* are the capacity to provide cognitive development (non-commodities); *Carrier functions* are the capacity to provide sustainable medium for human activities. Ling et al. (2007) identify two more landscape functions: *Economic functions* are the capacity to provide marketable opportunities or create wealth; and *Community functions* are the capacity to support social activity. Based on such definitions and classifications a preliminary compendium of landscape functions was assembled from different publications (Appendix 1). Although the selection is non-exhaustive and would benefit from future refinement, it has been reached via a structured search and reflects data accessibility (i.e. data availability in the public domain) and avoidance of double counting. Table 2.2 presents a summary of the landscape function classification and compendium review.

Table 2.2 Initial and preliminary landscape functions list

Classification	Landscape Function
Regulation functions	**1. Air quality regulation (de Groot et al., 2010)** Air Filtering (Bolund and Hunhammar, 1999)
	2. Gas regulation, Bio-geochemical cycler (CO_2/O_2 balance) (Constanza et al.,1997) Carbon sequestration (Whitford et al., 2001)
	3. Climate regulation (Constanza et al.,1997) Micro-climate regulation at street and city level (Bolund and Hunhammar, 1999; Albon et al., 2011) Energy exchange (Whitford et al., 2001) Wind break (Niemann,1986) Decrease of radiation (Niemann,1986) Compensation in temperature (Niemann,1986)
	4. Natural Hazard mitigation (de Groot et al., 2010) or Disturbance prevention (de Groot, 2006; Costanza et al., 1997) Land use dampening of extreme events (flooding) (Costanza et al., 1997) Interception of rain (Whitford et al., 2001) Soil drainage (McHarg, 1971)
	5. Water regulation (de Groot, 2006; Costanza et al., 1997) Water infiltration, gradual release of water, evaporation of water (Whitford et al., 2001) Water cycling (Albon et al., 2011) Hydrological cycle (Costanza et al., 1997; Daily, 1999)
	6. Water supply (de Groot, 2006). Retention and storage of fresh water (Costanza et al., 1997) Groundwater recharge (Meyer and Grabaum, 2008)
	7. Waste treatment (Costanza et al., 1997) Biota and abiotic processes in removal or breakdown of organic matter Nitrogen reduction (Bolund and Hunhammar, 1999)
	8. Erosion protection (Costanza et al., 1997; de Groot et al., 2010) Soil retention (Costanza et al., 1997; de Groot, 2006). Soil (dust) sedimentation (Niemann,1986)
	9. Soil formation (Constanza et al., 1997; Millennium Ecosystem Assessment, 2005; de Groot et al., 2010; Albon et al., 2011)
	10. Pollination (Constanza et al., 1997; Albon et al., 2011; Millennium Ecosystem Assessment, 2005; de Groot et al., 2010) Translocation processes, dispersal of seeds (Daily, 1999) Movement of global gametes (Constanza et al., 1997)
	11. Biological regulation/control (Constanza et al., 1997) Control of pest populations (Albon et al., 2011)
	12. Nutrient regulation (de Groot, 2006)

	Nutrient cycling (Constanza et al., 1997; Albon et al., 2011; Millennium Ecosystem Assessment, 2005)
Habitat functions	**13. Refugium functions** (Constanza et al., 1997; de Groot, 2006). Living, breeding, feeding and resting space and conditions for species
	14. Genepool protection Evolutionary processes and wild species diversity (Albon et al., 2011)
Production functions	**15. Food production** (Constanza et al., 1997; Daily, 1999; Millennium Ecosystem Assessment, 2005; de Groot et al., 2010)
	16. Raw materials (Constanza et al., 1997; de Groot et al., 2010)
Information functions	**17. Aesthetic** (Natural England, 2009b; de Groot et al., 2010 ; Church et al., 2011) Sensory and visual experiences (Gobster et al., 2007)
	18. Recreational (Constanza et al., 1999; Bolund and Hunhammar, 1999; de Groot et al., 2010) Using the landscape for recreational activities
	19. Cultural heritage Sense of History (Natural England, 2009b) Provision of information of past generations (Antrop, 2005)
	20. Education and science (de Groot et al., 2010) Outdoor learning experience (Fjørtoft and Sageie, 2000)
Carrier functions	**21. Space for:** Housing, energy conversion facilities and cultivation (de Groot, 2006)
	22. Transportation (de Groot, 2006) Green travel routes (The Mersey Forest, 2009) Active transport (Cerin et al., 2007)
	23. Tourism (de Groot et al., 2010) Facilities, opportunities for
Economic Ling et al., 2007	**24. Support sectors of economy** (Benedict and McMahon, 2006) Protection of working land as business Investment attraction
Communitarian Ling et al., 2007	**25. Connection of communities** (Benedict and McMahon, 2006) Building cooperation and collaboration (Selman, 2006)

2.6 Landscape planning and management

Landscape practice throughout purposeful planning and management strategies aims to influence the trajectories and character of places at a landscape scale. The literature reflects a continuous discussion and change of perspective from pursuing the delivery of *sustainable* landscapes to the acknowledgement that landscapes are constantly dynamic and changing within a contextual framework driven by relationships between nature, people and economy (Potschin and Haines-Young, 2006; Antrop, 2006; Albon, et al., 2011; Selman, 2012).

The recognition of such interconnected relationships and their potential synergies between functions (multifunctionality) demand that landscape practitioners (planners and managers) address a wider range of social and ecological objectives. Among these are conservation and protection of habitats and biodiversity, re-connection of fragmented landscapes, heterogeneity, self–organised and resilient landscapes, climate change adaptation and mitigation, social well-being, community empowerment and economy recovery (Lovell and Johnson, 2009).

The challenge is how to deal with the complexity generated by social-ecological dynamics to properly inform the direction, research and monitoring of the actions, policies and strategies for landscape re-generation (Selman, 2002; Lovell and Taylor, 2013). The integration of multiple stakeholders and the understanding of interactions between social-ecological processes (landscape functions) are two important aspects for approaching the protection, creation and re-generation of landscapes (Potschin and Haines-Young, 2013). The following sections will describe current approaches to landscape multifunctionality, aiming to address a wide range of social-ecological objectives.

2.6.1 Landscape Multifunctionality: *assessments*

To date, landscape multifunctionality assessments aim to generate knowledge and insights relevant to inform decisions and approaches for spatial planning, landscape management and policy making. However, the approaches to these assessments come from different perspectives and methodological frameworks (Mastrangelo et al., 2014). There are two key frameworks from which landscape multifunctionality is assessed, namely, spatial mapping of landscape functions, and quantification of ecosystem/function services and interactions. Some assessments comprise both analyses, such as the analysis of functions accompanied by their spatial association (mapping). The complexity of these approaches increases when they include a certain degree of stakeholder participation.

These frameworks are approached through different methods including GIS mapping, statistical models, scenario development and trade-off analysis. Table 2.3 summarises current methods of landscape multifunctionality assessment and presents some examples. The following sections explore these two key frameworks in more detail.

2.6.1.1 ***Ecosystem Services framework***

Analyses of landscape multifunctionality through ecosystem services (ES) aim to identify and quantify the capacity of the landscape to provide goods and services. This evaluation is mainly assessed through four approaches; one, ecosystems or functions are associated with land cover; two, services are quantified by indicators or proxies; three, services and functions are identified based on existing literature regarding the service on scope (for example Willemen et al., 2008); and four, the landscape is simulated through mathematical and statistical models. Then the assessments take different directions: one is the identification of the value and benefits yielded to people; the second is the assessment of the total economic value of services over a determined time period (Hermann, et al., 2011).

Table 2.3 Example of landscape multifunctionality assessments and methods.

		Methods	Examples
Multifunctionality Assessments Frameworks	Quantification of Landscape function and services and their interactions	Statistical models Trade-offs Multi-criteria analysis ES evaluation Scenarios	Meyer and Grabaum (2008) Crossman and Bryan (2009) Willemen et al. (2010) Van Berkel and Verburg (2012)
	Landscape function and Ecosystem Services mapping/ Spatial representation	Using GIS to link spatially: Indicators Proxy or associations of land cover and land use to functions	Gimona and van der Horst (2007) Willemen et al. (2008) Wolf and Meyer, 2010 Bastian et al. (2012) Mander and Uuemaa (2010 Tveit et al. (2006) Fry et al. (2009) Gulickx et al. (2013)

Ecosystem services can be identified and valued throughout different theoretical frameworks as explored by Potschin and Haines-Young (2013), namely: place-based, systems-based and habitat-based approaches. According, to these approaches, local context, participation and different analytical methods aim to integrate and understand landscape multifunctionality complexity. For example, landscape function indicators, multi-criteria analysis, and statistical analyses of spatial relations consider stakeholder participation to provide weights and values for optimization and trade-offs. However, the final aim of ecosystems services quantification is to evaluate, assess and represent the current or potential capacity of landscape functions to deliver services (Termorshuizen and Opdam, 2009; Manstrangelo et al., 2014). As previously discussed, ecosystems services exist because people value them, yet underlying functions producing or supporting them cannot be identified.

2.6.1.2 *Spatial analyses: landscape function mapping*

Landscape multifunctionality assessments through landscape function mapping aim to spatially identify landscape functions and their related ecosystems services. Landscape function mapping methods use GIS to link spatially referenced raster cells and their hierarchical weight in terms of the capacity (quantification) of specific landscape functions.

Existing studies discuss two main purposes for landscape function mapping. One purpose is to identify areas of opportunity for intervention (Verburg et al., 2009). These spatial analysis produce three different maps: i) individual landscape function maps illustrating how many ecosystem services are provided; ii) multifunctionality maps (quantification of landscape functions juxtaposed in a determined land cover, e.g. Willemen et al., 2010, The Mersey Forest, 2009); iii) hot or cold spots maps (the spatial identification of landscape functions enhancing or hindering another function, e.g. Gimona and van der Horst, 2007, Egoh et al., 2008 and Willemen et al., 2010). The second purpose explored is the use of maps for supporting communication between stakeholders and assessing specific locations and current capacity in multifunctional landscapes (Kienast et al., 2009; Bollinger et al., 2011).

2.6.1.3 *What is the problem? Assessment constraints*

To date, there is a continuing discussion within studies assessing and exploring landscape multifunctionality. The general argument is that existing data and methods do not provide a holistic account of landscape multifunctionality complexity.

Existing and available data in the form of indicators, proxies, census and spatial data are described as dealing with high levels of bias, uncertainty and ambiguity (Beunen and Opdam, 2011; Hermann et al., 2011). For example, Verburg et al. (2009) explore data limitations: in certain countries, census data is economic sector driven and the sampling and reliability of variables is poor; remote sensing data for land cover/ use identification has not been interpreted properly, is missing linear landscape structure, and is constrained to regional scale; and not all landscape functions can be observed directly from land cover analysis, something which applies even more seriously to interactivity between functions.

Furthermore, when primary or baseline data from the region under review or the processes itself are not available, then *proxies* (proxy data) are commonly used in landscape function and services mapping approaches. Proxies are generally not developed for the specific purpose of mapping landscape functions or services, but are retrofitted by giving them specific interpretations (Maes et al., 2012). Examples of proxies used within landscape function mapping are: representative sampling and raster land cover maps (Eigenbrod et al., 2010); and identification of ecosystem components that indirectly inform the spatial location and capacity of landscape functions (Egoh et al., 2008). Another type of proxy includes estimates derived from modelling ecological processes used as indicators to identify and quantify landscape functions and services (Maes et al., 2012). However, although proxies have been successfully applied (e.g. Egoh et al., 2008; Naidoo et al., 2008; Eigenbrod et al., 2010; Willemen et al., 2010), they sometimes fail to respond to local contexts, particularly those relevant to social and cultural landscape functions (Verburg et al., 2009).

Because of the complex nature of landscape functions and ecosystem services valuation assessments tend to constrain the number of landscape functions explored. These analyses depend on accessibility to data or the objectives of the study. Because of the complexity of dynamics between functions, assessments also have the tendency to break down processes and analyse them individually. More recent studies agree on the need to move from the static representation of stocks and flows of landscape functions, to focus on their relationships and feedbacks (de Groot et al., 2010; Hermann et al., 2011, Bastian et al., 2012; Potschin and Haines-Young et al., 2013; Manstrangelo et al., 2014). However, to date, methods and data still fail to support landscape practitioners with a comprehensive illustration of landscape function dynamics (Bastian et al., 2012; Potschin and Haines-Young et al., 2013; Manstrangelo et al., 2014). This literature review is therefore reaching the shared conclusion that a combination of approaches is necessary in order to truly understand landscape dynamics (Potschin and Haines-Young et al., 2013; Manstrangelo et al., 2014).

2.7 Landscape Multifunctionality and Stakeholder Participation

People have an integral and fundamental role in the emergence of multifunctional landscapes (Lovell and Johnston, 2009). As explored previously, landscape multifunctionality is the manifestation of interactions between natural and social systems, placing land users and landowners as fundamental parts of the systems. Other multifunctionality attributes related to people include crossing multiple scales, boundaries and levels of organisation, as well as addressing landscape multifunctionality through a trans-disciplinary approach (section 2.3).

Parallel to landscape multifunctionality, landscape practitioners and policy makers are encouraging participation processes, with citizens now being increasingly willing to engage in stakeholder participation exercises (Beunen and Opdam, 2011; Fish and Saratsi, 2015). In Europe, the European Landscape Convention (ELC) (Council of Europe, 2000) is one of the main instruments promoting stakeholder participation in landscape practice (Jones, 2007; Sevenant and Antrop, 2010). At a global scale, stakeholder participation is also recognised as an important approach towards knowledge generation and decision-making (Beunen and Opdam, 2011). Stakeholder participation is a subject of study in its own right. Its discussion ranges from philosophical arguments of democracy, empowerment and legitimation of approaches and decisions to methods, efficiency and impact of its application (Schroth, 2007). But also, participation and public engagement research identify negative issues related to conflicting perspectives, objectives and difficulties in encouraging equal opportunities for participation (Butler and Berglund, 2014). This literature review explores these elements and ways of proceeding towards stakeholder participation. The following sections will explore attributes important to stakeholder participation approaches.

2.7.1 Results from stakeholder participation

Stakeholder participation is defined as a collaboration process (Opdam et al., 2008; Palacios-Agundez et al., 2014). The term stakeholders refer to individuals and groups that share an interest or responsibility in influencing and promoting decisions that have an effect on them or on others (van Asselt Marjolein and Rijkens-Klomp; 2002; Reed, 2008; Palacios-Agundez, et al., 2014). Participation processes aim to inform routes of action by interacting with and learning from pertinent beliefs, interests and knowledge (Reed, 2008).

The literature classifies the results generated from participation in two: a) normative benefits and b) pragmatic benefits. Normative benefits are those related to democracy of decisions and empowerment of citizens. Pragmatic benefits relate to the quality of knowledge generated and the acceptance and efficiency of decisions negotiated (Reed

2008). These qualities are mainly achieved by increasing public trust through a transparent consideration of existing points of view; and by the co-generation of knowledge and increasing stakeholder capacity to understand and use such knowledge (Jones, 2007; Reed, 2008). Knowledge interchange between stakeholders provides information about local needs and priorities; then scientific and generic knowledge can be adjusted to local conditions. When stakeholders are empowered by allowing them to identify and establish their own needs and values, and share their empirical knowledge, then the community tends to understand, accept and lead and protect the decisions reached (Termorshuizen and Opdam, 2009; Reed, 2008).

2.7.2 Participation goals

Stakeholder participation has different degrees of 'participation'. The degree of involvement underpins planning, justification, approaches and analysis of participation processes (Reed, 2008). Arnstein (1969) described participation involvement as a "ladder" that climbs from "passive dissemination" of information between participants, to "active engagement" of citizens when they take control of the situation on scope. Rowe and Frewer (2000) identify types of involvement as an alternative to classifying participation in terms of 'how much'. Their first type of participation is referred as "communication" or provision of information to stakeholders. Then there is "consultation", which occurs when information is collected from stakeholders. Finally, there is "participation", regarded as the actions of "*dialogue"* and *"negotiation"* between stakeholders and the governance body. Another and more recent analysis of participation levels comes from Stirling (2006). He ranks participation according its targets. He identifies participation as *"normative"* when it aims to achieve equity, empowerment and democracy, without leading to something else. He sees *"substantive"* participation as something which integrates participation with a type of analysis centred on collecting multiple perspectives and *"local-context"* information for a complete and extensive description of needs and values. Finally, he notes *"instrumental"* participation aimed at increasing "*credibility"* and *"trust"* by looking at how to apply, justify and legitimate the decisions reached. According to Sevenant and Antrop (2010), the European Landscape Convention (Council of Europe, 2000) encourages *substantive* and *instrumental* participation.

2.7.3 How to approach stakeholder participation

To approach stakeholder participation, it is necessary, first, to establish the degree or proportion of participation which is being aimed for (as the above section explores). These set the premises for how participation will be approached in terms of when participation will occur, who is going to participate, the methods to collect and analyse the information, and how to facilitate dialogue. The establishment and planning of a clear participatory methodology contributes to the achievement of a transparent, articulated and legitimate participation process that offers opportunities for dialogue, learning and knowledge generation (van Asselt Marjolein and Rijkens-Klomp., 2012; Henningsson et al., 2014).

The literature suggests that inputs from participation vary according to the process at which participation occurs. Participation at the beginning of the process relates to goals and objectives setting. At the middle, participation is associated with analysis and design phases. And at the end of the process it is concerned to the evaluation and monitoring of something already determined (Beunen and Opdam, 2011; Henningsson et al., 2014). Literature suggests that stakeholder participation is important through all the assessment process; however, it is generally limited according to resources available (Reed, 2008).

As explored before, stakeholders are the individuals and groups that share an interest in influencing knowledge and decisions; such generated understanding will have an effect on them or on others (van Asselt Marjolein and Rijkens-Klomp; 2002; Reed, 2008; Palacios-Agundez, et al., 2014). In the landscape context, stakeholders are the general public, authorities (local and regional), volunteering organisations, landowners, land users, practitioners and other experts. It is important to demonstrate a clear approach of stakeholder identification (van Asselt Marjolein and Rijkens-Klomp, 2002). Stakeholder selection requires that the practitioner has a clear understanding of their interest and their character (Sevenant and Antrop, 2010).

Objectives of participation methods are to provide a platform for collecting information from stakeholders, analysing and making sure that what they said is taken into account, and encouraging dialogue and communication between participants (Henningsson et al., 2014). Existing literature explores a wide range of stakeholder participation methods. These are characterised by openness and flexibility to adapt to the researcher or practitioner needs (Patel et al., 2007), but also these are criticised for lack of structure (van

Asselt Marjolein and Rijkens-Klomp, 2002). Although methods are thus flexible, their selection has an impact on the *"size, quality and diversity"* of participation (Patel et al., 2007). Existing methods can be classified according to *'one-way'* or *'two-ways'* communication types. One-way flow communication occurs when there are no opportunities to interchange dialogue. Two-way communication requires interacting in order to encourage discussion, reflection, moderation and debate (Patel et al., 2007). Table 2.4 illustrates a list of methods used in stakeholder participation processes.

Table 2.4. Stakeholder participation methods, based on van Asselt Marjolein et al., 2002; classified according to flow of communication.

Method	One-way communication	Two-way communication
Focus groups		x
Stakeholders workshops		x
Scenario Analysis Techniques: backcasting and forecasting (Patel et al., 2007)		x
Participatory modelling		x
Participatory planning		x
Consensus conferences	x	
Policy exercise	x	
Citizens' juries	x	
Interactive landscape visualization (Schroth et al, 2011)		x
Public meetings	x	
Questionnaires	x	
Multi-criteria evaluation	x	

In methods classified as "two-way communication" approaches, it is important to consider the role of facilitation and facilitators (Luz et al., 2000; Schroth et al., 2011; van Asselt Marjolein and Rijkens-Klomp, 2012). Facilitation is the process that leads and guides dialogue. Facilitators have the responsibility of understanding the principles of methods and existing communication strategies. These encourage gaining the interest and focus of participants but also avoid reinforcing negative group dynamics, stakeholders' personalities and attitudes between power structures, privileged and minority voices (Reed, 2008).

Although stakeholder participation is widely promoted and applied to landscape research and practice, there are still several barriers and consequences to participatory approaches. The key barriers to participation are governance attitudes and resources. Stakeholder participation requires large input of time and monetary resources (van Asselt Marjolein and Rijkens-Klomp, 2002). Attitude barriers correspond to the integration and dialogue between scientific/expertise knowledge and empirical evidence. The literature argues that resistance to listen, consider and discuss empirical evidence comes from experts and scientists (Luz et al., 2000). However, stakeholders have negative attitudes to participation, which adversely affects participation and engagement (Reed, 2008). Attitudes reinforce feedback processes between each stakeholder party (expert vs. lay). Although interests will continue to exist and will not remove conflicts (Fry, 2001), a successful participation process will reduce or enhance credibility, perception of rewards and gains, and willingness to participate (Reed, 2008).

Through sections 2.6 and 2.7 this literature has explored existing key frameworks aiming to assess landscape multifunctionality, including stakeholder participation processes. In response to existing assessments' elements such as constraints of data quality, uncertainty and dynamics generated, this thesis aims to explore landscape multifunctionality through a systems theory lens with the purpose of approaching landscape multifunctionality as a property and framework to encourage the emergence of highly valued landscapes. The following sections will explore in detail the theoretical background of systems thinking.

2.8 Systems thinking

The literature proposes that the objective of exploring landscape multifunctionality as a system, in particular as a social-ecological system, is not only the study of relationships between landscape functions, but also of placing people as an integral part of the system. It is important to highlight that landscape multifunctionality does not study the stock and flow of ecosystems services and the values derived from them. In principle, it proposes that if the relationships and links between underlying landscape processes are understood, then landscape practitioners will be enable to identify how to intervene *purposefully,* to then change and *transform* the dynamics to regenerate or restore damaged landscapes (Pickett et al. 2004; McAlpine et al., 2010; Lovell and Taylor, 2013).

The study and exploration of social-ecological systems and complex systems is based on the construction of analytical models. In this context, models are constructions of a situation, and represent the components, boundaries, interactions and dynamics of a system (Pickett et al., 2004). In the particular case of social-ecological systems, modelling approaches aim to describe the system's dynamics and to support novel knowledge and decisions that will lead to changes in the system (Pickett et al., 2004; Paavola and Hubacek, 2013). Nevertheless, the challenge in practice is the representation and analysis of social-ecological systems without missing the key properties previously discussed, namely, understanding systems as a whole; observing them throughout multiple perspectives; and not modelling social dynamics in a mechanistic way (Polhill and Gotts, 2009) as the systems are unpredictable and have non-linear feedbacks (Moore et al., 2014).

Modelling can be approached through quantitative and qualitative methods. Quantitative approaches aim to simulate and predict a particular system by segmenting and modelling its subsystems and components. These are described as "hard systems", and favour modelling through mathematical, statistical and computer simulations. Although hard systems analyses are characterised by their rigour and validity in the science sphere, there are certain limitations to their application, especially when dealing with the complexities generated by integrating people in the system (Oreszczyn, 2000). The other limitations to hard systems approaches are similar to the ones discussed on section 2.6.1.3 of this chapter, for example: data is uncertain and fragmented (The Open University, 2013); indicators and proxies do not provide local context information; and models tend to be inaccessible because their interpretation requires knowing the specific language of for example the software used (Polhill and Gotts, 2009; Potshcin and Haines-Young, 2013). The integration and analysis of social processes is the main challenge of hard systems analysis. Hard systems either treat social processes as mechanisms that can be *engineered* to a specific state (Cundill et al., 2012), or else places people outside the processes. Also, hard systems analyses fragment the system into individual processes, representing 'reductionist' thinking (The Open University, 2013). Some researchers argue that analysing an individual system's processes and components does not address the complexity generated by relationships between the systems components, thus failing to understand a system as the whole (Polhill and Gotts, 2009).

As a response to these limitations the approach of *Systems Thinking* emerged. Systems thinking challenges hard systems not as a particular methodology but rather as a *thinking* process (Bosch et al., 2007; Cabrera et al., 2008), which aims to study a system as a *whole* that is yet part of larger relationships with other systems, which in turn give the system its context and significance (Oreszczyn, 2000; Bosch et al., 2007; Cabrera et al., 2008; The Open University, 2013).

Systems Thinking is an approach that places special importance on the enquiry and learning processes rather the procedures *per se* (Cundill et al., 2012). It encourages *systemic* thinking (integral to connected wholes) as opposed to systematic thinking (linear procedures and their cause and effect relationships) (The Open University, 2013). Oreszczyn (2000) explains that systems thinking modelling aims to model the logic of (inter alia) social-ecological systems, as opposed to hard modelling that aims to model the system individually. The logic of the systems is understood by making explicit that models are constructed from a particular 'perspective' of the world and makes it evident, so other perspectives can be compared. This is one way whereby systems thinking integrates people within the systems. In the case of social-ecological systems, because of their multiple actors with different objectives, there will be many ways to describe their logic (Polhill and Gotts, 2009). Systems thinking is characterised as a qualitative, participative and action research approach (Oreszczyn, 2000).

Furthermore, systems thinking approaches are frameworks that comprise methods of analysis that define the system of interest and its components and techniques of modelling through the use of diagramming. One approach which has emerged within Systems Thinking is Soft Systems Methodology. Peter Checkland and collaborators from Lancaster University, in England, developed Soft Systems Methodology (SSM) as a response to deal with the complexity generated within *"problematic social situations"* where people involved have different points of views, which are continuously changing as they aim to do something to transform a system *"purposely"* and *"intentionally".* More aspects on SSM will be explored in the following section.

2.9 Soft System Methodology (SSM)

SSM is a system thinking approach which is mainly described as process of enquiry. SSM aims to structure *thinking* and *debate* in order to *learn* about a *problematic situation* to be described in terms of systems and relationships. In turn, this new learning about the system and its interconnectedness will direct and formulate what is necessary to improve and transform the relationships' trajectories of the situation in scope. Initial applications of SSM describe the process as a seven stage cycle (Checkland, 1981; 1999; Checkland and Scholes, 1999; Checkland and Tsouvalis, 1997). However, throughout years of practice and maturity, SSM has been developed into a four stage approach (Checkland and Poulter, 2006; 2010). Figure 2.4 illustrates the SSM learning cycle.

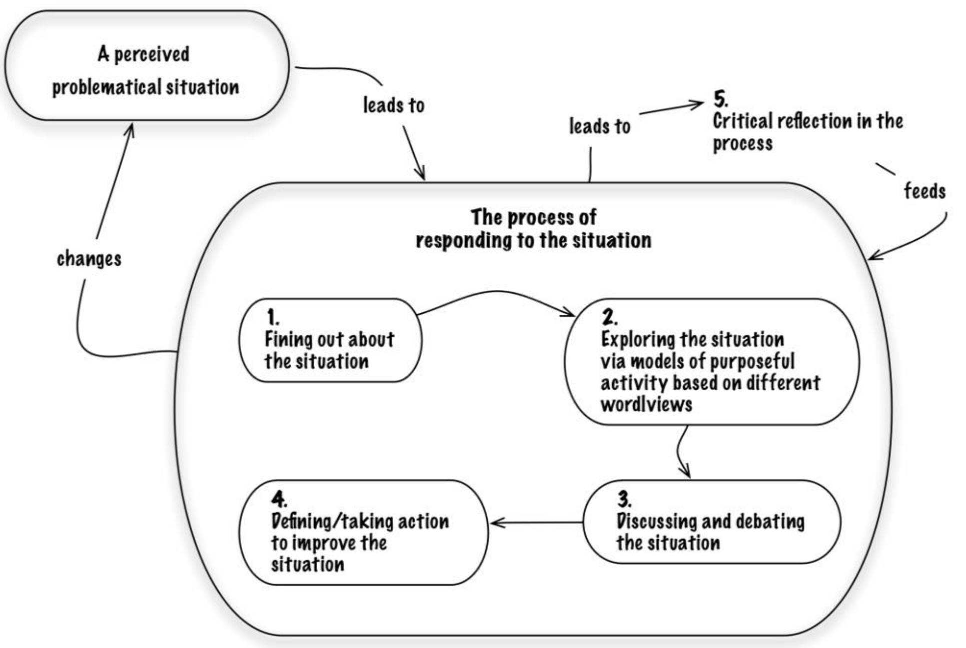


Figure 2.4. The SSM learning cycle and its key activities, based on Checkland and Poulter (2010).

The first SSM stage is referred as the *"finding out"* stage. *Finding out* about the problematic situation requires collecting as much information as possible through meetings, talking informally or formally interviewing people. This stage presents opportunities for stakeholder participation. The information assembled should represent the multiple perspectives and relationships between components, stakeholders and organisations occurring within the system. SSM recommends representing the information collected through the use of *"rich pictures"* diagrams; Checkland and colleagues identify graphics as helpful tools to illustrate complex relationships. During this stage, there are three analysis exercises, namely, "Analysis One, Two and Three". These three analyses aim to identify the roles, norms, values of stakeholders, as well as to recognise who is asking to intervene and who is carrying out the analysis. Attributes of this SSM stage relate to properties sought on research studies aiming to understand complexity, for example Kay et al. (1999) comment on the importance of understanding a system through different perspectives, including ecological and social points of view.

The second SSM stage aims to build *"purposeful activity models"*. These conceptual models are constructed through carrying out a series of analyses that will lead to carefully defining the *"transformation process"* and the *"perspective"* from which these will be built. The models will attempt to illustrate the situation from a single perspective only, and they should be different to what is happening in "reality". These differences are what will encourage dialogue and discussion in the following stage. The transformation processes identified in this stage relates to the social-ecological system's property of transformability, a quality which refers to the capacity of the system to change the directions of its dynamics (Folke et al., 2010). This thesis will pay particular attention to this and the following discussion stages as they could potentially inform where and how landscape practitioners can intervene to transform the system towards desirable change supporting emergent properties (Moore et al., 2014).

The objective of the third SSM stage is to carry out a structured discussion between the system actors. For this discussion stage, the conceptual models are used as instruments to ask questions and prompt dialogue. Then, from this dialogue the aim is to exchange points of view about the activities, such as, who will conduct the activities and how will they be carried in the real world situation and what or how can they change and who else could effect the changes. Figure 2.5 illustrate the role of conceptual models within this SSM discussion stage.

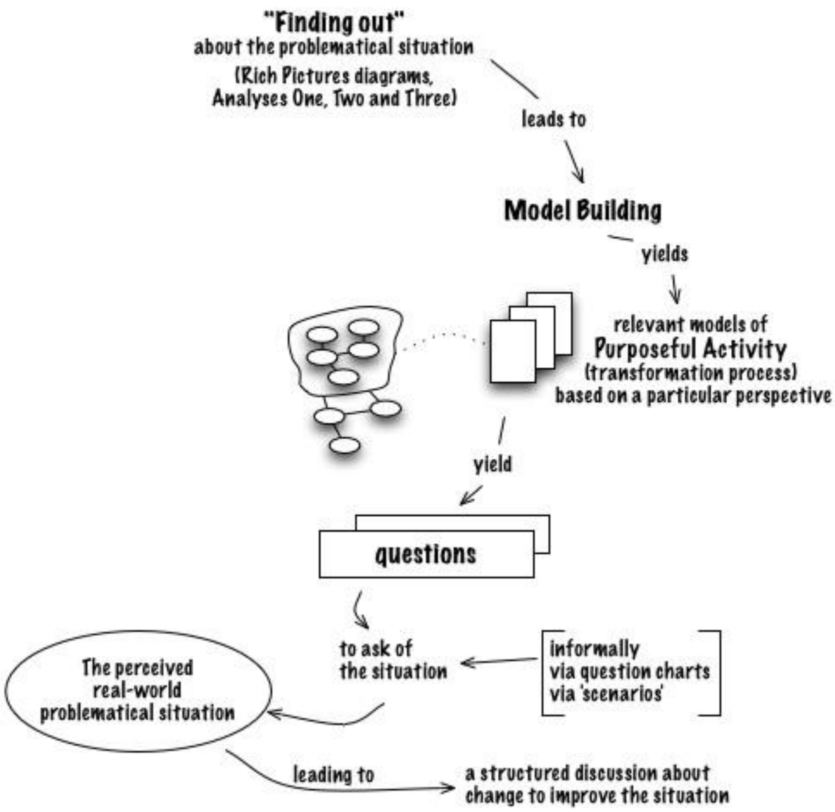


Figure 2.5. The role of conceptual models within SSM, based on Checkland and Poulter (2010).

Finally, the purpose of the fourth SSM stage is to discuss and analyse the results from the third SSM stage discussion, aiming to identify and determine specific courses of actions to improve the *situation*. Checkland and Poulter (2010) explain that consensus between people is rarely reached, and it is generally more common that people will have to agree to adapt, adjust or tolerate to some degree the proposed changes within the particular local context of the situation; a research study by Butler and Berglund (2014) evaluating participation in landscape character assessment uncovered the same issue of difficulties of reaching true consensus through participation.

For purposes of legibility, the literature describes SSM as a linear process comprised of steps, nevertheless SSM authors discuss that in practice SSM takes the form of an interactive and dynamic learning cycle process which requires to actively involve key people within the system and the situation.

2.9.1 SSM application

SSM was originally developed within the context of institutional and human management practice (Mingers and Taylor, 1992). However, there are growing numbers of relevant examples of SSM applied to social-ecological systems. For instance, Bunch (2003) applied SSM to explore and re-define the Cooum River in southern India as a social-ecological system. In this research study, SSM allowed stakeholders to re-assess the problem of pollution by including “human activities” as the responsible driver leading to the contamination and alteration of the river. Furthermore, the study carried workshops within the discussion stage that led to identifying desirable cultural interventions (for instance, educational awareness) to improve the problematical situation of the river, rather than only considering physical interventions to the river. Another example is the research study carried out by Habron et al. (2004). They used SSM to gain a better understanding of social processes and organisational structures impacting watershed management, with a particular focus on integrating social processes for studying the effect of road salt use for de-icing on the analysis of biochemical water processes. Through the use of SSM the researchers were able to identify organisational interactions and roles, which in turn facilitated collaboration between agencies and the development of mutual goals and objectives and establishment of new data collection and sharing practices, for example precise data concerning the transport, destination and use of road salt each winter season.

In 2006, Bowler used certain SSM approaches in order to integrate qualitative components and social processes in the study of the Irish Sea as a social-ecological system. Rich picture diagrams were developed and supported the collection and analysis of data from natural and social science; conceptual diagramming techniques supported a further DPSIR (Drivers, Pressures, State, Impact and Responses) framework modelling stage, and emphasised the importance of a research focus on social-ecological systems. In a more recent study, Alexander et al. (2015) applied SSM in an expert workshop for inquiring into the implementation of the Marine Strategy Framework Directive (MSFD) as a European Union policy and its influence on provisioning ecosystems services in the marine region referred to as the North East Atlantic sea. During the workshop and through exploration of three case studies participants described the *‘problematical situation’ and* developed a conceptual model, which in turn was used to discuss and examine the *‘problematical situation’* and finally to define the actions required. The main result from this enquiry process was the identification of four issues that hinder the implementation of MSFD, namely: "*variability in the system, cumulative effects, ecosystem resilience, and conflicting policy targets".*

SSM has been applied in the context of environmental management aiming to include and explore a wide range of social and ecological objectives. For example, Mendoza and Prabhu (2006) explored SSM and different conceptual models methods to assess sustainable forest management. They identified SSM as participatory method that provided structure to discuss and evaluate different management strategies. Matthews and Selman (2006) reviewed SSM as a helpful approach for an initial identification of the "nature, direction and strength" (p.206) of the interactions and feedbacks between the systems' components. Another example is Watkin et al. (2012), who applied SSM to explore the problems related to the development of a micro-hydropower source; SSM supported the identification of several conflicts with stakeholders that changed the original project objectives from further investigation to stopping the development. Dobson et al. (2014) used SSM to structure and frame a problematic situation regarding energy planning in an urban area, to then carry out a multi-criteria analysis to assess different possible approaches. The final example is the research study by Guay and Waaub (2015), who applied SSM to gather and structure information to support decisions regarding regional spatial plans in Quebec, Canada.

These SSM examples approach the methodology in different ways; for example, through different approaches to modelling or participation processes. The results from these SSM examples show that the methodology is participatory, as well as a learning process that satisfactorily informs and explores complex situations; furthermore, despite SSM limitations as '*inquiry process'* only it has successfully accounted for important social issues, processes, roles and structures within the systems under review.

2.10 Conclusions

The objective of this literature review was to review and explore relevant concepts of multifunctional landscapes systems and provide a theoretical research background to support the various steps of this research study. First, it explored landscapes as social-ecological systems characterised by complex dynamics between underlying processes which in turn are responsible for desirable emergent properties such as multifunctionality, resilience and distinctiveness. Then, it explored and defined landscape multifunctionality not only as a landscape quality but also as an approach that through certain attributes aims to comprehensively address landscape dynamics. The literature review also emphasised how this research study aims to shift the focus towards landscape functions contrary to current tendency of research to look at ecosystem services. Thus, landscape functions were examined as the appropriate term to refer to a wide range of social and ecological underlying processes at a landscape scale. This chapter has also assessed existing approaches to landscape multifunctionality and their limitations, concerning landscape dynamics and complexity; limitations typically referred to existing data quality, such as uncertainty and lack of availability, often in relation to interactions occurring at different spatial and temporal scales. Furthermore, as part of its review of landscape multifunctionality attributes, this considered aspects of stakeholder participation processes.

The literature review illustrates a current shift of thinking beyond sustainability towards complexity generated from interactions and feedbacks between social and ecological systems; although some studies look into social-ecological systems through process-based and systems theory approaches, hard systems methods are subject to the previously noted limitations. There are, however, some studies which have used systems thinking approaches in order to address complexity by learning about the system and engaging with stakeholders.

Some research studies have explored social-ecological systems throughout SSM as a specific approach to systems thinking. The present research study identifies certain SSM qualities appropriate to address landscape multifunctionality attributes for landscape practitioners to identify points of intervention to encourage the emergence of resilient, multifunctional and distinctive landscapes. However, this literature review identified gaps which need to be addressed before applying SSM; these include the lack of clarity and distinction (spatially and descriptive) of a wide range of cultural and ecological landscape functions underlying processes and components. Subsequently, the thesis aims to develop through SSM a range of conceptual models aiming to depict landscape function dynamics, and to explore and apply those in a specific case study. The introductory chapter and the literature review provide the theoretical context to this research thesis; the following chapter will explore the proposed methodological framework, case study and methods.

Chapter 3| Research Methodology

3.1 Introduction

The purpose of this chapter is to describe the methodological approach adopted in this thesis. The initial review of literature (Chapter 2) explored landscape multifunctionality as an approach that, through purposive landscape interventions, could support and set appropriate 'initial conditions' to speed up the emergence of multifunctional, resilient and distinctive landscapes. Also, the literature review provided an overview of landscape multifunctionality assessments based on underlying functional processes as an alternative or complement to the current emphasis on linear evaluations of ecosystem services and benefits delivery. Finally, the literature considered opportunities to explore landscape multifunctionality as a complex social-ecological system, specifically through a systems thinking view associated with Soft Systems Methodology. These reflections led to the development of this thesis aim, research objectives and methodological framework.

3.2 Research aim and objectives

Although this study aim and objectives have already been set out in the introduction chapter, it is helpful to re-state them in this methodology chapter to explain their implications and rationale.

An analysis and interpretation of existing literature has underpinned the thesis aim: *to explore and to apply a systems thinking approach to support and to provide a comprehensive illustration of landscape function dynamics and landscape multifunctionality properties.*

The literature review found a number of gaps regarding the clarification and definition of landscape functions, so, in pursuit of the thesis aim, the following study objectives were elaborated:

1. To critically disambiguate and establish the current state of knowledge and theory with regard to the range and nature of landscape functions as landscape systems.

2. To develop an approach to landscape function mapping in order to spatially identify and reflect the extent and direction of landscape systems.

3. To explore Soft Systems Methodology as a Systems Thinking approach to understand and address landscape multifunctionality properties in order to inform potential applications of this framework in landscape practice in future.

3.3 Methodology: *a systems thinking approach*

Overall, this thesis methodological framework comprises a diverse range of methods. These methods are each directed at resolving a particular objective; nevertheless, the exploration and outputs of all the proposed objectives interact to form an overall assessment of landscape multifunctionality complexity. Figure 3.1 explores the overall framework and the relationship between each method proposed.

This research strategy and theoretical framework are underpinned by *systems thinking* approaches. This thesis will study the landscape as a *social-ecological system* where people are integral to the ecosystem but also have an interconnected relationship with the landscapes. *Systems* are wholes formed by interacting and interconnected parts (O'Leary, 2007; Ison, 2008). There are two positions approaching *systems thinking* (Cabrera et al., 2008; Ison, 2008; Reynolds and Holwell, 2010). One relates to *thinking about the systems* (Cabrera et al., 2008) as the representation of entities and processes that could be reached and described through defined and interconnected components, also referred to as *'hard'* systems. Here the systems are assessed through mathematical modelling aiming to find how they can be "engineered" towards effective and efficient performance (Oreszczyn, 2000; Reynolds and Holwell, 2010). The second approach is *systemic thinking*, referring to the process of ***learning*** about a system in order to understand the nature of the relationships and interconnections between the system's parts (components); this is referred to as a 'soft' system approach (Checkland, 1999). This position emerged as a response of hard systems approaches failing to support complexity involving humans and social phenomena (Oreszczyn, 2000; O'Leary, 2007). Table 3.1 illustrate main differences between hard and soft systems approaches.

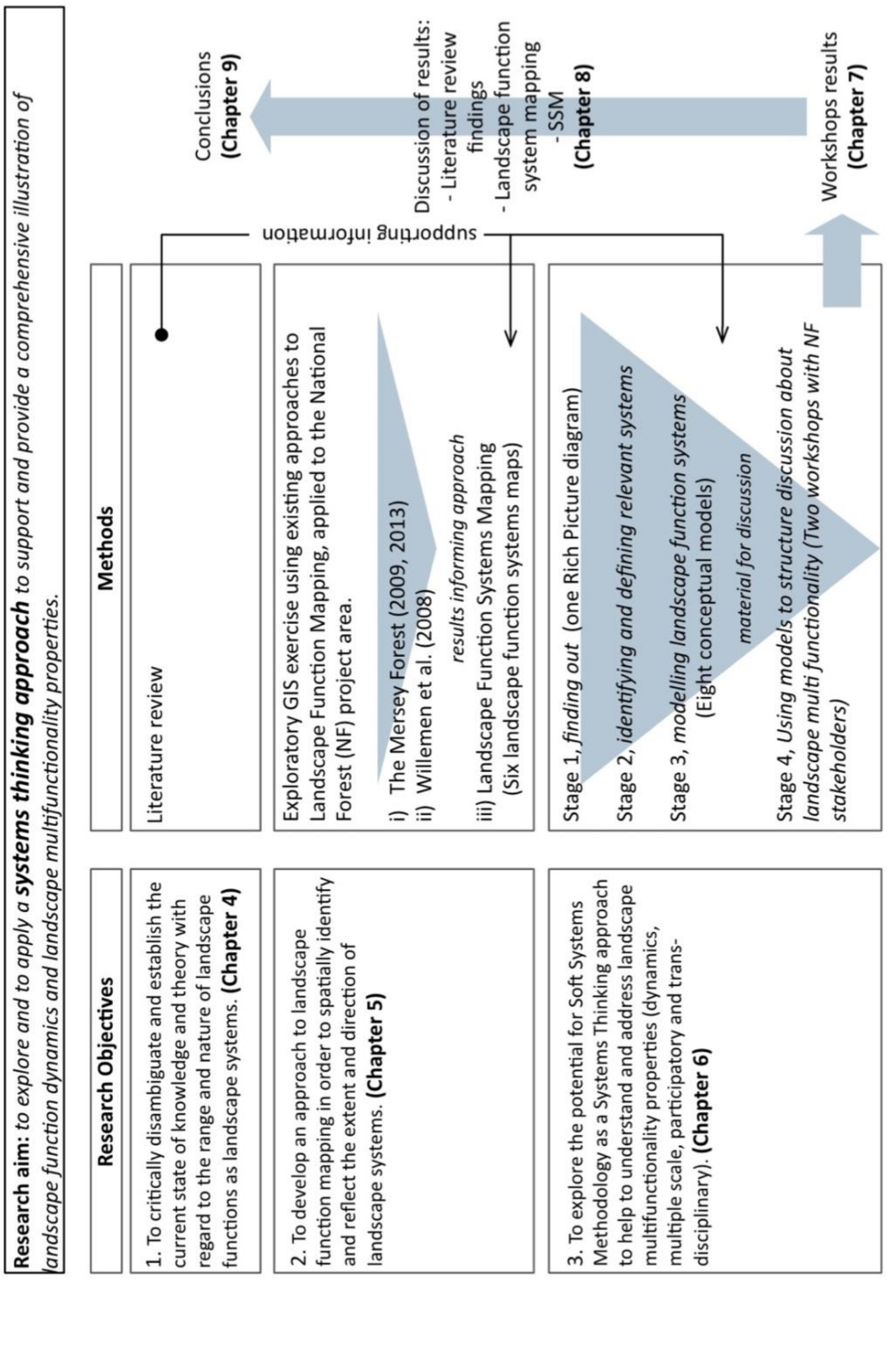


Figure 3.1 Diagram illustrating the overall methodological framework of the thesis.

Table 3.1. Differences between *hard* and *soft* systems approaches, adapted from Checkland, 1985; Oreszczyn, 2000; and Ison, 2008.

Hard Systems	***Soft Systems***
Pursues to achieve goals and objectives	Pursues learning
Presumes that all systems can be modelled and engineered	Presumes that problematical situations can be explored in systemic models
Identifies *problems* to find *solutions*	Identifies *issues* to explore *adjustments*

It is important to highlight and not to confuse *systemic thinking* with *systematic thinking*, where the latter refers to the use of pre-determined and successive steps (Ison, 2008). In addition, *systemic thinking* requires *holistic thinking* (The Open University, 2013) aiming to look at wholes and not the individual parts; holistic thinking includes identifying what is a whole and what is a part; and looking at interconnections and relationships of the whole within the whole's context (Oreszczyn, 2000; Cabrera et al., 2008; Reynolds and Holwell, 2010).

Regarding an epistemology position, Reynolds and Holwell (2010) argue that systems practitioners see systems approaches as *conceptual constructs* of the real world through different contexts, and they view systems thinking as a constructivist epistemology. The goal of this epistemological position is to develop an understanding constructed within an individual, instead of truly to resolve, predict or control something (Saldaa, 2011). Figure 3.2 illustrates systems approaches in a constructivist epistemological position.

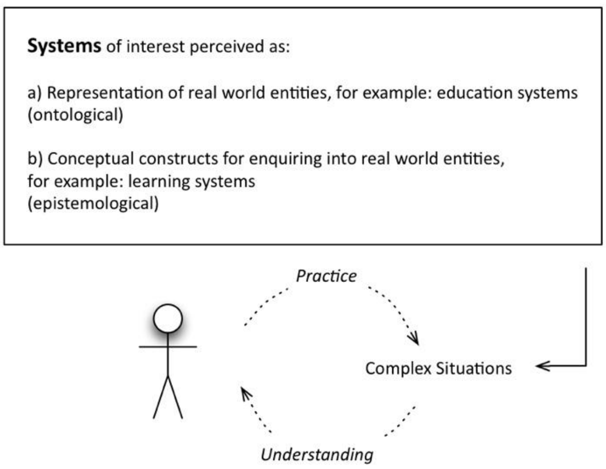


Figure 3.2 Illustrates Systems Thinking in a constructivist tradition, based on Reynolds and Holwell (2010) (p.7)

This thesis considers soft systems approaches to be more appropriate to studying landscape multifunctionality because of their three main properties emphases: on relationships between components and people; on context; and on people's learning process that requires including multiple perspectives or points of view. Reynolds and Holwell (2010) describe soft systems thinking properties as holistic and plural.

In summary, this thesis methodology strategy is based on a systems thinking approach; it will combine different methods and multiple resources (section 3.5), aiming to inform landscape multifunctionality through studying context, relationships and interactions and incorporating multiple points of view. All the proposed methods will be applied to a particular case study, the National Forest Company (section 3.4).

3.4 Case study

A case study research approach aims to explore situations or cases that are either of interest for the researcher, or have the capacity to illustrate and inform a phenomenon regarding the issue or situation (Francis, 2001; Mabry, 2008; Baxter and Jack, 2008). Case study approaches have twofold qualities: a) their ability to study complex social processes, and b) their consideration of the contextual circumstances influencing the situation, such as cultural, political, historical, organisational factors (Mabry, 2008). A single case study approach was selected for this thesis, as a way of applying multifunctional methods in a real landscape.

A single case study allows resources to be concentrated on the extensive exploration of the context and circumstances that make a case unique and or exceptional (Stake, 2000; Simons, 2009). However, a single case study does not allow cross-case analyses, where information gathered from several case studies is compared; and for example, differences or similarities are identified within different contexts, which therefore supports generalisation of findings. Results from multiple case studies are characterised as valid and reliable (Baxter and Jack, 2008). Nevertheless, case study exponents maintain that a single case study provides an opportunity to explore a *situation* in-depth, and that this is equivalent to the advantages of a multiple case study approach; but requires the researcher to identify any limitations on the transferability of the results. The research should also be ready to justify the merits of the findings by adequate case study selection, and an appropriate research design with rigorous procedures for data collection and analysis, which in turn will provide an adequate understanding and interpretation of the findings (Stake, 2000; Baxter and Jack, 2008; Simons, 2009).

The selected case study is the project area of the National Forest (NF) in the East Midlands, England. The use of this case study is “exploratory” (Yin, 2003) and “instrumental” (Stake, 1995). It is exploratory because it provides contextual information to the thesis methodology; and it is instrumental for its supportive role in accomplishing the landscape function mapping exercises (section 3.5.2 and Chapter 5) and applying Soft Systems Methodology (section 3.5.3 and Chapter 6).

The NF project area was selected as an example of landscape regeneration that aims to deliver a wide range of social-ecological objectives (Potschin and Haines-Young, 2006; DEFRA, 2013; NFC, 2007). From its establishment in 1991 to date, the NF’s strategies, objectives and actions comprise opportunities for the creation of multifunctional landscapes. For example, the NF’s strategies were drawn through stakeholder and community participation (Sheail, 1997; Williams, 2006; NFC, 2014); the NF includes a strategy reflecting landscape character and landscape change and the European Landscape Convention (NFC, 2008); and finally, their strategies are delivered through existing organisational partnerships. Furthermore, it is an active project area informing research (NFC, 2014) and developing a comprehensive spatial geo-data base (Ordnance Survey, 2015), which could be accessed by establishing a collaboration between the author and the National Forest Company. The following section describes the NF project area.

3.4.1 The National Forest (NF)

The NF project area covers 500 sq. km. It is located in the Midlands region of England, between the cities of Nottingham (north east), Birmingham (south west) and Leicester (east) (Williams, 2006). The area covered by the NF includes parts of three counties: Derbyshire, Leicestershire and Staffordshire. Before the establishment of the National Forest, the area had a diverse history. Along the River Trent and its floodplain, in the west of the NF, early settlements of people benefited from the river, as it provided food resources. The river has also been an important element for transportation, developing trade (e.g. extraction of sand and gravel) and industry. In the centre of the NF, geological processes led to the formation of coal deposits, which have been exploited since 1293. Because of the proximity of the coalfields and water availability, the River Trent provided a prime location for several coal-fired power plants, although today these have been demolished (Natural England, 2013a), and these were important drivers impacting and affecting the area. Through time, mining had a major impact on this area, influencing urban settlements and the landscape. Now, though, coal mining has also ceased and the NFC has reclaimed and regenerated derelict mines, yet the region still suffers from the aftermath of mining activities, such as potential surface water pollution (Natural England, 2014). In the east of the NF area, agriculture and quarrying activities have significantly influenced the landscape through the years. Since early times the area has been described as “wooded”; nevertheless, The Enclosure Acts divided remaining unenclosed habitats such as woodland, heathland, and moorland into small land parcels for farming which now days remain delimited by hedgerows and dry stone walls. In addition, quarrying activities led to the development of important industrial heritage in the area (Natural England, 2013b).

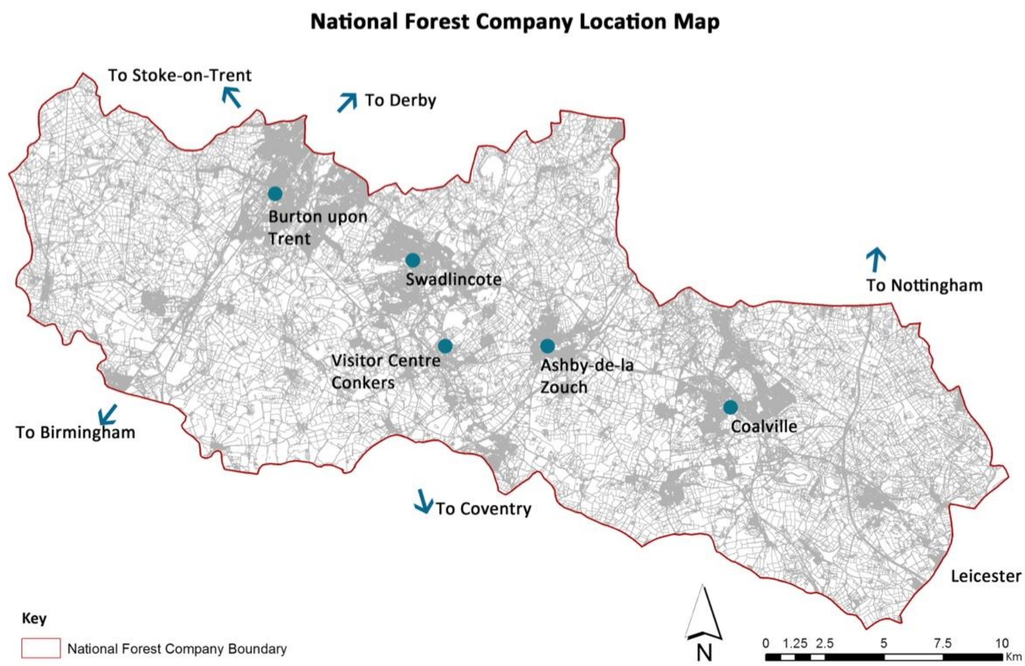


Figure 3.3 Location and geographical context of the NFC

The NF area is managed by the National Forest Company (NFC) and one of the initial and key objectives of the NF is to increase the forest cover of the area and to link two existing remnant ancient forests: Needwood to the east and Charnwood to the west (Figure 3.3). Although tree cover is the main attribute of the forest, the NF aims to create, include and connect other habitats in a coherent way to improve the habitat connectivity of the NF project area. The creation of forests and habitats is guided by the NF landscape character areas (LCA), acknowledging landscape change, providing an attractive, adequate and useful landscape for the community, and providing adequate habitats and landscape connectivity. The NF’s strategies identify six types of landscape character areas (Figure 3.4). LCAs include the Needwood & South Derbyshire Claylands area, characterised in part by the ancient Needwood Forest and other ancient woodlands and parklands. The Trent Valley Washlands area comprises a large area of flat floodplain, rivers, industrial and urban development, open cropped fields and various land covers comprising grassland, wetland and wet scrub woodland. The Mease and Sence Lowlands LCA is distinguished by its rural character formed by agricultural fields and hedgerows, including small villages. The Leicestershire and South Derbyshire Coalfield LCA has urban character of irregularly spread towns and villages, comprising derelict land from mining activity and opencast coal and clay workings, and new woodland planting and new housing giving the area a transitional landscape character. The Melbourne Parklands has a strong rural character with an upland feel allowing views across the Trent Valley, including two reservoirs, parklands and wooded estates. Finally, the Charnwood LCA comprises the former Ancient Forest remnants of ancient woodlands and parklands, and has an upland character that includes heathland and rugged hills. Figure 3.5 presents a panoramic view of the new transforming forest of Feanedock Wood towards the heart of the NF -Moira, Swadlincote -.

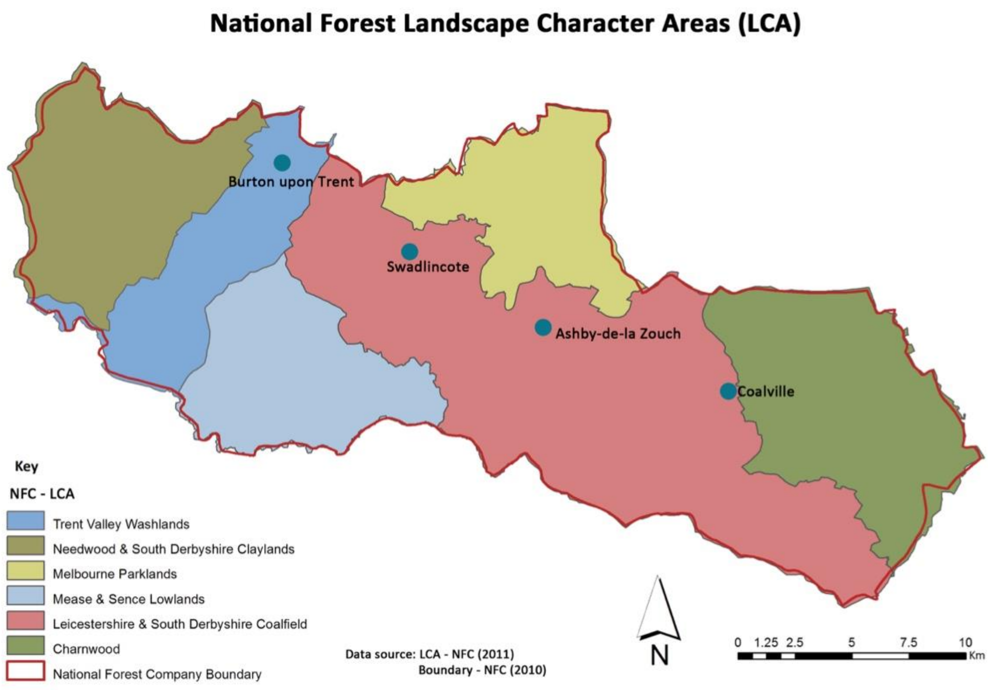


Figure 3.4. NF LCAs map, from The Forest Strategy 2004-2014 (NFC, 2004)

Figure 3.5. Feanedock Wood, NF.

One of the distinctive attributes of the NF is the vision, purpose and thinking behind its creation. It was conceived in the 1980's by a former non-departmental government body (Countryside Commission) responsible for protecting the English countryside and making it accessible to people. In their policy document, the Countryside Commission (1987) encouraged the creation of new forests with multi-purpose objectives, located near urban centres. This policy was opposed to contemporary forestry practice, which comprised forest creation far from cities and towns, inaccessible and with the predominant purpose of timber production. The aim of these proposals was to create broad-leaved forests to regenerate damaged landscapes and encourage people to use and enjoy them. Through a governmental initiative, the creation of a New National Forest at the centre of England was proposed. The area selection processes comprised a public consultation that, according to Sheail (1997), had a large positive response from local groups, individuals, authorities and national organisations. Then in 1990 the current NF area was selected from five potential locations. The current NF project area was characterised by having the poorest wooded land cover in the region, by large areas of derelict land from the mining and material extraction industry, by a deprived area affected by post-industrial decline, and by not having any designated protected areas (Allison, 1996; Sheail, 1997; Bell and Evans, 1998; Williams, 2006).

In 1991 a National Forest Development Team was appointed to develop a strategy and business plan for the project area (Sheail, 1997; Bell and Evans, 1998). This team developed the first ten-year strategy of the NF, from 1994 to 2004, and in 1995 it was established as The National Forest Company (NFC). The NFC is the agency responsible for the administration, management and delivery of the NF's resources and strategies. The forest creation model is based on the provision of grants to private owners, complemented by strategic purchase of land and increasing tree cover through planned green infrastructure (DEFRA, 2013). As part of the delivery model the NFC has an established network of partnerships between government agencies, private business, voluntary organisations and landowners. The last two 10-year strategy and delivery plans have sections dedicated to the establishment and strength of partnerships at local and regional scales (NFC, 2004; 2014a). The NFC is designated as a non-departmental public body, sponsored by the Department for Environment, Food and Rural Affairs (DEFRA). The NFC receives a core grant from DEFRA (£3 million), which is complemented by funding from sponsorship and other funds (in 2012, this accounted for approximately £1 million) (DEFRA, 2013). The DEFRA review (2013) and the 2014-2024 strategy recommend that by 2024 the NFC should become an independent funded body, receiving a lower income from the government as payment for ecosystem services.

From its origins, the NF strategies, delivery plan and evidence base have included stakeholder and community consultations. The three existing 10-year strategies reflect a shift from regeneration through creating forests and different habitats with multi-purpose objectives, to enhancing the identity and recognition of the NF, and finally to stewarding the forests to maturity by maintaining good quality management and accessibility, and continuing being an exemplar of landscape regeneration and sustainable development. Table 3.2 summarises the objectives from the three different 10-year strategies. Generally, through the years the NFC aims to address many objectives -forestry, landscape character and landscape change, biodiversity enhancement and protection, ecological connectivity, climate change mitigation, accessibility, recreational opportunities, historic environment conservation, community participation and inclusion, economic recovery and growth, land reclamation and regeneration, agriculture, tourism , green infrastructure planning, and finally research and monitoring (NFC, 2004; 2009; 2014a)-.

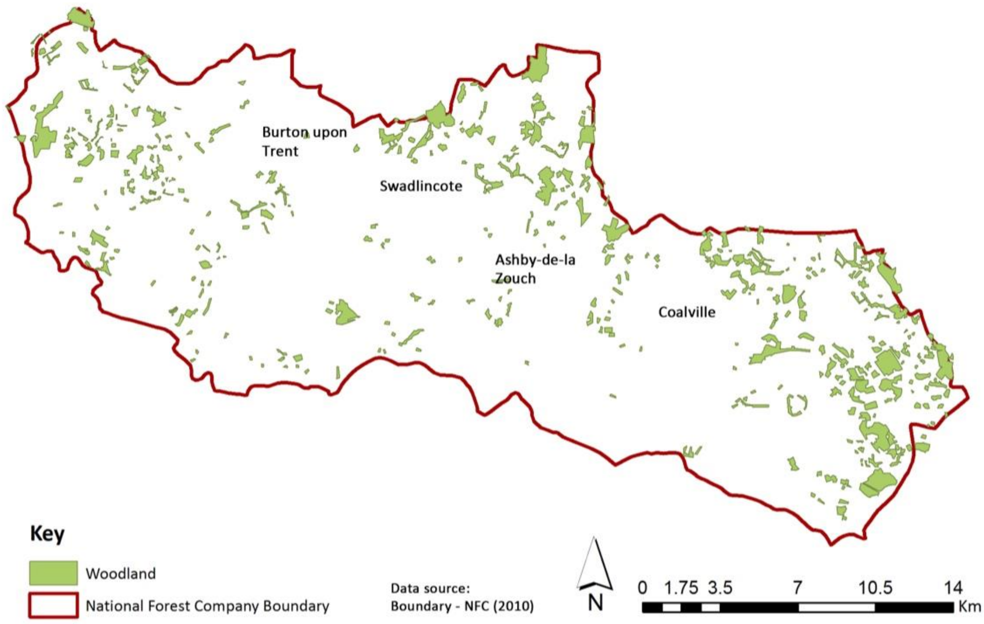
Table 3.2 National Forest 10-year strategies: comparison of objectives

National Forest Objectives		
1994-2004 (DEFRA, 2010)	**2004-2014** (NFC, 2004)	**2014-2024** (NFC, 2014a)
To enhance and create a diverse landscape and wildlife habitat	*To create a coherent and identifiable new identity known as The National Forest*	*To increase forest cover, and to manage forests for tree health, climate change , people, beauty and biodiversity*
To create a major recreation and tourism resource	*To transform the area through a purposeful conversion of land use on a significant scale and at an exceptional rate*	*Woodland economy to grow in line with maturing forests and sustaining good management*
To provide an alternative productive use for agricultural land in a manner that meets environmental objectives	*To be recognised as a forest through increasing woodland cover*	*To be nationally recognised as an emerging visitor destination*
To contribute to the national timber supply	*To enrich biodiversity of landscape and wildlife habitats*	*The NF brand to be adopted widely*
To stimulate economic enterprise and create jobs	*To be enjoyable, welcoming and accessible for all*	*The NF to be enjoyed from people from all backgrounds and to be experienced as a place for their health and well-being*
To stimulate community involvement and educational use of the Forest	*To involve local communities in the Forest's creation*	*To mature as a national exemplar, a centre of excellence and as test bed for research.*
To contribute to wider environmental objectives such as a reduction in carbon dioxide in the atmosphere	*To stimulate and add value to social and economic development*	*To reinvigorate partnerships*
	To be a working forest that contributes to national timber supplies	*To become independent from DEFRA by 2024 through new business models and income generation*
	To be environmentally, economically and socially sustainable	*To develop a stronger local representation as charitable and non-departmental public body.*
	To be geographically diverse and sensitive to landscape, natural and cultural history	
	To help to integrate urban and rural environments	

To date, the NF has increased its forest cover from 6% in 1991 to 19.9% in 2014; see Figure 3.6 (NFC, 2014a). Biodiversity support and protection has been led through studying habitat connectivity models to inform decisions on habitat creation and management. The main habitats created and restored are woodlands, hedgerows, meadows, heathland and wetlands. As well, there has been an increase of agricultural land managed through agro-environmental schemes (NFC, 2009). The NF strategy for climate change mitigation is through carbon sequestration by trees, litter cover and soil (above and below ground biomass) and planting appropriate tree species resilient to future temperature changes. The new strategies towards 2024, describe the importance of guiding adequately existing forests, which after 20 years are now visible, growing towards maturity, highlighting the importance of tree health maintenance.

Early studies on the NF creation process identify that although it had a majority positive response, there was some scepticism regarding the role of the forest in the community. Some of this arose from farmers opposed to forestry as an option for economic growth and the community perception of new forest created on private land from public funding but potentially inaccessible to people (Allison, 1996; Sheail, 1997). A study by Kitchen et al. (2006), reviewing community forest and regeneration of post-industrial landscapes, still identified negative responses from farmers against forestry, and negative community perceptions of forest in particular towards fear of anti-social behaviour and social exclusion. In the same year, a study carried by Morris and Urry (2006) also reported negative perceptions towards the forest, which related more to the community desire to be part of and have a voice on their changing surrounding landscape. They also found that people relate the forests to better environmental and economic circumstances, and that in the NF communities were growing and providing a place for social capital to improve. More recently, as part of the 10-year strategy review, a report for the NFC regarding community perceptions identified a positive continuously growing perception towards the NF; for example, in comparison with a report in 2008 people were noticeably more proud to belong to and to tell others they are from the NF. The report also identified that people perceive recreational opportunities and highlight cycling as an important recreational activity for families; furthermore, they reported that the community is interested in what was occurring within the NF area in terms of biodiversity and landscape change (Alison Millward Associates, 2014).

NF woodland cover in 1991



NF woodland cover maps in 2014

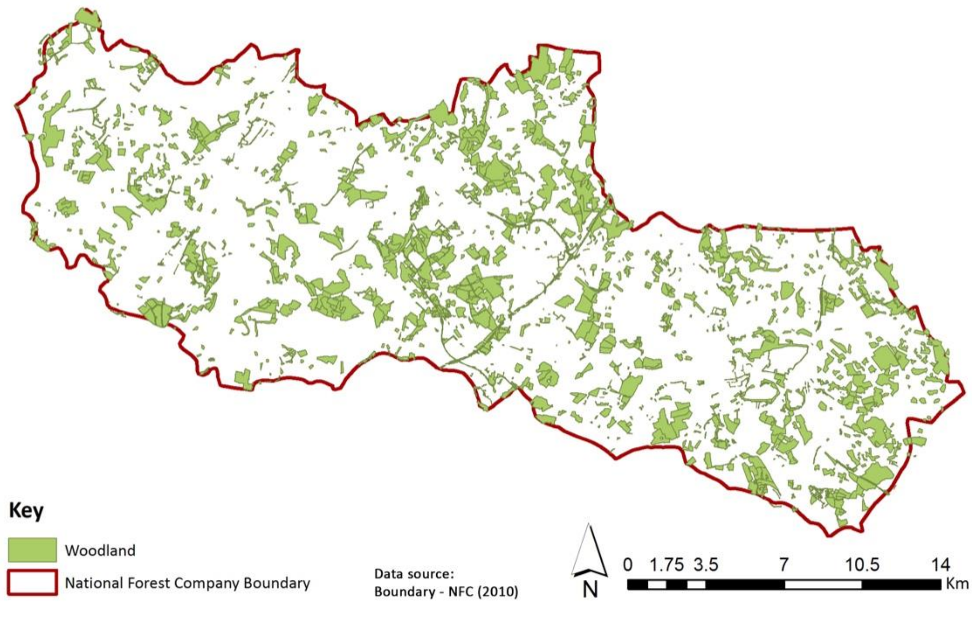


Figure 3.6. NF forests cover maps in 1991 and 2014 (NFC, 2014a)

The NFC encourage economic investment in the NF project area through promoting the NF as a touristic destination, as an attractive place for business, and as a woodland economy in its own right, for example management and maintenance of woods, and increasing biomass as climate change mitigation by producing woodfuel and tree carbon sequestration. Since 2001 the NF has attracted £1 billon investment to the area. Growing population and new housing development has been an important contribution towards economic investment in the area (NFC, 2014a; 2014b).

To summarise, the NF and NFC are identified as a good example of landscape regeneration through the creation and management of forest and habitats with multiple social-ecological objectives. From the outset of its creation it has included community participation and consultation. Forest creation is delivered through clear and established strategies and delivery plans that guided the creation of forest through studying landscape connectivity, character and sensibility towards change.

3.5 Methods

This section provides an overview of the methods and resources applied in this research study.

3.5.1 Literature review of landscape function systems

Landscape function is the term sometimes used in landscape multifunctionality studies to explore landscape's social and ecological complexity. The literature review carried out in Chapter 2 reported a current discussion among researchers regarding ambiguity, appropriateness and the interchangeable use of terms of landscape and/or ecosystems: functions, services and benefits. This thesis has found that literature defines landscape functions as systems that have the *capacity* to regulate and support natural and social processes. This definition is primarily based on Haines-Young and Potschin's (2010) cascade model which uses the term *landscape function* to describe the underlying processes that perform and interact within particular social and ecological systems; then subsequently, these landscape functions deliver *ecosystem services*, which are tangible and non-tangible manifestations of the interactions between functions; these, successively, consider the benefits that people value. Contrary to current mainstream research focusing on the delivery of ecosystems services this research thesis argues that, by studying and understanding the *underlying* processes occurring and interacting among social-ecological systems, landscape practitioners can identify how to accelerate the emergence of new and regenerated landscapes; practitioners cannot intervene in the services *per se*, but they can intervene and influence processes and elements affecting landscape functions.

After defining and disambiguating the term *landscape function* this led to the identification of twenty-five different landscape functions (see Chapter 2, section 2.5). Nevertheless, because most of the research studies are inclined to focus on the service-benefit flow perspective, or the quantification, justification, valuation and payment of ecosystems services, there is a limited description and analysis of landscape functions. This thesis identifies that is necessary to describe the nature and range of processes supported by each landscape function. Landscape functions comprise social and ecological processes, which individually are well studied and documented from a wide range of disciplines. This is why this thesis uses a literature review as a method for identifying, reviewing and synthesising existing relevant studies describing processes, components, character, structure, relationships and drivers that influences the creation and regeneration of landscapes (Chapter, 4).

A literature review is a method that aims to present a comprehensive overview of different bodies of information. It can have two purposes: as a preliminary study to justify and provide theoretical context to a research project; or as a study that aims to answer specific research question(s) through an assessment of existing literature (Pettigrew and Roberts, 2006; Aveyard, 2014). This literature review seeks to be transparent and valid, and uses systematic steps which were established at the outset (Aveyard, 2014).

3.5.1.1 *Literature review scope*

The ***first objective*** of this thesis sets the context for the literature review (see section 3.2) – namely, to critically disambiguate and establish the current state of knowledge and theory with regard to the range and nature of landscape functions as landscape systems. An individual literature review was carried for each landscape function (see table 2.2, Chapter, 2). The following questions were produced to provide a specific focus, and to distinguish studies and information relevant to each landscape function system, namely:

1. What is the process that describes the landscape function?
2. What is the role of landscape components and structure within the process?
3. What and who is necessary for the process to occur, and at what scale?
4. What and who influences the process?

5. What and whom are influenced by the process? Are those influences positive, negative or neutral?
6. Evidence and examples of how and what interactions/influences occur between this and other landscape functions.
7. What are the outcomes from such interactions?

3.5.1.2 *Material search strategy*

The relevant material that informed the literature review was collected initially through the following academic search engines: *Scopus, Web of Science* and *Google Scholar.* Then, more literature was collected from references cited in the initially identified publications. The collected studies comprised: peer-reviewed research publications, government reports and policies, postgraduate theses, conference proceedings and books. The search of literature on search engines was delimited by *keywords* and *supporting keywords*. Box 3.1 illustrates the list of keywords used; this list comprises the terms of landscape functions and ecosystems services identified in Chapter 2. An initial screening of identified papers and publication was carried out by reading abstracts, summary and conclusion. The purpose of this initial screening was to identify potentially useful material as a precursor to downloading and copying publications.

Box 3.1. Keywords used for literature search.

- Production of food
- Production of non-food
- Hydrological cycle
- Interception
- Infiltration
- Water storage
- Water filtration
- Pollution filtration
- Air pollution filtration
- Carbon sequestration
- Carbon storage
- Microclimate regulation
- Soil stabilisation
- Biodiversity
- Habitat
- Habitat connectivity
- Pollinators
- Cultural services
- Aesthetics
- Visual properties
- Visual qualities
- Character
- Attractiveness
- Visual elements
- Aesthetics experiences
- Heritage
- Landscape legacy
- Tradition
- History
- Culture
- Health and well-being
- Mental health
- Physical health
- Social well-being
- Recreation
- Leisure
- Amenities
- Education
- Teaching outdoor
- Learning outdoor
- Learning experience
- Forest schools
- Outdoor education
- Shelter
- Transportation
- Waste assimilation
- Recycling
- Conversion of non-fossil sources
- Wind energy
- Solar energy
- Biomass production
- Social capital
- Social learning
- Institutional thickness
- Economic
- Partnerships
- Landscape function
- Landscape process
- Landscape service
- Land function
- Ecosystem service
- Ecosystem function
- Ecosystem process

3.5.1.3 *Quality appraisal*

After identifying and storing all potential publications on each landscape function, each one was read. Information pertinent to answering the literature review focus questions (section 3.5.1.1) was noted. However, as part of the literature analysis and the extraction of information, it is preferable to critically assess the relevance, strength and limitations of each publication. Aveyard (2014) proposes certain questions that prompt critical thinking, (Box 3.1). In this thesis, those questions were borne in mind when reading the material; through a second reading these questions were answered.

Box 3.2. Questions that encourage critical thinking to evaluate selected literature, based on Aveyard (2014).

- Where did you find the information?
- How has the author come to their conclusion?
- When was this written?
- What is it and what are the key messages, results and findings?
- Is it a research study, professional opinion, discussion, website or other?
- Who has written this?
- Why has this been written?

3.5.1.4 *Synthesis of findings*

Finally, the data collected were synthesised; the findings are presented and described in a narrative form in Chapter 4. Initially this thesis recognised twenty-five landscape functions (see Chapter 2, section 2.5). However, this study explores landscape multifunctionality through Soft Systems Methodology, which recommends that only a limited number of systems (between 7 and 9) are analysed (Checkland and Poulter, 2010). Thus, the landscape functions were clustered into seven related systems; in order to provide legibility and coherence to this thesis, the literature review findings are presented according to this structure.

The literature review findings provide a summary of the processes, elements and roles of each landscape function system. Also, this literature analysis has been valuable in providing relevant information for the following stages of this thesis: landscape function systems mapping (Chapter 5, section 5.5), and the development of conceptual models of each landscape function system (Chapter 6, section 6.4). The evaluation of the conceptual models, through stakeholder participation (Chapters 6 and Chapter 7), corroborated that the information collected adequately informed processes and elements of each landscape function system (Chapters 8 and 9).

3.5.2 Approaches to landscape function systems mapping

Landscape function mapping (Chapter 5) is one element of landscape multifunctionality assessment. Landscape function mapping aims to spatially represent the distribution, capacity and/or quality of actual or potential landscape functions. The resulting maps are then used to illustrate specific locations and current capacity of landscape functions for providing ecosystems services; also, some studies aim to spatially represent and analyse dynamics between landscape functions. Through the literature, landscape function mapping is a well attested assessment stage, and there is a continuously growing range of spatial assessments. However, to date there is no consensus between researchers that landscape multifunctionality has been successfully achieved, and few assessments aim to illustrate landscape complex dynamics between landscape functions (Vorstius and Spray, 2015).

The literature discusses common problems found by researchers when assessing landscape function mapping, for example: existing methods struggle to achieve a holistic account of landscape complexity; or existing and available data (indicators, proxies, census and spatial datasets) are characterised by bias, uncertainty and ambiguity (section 2.6.1.3, Chapter 2). This thesis shows that many of these constraints will be encountered in any future proposed mapping assessment, because of the complexity associated with integrating landscape multifunctionality properties, for example information occurring at multiple scales (time, space and organizational). Nevertheless, as a ***second objective***, this study aims to advance on existing approaches to landscape function mapping by exploring landscape functions as social and ecological systems.

To achieve this objective, this study found it necessary to explore and build on an understanding of existing landscape function mapping approaches. Therefore, it was decided to carry out an exploratory exercise of published landscape function methods relevant to landscape multifunctionality. Two studies were chosen, namely, the proposed approaches to landscape function mapping by The Mersey Forest (2009; 2014) and Willemen et al., (2008).

Each methodology was applied to the National Forest (NF) case study (section 3.3), specifically a more manageable zone within the NF project area. This region was delimited by the political boundary of the former mining village of Moira. To date, the area is characterised as the centre of the NF, where the visitor centre *'Conkers'* is located (Figure, 3.7).

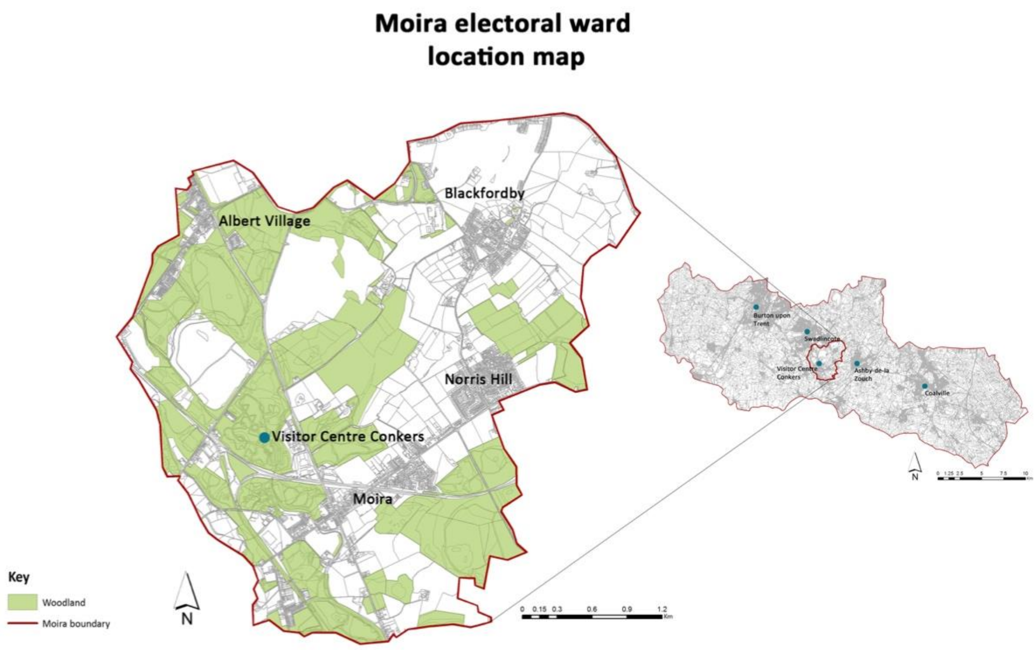


Figure 3.7. Moira location map

Findings from the two exploratory exercises provided insights on approaches to mapping landscape functions; for example, the practical aspects of assessments, required skills and technology for mapping, range and nature of available databases for the NF region, spatial scale appropriateness, and efficacy of illustrating and analysing dynamics between landscape functions. A detailed discussion of these findings is given in Chapter 8, section 8.3. Building on these exploratory exercises and analysis, this PhD study proposes to map landscape functions through the identification of system components and/or conditions that indicate the possibility and potential degree of occurrence of each landscape function system. This method was applied to the full region of the NF. The methodological frameworks for the exploratory exercises, including the selected approach to landscape function mapping, are set out in sections 3.5.2.1, 3.5.2.2 and 3.5.2.3 respectively; however, their detailed application and results are described in Chapter 5.

3.5.2.1 *The Mersey Forest (2009)*

The Mersey Forest in conjunction with local authorities and local regions developed an approach to Green Infrastructure (GI) planning. From early piloting explorations (for example, The Mersey Forest, 2009) to this date, the methodology has been widely applied within the region and integrated in the production of GI frameworks, for example Liverpool GI framework and strategy and action plans (Liverpool City Council, 2010; The Mersey

Forest, 2014). This particular study was of interest because it discusses and integrates landscape multifunctionality properties, landscape functions and participation. Its background development was on a similar setting of creation of woodlands, within a community woodland and an established partnership. However, its final objective is to develop a 'needs assessment' that will help to identify priorities and actions.

The Mersey Forest methodological framework comprises five steps (Figure 3.8). This PhD thesis explored and applied in detail the methodological approach to *landscape functions* assessment (Steps 2 and 3). It is important to mention that this exploratory exercise was based on early guidance on the methodological approach, which used as its case study the Weaver Valley region (The Mersey Forest, 2009). There is now a more recent set of guidance to the methodology (The Mersey Forest, 2014), but an analysis of differences between the two guides did not find significant differences likely to affect this exploration.

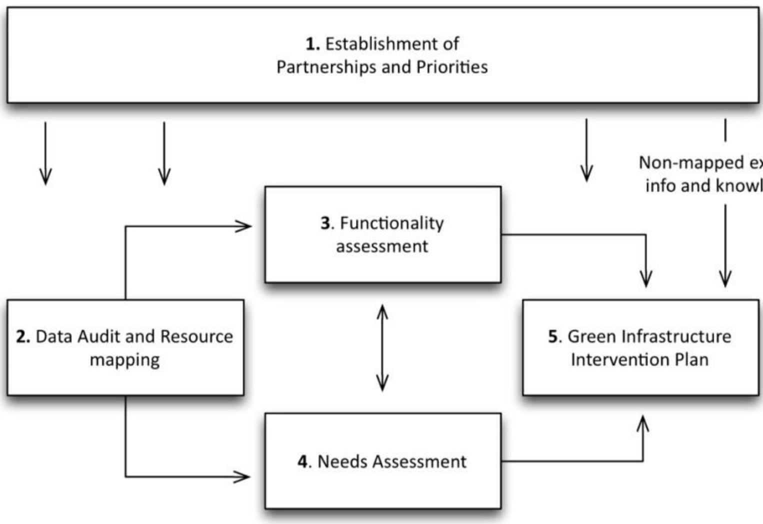


Figure 3.8. Methodological Framework to Green Infrastructure planning, based on The Mersey Forest (2009; 2014).

The application of the methodology begins with an assessment of available data and resources for mapping, namely *data audit*. This is followed by identifying and mapping the region's *GI typology*. The generated map is used as the basis for the *landscape functionality assessment*, and a map for each landscape function is generated. Then finally, a juxtaposition of the created landscape function plans generates a *multifunctionality map*. The maps were created using Geographical Information Systems (GIS), specifically the spatial data was processed using ESRI ArcMap 10.1. As mentioned before, Chapter 5 explores in detail the methods, the datasets used and the resulting maps.

3.5.2.2 *Willemen et al. (2008; 2010)*

Willemen et al. (2008; 2010) conducted a research study in which they proposed a quantitative approach to landscape function mapping and interaction analysis. Their research study was considered relevant to this exploratory exercise because one of their main objectives was to study *landscape function interactions* to determine how spatial and landscape components influence the capacity of the landscape to be multifunctional and its effects on ecosystem services delivery. They classified landscape function interactions in three types: conflicting interactions, synergetic interactions and compatible interactions. Although this thesis is not focused on ecosystem services delivery, it was particularly interesting to study how Willemen et al. integrated landscape components and drivers to map landscape functions.

This methodology framework was applied as a case study to the region of Gelderse Vallei, in The Netherlands. This region is characterised by an emerging and growing pressure on ecosystems services. According to Willemen et al. (2008; 2010; 2012) 70% of the region area has an agricultural land use, including a significant portion of livestock production of the country; 17% of the region area comprises urban areas where population is continuously increasing and transforming the rural character of the region into peri-urban. Finally, the remaining land use percentage comprises two national parks at the edges of the region and ecological corridors connecting these parks. Gelderse Vallei’s current planning policies outlines management actions aiming to enhance the environment for multiple ecosystem service supply; by studying the multifunctional capacity of the region, Willemen et al. (2008; 2010) want to analyse if the landscape functions prioritised by the policies have conflicting interactions with other landscape functions and therefore hindering ecosystem services supply. The indicators and measures proposed by this study reflect the Dutch approach to landscape planning. This landscape approach highlights and assesses the importance of the landscape scale and participation, aiming to protect and preserve cultural landscapes as well as delivering key ecosystem services (van der Horn and Meijer, 2015). Landscape planning initiatives in the Netherlands, as in England, takes place at a local scale but is supported by national planning policy guidance (Bass et al., 2011). Key landscape approaches are promoted by the European Landscape Convention too; for example, the *Landscape Biography* approach (not applied in the UK), analyses the cultural-historical character of the Dutch Landscape through stakeholder and expert participation, and supports the creation of *future visions* and the development of landscape and village plans (Bass et al., 2011; Steneke and Jones, 2011).

The framework comprised three analyses: i) to spatially identify and then map landscape functions throughout the use of landscape indicators, ii) to quantify and then map multifunctionality throughout the integration of the previously created landscape function maps, and finally, iii) to analyse multifunctionality and its effects on the capacity of individual landscape functions and to identify hot spots (Figure 3.9).

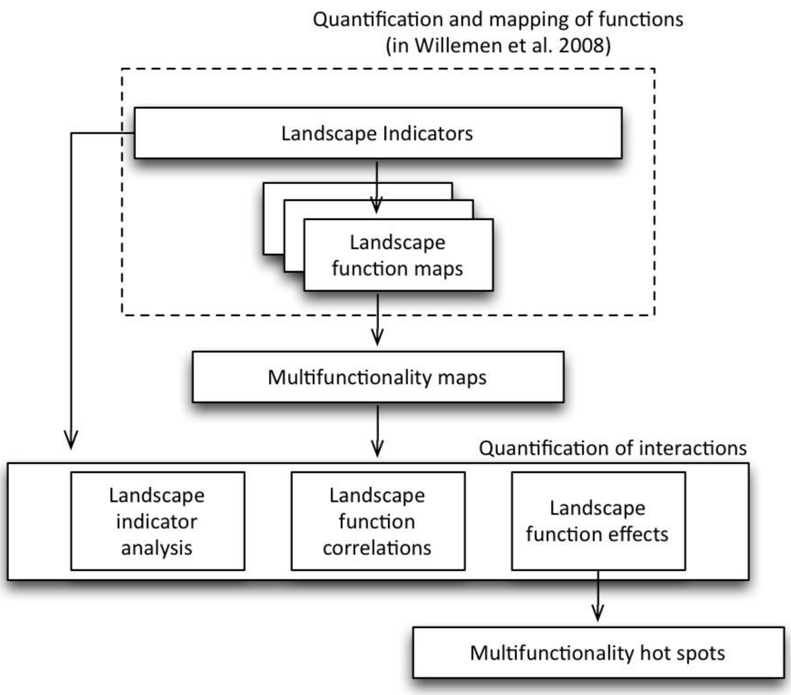


Figure 3.9. Research framework to analyse landscape multifunctionality, based on Willemen et al. (2010).

This thesis exploratory exercise focused specifically on the methods to map landscape functions. The Willemen et al. (2008) study explored only eight landscape functions; these landscape functions were selected in the light of current planning policies and spatial datasets on accessibility in the Netherlands. The landscape functions were analysed in terms of spatial location (mapping) and extent of occurrence (quantification). There are three methods for quantifying and mapping the proposed landscape functions. In first place are the *completely delineated functions*; these landscape functions are identified throughout land cover spatial information and quantified through indicators from policy regulations or census data that can be directly related to the spatial location of the landscape function. Secondly, there are the *semi-delineated functions,* which are spatially located by complete delineated characteristics (for example land cover); however, to identify the extent of the landscape function it is necessary to analyse several independent indicators through *multivariate regression techniques* aiming to *empirically* quantify the occurrence of the function. Finally, there are the *non-delineated* landscape functions; these are not possible to identify spatially by specific spatial features, but indicators and appropriate thresholds of occurrence are selected from existing literature or policies. Figure 3.10 illustrates a summary of the landscape function mapping approach. Maps and spatial data were processed using GIS software ESRI ArcMap 10.1. The statistical analyses were carried out using the statistical package *R 2.15.0*. As previously discussed, the techniques and application to this case study will be explored on detail in Chapter 5.

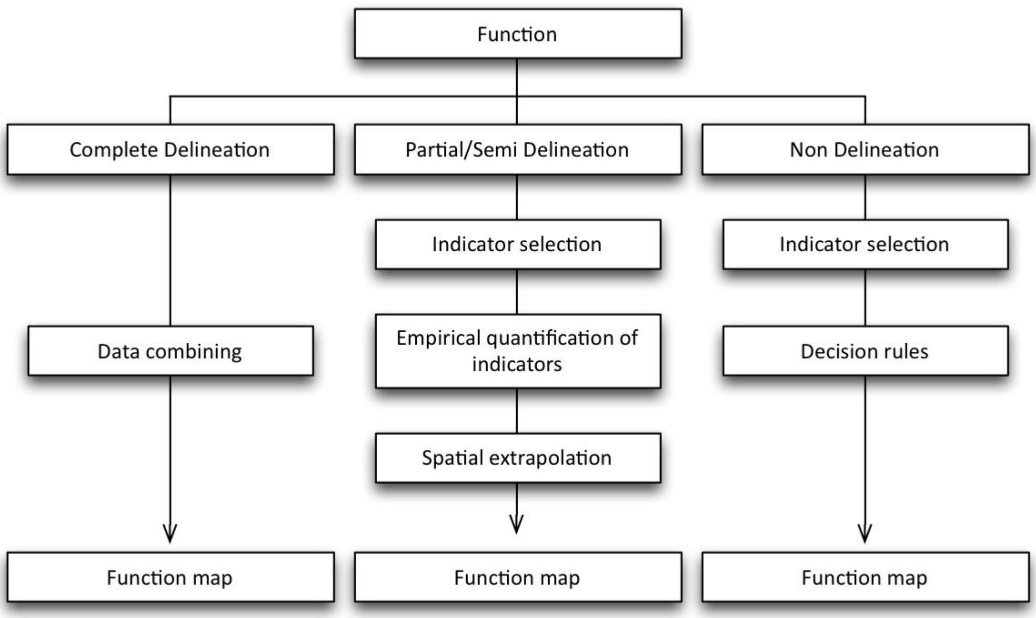


Figure 3.10 Summary of the landscape function mapping approach, based on Willemen et al. (2008).

3.5.2.3 *Landscape Function System Mapping*

Following the exploration of methods by the Mersey Forest and Willemen et al., the thesis experimented with an approach based on landscape function mapping. In summary, the nature, range, accessibility and available tools and techniques of existing approaches restrict the illustration of dynamics and interactions between landscape functions systems. Thus, this thesis aimed to develop landscape function mapping focused on illustrating to others (landscape professionals and stakeholders) how relevant and representative underlying processes of each landscape function system could be referenced in space and extent, contrary to the static illustration of ecosystem service delivery.

This method follows in particular the approach to *non-delineated* landscape functions proposed by Willemen et al. (2008). This main approach of this strategy is to search through published literature and other studies, for examples of components, conditions or processes that could indicate: a) the possibility of occurrence and b) an acceptable threshold of a specific landscape function system. The final anticipated outcome is to generate landscape function system maps illustrating pertinent underlying social and ecological processes.

This proposed approach was applied to the full project area of the National Forest. The proposed approach comprised three phases. First, through the literature review of landscape function systems (section 3.3), potential components (spatial and proxies) of the underlying process of each system were identified and selected. Secondly, an assessment was carried out of accessible spatial databases, assessed in terms of quality, scale and appropriateness to the selected information. Available and accessible databases were drawn from the NFC dataset, Natural England, MAGIC, Cranfield University's National Soil Resources Institute, Environment Agency and the Ordnance Survey. GIS ESRI ArcMap 10.1 was used to process the data and create and format the maps.

The rationale and references of each selected component and proxy used to create the landscape function systems maps are described in detail in Chapter 5, along with details of the databases used and the resulting maps.

3.5.3 Soft Systems Methodology

This thesis aims to explore how understanding dynamics between landscape functions could inform purposeful interventions so that appropriate initial conditions speed up the emergence of multifunctional, resilient and distinctive landscapes. After exploring, theoretically and spatially, landscape functions as social and ecological systems, the remaining challenge was to analyse the dynamics between those systems. The ***third objective*** of this thesis study is to explore Soft Systems Methodology (SSM) as an approach to help landscape professionals and stakeholders to explore together landscape's dynamics between social and ecological systems (Chapter 6).

This thesis identified SSM as an appropriate method for studying interactivity between systems. SSM aims to learn about a complex situation so that action can then be taken (Checkland and Poulter, 2010). The learning process is underpinned by identifying and taking into account people's different perspectives of a situation and how people want to act or intervene purposefully to promote desirable and appropriate change to a system (Checkland, 1999; Checkland and Scholes, 1999; Checkland and Poulter, 2006; Checkland and Poulter, 2010) (Figure 3.11). This method section aims to provide an overview of SSM as applied to the case study. The detailed application and results are explored in Chapter 6.

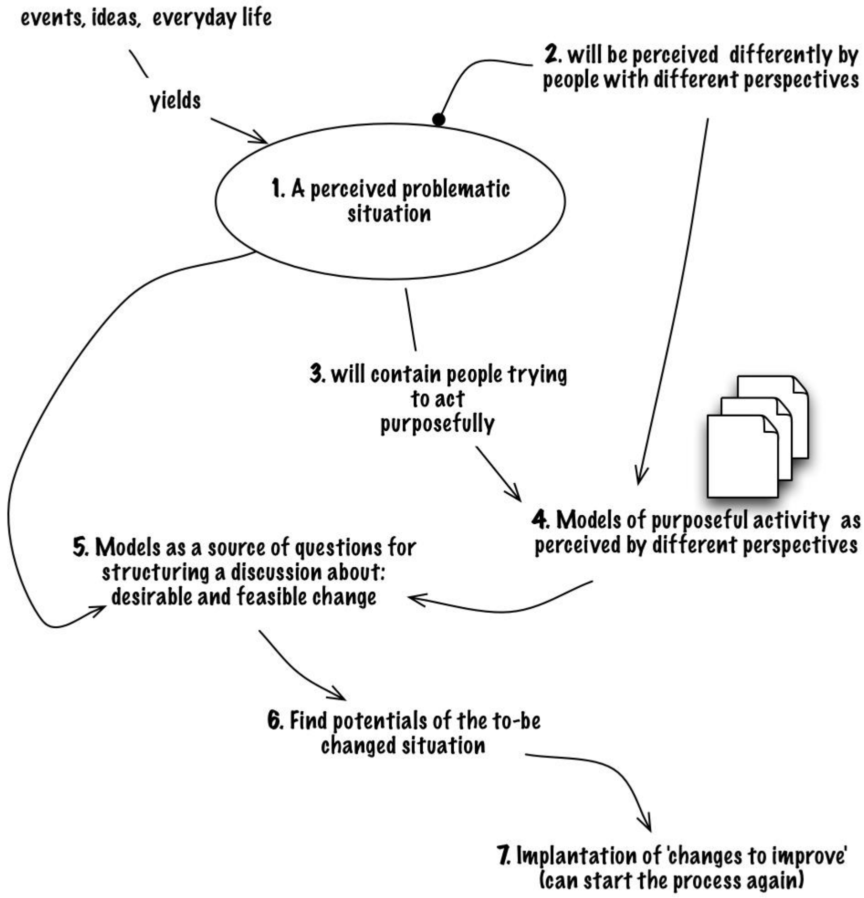


Figure 3.11. SSM's cycle of learning for actions, based on Checkland and Poulter (2010).

SSM is a qualitative and participatory enquiry process. The expected outcome is social learning informing *'action to improve'* (Checkland and Poulter, 2010). The learning cycle provides rigour and structure to analyses and debates. There are three main terms used in SSM that are important to acknowledge and clarify. First, *problematic situations*: SSM guidance suggests using this term instead of *problems,* thereby aiming not to focus the learning process on solutions but rather on learning about it. Secondly, the terms *worldview* or *perspectives* refers to the different perceptions of people to any *problematic situation.* Finally, *purposeful activities* are actions for *transformation* or *change* to occur.

This thesis applied four SSM stages to the NF case-study. The first stage refers to a *finding out* stage where data collection occurs and, through certain analyses, the researcher builds a comprehensive overview of the problematic situation (section 6.2). Then, the second stage relates to identifying and defining relevant systems through a number of analyses supporting this stage (section 6.3). Subsequently the third stage purpose is to develop conceptual models of the identified systems (section 6.4). *Influence diagrams* conventions were followed to develop the conceptual models. The conceptual models were drawn using the diagramming software OmniGraffle 5.4.4. The final stage refers to the use of conceptual models as a supporting material to generate and encourage discussion and dialogue, (section 6.5). Thus, the models are the subject of discussion, but also are the tools for enabling dialogue. The outcome expected is to answer questions such as: does this activity occur like this? Who carries out this activity? When does this activity happen? Is there someone else that could carry out this activity? This discussion was carried out through two workshops with NF stakeholders. The results of the discussion are presented in Chapter 7.

3.5.3.1 *Data collection*

There were several data sources for the application of SSM. For the finding out stage that aims to create a comprehensive and rich picture of the *problematic situation,* information was collected through an analysis of existing literature on the NF (case study) and landscape multifunctionality. Additionally, information was collected through two informal meetings, one with a senior landscape advisor of Natural England, and the other with the NFC landscape advisory group.

For the development of the conceptual models, information was compiled from two sources. One source was the literature review on landscape function systems (Chapter, 4); this literature review identified the generalised systems components and processes of each landscape function. The second source was information derived from the *finding out* and *definition of relevant systems* stages; these provided local context information to the conceptual modelling process such as local drivers, organisations and landscape character.

Another source of data was from two workshops organised as part of SSM stage 4. The aim of the workshops was not only to discuss the conceptual models but also to evaluate SSM as an approach for landscape professionals to identify points of intervention. The workshops generated two types of data for analysis. One type was the written annotations on the conceptual models and on flip-chart paper used by participants to annotate their key comments during the conceptual model evaluation session. The second type of data was the audio recordings of the discussions; these were processed to produce written transcripts. Overall, the data collected from the workshops is described as verbal communication in the form of text.

3.5.3.2 *Stakeholder participation: workshops*

Formal stakeholder participation occurred at the end of the SSM process through Stage 4. This stage refers primarily to the discussion of the conceptual models against different stakeholders' perspectives; this stage should be achieved through dialogue between stakeholders (section 6.5). The SSM approach to this stage is flexible, as examples of the degree of stakeholder participation vary from interviews and focus groups to workshops. This research study had the opportunity and resources to carry out two workshops, the objectives of the workshops were twofold: i) to review the models by evaluating their success in depicting interactions, processes, elements and dynamics of and between landscape functions; and ii) to discuss the usefulness of SSM and the landscape function models as an approach to understanding interactivity. These were evaluated in terms of: a) usability, b) feasibility, c) credibility, and d) relevance and impact of the understanding facilitated by the models.

This study aimed to achieve *"substantive"* participation, as described by Stirling (2006), to collect multiple perspectives and specific local context to inform the evaluation of the conceptual models. Stakeholders were identified through a discussion between the researcher and thesis supervisors, starting from a list generated from the NFC web page (NFC, 2015) describing their current partners. Workshops were selected as an appropriate method because of their potential to encourage interactive dialogue between participants and the facilitator. The workshop structure was designed in two phases, session A and session B. Session A explored the conceptual models *per se*, and session B evaluated SSM. The researcher facilitated the workshop. Details about the workshops are explored in Chapter 6, section 6.5.

3.5.3.3 *Approaches to data analysis*

This thesis aims to explore SSM as an approach to understanding the complex interactions of landscape multifunctionality, using stakeholder participation. After applying SSM to the case study, the output was evaluated through the NF stakeholder workshop. As noted previously the data generated from the workshops is described as verbal communication in the form of text. Thus, the data was analysed through two qualitative methods – Grounded Theory and Content Analysis. Data were analysed in an inductive and deductive manner respectively; however, the choice was made to analyse data inductively first and then deductively in order to avoid influencing the coding and analysis by biases (Hsieh and Shannon, 2005; Schutt, 2011).

Grounded Theory is a qualitative research method and its purpose is to identify and build a *'theory grounded in data'*. Grounded Theory approaches a phenomenon in an inductive reasoning logic. Grounded Theory research enquiry starts by systematically collecting and simultaneously analysing data, then data collection and analysis directs each other until a hypothesis is generated and a theory emerges (Strauss and Corbin, 1998; Bryant and Charmaz, 2007; Birks and Mills, 2011). Grounded Theory preparations include for example the exclusion of a literature review with the purpose of not developing assumptions that could influence data analysis (Bryant and Charmaz, 2007). However, Grounded Theory data analysis tools have been widely applied as an inductive analytical approach to data analysis only (Bryman and Burgess, 1994). The exploratory nature of this research study aims to study a specific phenomenon throughout a particular research approach; therefore, this thesis did not approach Grounded Theory as a research methodology. However, this thesis follows Grounded Theory analytical approaches to data analysis, aiming to explore data through an inductive logic. In particular, this thesis used the following Grounded theory data analysis techniques, namely, *open* and *axial coding* and *thematic category development.* For thesis legibility, details of data analysis are explored in Chapter 6. Results were organised and described through concepts, categories and subcategories determined through open and axial coding (grounded theory analysis) and predefined codes from existing literature (content analysis). These results are explored in Chapter 7.

3.6 Research ethics

Research ethical competence refers to planning and carrying responsible and transparent measures when approaching organisations, persons and managing data generated throughout the research study (Fisher and Anushko, 2008). The Department of Landscape Ethics Review Committee, through its review procedure, granted ethical approval to this research study.

The National Forest Company (NFC) agreed to collaborate and provided permission to use the NF project area as case study for this research study. One of the NFC contributions to this thesis was to access and use part of their GIS database. The researcher signed a spatial data agreement for the following GIS databases: accessible woodland, attractions, landscape character areas, NFC published walks, NFC woodlands, tender scheme, and woodland connectivity.

Other free and accessible GIS databases from Natural England, English Heritage, Environmental Agency, Ordnance Survey, Office for National Statistics and Cranfield University Land Information System, had been used according to their spatial database agreement, terms and conditions.

The application of SSM involves stakeholder participation. This thesis accomplished this SSM stage throughout two workshops involving NF's stakeholders and other appropriate individuals, agencies and groups (Chapter 6, section 6.5). The workshop participants were identified through a discussion between the researcher and her thesis supervisors based on a list generated from the NFC web page describing their current partners (see NFC, 2015). Potential participants' contact details were collected from their correspondent organisations or groups' web pages. Then potential participants were invited to take part in the workshop through an invitation email sent by the researcher. The email displayed an invitation/cover letter, which contained information regarding the purpose of this research study and the workshops; also it briefly explained where the workshop would take place and what the activities would involve. Furthermore, it included asking their permission to digitally audio record the workshop and use and reproduce any written and visual material generated in this thesis and other publications. It stated that the audio records would be kept in a safe place, at the thesis writing stage, files (audio and transcript) were encrypted in a password safe computer, but will be deleted after completion of the thesis and viva voce examination. Finally, potential participants were asked if they would prefer to remain anonymous or to be referred by name and organisation. They were asked to read the attached information form but to sign and date it in the day of the workshop and in the presence of the researcher; after signing, they received a printed copy of the invitation email and consent form. Appendix 1 includes a copy of the email invitation and the information consent form.

A couple of weeks before the workshop took place, a workshop briefing paper was sent to the confirmed participants; this included a detailed account of this research study purpose and workshop activity program. On the day of the workshop, two people agreed to be referred to by name and organisations, but during data analysis and coding the researcher treated all participants anonymously aiming to achieve consistency.

Chapter 4| Literature Review: *Landscape Function Systems*

4.1 Introduction

Landscape functions are underlying processes that interact between each other, creating complex interrelationships which define landscape multifunctionality. Landscape functions are systems in their own right. The literature suggests that understanding landscape functions is the key to studying landscape's social-ecological complexity (de Groot, 2006; de Groot et al., 2010; Kienast et al., 2009; Willemen et al., 2008; 2010). Nevertheless, from the emergence of landscape functionality as a concept (for example, de Groot, 1992) to date, there is a continuing discussion regarding ambiguity, definitions and classification between the terms of landscape function and ecosystem service (Hermann et al., 2011; Bastian et al., 2012; Krováková et al., 2015). In Chapter 2, this thesis explored and analysed existing studies and their proposed definitions, lists and classifications of landscape functions. The literature review identified that landscape function in contrast with ecosystem service refers to a wider range of cultural and ecological processes concerned with the overall emergence of the landscape through various underlying processes. Therefore, this research study focuses on landscape functions aiming to identify the functions, processes and components associated with social-ecological systems.

To date, detailed descriptions and analysis of landscape functions are absent from the literature. Most studies identifying and describing landscape functions are more concerned with comparing landscape function and ecosystem services rather than analysing the actual functions; or else their exploration of the underlying process and components are limited to reviewing only a few functions (e.g. Kienast et al., 2009 and Willemen et al., 2008). This thesis found it necessary to critically analyse and describe the nature and range of landscape functions from a systems and process-oriented point of view. In particular, the objective of this literature review is to comprehensively describe landscape functions as systems through the identification of components, drivers, influence of other functions, spatial relationships, spatial characteristics, elements and conditions required to satisfactorily support the function's processes. Chapter 3 noted the role of the literature review of landscapes functions (section 3.5.1): here each landscape function system is described in turn (sections 4.2 to 4.8).

Prior to this literature review of landscape functions, we used the cascade model developed by Haines-Young and Potschin (2010) to differentiate functions processes and services. Through this analysis this thesis identified a preliminary list of 25 landscape functions. However, because this study explores landscape multifunctionality through Soft Systems Methodology which recommends analysis of 7 to 9 systems (Checkland and Poulter, 2010) the landscape functions were clustered in seven related systems. This proposed systems and landscape functions cluster follows de Groot (2006) landscape function categories. These categories were selected because of de Groot (2006) influence to the landscape function concept; nevertheless, this thesis is aware of the limitations and appropriateness of these categories names to represent the nature of its clustered processes. In particular the *Information, Carrier* and *Community* systems, usually referred in others studies as cultural functions/services (e.g. Millennium Ecosystem Assessment, 2005), are the systems that represent and support social processes, cognitive development and health and well-being; these landscape functions processes requires active involvement of people within the landscape contrary to simple contemplation and *"information"* or *"cultural"* exchange (King, 2012). In order to provide legibility and coherence to this thesis, the literature review findings are presented following this structure (Table 4.1).

Table 4.1. Identified Landscape Functions

Sub-systems *(chapter section)*	Landscape function cluster
1. ***Provision*** *(4.2)*	• Soil structure • Provision of Food and Raw materials • Energy conversion of non-fossil sources
2. ***Hydrological Cycle Support*** *(4.3)*	• Interception and infiltration of rainfall • Water quality • Water storage
3. ***Atmospheric Regulation*** *(4.4)*	• Air pollution filtration • Carbon sequestration • Microclimate regulation
4. ***Biodiversity Support*** (4.5)	• Habitat provision • Habitat connectivity • Pollinator support
5. ***Information*** *(4.6)*	• Aesthetic experience • Heritage interpretation • Outdoor learning experience • Health and well-being encouragement
6. ***Carrier*** *(4.7)*	• Recreation opportunities • Sustainable transport opportunities
7. ***Community*** *(4.8)*	• Institutional thickness • Economic

4.2 Landscape system: ***P r o v i s i o n***

The literature describes this landscape function system as the landscape’s processes that support a transformation of inputs such as energy, nutrients and water to plant growth and a subsequent production of a wide range of biomass. Within the provision system, people use this biomass as food, raw materials and resources for energy (de Groot et al., 2002; de Groot, 2006).

4.2.1 Soil structure

The soils through chemical and physical properties have the capacity to: i) store nutrients and water; ii) provide an attaching medium for vegetation roots and plant growth; iii) maintain microbial processes that decompose organic material placed on the soil; and iv) recycle mineral nutrients (Harvey et al., 1994; Wienhold et al., 2004; Powlson et al., 2011; Franzluebbers, 2015).

Chemical properties are described by the quantity of organic matter and macronutrients available for plant growth. Organic matter comprises plant parts (dead plants parts, for example, fallen leaves and branches; and living parts of plants such as roots) and animal deposits and living soil organisms (worms, insects and microbes) (Post and Kwon, 2000). Soil organic matter provides much of the macronutrients essential for plant growth - Nitrogen (N), Phosphorus (P) and Potassium (K) and organic Carbon (C) - which have an important role on nutrient cycling and sequestration and storage of CO_2 (Franzluebbers, 2015). Soil physical properties (porosity, particles, water retention capacity, aggregate content, and texture) and landscape attributes (topography and aspect) determine type and amount of vegetation able to grow (Oades, 1993; Harvey et al., 1994; Muller et al., 2010).

Physical and chemical soil properties influence soil structure and soil quality. Sound and desirable soil structure allows water and nutrient movement and storage, essential for plant growth (Harvey et al., 1994; Muller et al., 2010; Powlson et al., 2011). Erosion, drought, compaction and agriculture deter soil structure and hinder plant growth and soil capacity to store water (Muller et al., 2010). Vegetation is central to other landscape functions such as rainfall interception, habitat provision, landscape character, prevention of soil erosion, and CO_2 sequestration and storage (Wienhold et al., 2004; Defra, 2009). Within the provision systems, plant growth relates to the production of biomass for people's consumption and use (Wienhold, 2004; Muller et al., 2010), yet practising agriculture can lead to a deterioration in soil quality. Soil protection practices aim to increase CO_2 sequestration and storage (Defra, 2009). Soil quality measures consider biological, chemical and physical soil properties in order to assess the capacity of the soil to sustain plant growth.

4.2.2 Provision of food and raw materials

Landscapes through their soils have the capacity to support chemical and physical processes (for example seed germination, root growth, and nutrient and water uptake) that lead to the production of biomass. This biomass among other things includes food and raw materials essential for humankind (Powlson et al., 2011; de Groot et al., 2002; Shröder et al., 2003). Despite, the intrinsic capacities of the landscape to produce beneficial biomass, production of food and raw materials is led by human activities, such as agriculture.

Consequently, the capacity of landscapes to produce beneficial biomass is then regulated by both landscape characteristics and management actions.

The landscape characteristics that determine the capacity of landscapes to produce beneficial biomass are (Natural England, 2009c; Muller et al., 2010):

a) Climate and water availability, including weather circumstances such sun light and rainfall which determine thermal and moisture conditions;
b) Soil properties and its characteristics that limit or enhance root growth and nutrition of plants.

Therefore, the potential capacity of the landscape to produce beneficial biomass can be determined by its soil properties, water availability and land management.

The management actions that encourage the provision of food and raw materials function are:

a) Agriculture intensification to achieve yield targets;
b) Nutrient inputs;
c) Artificial pest/weed control;
d) Irrigation;
e) Modifications to soil structure.

Yield targets prompt farmers to optimise soil physical properties and water availability. Agricultural systems will always change the original soil properties, such as: nutrients levels, structure, organic matter content and pH among others (Powlson et al., 2011). The more "improvements" are made to the soil, the more they change soil properties (Aneja et al., 2009). Serious changes in soil properties will hinder the capacity of the landscape to sustain the provision of biomass. In addition, negative changes in soil structure lead to a widespread deterioration of landscape structures, for instance, eutrophication of water bodies, soil erosion or acidification of soils (Powlson et al., 2011).

To sustain the provision of biomass and protect soil properties and landscape structures, it is necessary to attain a balance between inputs and outputs of water, nutrients, soil structure and crops through appropriate agricultural management systems (Powlson et al., 2011). Depending of the agricultural system and spatial arrangements within the landscape, compatible interactions can be encouraged (Aneja et al., 2009). Agricultural systems using "resource-conservation" farming technologies promote compatible interactions with other landscape functions while reasonable yields and economic gain can be sustained (Pretty et al., 2006; Aneja et al., 2009; Shröder et al., 2003).

Resource-conservation farming systems are referred to as organic and high bio-diverse farming techniques. Practices include the avoidance of artificial fertilizers and agrochemicals, and inclusion of spatial arrangements and non-agricultural landscape structures. Spatial arrangements vary from encouraging smaller and more diverse fields to vegetated buffer strips, forest edges, riparian zones and hedgerows; the application of different spatial arrangements aims to increase landscape heterogeneity (Bossio et al., 2010; Borin et al., 2010; Shröder et al., 2003; Ryan et al., 2010).

The combination of resource-conservation practices and spatial arrangements within agricultural fields encourages positive dynamics with other landscape function systems, for example supporting the prevention of diffuse pollution and improving quality of crops and food; for example, Buller (2008) shows that high bio-diverse pastures provide higher meat quality in terms of higher levels of vitamin E and beneficial fatty acids, as well more tender and flavour-intense meat.

It is important to consider that the provision of beneficial biomass does not only happen at the rural scale and in large expanses of land. This function system occurs at the urban scale too, in landscapes structures such as community gardens, allotments and city farms. Urban agriculture, as has more recently been noted, has existed in Europe from the early 20th century as a measure for meeting population food demand (Perez-Vazquez et al., 2008). In recent years it has been recognised that urban agriculture has a positive role on other land uses in respect of other landscape function systems (Mouget, 2008). Mouget (2008) identifies that urban agriculture usually is opportunistic, but should be move towards a purposive implementation through Green Infrastructure implementation. In this case, in addition to considering optimal soil properties and agricultural systems, potential urban green spaces for urban agriculture need to identify accessibility, connectivity within existing green infrastructure, and the community that will work the land, who need to benefit directly from its management and yields.

4.2.3 Energy conversion of non-fossil sources

The capacity of the landscape to provide non-fossil resources for energy conversion relates to the yield of energy from fundamental environmental elements: sun, water, wind and soil (Rygg, 2012). Energy from water, sun and wind is harvested through man-made technology and processes, for example hydrological and tidal energy plants, solar panels and wind turbines. The landscape is the spatial framework that supports these installations. The impact of these technologies is associated with land use change, conservation and landscape protection, landscape pattern, noise generation and visual and landscape character (Haughton et al., 2009; Rygg, 2012).

Renewable energy sources can be generated through processing biomass too. This specific biomass is referred as energy-crops. The ecological process to generate energy-crop biomass is the same as explored above (transformation of energy and resources inputs through the soil). However, this biomass purpose is different from the provision of food and materials; its system components influence and affect the processes differently.

Energy crops can be used directly as biofuels (burned to produce heat or electricity) or can be transformed to liquid biofuels such as ethanol or bio-diesel (Graham, et al., 1995; Beccali, et al., 2009). The main sources of energy crops are: energy cultivars (wheat, rapeseed, sugar beet), perennial biomass crops (*Miscanthus* and *Salix* spp) and agriculture and forest waste (pruning waste, branch wood). Energy cultivars are sought for their carbohydrate content (Graham, et al., 1995). Their growing processes are the same as agriculture processes, requiring an annual cultivation cycle (Beccali et al., 2009; Haughton et al., 2009). Perennial energy crops are woody and fast growing species; and are characterised by their high content of cellulose (Graham, et al., 1995). These have a much longer cultivation cycle. For example, *Miscanthus* crops can be harvested after the first year planted and this cycle will continue up for 20 years. Willow crops (Salix spp) are harvested after 3 years through short rotation coppice practices, this cycle can continue up to 25 years (Haughton et al., 2009). Perennial energy crops put less pressure on natural resources, in particular on soil and water, these require lower inputs of fertilizers and pesticides too; furthermore, their perennial qualities support improvement of soil properties, for example reduction of soil erosion (Haughton et al., 2009; Fernando et al., 2010). Yet, perennial energy crops and their growing characteristics have an impact on landscape character and aesthetic qualities; perennial energy crops are large and dense cultivars, reaching between 3-5 meters tall (Haughton et al., 2009). According to the literature, impacts on biodiversity have not been widely studied, yet there is a suggestion that native species could impact positively fauna biodiversity (Haughton et al., 2009; Fernando et al., 2010).

Support of renewable energy sources is a process encouraged at global and national scales, as a measure for climate change mitigation and future energy security; it is politically and market driven and requires financial support to compete against fossil sources (Haughton et al., 2009; Fernando et al., 2010; Burgess et al., 2012; Rygg, 2012). However, opposition to its development is located at the local scale. The main argument from communities not supporting in particular wind power is that wind turbine installations affect the landscape negatively. Rygg (2012) found that lack of support for wind turbines came from a top-down decision-making approach, which fails to consider local community voices and needs. Also, communities over the years have been detached from the energy production process (energy plants tend to be located far from settlements) affecting the acceptance of having energy production in everyday landscapes and in their ‘own back gardens’, requiring a change in culture. In the case of energy crops, rejection comes from planning restrictions on suitable resources (soil type, slope) and restriction on designated and protected areas. Haughton et al. (2009) noted that Natural England provided financial incentives for energy crops only on agricultural land classified as Grade 3 and Grade 4. Authors suggest that perennial energy crops are more suitable for the regeneration of degraded and damaged land, leaving high quality agricultural land for other purposes, such as food and conservation (Fernando et al., 2010; Franzluebbers, 2015). There are other arguments opposing renewable energy technology in terms of innovation, efficacy and building costs.

4.3 Landscape system: ***Hydrological cycle support***

Water is in constant interchange between the atmosphere and earth; this process is referred as the *hydrological cycle* (de Jong and Jetten, 2007). The landscape has specific functions completing and affecting this cycle. The hydrological cycle starts when precipitation occurs, then rainfall is partially intercepted by vegetation, some passing through openings within vegetation canopies and some draining through the vegetation structure (Neal, 2002; Xiao and McPherson, 2002). When there is no vegetation, rainfall falls directly to bare ground. All the water that has reached the ground is called overland flow. A portion of such water will infiltrates into the soil, other portion will flow and move over the ground and another portion will be evaporated (evaporation occurs as well when water is intercepted and temporarily stored in the vegetation structure). The overland flow that runs through the soil is discharged and collected into water bodies. Here evaporation occurs as well. Additionally, when water infiltrates the soil some is absorbed by the vegetation roots, again returning to the atmosphere through plant transpiration, whilst remainder flows through subsoil cavities and is collected in groundwater aquifers (de Jong and Jetten, 2007).

Catchments or watersheds are areas where rainfall is processed through the hydrological cycle components (Wheater and Evans, 2003; Hornbeck and Swank, 1992). Certain landscape elements, mainly vegetation and soil, maintain the balance of the hydrological cycle and the resilience of catchments when changes in the precipitation regimens are presented. The landscape and its elements have three specific functions within the hydrological cycle and its catchment:

1. To intercept rainfall through vegetation and to infiltrate overland flow into the soil (Wheater and Evans, 2003; de Jong and Jetten, 2007; Ryan et al., 2010).
2. To mitigate the Impact of overland flow and anthropogenic drivers on water quality (Anderson et al., 1976; Kübeck et al., 2009; Ryan et al., 2010; Bredemeier, 2011)
3. To store and conduct overland flow for water consumption (Wheater and Evans, 2003).

4.3.1 Rainfall interception and infiltration

This particular section explores the landscape function of rainfall interception and infiltration. Rainfall interception occurs when rainfall is captured by vegetation. This water is briefly stored in plant components (such as trunks, branches, leaves and twigs) until all plant surfaces are full, then the water flow down to the ground. The volume of rainfall intercepted varies; it depends on local conditions such as vegetation type and structure and plant transpiration rates (Xiao and McPherson, 2002; de Jong and Jetten, 2007). Studies on water interception show that interception does not reduce significantly the volume of overland flow; however, rainfall interception reduces the velocity of the overland flow allowing the catchment not to reach its storage capacity before all water is collected (Wheater and Evans, 2003; Ryan et al., 2010).

The process of overland flow infiltration into the soil has effects on volume reduction. The capacity of the soil to absorb overland flow depends on the soil properties, specially, structure, texture and organic matter content (Ryan et al., 2010) (see section 4.2.1), and also on the depth of the water table, since the greater the depth of the water table, the bigger the capacity to absorb water (Cranfield Soil and Agrifood Institute, 2015).

Landscape change and human activities disturb the capacity of the catchments to respond to precipitation events (Selman, 2012). Land changes such as land clearance, management regimens for soil structure, development on floodplains, large urban impermeable surfaces and the spatial modification of water bodies are the main drivers that hinder rainfall interception and overland flow infiltration processes. Rainfall interception by vegetation is an important function that prevents soil erosion (Hornbeck and Swank, 1992) by reducing the impact of raindrops in the soil; in turn, protected and favourable soil structure reduces soil compaction. These, together with a favourable amount of soil organic matter, are important components to overland infiltration (Ryan et al., 2010; Nunes et al., 2011).

When rainfall is not intercepted by vegetation and there is a low rate of overland flow infiltration, then the balance between volume and intensity (time and velocity) of the overland flow decreases, reducing the capacity of floodplains to collect, store and release overland flow (Wheater and Evans, 2003). This prompt saturation of overland flow leads to floods in rural and urban environments. Cities have a major impact on floodplain capacity because of their bigger area of impermeable surfaces and because of the way overland flow is managed through storm water drainage, which involves collecting overland flow and redirecting such water through pipes to water bodies and increasing overland flow velocity. Also, global warming affects precipitation patterns (frequency, intensity, volume and seasonal) by increasing rainfall rates; in England it is observed that winters are wetter, and summers are affected by severe rainfall events. Rural floods derive from overarching soil capacity to infiltrate runoff. Urban floods derive from the decreased capacity of floodplains to adapt to rainfall events; flooding in urban areas is more likely to happen and to cause more severe damage (Gill et al., 2007; Wheater and Evans, 2003; Selman, 2012). Models studying scenarios on climate change indicate that even if the proportion of vegetation cover is increased, especially in cities, the volume and intensity of precipitation still cannot be balanced (Gill et al., 2007).

4.3.2 Water quality

The assessment of physical and chemical elements in the water determine its quality. Acceptable values of water quality define the purpose and use of available water (Anderson et al., 1976; Beamonte Córdoba et al., 2010). It is well known that water is a fundamental resource for biodiversity (plant growth and fauna) and human consumption. Inorganic and organic particles, chemical substances and gases are elements that affect the quality of the water (Anderson et al., 1976; Environment Agency, 2009). Overland flow transports some of these elements, others are caused directly by pollution, for example diffuse pollution from agricultural systems and horticulture practices, industrial use and abstraction (Environment Agency, 2009) and, in some countries, discharge of drainage without treatment (Bossio et al., 2010).

Overland flow causes, particularly through poor soil structure or bare ground, soil erosion. Sedimentation is the movement of eroded soil and its related elements and pollutants: organic matter, nutrients, chemicals (pesticides and fertilisers), heavy metals and microbes. Atmospheric pollution through acid rain influences overflow pollutants (Neal et al., 2010). Deposition is the accumulation of eroded soil discharged into water bodies (Anderson et al., 1976; Neal, 2002; Wheater and Evans, 2003; Bossio et al., 2010). Erosion, sedimentation and deposition are the processes that pollute and reduce the quality of water in water bodies. Semi-natural vegetated areas have an important role in preventing soil erosion and removing pollutants. As explored previously, vegetation helps to prevent soil erosion by intercepting rain and reducing the velocity of raindrops and overland flow. Secondly, the roots from plants work as anchors to retain the soil; furthermore, vegetation helps to maintain an adequate amount of soil organic matter that improves soil structure and consequently soil capacity to absorb water. Some studies claim that more than 60% of shrub cover can reduce soil erosion and run off (Nunes, et al., 2011). At an urban scale, design and management approaches such as green and blue infrastructure and *sustainable drainage (SUDS)* schemes help to reduce the velocity and volume of overland flow and filter pollutants from run off from urban impermeable surfaces (Environment Agency, 2009; Selman, 2012).

Groundwater quality can be reduced too, as polluted soils will contaminate water during the infiltration processes (Kübeck et al., 2009; Faulkner et al., 2010). Appropriate management practices are required to prevent the over use of chemical affecting water quality. Another pressure on water quality is changing water temperature associated with climate change; elevated water temperature promotes the more rapid decomposition of organic debris, depleting the oxygen necessary for aquatic species to thrive (Anderson et al., 1976).

4.3.3 Water storage

As overland flow is subjected to gravitational forces, water will move through landscape components and structures. Overland flow is temporarily *detained* in the soils and small topographic depressions and is *retained* in surface water bodies (e.g. streams, rivers, lakes, reservoirs and channels) or in groundwater aquifers. From the total precipitation, one portion will be absorbed by vegetation, then plants will lose water through *transpiration* processes; another portion will be directly *evaporated* to the atmosphere. After these processes the remaining water retained in water bodies is referred as water yield (Anderson et al., 1976; Roberts, 2000; Lutz et al., 2010.

According to the quality of the water yielded, pressures on its use and demand comes mainly from fauna, human consumption, irrigation for agriculture, feeding livestock, horticulture, recreational use, and industrial abstraction (Environment Agency, 2009). Climate change, vegetation clearance by agriculture, urban development and deforestation has changed precipitation patterns and decreased the quantity and quality of water yield on groundwater aquifers and surface water bodies, putting more pressure on water resources (Danielopol et al., 2003). Vegetation has an important role on returning and recycling moisture to the atmosphere, which in turn generates precipitation (Ryan, et al. 2010). It is desirable to encourage precipitation, particularly in areas subject to drought, but for water yield improvement the reduction of evaporation is desirable. Blue and green infrastructure can improve water yield by providing shade to water bodies and avoiding evaporation; however, trees have a high consumption of water (Anderson et al., 1976).

Surface water quality is more variable than groundwater (Kübeck et al., 2010). Although, groundwater is the major resource of fresh water in the Earth (Danielopol et al., 2003) in some regions it is not sufficient to meet human composition (Kübeck et al., 2010).

4.4 Landscape system: ***A t m o s p h e r i c   r e g u l a t i o n***

This landscape function system is described as the capacity of the landscape to influence, filter and intercept gases, aerosols and pollutants suspended in the atmosphere; these processes have an effect on air quality and temperature and support climate change mitigation.

4.4.1 Air pollution filtration

Trees and shrubs are the vegetation cover with greatest capacity to intercept and filter pollutants suspended in the atmosphere (Beckett et al., 2000; Donovan et al., 2005; Nowak et al., 2006). Ozone, nitric oxide, nitrogen dioxide, nitric acid and carbon monoxide are some of the pollutants that negatively influence air quality. Poor air quality has its main impact on human health (Beckett et al., 2000; Donovan et al., 2005; Nowak et al., 2006). In a study conducted in the west Midlands, UK by Donovan et al. (2005) it was concluded that if tree cover was doubled it could reduce 25 % of airborne particles, hence the possible reduction of 140 deaths related to poor air quality.

Trees improve air quality through two main processes:

1. Temporal interceptions of airborne particles through leaf and bark areas.
2. Elimination of gaseous air pollutants through leaf stomata, which occurs during photosynthesis (Nowak et al., 2006).

Sources of polluting particles are derived mainly from road traffic and exhaust fumes (Beckett et al., 2000). Trees have the capacity to intercept and temporarily capture pollutant particles. These processes improve air quality by reducing the concentration of particles in the atmosphere. Not all particles are absorbed by tree leaves; deposition of pollutants occurs by wind and rainfall (Beckett et al., 2000; Nowak et al., 2006).

Tree species and physical characteristics are important components to air interception and filtration processes. Conifers and broad-leaved trees with coarse leaf texture are the tree species that more efficiently capture airborne particles; Beckett et al. (2000) found *Pinus nigra* and *Cupresoyparis leylandii* among the conifer species that more efficiently intercepted particles; *Sorbus ssp.* was the broad-leaved tree species that had the greatest capacity to capture pollutants; while *Poplar ssp.* was the least efficient. Nevertheless, airborne particles will be only temporary retained. Particles will be removed by dry and/or wet deposition, for example particles will fall to the soil when leaves fall or the pollutant will be cleaned off by rainfall.

Furthermore, some tree species can influence air quality negatively, particularly in urban areas. All trees emit volatile organic compounds (VOCs), and some of these gases combine with anthropogenic-generated pollutants (for example, oxides of nitrogen) to form other air pollutants such as ozone (Donovan et al., 2005; Nowak et al., 2006). Different tree species have different levels of VOCs emissions. Tree species with high levels of VOCs emissions are: *Populus spp., Platanus, spp., Quercus, spp., Salix, spp.,* among others. Examples of species with low levels of VOC are: *Prunus spp., Tilia spp., Morus, spp. and Gleditsia sp.* At rural locations VOCs emissions do not contribute to ozone because there are lower levels of nitrogen oxide emissions. In urban areas, if species with low levels of VOCs emissions are selected in combination with their capacity to reduce air temperature then they can efficiently reduce ozone and improve air quality (Donovan et al., 2005; Nowak et al., 2006). Finally, climate change drivers such as rising temperatures, changing weather patterns and reduced dependency on fossil fuels, will also constrain the choice of tree species in terms of factors such as their tolerance to higher temperatures and drought and their maintenance input requirements (Nowak et al., 2006).

4.4.2 Carbon sequestration

Carbon is a key element, along with water and nitrogen, to sustain life. There is a constant interchange of gases and aerosols between the atmosphere and the biosphere, including Carbon; however human activities disrupt such cycles. Climate disturbs the exchange of gases in the atmosphere by the disproportional emission of *greenhouse* gases emitted by anthropogenic activities; the consequence is that these gases trap radiation and increase air temperature (Nowak and Crane, 2002). Higher air temperature affects climate events (rainfall and drought) and puts more pressure on ecosystem resources. CO_2 is a major greenhouse gas, and its emissions come from two main sources: i) land use change, in particular deforestation and ii) fossil fuel combustion (Nowak and Crane, 2002; Bailis, 2006). As explored above, trees have the capacity to intercept and absorb pollutants in the atmosphere. This section will explore the capacity of trees to absorb and store Carbon Dioxide (CO_2).

As part of the Carbon cycle, vegetation, particularly, trees, through photosynthesis can absorb CO_2, which is then this is stored as carbon in foliage and branches (above ground sequestration and storage) (Nowak and Crane, 2002; Bailis, 2006). Then, when plant matter falls to the soil (below ground storage), carbon is assimilated into different types of Soil Organic Matter (see section 4.2.1, soil structure). Eventually, carbon will be released again to the atmosphere when trees die and decompose (Nowak and Crane, 2002). However, through increasing tree cover and considering maintenance approaches trees have an important role in climate change mitigation by sequestering and decreasing levels of atmospheric CO_2 (Nowak and Crane, 2002; Bailis, 2006).

Direct contribution to CO_2 sequestration as explored above is through absorbing and storing carbon above and below ground. At the urban scale, trees influence indirectly CO_2 emissions by influencing microclimate conditions and potentially reducing energy use to cool and heat buildings (Gill, 2007; Nunery and Keeton, 2010), (see section 4.4.3). However, CO_2 absorption and sourcing interactions are influenced by the management and maintenance of trees and forests. Intense and frequent harvesting approaches, fuel emission from maintenance practices such as pruning or soil nutrient input, or the transport and final use of biomass, considerably increases CO_2 emissions, contrary to encouraging trees' CO_2 sink properties (Nowak and Crane, 2002; Nunery and Keeton, 2010). Low harvesting frequencies, forest spatial structure, low soil disturbance and age of trees are key considerations in establishing the direct contribution of trees and forest, both at urban and rural scales, to reduce levels of CO_2 (Nowak and Crane, 2002; Nunery and Keeton, 2010).

4.4.3 Microclimate regulation

The landscape through vegetation and surfaces has the capacity to influence and modify microclimate conditions. Climate change is raising the temperature of the air. Higher temperatures have effects at rural and urban scales. At the rural scale, higher temperatures affect negatively biodiversity, soil's biological components and water availability. Ryan et al. (2010) report that trees, through their cooling effects, reduce water evaporation near water bodies and, by influencing wind speed, reduce soil erosion maintaining a desirable soil structure and organic matter content.

Higher temperatures at urban scales produce the *urban heat island* effect (Akbari et al., 2001; Gill, 2007). This phenomenon has negative consequences on people's health and well-being and increases the demand of energy consumption for cooling purposes, which in turn aggravates global warming. The urban heat island increases air temperature through surfaces absorbing energy and reflecting back heat, that is, with little poor vegetation cover. Research affirms that vegetation, in particular trees, reduce air temperature though shading from trees' canopies and their transpiration process (Akbari et al., 2001; Gill, 2007). Moreover, trees can protect buildings from cold winds, thereby reducing the demand for energy for space heating. Reflective, green and permeable surfaces such as green roofs and walls reduce reflected heat and insulate buildings preventing gain and loss of heat/cold. Rising air temperatures affect air quality too, as many pollutants are temperature dependent. Reducing air temperature contributes to the reduction of ozone formation (Nowak et al., 2006). These effects have a high impact at site scale, but are accumulative too, and so will affect positively the landscape-city scale (Akbari et al., 2001). Unfortunately, pressures on water availability, because of drought and precipitation patterns changing due to climate change, are limiting tree planting, especially in cities where resources are more constricted. As with the improvement of air quality function, selection of tree species is important along with water management strategies. Various authors (Akbari et al., 2001; Gill, 2007; Selman, 2012) explore how selection of tree species and water management strategies are important for maintaining a desirable tree cover to modify microclimate conditions.

4.5 Landscape system: *Biodiversity support*

Biodiversity is term that describes and accounts for the biotic diversity contained within ecosystems in terms of species (e.g. genes and individual species) and habitats (e.g. plants communities and biomes) (Watts et al., 2005; Lawton et al., 2010). Biodiversity is a key characteristic that contributes to the balance of the environment at all scales, and from which humans benefit highly (Lawton et al., 2010). High levels of biodiversity help to stabilise and sustain other landscape function systems processes and services. Species through their population's dynamics (cycles of birth, death and movement) (Vellend and Geber, 2005) influence ecosystem properties, resilience and their resource flow balance (Hooper et al., 2005), especially when disturbances occur such as climate change and habitat degradation (Hall et al., 1997; Loreau et al., 2001; Hopkins, 2009).

To understand how the landscape can support and at the same time benefit from biodiversity is important to understand existing levels of biodiversity and how these are influenced by natural and social processes. Biodiversity is described by two main measures of species diversity: i) species richness (species diversity within the habitat, i.e. number of different species in a determined spatial portion), and ii) genetic diversity (diversity of genotypes existing within individual species) (Vellend and Geber, 2005). Both levels of biodiversity are important to avoid species decline and extinction. The second key information to understand is what influences species and genes. There are five processes that influence the two levels of biodiversity: 1) Mutation and/or evolution; 2) drift (*changes in frequencies of alleles);* 3) selection *(favour of species or alleles over others);* 4) migration (movement); and 5) spatial heterogeneity (Vellend and Geber, 2005). Processes 1, 2 and 3 are beyond the scope of this thesis as the landscape has no direct influence on such processes. However, the landscape directly influences processes 4 and 5, through its spaces and spatial structure.

Therefore, landscapes have the capacity to support biodiversity (large diversity of species and genes) in two forms. First, by providing high quality habitats with spatial heterogeneity (at site and landscape scale), where species can find refuge, obtain resources and transform energy. Secondly, by connecting those habitats allowing species to move through and complete their needs and dynamics, forming an ecological network (Lawton et al., 2010). This thesis explores the landscape function system of biodiversity support through analysing the processes of habitat provision (section 4.5.1), habitat connectivity (section 4.5.2) and pollinator support (section 4.5.3). The pollinator support function was added to the biodiversity support system because of the pollinator's role in enhancing biodiversity by sustaining plants' life-cycles.

4.5.1 Habitat Provision

As explored above, biodiversity is influenced and supported through different habitats from which species can have shelter and obtain resources necessary for their survival. The landscape, either by natural succession or influenced by human activities, has the capacity to provide these habitats. Habitat characteristics, quality and distribution are the components that determine the successful support of biodiversity. Research studies highlight three main characteristics that habitats should provide in order to truly support healthy levels of biodiversity. These characteristics are: i) habitat quality, ii) habitat heterogeneity (within the habitat and their distribution through the landscape), and iii) adequate habitat size (Hodgson et al., 2009; Lawton et al., 2010; Schooley and Branch, 2011).

Literature reviews carried out by Hall et al. (1997) and more recently by Mortelli et al. (2010) describe different definitions of habitat quality and their implications for biodiversity conservation studies. For purposes of describing landscape function processes, this literature review defines habitat quality as spaces not degraded or polluted by anthropogenic processes (Hodgson et al., 2009) and spaces capable of supplying resources for species to survive and thrive when coping with environmental disturbance, for example climate change (Hall et al., 1997; Mortelli et al., 2010).

Habitat heterogeneity is described as the diversity of physical and chemical characteristics within the habitat and within the landscape, such as hydrology, soils, geology and landform (Hopkins, 2009). These diverse components provide to species different spatial resources, and maintain a variety of microclimates that influences species abundance and ecological processes (Hopkins, 2009). Therefore, habitat heterogeneity encourages species richness by sustaining wider numbers of different species with different spatial and resources needs.

Habitat size relates to the provision of an adequately large habitat to protect species populations. An adequate size of habitat helps ecosystem components to be more resilient to disturbances, increasing the opportunities of biodiversity protection; however, small habitat patches are important as well, as these can act as support habitat of the core habitats contributing to and complementing resources (Shafer, 1999).

Anthropogenic activities and climate change are drivers that limit the capacity of the landscape to provide adequate habitats, by causing habitat loss, degradation and fragmentation. Habitat loss through agriculture, urban development, pollution and deforestation influences population species size and then species richness (Bender et al., 1998). Furthermore, anthropogenic processes lead to habitat fragmentation obstructing species movement (Lawton et al., 2010; Watts and Handley, 2010). Climate change influences species to modify their traits in order to respond to disturbances resulting from rising temperatures, droughts and changing rainfalls events (Hopkins, 2009). Species' responses require that landscapes provide protection through heterogeneous and high quality habitats.

Evidence on how species change their habitat needs and range in this changing climate (land use change and global warming) is currently developing, although many uncertainties remain (Hopkins, 2009). Researchers are closely looking at the role of conservation management practices, in particular, to the implementation of *"adaptive management".* This approach informs management and maintenance strategies through stakeholder participation, observations and learning feedback loops, aiming to adapt to constantly changing situations (Hopkins, 2009).

Current pressures on resources (human and economic) and adaptive management approaches seeks a strong collaboration between governance bodies at all scales (national and local), private and third sector organizations, and the community, in order to provide, implement and maintain high quality and connected habitats (Hopkins, 2009). Thus, the landscape supports biodiversity through sufficiently large, heterogeneous and high quality habitats, managed through a coherent institutional and community support.

4.5.2 Habitat Connectivity

As noted above, biodiversity support depends on the good quality, adequate size and heterogeneity of core habitats (Lawton et al., 2010; Schooley and Branch, 2011). Yet, for species to complete their life cycles, they require to move through the landscape (Nikolakaki, 2004; Lawton et al., 2010). The landscape provides essential resources, which are distributed through natural and semi-natural habitat patches. Species use these resources to fulfil their life-cycle and survival needs, such as: feeding, reproduction, migration, population dynamics, different habitat requirements (Nikolakaki, 2004) and, more recently proposed, the movement of species searching for new habitat due to climate change disturbances (Ray and Moseley, 2007; Hodgson et al., 2009; Lawton et al., 2010). Thus, species have the ability to move between patches to fulfil their needs or to supplement the existing resources found in their original patch. However, movement of species is determined by their own capacity for moving (foraging range) and the landscape spatial structure, namely, permeability and distance between habitat patches (Tischendorf and Fahrig, 2000; Taylor et al., 1993). Landscape connectivity is the measure that defines to what extent landscapes support or hinder species movement (Tischendorf and Fahrig, 2000; Taylor et al., 1993).

Landscape permeability between habitat patches is provided by natural or man-made landscape structures, such as corridors, stepping-stones habitats and the surrounding matrix. Allowing species to move through the landscape in conjunction with high quality habitats patches safeguards healthy levels of biodiversity values by encouraging species dispersal, species persistence and genetic diversity (Schooley and Branch, 2011). Furthermore, a functional, high quality, coherent and permeable network of habitat patches also supports the other landscape functions and processes (Ray and Moseley, 2007; Lawton et al., 2010).

Unfortunately, continuing anthropogenic processes are accelerating the loss of natural connections between habitat patches and limiting the complexity of the surrounding matrix (Lawton et al., 2010). These are the main causes that obstruct species' movement. Another factor reducing the support of landscape connectivity and habitat provision, is when habitat networks are established only by considering habitat patches physically (structural landscape connectivity) without considering species behaviour (species capacity and needs to move), hampering resource availability and species dynamics (Ray and Moseley, 2007; Lawton et al., 2010; Schooley and Branch, 2011). To conclude, the capacity of the landscape to protect and enhance biodiversity requires that habitat provision and habitat connectivity perform collectively.

4.5.3 Pollinator support

Successful reproduction and dispersal of plants depends on certain insects that, during their search for forage, move pollen across landscapes. Pollination of plants not only enhances biodiversity but also plays a major role in crop productivity (Jauker et al., 2009). Such insects providing this service are called pollinators; success on plant reproduction depends on a diverse number of pollinator species (Steffan-Dewenter and Westphal, 2008). Pollinator species range from bees to butterflies, wasps and beetles to mention a few, although major pollination services are provided by different species of bees. The landscape has the function of supporting pollinator populations by providing appropriate nest sites and floral resources (habitats and connectivity) required for their survival and colony development.

Pollinators' biological traits vary among species and generalization about species should be avoided; for example, Jauker et al. (2009) explored the differences between wild bees and hoverflies using the landscape, and found that wild bees' forage distance was limited by their need to go back to their nest to feed their offspring, whereas hoverflies' forage distance was less limited as, after they deposit their larvae in suitable habitats, they do not need to return to feed. These differences make it very difficult to evaluate the capacity of a landscape to support pollinators. However, this literature review identifies three core needs for pollinators' colony development among different species: i) shelter for hibernation and nesting, ii) structures for movement, and iii) forage resources. Landscapes have the capacity to provide these through their spatial composition, structure and, as explored above, species' capacities such as maximum forage distances and larval requirements (Jauker et al., 2009).

The landscape structures that provide support to pollinators can be classified as:

a) Non-linear semi-natural habitats which provide shelter and nesting opportunities;
b) Linear landscape structures providing corridors for pollinator movement, dispersal and nesting sites;
c) Areas with high flower diversity that provide forage.

There are particular land covers identified as favourable for certain pollinator species. High densities of bumblebee nests have been founded in gardens, grasslands and linear landscape structures such grasslands margins (Osborne et al., 2008b; Goulson et al., 2010). For some species, deciduous woodlands in spring provide forage resources, although when tree canopies close these represent an obstacle to pollinator movement (Osborne et al., 2008a; 2008b; Jauker et al., 2009; Goulson et al., 2010).

It is important to mention that the landscape matrix surrounding potential habitat patches for pollinators is as significant as the patch itself (Habitat connectivity). Jauker et al. (2009) found that along field margins wild bees (bumblebees in particular) declined with distance from their natural habitat, whilst Batáry et al. (2010) found the same observation. Wild bees heavily depend on the quality of the surrounding landscape matrix (availability of grasslands and flower resources in close radius); however, hoverflies were not restricted by the landscape matrix. Goulson et al. (2010) found that the landscape factors affecting nest survival of bumblebees varied from specie to species, but found that the positive effects of gardens can spread to adjacent agricultural or conservation zones up to 1km away. These positive relations found in gardens near farmlands indicate two possible options: if nests are located in farmlands then bees are finding food resources in the gardens or if nests are located in gardens then such areas are providing both nest and food resources. In summary, habitat heterogeneity is a key factor in maintaining the service of pollination (Rundlöf et al., 2008).

Unfavourable landscape change (habitat loss, fragmentation and agricultural intensification) is a major cause of pollinators' population decline, as for biodiversity more generally (Steffan-Dewenter and Westphal, 2008; Jauker et al., 2009; Barmaz et al., 2010). Agricultural intensification reduces resources of pollinators' favourite forage (Osborne et al., 2008a; 2008b; Rundlöf et al., 2008) and agrochemicals kill directly many pollinators species (Rundlöf et al., 2008; Barmaz et al., 2010). Nevertheless, research suggests that pollinators such as bees can be protected and enhanced through resource-conservation agricultural systems (Batáry et al., 2010) . It has been found that organic farms and their particular landscape structures have a positive impact on pollinators' populations in homogeneous landscapes (Holzschuh et al., 2007; Rundlöf, 2008).

Habitat loss decreases the number of sites appropriate for nests, limiting pollinators' populations and space for queen bees to hibernate (Jauker et al., 2009; Osborne et al., 2008a; 2008b; Goulson et al., 2010). Habitat fragmentation hinders pollinators' foraging movements (Steffan-Dewenter and Westphal, 2008). The pollinator support function will provide positive influence on bumblebee numbers up to 1 Km from the nesting site if a heterogeneous landscape matrix (such as semi-natural grasslands, woodland edges) providing forage is available.

4.6 Landscape system: ***I n f o r m a t i o n***

This landscape function system depicts how people through *experiencing* and *interacting* with the landscape information exchange and cognitive processes will benefit from opportunities to reflect, learn, inspire and improve health (de Groot et al., 2002; de Groot, 2006; King, 2012).

4.6.1 Aesthetic experience

The landscape function of aesthetic experience is the capacity of the landscape to connect people with their environment, in particular the natural and semi-natural environment (Gobster et al., 2007). This process is the relationship of landscape's biophysical elements and how humans perceive and experience the landscape and its elements (Bratman et al., 2012; Daniel, 2001). The response derived from this relationship is an aesthetic experience (Jorgensen, 2011). An aesthetic experience comprises three elements: the aesthetic object, in this case the *landscape*, the recipient's social, cultural and emotional background, and the aesthetic experience itself (Chenoweth and Gobster, 1990; Lothian, 1999).

Positive aesthetic perceptions can emerge from simple landscape contemplation, generating an immediate sensory experience (Gobster et al., 2007). This is related to the landscape's physical and *objective* qualities (Lothian, 1999). For the landscape to have the capacity to foster an aesthetic experience solely by landscape contemplation, its physical components need to be characterised by good visual quality. Research studies of visual landscape character and quality based theoretical studies of how humans perceive and develop a preference for a particular landscape - such as *"Information process theory"* (Kaplan, 1987), *"Biophilia"* (Wilson, 1984) and *"Topophilia"* (Tuan, 1974) -, have found common physical and visual landscape components that contribute to a good visual quality of the landscape and that have been correlated with positive cognitive responses. These physical components are the provision of certain levels of complexity (through vegetation or topography), coherence, disturbance, stewardship (appearance of care and maintenance), visual scale (size, shape), naturalness (vegetation structures, water bodies), historicity (heritage legibility) and ephemeral elements (seasonal changes) (Tveit et al., 2006; Ode et al., 2008). Other positive characteristics linked to landscape positive preferences are: landscape openness (Bjørn et al., 2002), waterways with their associated vegetation, and heterogeneity (Dramstad et al., 2006).

The second and third and equally important elements of an aesthetic experience are the individual's *subjective* feelings and thoughts developed throughout the aesthetic landscape experience. Philosophical and psychological approaches look these *subjective* responses; identifying that people's aesthetic values, cultural and emotional background, environmental awareness, memorability, knowledge, past associations, cognitive and perceptual abilities are key *subjective* elements influencing an aesthetic experience (Chenoweth and Gobster, 1990; Lothian, 1999; Gobster et al., 2007; Jorgensen, 2011). The acknowledgement of these subjective elements are important for evaluating and understanding people's aesthetic experiences (Chenoweth and Gobster, 1990; Lothian, 1999) which in turn are responsible to develop cognitive associations, feelings and reactions towards a landscape. Positive cognitive associations connected with aesthetic experiences are the stimulation of positive feelings and attitudes, memory creation (Jessel, 2006), sense of attachment and willingness for further exploration and contemplation. However, it is important to recognise that landscape experiences and interactions can as well cause negative associations and experiences such as fear, discord and harm (King, 2012).

An aesthetic experience is also prompted by developing an emotional response thorough actively using and living in the landscape (Bjørn et al., 2002; Jorgensen, 2011). The positive use and experience of the landscape allows the user to develop place attachment (Bjørn et al., 2002). Place attachment is a quality that is described as the development of a sense of fulfilment by being involved and having a sense of familiarity with the landscape. These qualities further develop more complex positive preferences, associations, meanings and attitudes towards the place people feel attached to (Bjørn et al., 2002; Jorgensen, 2011). Walking, cycling and community gardening are activities that have been studied and associated with place attachment, see for example Timms and Tight (2010) and Hale et al. (2011). However, many more landscape activities need to be studied to understand how they could encourage meaning and value in the landscape (Jorgensen, 2011).

In conclusion, an aesthetic experience has the potential to connect and improve the relationship between people and landscape. This is achieved through encouraging positive emotions towards the landscape and the development of place attachment. Furthermore, these two cognitive processes have the potential to change attitudes and behaviour towards the landscape (Jorgensen, 2011; Hale et al., 2011). For example, Dobson (2011) explores how guided community walks exploring heritage legibility change participants' attitudes of caring and desire to learn more about the landscape explored.

4.6.2 Heritage interpretation

Natural, semi-natural and man-made landscape structures, elements and composition have the capacity to provide, to conserve and to display evidence of past generations. Such legacy provides information about the history of the region, past generations' attributes, knowledge, skills and cultural activities (Antrop, 2005; Swense and Jerpåsen, 2008; Daniel et al., 2012; Rippon, 2012). Those elements provide identity, place character and a sense of common ground and collectiveness amongst community members (Daniel et al., 2012).

Cultural heritage can be identified within the landscape by studying and identifying for instance, agricultural field systems, land use patterns and place names to mention a few (Rippon, 2012). Furthermore, there is also *intangible* heritage that gives importance, value or meaning to the landscape, for example the reference to specific landscape features, ecosystems or species through narratives, stories and/or myths (Daniel et al., 2012). However, the heritage function can go beyond contemplation, touristic attraction or material for a museum in the same way it occurs in aesthetic experiences. Landscape heritage has the potential to be experienced on a day to day basis, helping to encourage social qualities important for distinctive resilient landscapes. For example, Rippon (2012) studied how *"droveways"* that were used to connect an island community to coastal resources survive in the present as public right of ways, and how these routes give community interest and sense of belonging to a new nature reserve that conserves and includes these heritage paths. Another example illustrated by Antrop (2005) is the importance of knowing and understanding past rural landscape as an important source of knowledge that can potentially provide local specific management techniques. Furthermore, landscape heritage "beyond the view" can function as a motivation and fascination element, and combining these elements with the performance of an activity within the landscape can engage people with their local environment (Dobson, 2011), for example through community walks.

To finalise, the understanding and interpretation of heritage's effect on the present landscape can provide not only a "story/history" to contemplate, tell, sell or visit, but can contribute to the formation of communities' identity. It can also potentially develop place attachment and sense of place, and contribute to social learning (Antrop, 2005; Daniel et al., 2012; Rippon, 2012) and reconnection to the local landscape.

4.6.3 Outdoor learning experience

The landscape has the capacity to offer complex, challenging and stimulating spatial conditions where people can learn and develop physical, intellectual and emotional capacities (Fjørtoft, 2004). This capacity is described as *outdoor learning experiences*, where the landscape is the *place* where the activities take place, as well as the *object* to understand (Szczepanski, 2011). An outdoor learning experience in natural or semi natural landscape can occur informally by playing, recreation and community work (Szczepanski, 2011; Fusco, 2001) or through formal structures such as outdoor classrooms and field trips as part of the education curricula (Dillon et al., 2006; O'Brien and Murray, 2007). There are important physical landscape qualities necessary to encourage learning experiences, namely, accessibility, wear resistance, diversity and complexity of natural elements, for example topography, vegetation and textures (Fjørtoft, 2004).

Szczepanski (2011) and Fjørtoft and Sageie (2000) explored how outdoor learning experiences that encourage physical activities have a positive influence on people's health. Outdoor learning experiences influence environmental stewardship by improving the understanding and knowledge of people about landscape processes, benefits and consequences of environmental damage. Other cognitive capacities improved from outdoor landscape experiences are positive individual behaviour, motor development, creativity in play and self-esteem (Fjørtoft and Sageie, 2000; O'Brien and Murray, 2007).

As explored in the aesthetic experience process, outdoor learning experiences foster the re-connection between people and their environment; these experiences are encouraged by the engagement and sensory experiences within the landscape (Szczepanski, 2011). Unfortunately, modern lifestyles, health and safety concerns, education sector bureaucracy and negative associations such as fear, are circumstances that affect the quality and quantity of outdoor learning experiences (Dillon et al., 2006; Maynard and Waters, 2007). However, there is evidence of the importance of encouraging outdoor learning experience within children's early years (Fjørtoft and Sageie, 2000) through educational frameworks, for example: Early Years Foundation Stage in England (Maynard and Waters, 2007), and Forest Schools in the United Kingdom, where educational programs offer opportunities to learn through outdoor classrooms in nearby forests (O'Brien and Murray, 2007).

4.6.4 Health and wellbeing encouragement

This landscape function refers to the capacity of the landscape to be a spatial framework where activities that encourage healthy living and well-being improvement can take place (Abraham et al., 2010). In addition, the landscape through supporting ecological processes has the capacity to improve environmental conditions essential for human health care, for instance quality good air and water provision, disease diminution and production of food among others (Millennium Ecosystem Assessment, 2005). This section in particular will look at how positive relationships between both landscape physical components and landscape experiences can potentially improve people's mental, physical and social well-being.

Mental health can be improved by contemplating natural and semi-natural physical landscape components such as vegetation layers and water bodies. This argument comes from the *"restorative landscape"* theories developed by Kaplan (1987) and Ulrich et al. (1991). They both argue that when humans contemplate and perceive natural and semi natural landscape elements, their cognitive processes can easily sort out the information contained within a good quality landscape (refuge opportunities, food resources, fascination) and, through aesthetic experiences, they can reach certain levels of relaxation. This is because, potentially, basic human needs can be satisfied providing rest from cognitive processes (Bratman et al., 2012; Grahn and Stigsdotter, 2003). For example, Tzoulas *et al.* (2007) carried out a literature review, which identified several survey studies, which showed that when people visited "natural" favourite places they would benefit from landscape restorative experiences inducing, for example, stress reduction.

Nevertheless, this study proposes that when the landscape function of health improvement takes place beyond contemplation, it will not only improve mental health but also physical and social well-being. Physical health improvement can be achieved by encouraging people to experience the landscape though physical activities: exercising (walking, running, swimming, cycling) and recreational activities. These activities contribute to reaching the recommended levels of physical activity suggested by the health sector to improve people's physical health. One way of encouraging and motivating people to use the landscape to get health benefits is through good quality landscape physical components, such as accessibility, opportunities for activities, closeness, safety and attractiveness to the five senses (Grahn and Stigsdotter, 2003; Giles-Corti and Donovan, 2003; Titze, et al., 2005; Abraham et al., 2010; Timms and Tight, 2010).

Nevertheless, current research has found that not only is an attractive landscape capable of encouraging an increase physical activity, but may also enhance how people engage with their community (Ogilvie et al., 2008, Timms and Tight, 2010). For example, Giles-Corti and Donovan (2003) found that people are more likely to achieve recommended walking levels if they had someone (including their dogs) to exercise with. Furthermore, Hale et al. (2011) explored that people well-being can be influenced indirectly through learning and aesthetic experiences as they studied how people involved in community gardens learned about bio-physical process and changed attitudes towards a healthy life style by improving their alimentation by eating fruit and vegetables. Studies reflect too that through, for example, community walks (Dobson, 2011), gardening communal gardens and allotments (Hale et al., 2011) and aesthetic experiences (Hale et al., 2011; Timms and Tight, 2010) will not only encourage physical activity and metal restoration but also can potentially improve social well-being by improving "social integration", encouraging "collective experiences of nature" (Abraham et al., 2010), developing social learning (section 4.8) and changing behaviour attitudes (Hale et al., 2011).

In conclusion, whether people are encouraged to get more active by landscape physical characteristics, by individual behaviour or by cultural influence, the landscape is the spatial framework where potential activities that benefit human health can take place.

4.7 Landscape system: ***C a r r i e r***

This landscape function relates to the landscape's spatial configuration of physical components, in particular linear and nodal structures, which encourage people's active engagement in and movement through the landscape. This engagement and movement provides opportunities for recreation and contributes to sustainable transport by travelling on foot or cycling. Space, place and connectivity are spatial qualities important to encourage movement and recreational opportunities. These will be described in this section before moving on to the recreational and sustainable transport landscape functions.

This literature review identifies *"space"* as the physical characteristics and the management actions (Van Berkel and Verburg, 2012; Pinto-Correira and Carvalho-Ribeiro, 2012; Namyun et al., 2012) that make a space suitable to carry out a certain type of recreational activity or a particular mode of active transport (examples of both activities are walking, cycling, hiking, fishing, gardening and tourism). Space qualities necessary to encourage recreation and active transport are accessibility, legibility, permeability, infrastructure, safety, comfort, visual quality, proximity, heterogeneous land cover and mixed land use (Mohan and Tiwari, 1999; Walker et al., 2006; Kienast et al., 2012).

Then, *"place"* is a non-tangible and subjective quality that it is built by people actively experiencing and interacting with the landscape; these interactions develop meanings, perceptions, feelings and attitudes towards the landscape (Kienast et al., 2012; Edwards et al., 2012; Namyun et al., 2012). Place development requires positive support from other landscape functions, in particular from the *information systems* (aesthetic experiences, heritage interpretation and outdoor learning) (Van Berkel and Verburg, 2012; Pinto-Correira and Carvalho-Ribeiro, 2012). These landscape functions encourage positive cognitive associations that foster the development of "places" (see section 4.6). Positive associations to "places" influence people's preferences to where, when or how to carry out a recreational activity (Pinto-Correira and Carvalho-Ribeiro, 2012; Walker et al., 2006); or, in the case of active transport, personal perceptions will encourage people to decide whether to walk or to cycle as a way to move between points (Selman, 2012; Walker et al., 2006).

Finally, physical *"connectivity"* relates to accessibility, meaningful and functional connections to desirable spaces and places. Spatial connectivity for human movement can be achieved, through the use of landscape linear elements, such as rivers, or through planned spatial network initiatives such as Greenways (Ahern, 1995). Nevertheless, meaningful connections can only be achieved through established policies and partnerships, that will ensure continuous and coherent network connections (Cerin et al., 2007; Selman, 2012).

4.7.1 Recreation opportunities

The landscape through its elements, structures, spatial composition and its community is able to provide "space" and "place" where opportunities for recreational activities can take place. As explored above, this thesis refers to "space" as the physical characteristics and the management actions (Van Berkel and Verburg, 2012; Pinto-Correira and Carvalho-Ribeiro, 2012; Namyun et al., 2012) that make an area suitable to carry out certain type of recreational activities. Then "place" is described as a quality that is developed through the community experiencing and interacting with the landscape. These in turn allow people to develop meanings, feelings and attitudes towards the landscape (Kienast et al., 2012; Edwards et al., 2012; Namyun et al., 2012). Then, these attitudes (positive and negatives) influence people's preferences to where to carry out a recreational activity (Pinto-Correira and Carvalho-Ribeiro, 2012). For instance, Namyun et al. (2012) found that place meaning influenced the frequency of visits to recreational spaces.

The physical characteristics that help the landscape to support recreational opportunities are, for instance, connectivity (Selman 2012), accessibility, visual quality, infrastructure and heterogeneous land cover. Kienast et al. (2012), through a survey carried out to identify

landscape suitability for recreation, found that in order for a space to be successfully used for recreation, a site should be as close as 5 to 10 minutes walking or cycling radius; a similar result was encountered by Namyun et al. (2012), where proximity from home to recreational "spaces" influenced positively the visits to recreational areas. Furthermore, Kienast et al. (2012) identified that an optimal landscape composition for recreational opportunities should comprise a certain degree of complexity provided by, for example, woodland patches (c.f. Edwards et al., 2012), peaks, hiking trails networks and open spaces for gathering.
However, for landscapes to have the capacity to offer recreational opportunities management objectives must not only focus on maintaining physical elements, but also include users' meanings (tangible and intangible) of "place" that encourage their landscape preferences (Namyun et al., 2012). Understanding why humans pursue recreational activities could aid understand and exploration of the meanings given to a *place* when experiencing the landscape.

As with the information and community functions, recreation centres on active social engagement and interaction with the landscape, and provision of opportunities for health improvement, learning, sense of achievement and enjoyment (Van Berkel and Verburg, 2012; Pinto-Correira and Carvalho-Ribeiro, 2012; Namyun et al., 2012).

4.7.2 Active transport

This landscape function system refers to the capacity of the landscape to connect and access purposefully and meaningfully spaces and places. Such connectivity in turn could encourage the community to actively travel through the landscape discouraging the current reliance on cars. Active transport influences positively people's health and well-being and contributes to climate change mitigation by reduction of CO_2 emissions from fossil fuel combustion from car exhausts (Toth-Szabo et al., 2011; Selman, 2012; Walker et al., 2006). As with the previous landscape function, people's decision to actively travel relies on space and place qualities. This landscape function occurs mainly at the urban scale.

Space qualities, for instance proximity to destinations, is a determinant factor to influence the decision of walking as transport (Namyun et al., 2012; Cerin et al., 2007). Kienast et al. (2012) recommend that walking or cycling distances should not be more than 5 to 10 minutes in order to encourage active transport, in particular for visit recreational sites.

Another physical characteristic is mixed land use in optimal landscape compositions to encourage human movement (Kienast et al., 2012; Edwards et al., 2012).

Positive associations to "places" influence people's preferences for active transport (Pinto-Correira and Carvalho-Ribeiro, 2012; Namyun et al., 2012; Selman, 2012; Walker et al., 2006). For example, Namyun et al. (2012) found that place meaning influenced the frequency of visits to recreation "spaces". Fitzhugh et al. (2010) identified that modifications to the appearance and infrastructure of the physical environment was not a determinant quality in increasing active transport, in particular journeys to schools. However, what did have a positive effect on determining active transport was the social interaction with other parents and the school, as explored in the health improvement function (4.6.4) where people felt more encouraged to do physical exercise if walking accompanied by someone else (Giles-Corti and Donovan, 2003).

Meaningful and functional connections from and to workplaces, schools, homes, shops, public transport nodes and recreation sites contributes to the selection of active transport as a medium to move from one place to another (Cerin et al., 2007). Connectivity should be planned in terms of demand, drawing upon an analysis of current formal and informal routes of movement (Selman, 2012).

4.8 Landscape system: ***C o m m u n i t y***

The *community* landscape system is not commonly found on existing landscape function and services typologies (such as: de Groot et al., 2002 and 2010; de Groot, 2006; Constanza et al., 1997; Millennium Ecosystem Assessment, 2005; Daily, 1997). This system terminology was identified from the study carried by Ling et al. (2007), but it differs as this thesis explores the community function system though wider and structured community processes such as social capital, social learning and landscape partnership (Selman, 2012). This system refers to the capacity of the landscape to support landscape experiences that will encourage cooperation and collaborative processes providing beneficial outcomes such as social learning and as well as improving the local economic capacity.

4.8.1 Institutional thickness

The literature refers to institutional thickness as a capacity to facilitate and encourage collaboration between community members through governance frameworks and organisational structures (Leibovitz, 2003; Selman, 2006). Social capital and social learning are qualities derived from social collaboration between members of a community and institutions. Thus, institutional thickness is the framework, whilst social capital and social learning are the potential qualities derived from collaborative processes. Community is defined as a group of people interacting and living in and influencing a particular locality.

Social capital is a community quality originated by *social interactions* between members of a community (Graham et al., 2009). These relationships generate groups or associations that share something in common, for example a specific place where they meet, or a common interest in hobbies or skills, so communities have a common goal or objective to be achieved (Selman, 2012). However, social capital can relate to negative associations too, for instance antisocial groups, exclusion and rejection. Graham et al. (2009) in their literature review found two types of social capital: i) *bonding* and ii) *bridging* or *linking*. *Bonding* social capital refer to interactions between selective and exclusive people with a strong bond to a place or an activity; whereas *bridging* social capital seeks to link community's members that might never be associated because of their cultural differences or interests. In both cases, it has been found that social capital emerges from a relationship between people and *place attachment* (Graham et al., 20009; Selman, 2012). From this discussion, this thesis proposes that a landscape has the capacity to be both the spatial framework where collaboration and associations between people occur through active engagement with and experience of the landscape, and the object that collaboration is focused upon (Graham et al., 2009). Positive and bridging social capital benefits can be found at two levels: individuals can benefit from actively engaging with people, and from undertaking activities within the landscape which improve their well-being and health; at the community-group level, social capital can encourage trust, commitment and place attachment with the landscape (Selman, 2012).

Social learning is a social process that emerges from learning and understanding about complex and uncertain issues through collaboration between agencies, institutions, governance bodies and sources of knowledge such as researchers, practitioners, landowners and landscape users (Kilvington, 2010; Selman, 2012). Social learning as a landscape process occurs when, through collaboration and mutual understanding between people, qualities of trust, awareness and legitimacy of perspectives lead to new knowledge, innovative approaches and new partnerships. In turn, these enhance the capacity to deal with current and future uncertain and complex environmental challenges, through long-term engagement and new attitudes (DEFRA, 2011; Selman, 2006; Selman, 2012; Tippett, 2004; Kilvington, 2010). This process is related to participatory contexts and approaches, and the landscape multifunctionality quality of including people at the centre of its approach.

To summarise, this thesis explores institutional thickness as the landscape function that embraces and fosters social processes between community members and institutions, to build positive social capital and social learning. These processes emerge through people actively engaging with the landscape and through participative approaches influencing the landscape's physical and cultural components through actions and attitudes.

4.8.2 Economic

This landscape function refers to landscape's economic contribution to local economic processes. The landscape has the capacity to influence economic processes and these in turn will provide resources for landscape management and maintenance. Selman (2012) identifies three economic processes within the landscape scale. First, landscape's provision function contributes to marketable products, especially 'locality products or crafts'. These productive practices, for example agriculture or forestry, influence the character of the landscape and place attachment.

Secondly, the landscape physical components, regulation functions and landscape character are influenced by governmental economic incentives such as agriculture subsidies or competitive tenders (for example in England, the Countryside Stewardship) that aim to pay to landowners from ecosystem services generated from ecological and conservation management practices (Courtney et al., 2013; Williams et al., 2012; Selman, 2012). Williams et al. (2012) found that these incentives contribute to local economies through the generation of employment and encouragement of local skills when landowners required for instance to restore hedgerows and drystone walls.

The third economic process refers to the landscape's economic competitiveness (Natural England, 2014b) and its role to the capture monetary investment reflected in investment and increasing value of properties and land (Forest Research, 2015). The literature suggests that this is a cyclical process, as private investment through, for example, sponsorship in the particular case of the National Forest contributes towards financial and volunteering input for the creation of new woodlands (NFC, 2015b). Natural England (2014b) explores evidence on the role of investment and economic activity from green tourism and recreational opportunities which largely depend on good quality and distinctive landscapes to attract visitors to the area. Economic activity from tourism and recreational investment is reflected by visitors expending money and the creation of employment. The voluntary sector contributes as well to economic competiveness, through their role in improving and conserving good visual quality and the functionality of the landscape. However, volunteering activities have wider objectives than increasing the landscape economic value, and contribute more broadly to maintaining and improving a desirable state when the governance authority loses the capacity to sustain the landscape, for example *'Friends of'* groups (Selman, 2012; Mathers et al., 2015).

4.9 Conclusion

As part of the first objective of this thesis, this chapter presented the findings of a literature review on each landscape function system. Information was collected throughout a wide range of research publications from different disciplines; and it aimed to describe the underlying processes and components of each landscape function systems. Individually, this literature review differs from discussions regarding stocks and flows of ecosystem services as it provides a process-oriented account of landscape function systems. Nevertheless, within this thesis, this literature review aims to provide support and background information in the subsequent explorations of landscape multifunctionality assessments, namely, mapping landscape functions (Chapter 5) and Soft Systems Methodology (Chapter 6).

Chapter 5| Approaches to landscape function systems mapping.

5.1 Introduction

Landscape function mapping aims to understand and communicate landscape multifunctionality approaches and the delivery of ecosystem services within a defined spatial context. Landscape function mapping approaches primarily seek to link data (surveys, indicators, statistical results, proxies) to spatially referenced polygons, land units or grids. Spatial assessments and mapping have two aims: i) to identify and represent areas of opportunity for intervention and prioritisation (regeneration or conservation); and ii) to use maps as instrumental tools to communicate between stakeholders (Verbug et al., 2009; Hermann et al., 2011; Vorstius and Spray, 2015).

Despite a continuously growing number of proposed approaches to mapping, a review of the literature indicates an absence of consensus as to whether landscape function mapping or ecosystem services mapping has been successfully accomplished (Hermann et al., 2011; Vorstius and Spray, 2015). There are two common constraints to landscape function mapping. One refers to the nature of available data to illustrate the complexity of social and ecological processes and pressures at multiple scales (spatial, time and organisational), or of interactions, feedbacks and synergies between systems and processes. The second limitation concerns methods to produce and interpret data. Some research discusses the need for accurate, transparent and rigorous approaches to data generation and spatial modelling; however, these have been assessed as difficult, expensive and not accessible to a range of skills (Vorstius and Spray, 2015). The other side of the debate discusses the importance of practical and accessible mapping approaches, especially if these are going to be used for communication among a range of stakeholders; but then these are criticised for their lack of imprecision and accuracy (Vorstius and Spray, 2015).

This thesis section in particular aims to develop existing approaches to landscape function mapping by exploring landscape functions as social and ecological systems, as opposed to the current research emphasis on assessing the stock and flow of ecosystems services delivery. The selected approach therefore seeks to understand complex relationships between landscape functions, and could potentially be promoted by exploring the underlying dynamics of social and ecological system.

To build on existing approaches to landscape function mapping, this study first explored previously published methods relevant to landscape multifunctionality (Chapter 3, section 3.5.2). The studies proposed by The Mersey Forest (2009; 2013; 2014) and by Willemen and others (2008) were chosen. These approaches were particular relevant when this PhD study began, because they centred on landscape functions rather than of ecosystem services. As discussed previously in Chapter 3, the exploratory exercises were applied to a selected area of the National Forest (see figure 5.1). The following sections (5.2 and 5.3) explore in detail the application and results of the two explorative exercises, section 5.4 reflects on these, and the chapter concludes with the exploration of a proposed approach to landscape function mapping as a basis for soft systems analysis (5.5).

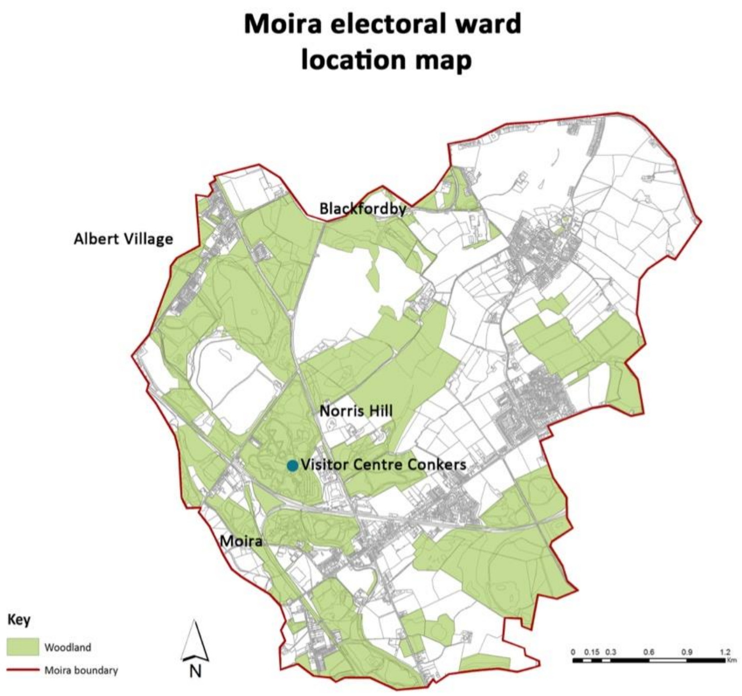


Figure 5.1. Moira location map

5.2 The Mersey Forest: *landscape multifunctIonality mapping*

The Mersey Forest, from 2009 to 2014, has been developing and applying a methodology for Green Infrastructure Planning. According to the Mersey Forest (2009, 2014), the main purpose of this spatial planning assessment is to produce an evidence base that could inform decision-makers to identify priorities, changes and improvements for green infrastructure planning and management. The framework aims to assess the *functionality*, needs and benefits of the region and then develop an intervention plan. Overall, through four steps, the methodology aims to develop three main spatial assessments: a green infrastructure typology; functions and multifunctionality maps; and a needs map. This thesis aimed to explore in particular the functionality spatial assessment in order to gain insights into a practice-oriented approach for studying and mapping landscape functions. As discussed in the methodology chapter (3.5.2.1), these following chapter sections (5.2.1 and 5.2.2) will present in detail the results of the application of the framework steps concerned with data availability, green infrastructure mapping and functionality assessment for the Moira electoral ward in the National Forest (Figure 5.1).

5.2.1 Data audit and resource mapping

The purpose of this step is to create a green infrastructure resource assessment by mapping different types of green infrastructure assets of the area. The development of this typology map is the basis for the following functional assessment step. The approach comprises allocating a green infrastructure type to specific land covers at a land-unit scale. All the datasets and generated maps of green infrastructure typology were processed using ESRI ArcGIS 10.1. The boundary of this case study explorative exercise was determined by the electoral ward of Moira, covering a total area of 12.97 km^2.

According to The Mersey Forest guidance (2009; 2013; 2014), the mapping process begins with the identification of a parcel-system database which could provide initial information of land unit boundaries and land cover information. For the UK, they recommend using the Ordnance Survey MasterMap Topography Layer. This research study through the University of Sheffield resources had access to Digimap database which provides access to the Ordnance Survey data.

The Mersey Forest proposes a green infrastructure typology based on UK practice policy guidance on open space, sports and recreation facilities, notably the PPG 17 (Department for Communities and Local Government, 2002) open spaces typology, which at the time of the initial guidance development was applicable to the planning system. Nevertheless, The Mersey Forest identified that the PPG list only comprises public open spaces, so they added private green infrastructure types such as agricultural fields and gardens; Table 5.1 contains the green infrastructure typology proposed by the Mersey Forest.

Table 5.1. Green infrastructure typology provided by the Mersey Forest

Mersey Forest Green Infrastructure Typology	PPG open space typology
Agricultural land	
Allotment, community garden or urban farm	x
Cemetery, churchyard or burial ground	x
Coastal habitat (not applicable to the case study project area)	
Derelict land	
General amenity space	x
Grassland, heathland, moorland or scrubland	Integrated as Natural and semi-natural open space
Green roof (not data)	
Institutional grounds	x
Orchard	
Outdoor sports facility	x
Park or public garden	x
Private domestic gardens	
Street trees (no data)	
Water body	x
Water course	
Wetland	
Woodland	Integrated in Natural and semi-natural open space
No-green infrastructure, non-permeable, no-data	

The following step refers to the mapping process. This process involves assigning, if appropriate, a green infrastructure typology to each land parcel unit. Each parcel unit is assessed through a GIS query on the MasterMap dataset attributes table that contains land cover information of each polygon. Then, with support from aerial photographs and any other available open space spatial dataset, green infrastructure typology can be confirmed or corrected as necessary. The Mersey Forest guidance suggests the potential use of automated analysis tools within ArcMAp for a more efficient mapping approach, and also an automated analysis of the aerial photographs to confirm green infrastructure typology assignations. However, because of the scale of the project area, and because of the restricted access to good quality aerial photography, all procedures were carried out by general enquiry ArcMap tools such as “selection by attributes”. Furthermore, the Mersey Forest early guidance (2009) provided a “tree decision diagram”, which uses the OS MasterMap attributes to guide decisions on how to allocate appropriate green infrastructure typology. This “tree decision diagram” proved to be very useful during the green typology mapping process. The attributes information of the OS MasterMap dataset was supported by examining other datasets such as OS raster maps, aerial imagery provided by Google Earth and street view by Google maps and datasets provided by the National Forest Company (NFC). These databases were helpful for spatially referencing and corroborating the current land cover of a particular parcel unit. Table 5.2 compares the databases proposed by the Mersey Forest and used in one of their case studies (Weaver Valley, Mersey Forest, 2009), and the databases used in this thesis.

Table 5.2. Comparison between databases used by the Mersey Forest in Weaver Valley Study (2009) and this PhD study.

Databases available to this PhD thesis and used to the project area of Moira in the National Forest (NF)	**Databases available to the Weaver Valley study.**
OS Master Map Topography	OS Master Map Topography
Ordnance Survey raster map, 1:10000	Ordnance Survey raster map
Landform profile, 1:10000 (terrain contours)	Aerial photography
Aerial photography and Street View from Google Earth,	The Mersey Forest’s new woodland planting data
National Forest new woodlands (NFC database)	Local Authority Open Space Studies
Public access sites (NFC database)	Public Rights of Way data
Recreation/ tourism attractions (NFC database)	

Finally, the green infrastructure map produced for the Moira ward can be explored in Figure 5.2. To conclude, the process for the creation of a green infrastructure typology map can be described as practical and accessible; from this map a functionality assessment of the project area will be developed (section 5.2.2). The limitations encountered in this particular mapping exercise related to inability to map two important green infrastructure types -green roofs and street trees- because of limited access to good quality aerial photographs and travel to the project area, which did not allow identification of such land units within the project area.

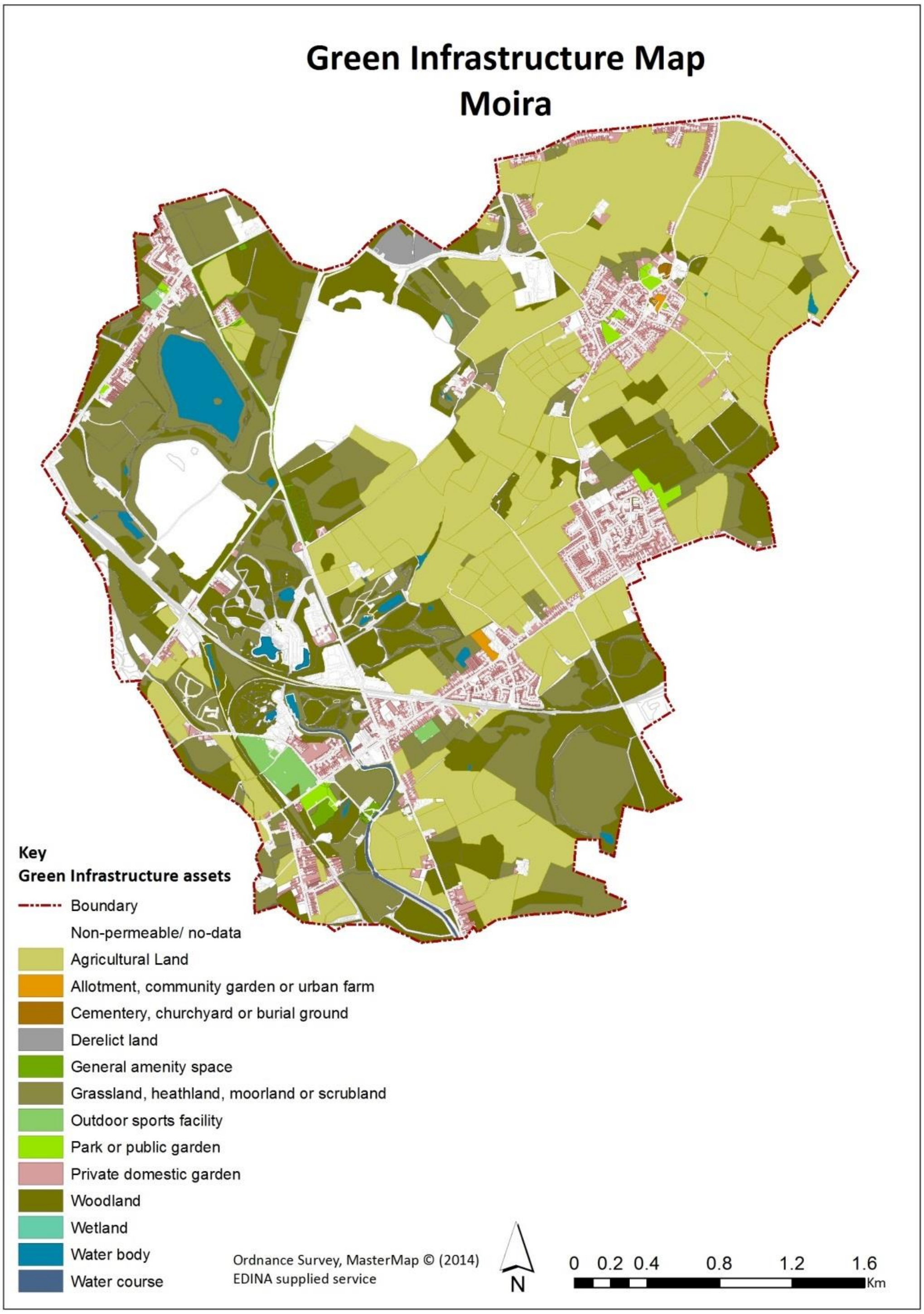


Figure 5.2. Green Infrastructure map of Moira in the National Forest project area.

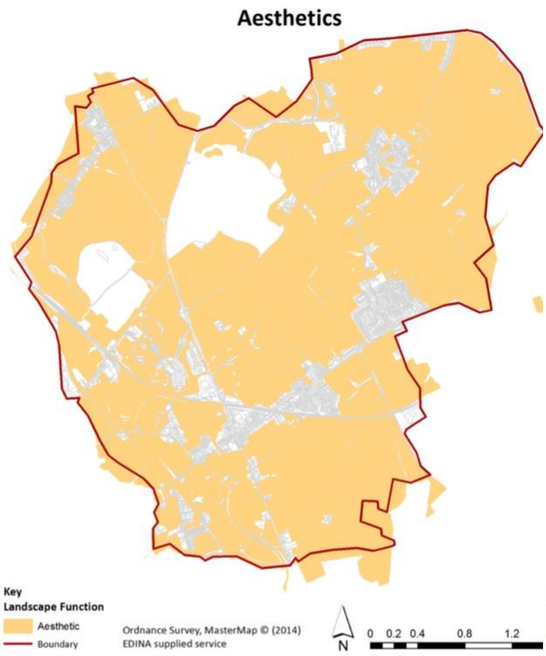
5.2.2 Functionality assessment

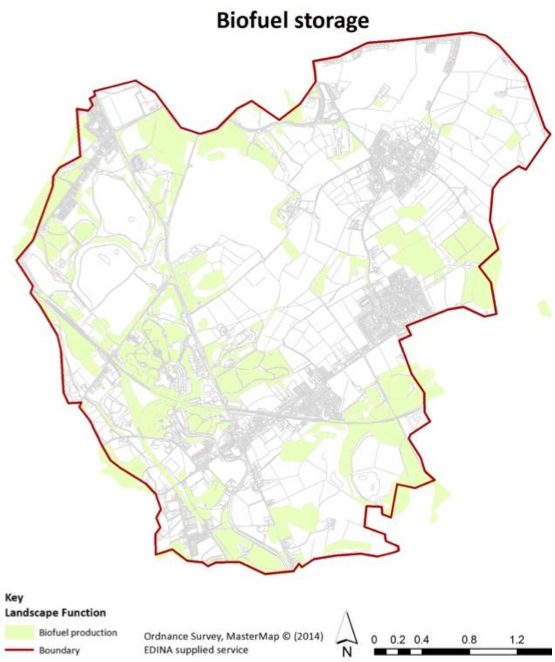
The functionality assessment consists of identifying and mapping which landscape functions are potentially supported by green infrastructure assets. The Mersey Forest methodology (2009, 2014) identifies 24 landscape functions. Contrary to other studies where landscape functions and ecosystem services are classified within groups, the Mersey Forest (2008) authors aimed to break down landscape functions into the *"smallest function unit"* (p. 9) as they argue that this allows more accurately identification of which landscape function is performed by each green infrastructure type. Box 5.1 contains the 24 landscape functions proposed by the Mersey Forest (2009; 2014).

Box 5.1 Landscape functions proposed by the Mersey Forest (2009; 2013)

Recreation-public	Shading from sun	Cultural asset
Recreation-private	Evaporative cooling	Carbon storage
Green travel route	Trapping pollutants	Food production
Aesthetic	Noise absorption	Timber production
Water storage	Habitat for wildlife	Biofuels production
Water interception	Corridor for wildlife	Water supply
Water infiltration/natural drainage	Soil stabilisation	Wind shelter
Storm protection-coastal	Heritage	Learning

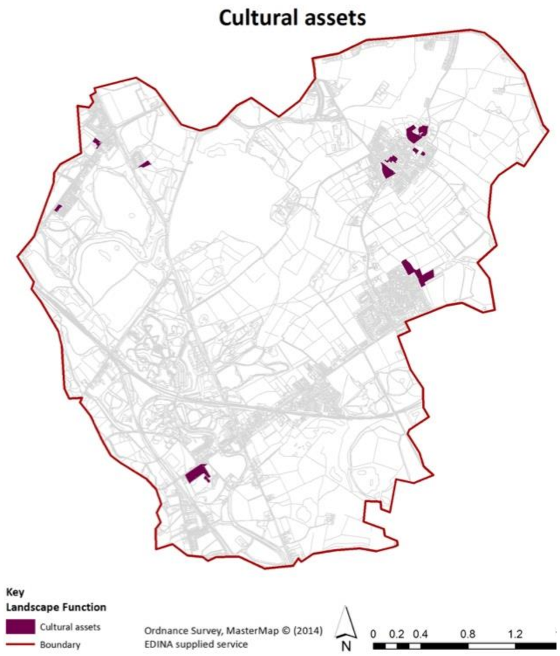
The mapping process comprises assigning to each green infrastructure type a potential landscape function. This task is supported by a matrix table created by the Mersey Forest (2009; 2014). This table indicates which green infrastructure (GI) type performs a landscape function (LF): for example, water bodies (GI) support water storage (LF). The Mersey Forest (2009) explain that this matrix was generated by accepting that landscape functions cannot be measured equally and consistently as there are different conditions that influence the landscape function performance; thus, they proposed to allocate landscape functions only if a review of conditions and constraints showed that the landscape function could perform *"at a level above a reasonable threshold"* (p.9). There are two versions of this table. The matrix table version from early guidance reports (Mersey Forest, 2009) indicates if a GI type "always", "sometimes" or "never" supports a landscape function. These values are accompanied by annotations such as woodland (GI) supports heritage (LF) if identified as ancient woodland; the table is accompanied by suggested datasets and ArcMAP analysis to identify conditions. This thesis exercise used this version of the matrix table to map landscape functions. The second version of the table proposed in more recent guidance (Mersey Forest, 2013) includes values from 0.0 to 1.0 that estimates the likeliness of a GI type supporting a landscape function, also accompanied by specific conditions, analysis and supporting databases. The Mersey Forest (2013) guidance explains that these values were estimated through experience gain as on applying the methodology, and expert judgement. The mapping process in ArcMap sought to “attribute” a specific landscape function to each GI polygon. This landscape function exercise generated a total of 21 individual landscape functions maps (see Figures 5.3, 5.4, 5.5, 5.6, 5.7 and 5.8).





a) Aesthetics

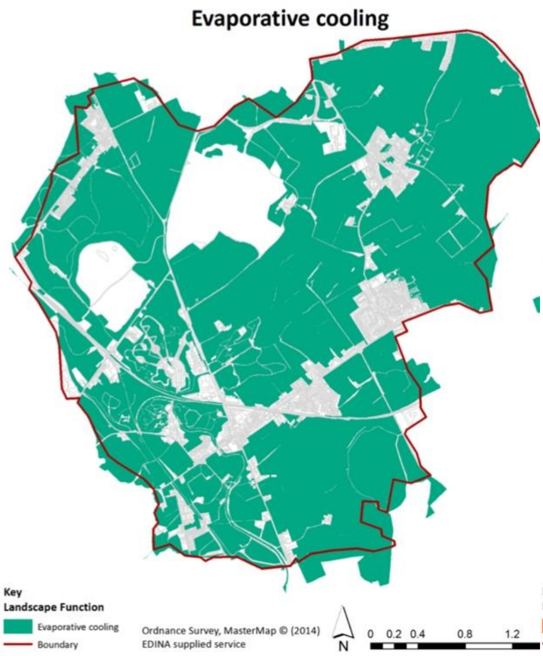
b) Biofuels



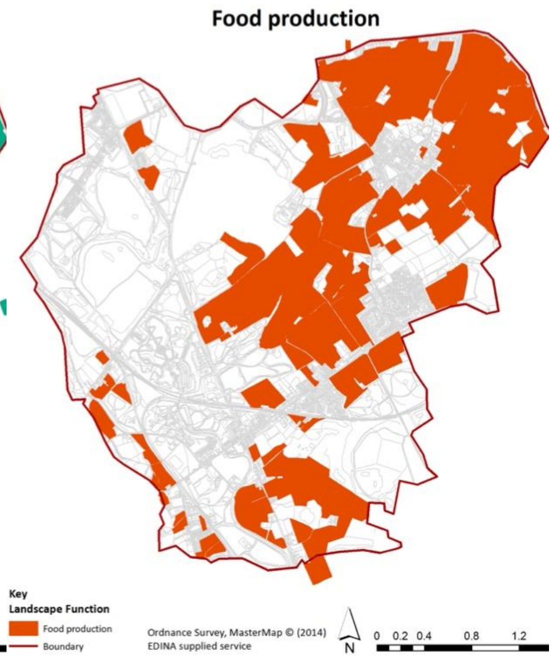
c) Carbon storage

d) Cultural assets

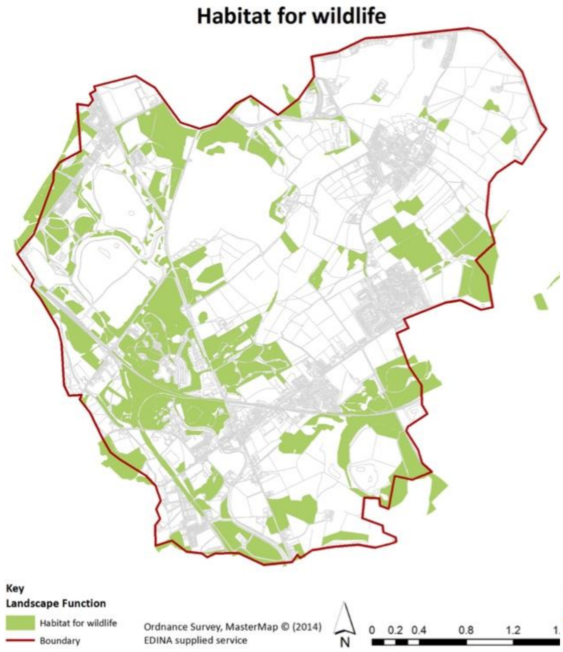
Figure 5.3. Landscape function maps of: a) aesthetics, b) biofuels production, c) carbon storage, d) cultural assets



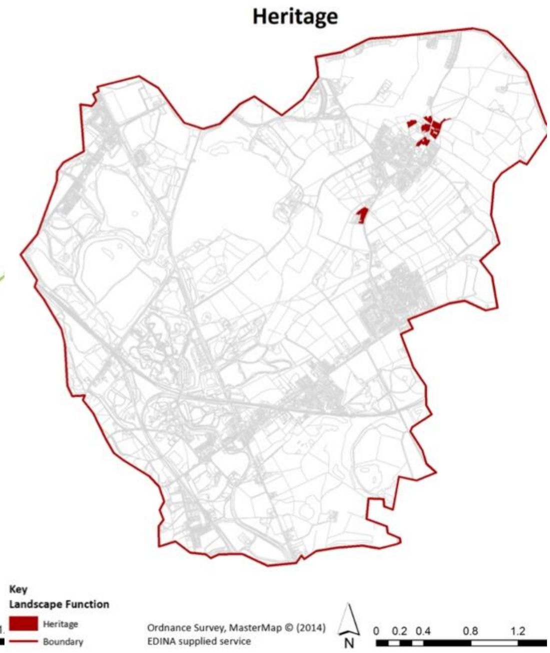
a) Evaporative cooling



b) Food production

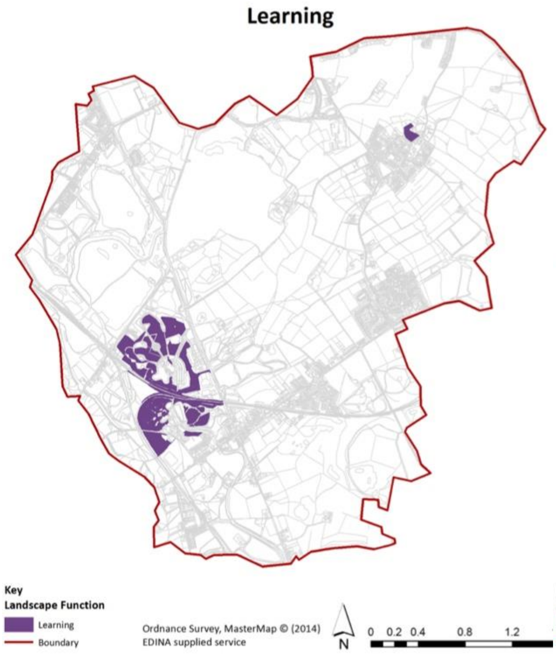


c) Habitat for wildlife

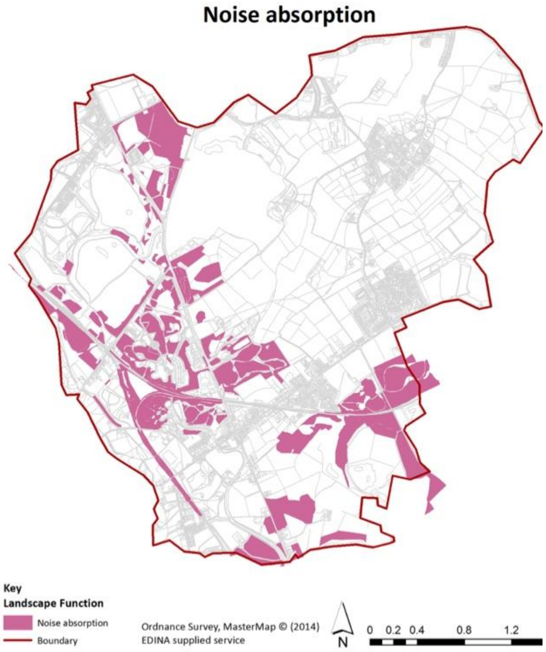


d) Heritage

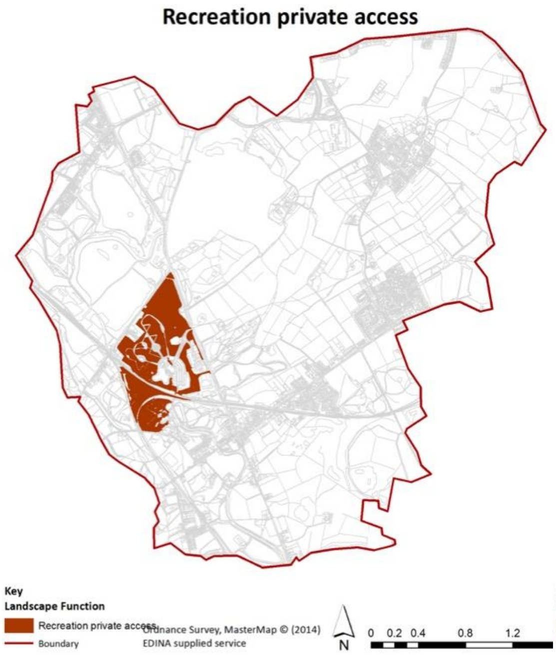
Figure 5.4. Landscape function maps of: a) evaporative cooling, b) food production, c) habitat for wildlife, d) heritage



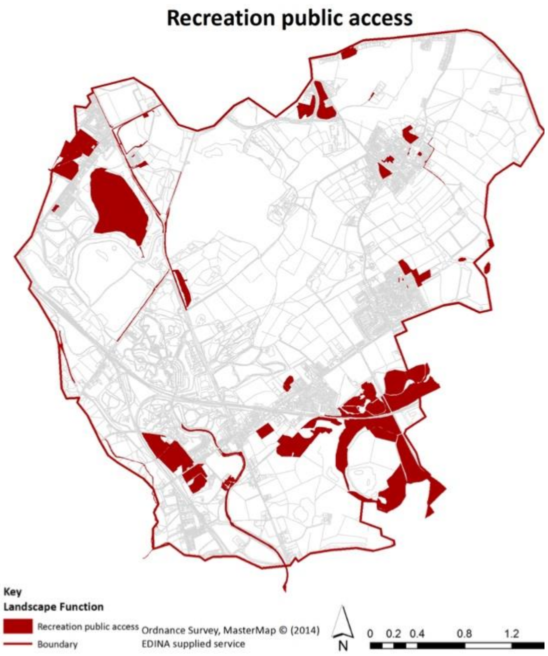
a) Learning



b) Noise absorption

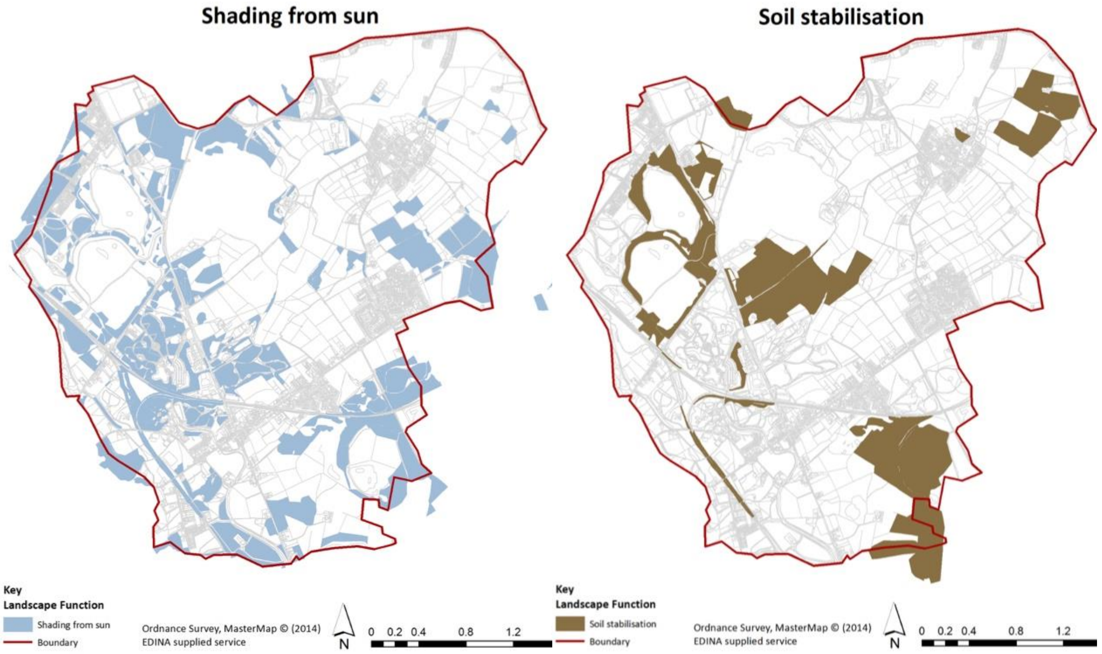


c) Recreation private access

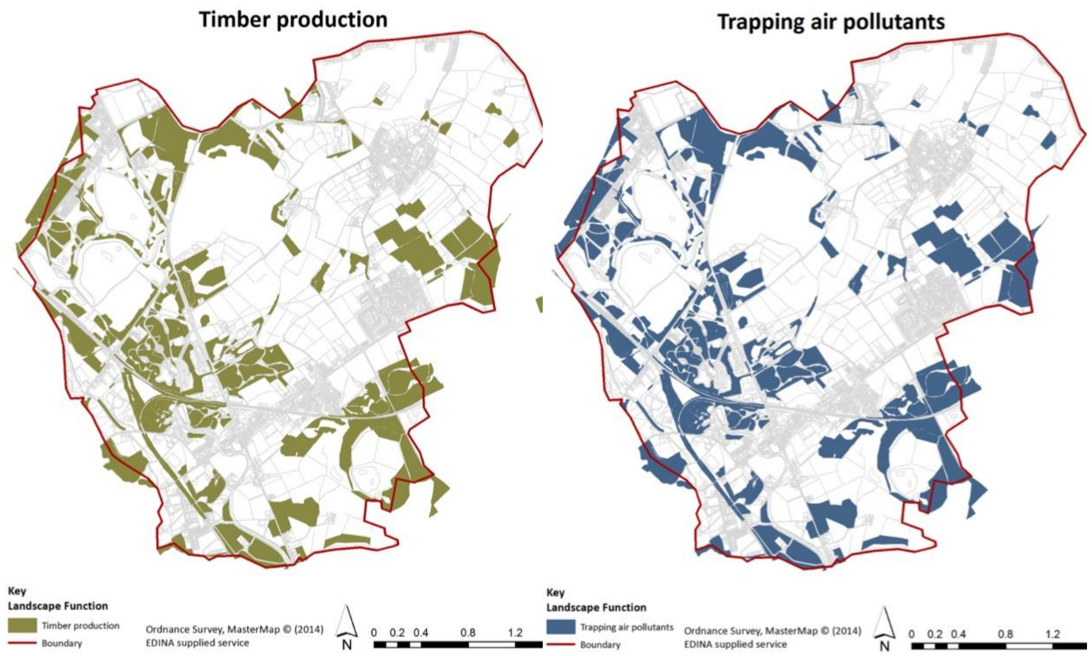


d) Recreation public access

Figure 5.5. Landscape function maps of: a) learning, b) noise absorption, c) recreation private access, d) recreation public access.

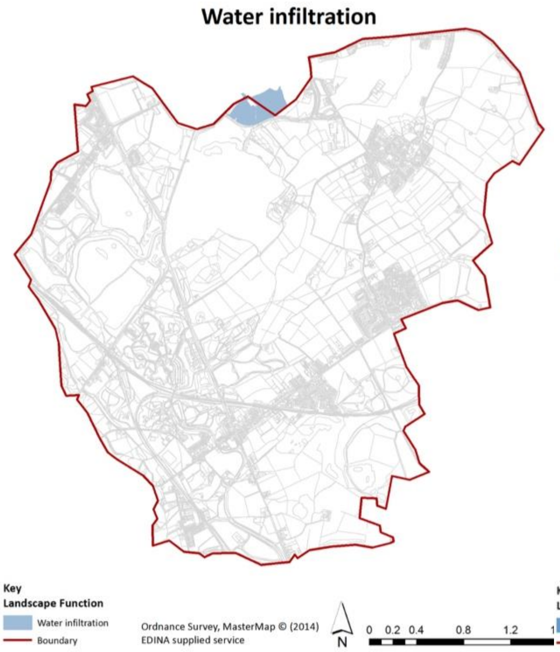


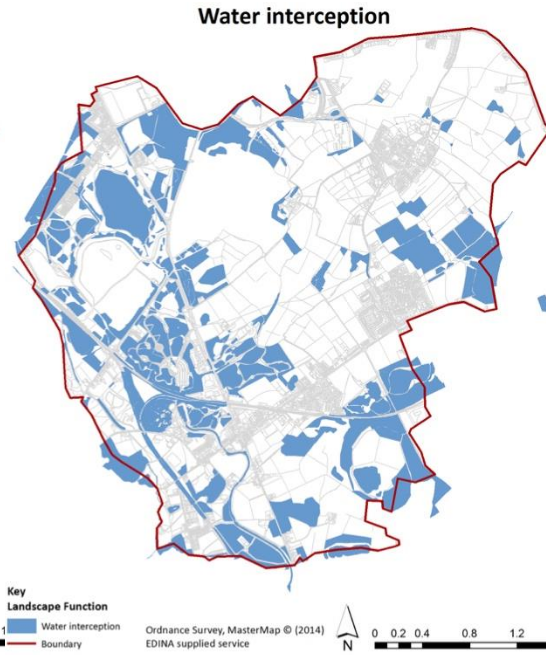
a) Shading from sun, b) Soil stabilisation



c) Timber production d) Trapping air pollutants

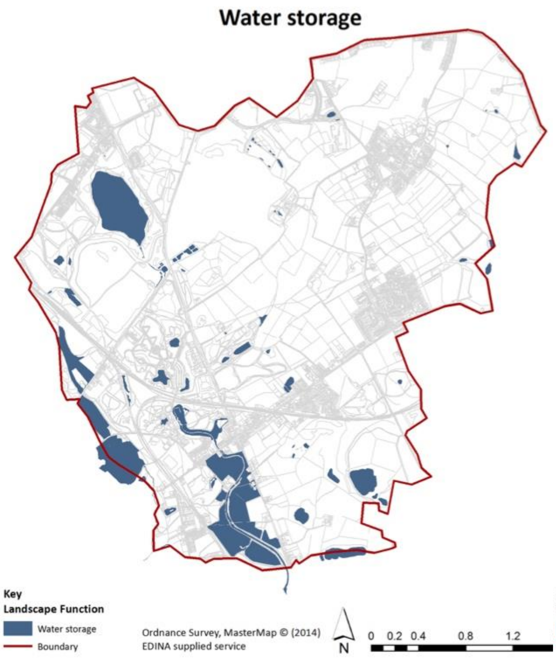
Figure 5.6. Landscape function maps of: a) shading from sun, b) soil stabilisation, c) timber production, d) trapping air pollutants

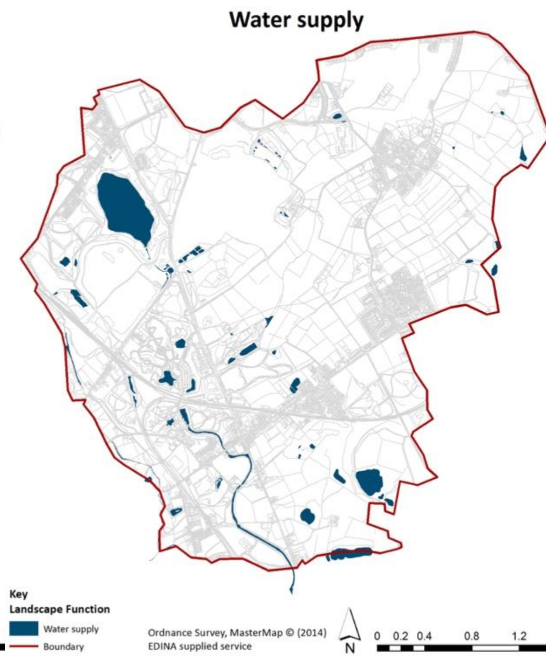




a) Water infiltration

b) Water interception





C) Water storage

d) Water supply.

Figure 5.7. Landscape function maps of: a) water infiltration, b) water interception, c) water storage, d) water supply.

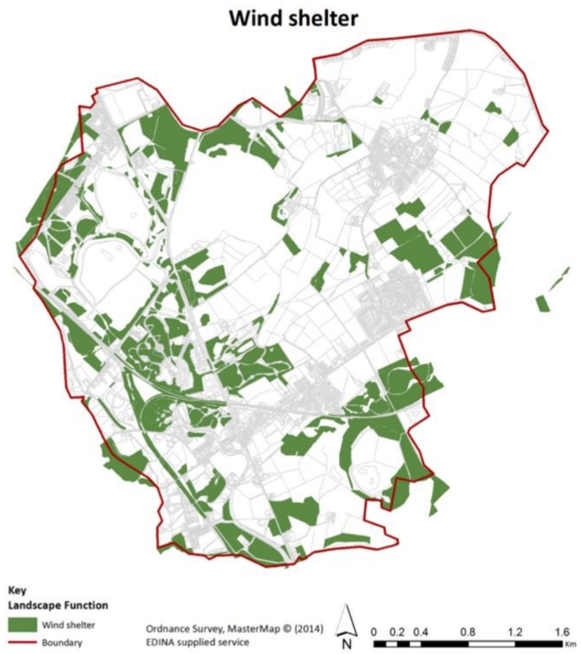


Figure 5.8. Landscape function maps of wind shelter.

The functionality assessment methodology includes the creation of a multifunctionality map. This map is created by layering each landscape function map created, to then quantify the number of potential landscape functions that each GI type can support. Figure 5.9 illustrates the resulting multifunctionality map of Moira; Table 5.3 explores the number of landscape functions delivered by each green infrastructure type. In the particular case of Moira, woodlands support the major number of landscape functions (13 in total in some GI parcels/land units), whilst allotments, community gardens or urban farms, private domestic gardens and derelict land support the fewest landscape functions (3).

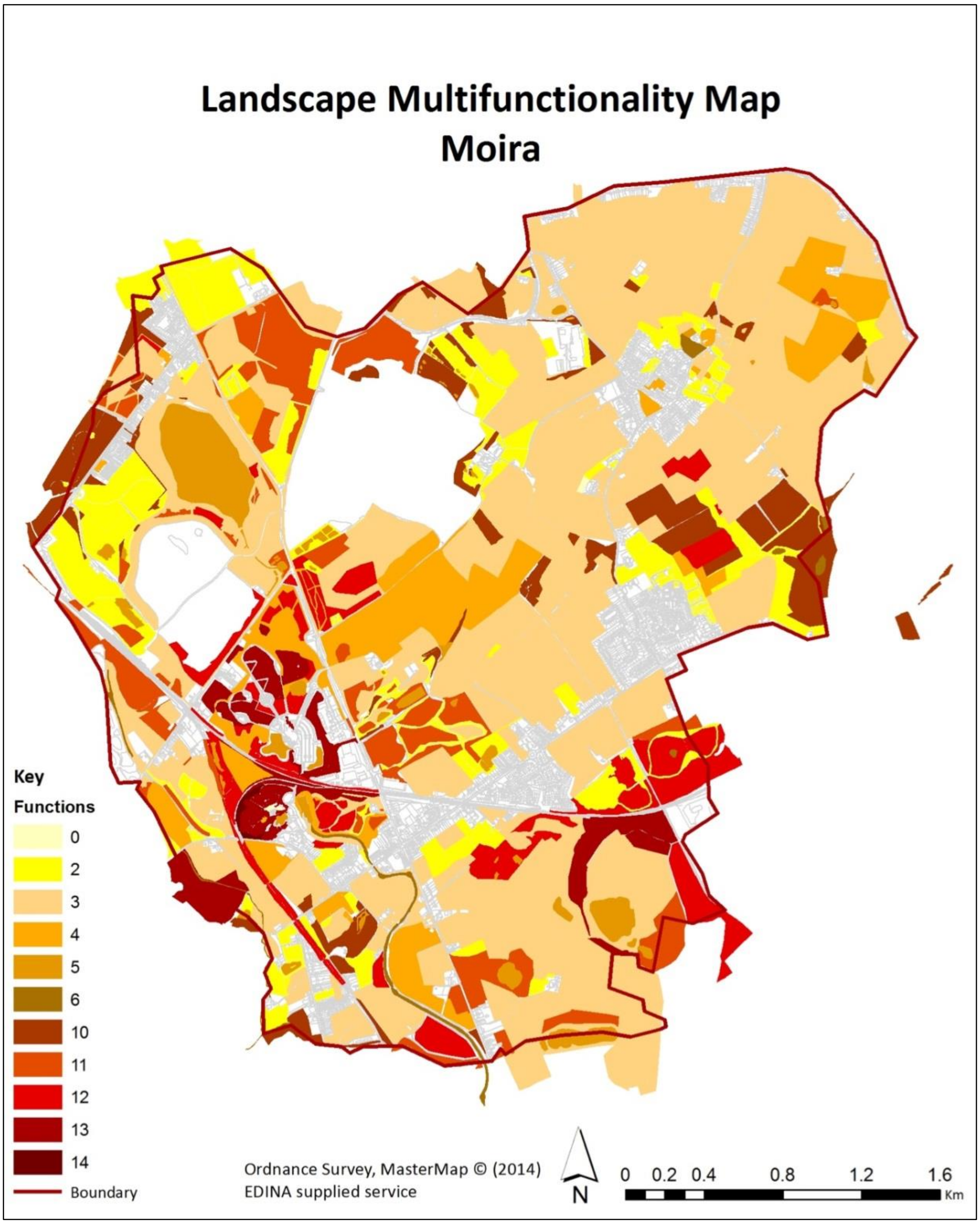


Figure 5.9. Multifunctionality map of Moira in the National Forest.

Table 5.3. Landscape functions supported by green infrastructure assets of Moira.

Green infrastructure typology	Number of landscape functions (min-max)
Agricultural land	(3-4)
Allotment, community garden or urban farm	(3)
Cemetery, churchyard or burial ground	(4)
Derelict land	(3)
General amenity space	(3-4)
Grassland, heathland, moorland or scrubland	(3-4)
Outdoor sports facility	(3-4)
Park or public garden	(4-6)
Private domestic gardens	(3)
Water body	(4-6)
Water course	(6)
Wetland	(5-6)
Woodland	(10-13)

The Mersey Forest guidance reflects the role of the resulting landscape function maps and multifunctionality map in reflecting the current situation of the project area to support the creation of detailed GI plans, policy making and monitoring (Mersey Forest, 2013). Finally, within the complete GI assessment methodology the following stages refer to benefit and needs assessments. The benefits assessment assigns to each landscape function a benefit, whilst the needs assessment creates a map independently from previous GI typology, functions, multifunctionality and benefit maps, aiming to identify areas of opportunity or need. All created maps are compared and analysed to then inform a green infrastructure strategy and plan.

In conclusion, this process of mapping landscape functions and landscape multifunctionality was accessible and practical. However, the way in which landscape functions are assigned to each GI type remains an area of discussion. This analysis will be explored in section 5.4 of this chapter through a comparison the Mersey Forest approach and the following approach of Willemen et al.

5.3 Willemen et al.: *landscape function mapping*

The methodological framework developed by Willemen and others (2008 and 2010) has been relevant to this research study not only for its proposed approach to landscape function mapping, but also for its discussion of landscape multifunctionality, landscape functions and interactivity between them. They define landscape functions as the “capacity” to deliver ecosystem services. Spatial heterogeneity and social and economic drivers restrict the number of landscape functions occurring in a determined place; landscape functions interact between each other in ways that could affect their capacity to deliver goods and services; and the sum of the landscape function capacities determines the multifunctionality of the landscape and its effects on the provision of ecosystem services.

Compared with the approach proposed by the Mersey Forest and explored in the previous section, Willemen et al.’s approach can be described as a quantitative method of landscape function mapping. Their study was applied to the region of Gelderse Vallei, in The Netherlands. Their proposed overall methodological framework comprises three steps: a) to quantify and map landscape functions; b) to quantify and map landscape multifunctionality; and finally, c) to analyse multifunctionality effects on the capacity of individual landscape functions (Figure 5.10). This exploratory exercise focuses on the methods proposed to quantify and map landscape functions (step a).

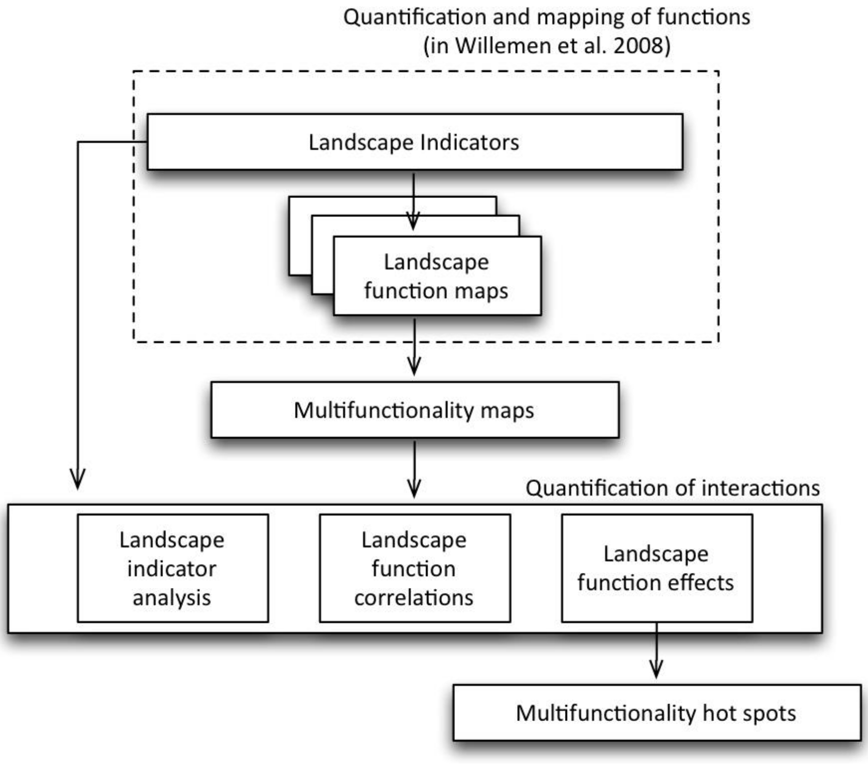


Figure 5.10. Overall methodology for landscape function and multifunctionality mapping by Willemen and others (2008; 2010).

The approach to landscape function mapping is described in Willemen et al. (2008). The authors sought to study eight landscape functions, selected according to planning policies and spatial data accessibility of the study region. They proposed three different methods for quantifying and mapping landscape functions; the appropriate method is assigned to each landscape function according to the landscape function's spatial characteristics. In the first place are the *completed delineated* functions, namely landscape functions which can be identified and quantified through land cover spatial information or spatial policy information. Then, there are the *semi-delineated* functions; these are quantified through empirical predictions of different spatial indicators. Finally, there are the *non-delineated* landscape functions, which do not have a single spatial characteristic to identify, so parameters and spatial indicators are derived from available literature. Table 5.4 illustrates the landscape functions and the method proposed by Willemen et al. (2008). The following sections (5.3.1, 5.3.2 and 5.3.3) discuss the application of these methods to the Moira project area (Figure 5.1).

Table 5.4. Proposed landscape functions and methods for landscape functions mapping and quantification, according to Willemen et al., 2008.

Method for mapping and quantification	Landscape function (the capacity of the landscape to provide)
Delineated landscape functions	Residential (areas for residential use)
	Intensive livestock (locations for intensive livestock production)
	Cultural heritage (Information on cultural heritage)
	Drinking water (Zones for drinking water extraction)
Semi-delineated landscape functions	Tourism (attractive landscape for overnight tourism)
	Plant habitat (habitats for rare, endemic and indicator plant species)
	Arable production (crop production fields)
Non-delineated functions	Leisure cycling (attractive landscape for leisure cycling)

5.3.1 Delineated landscape functions

This particular method to landscape function mapping entails spatially identifying the function through observable land cover references, and its quantification comprises using indicators from census data and regional and local policies. Willemen et al. (2008) argued that the following landscape functions can be mapped and quantified by this method: residential, intensive livestock, cultural heritage and drinking water.

The proposed spatial references and indicators proposed by Willemen et al. (2008) were selected as appropriate to their case study area in the Netherlands; however, for this thesis case study in England, it was necessary to find appropriate spatial references and indicators for the National Forest project area. Nevertheless, this selection was largely based on Willemen et al.'s (2008) proposal.

First, the residential landscape function requires to be mapped by identifying existing residential areas and it is quantified by the population living in such areas. In the case of the Gelderse Vallei case study, Willemen et al. (2008) spatially identified the residential neighbourhoods of the area; then they quantified the function by looking at the number of residents of the area per hectare. Within the English context, this thesis delineated the residential landscape function by spatially identifying housing units of the area. Potential housing units of the Moira region were mapped by selecting polygons contained in the OS MasterMap database and attributed as "*building".* Clearly, not all the polygons attributed as "building" are used for housing; however, the selection of polygons was reduced by selecting *buildings* next to *gardens.* This landscape function was quantified by looking at the resident population per output areas according to the Office for National Statistics (ONS) data from the 2001 Census, output areas being the smallest geographical areas containing census estimates. Figure 5.11 shows the resulting residential landscape function map.

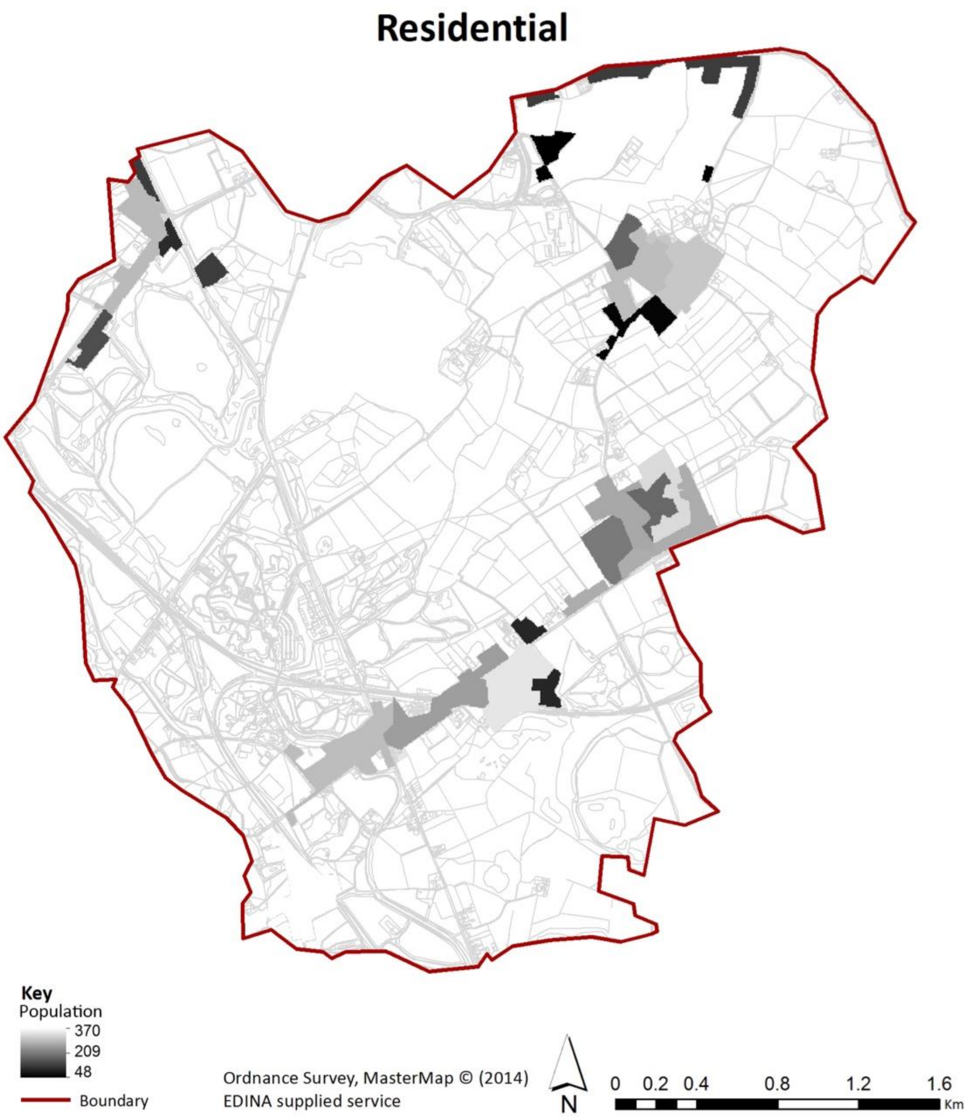


Figure 5.11. Residential landscape function map.

The intensive livestock landscape function has been delineated in the Gelderse Vallei study by locating intensive livestock farms, and then the function was quantified through the economic size of each farm according to Dutch indicators. In the case of Moira, this exploratory exercise identified farms with the support of the information within the OS MasterMap database, using specifically the *"carto_text"* layer. For this function quantification, there was a problem locating an adequate and accessible indicator in an appropriate scale, and so an indicator indicating the average farm holding size in terms of Standard Gross Margin was used – a SGM of small, medium or large was derived from the Department for Environment, Food and Rural Affairs (DEFRA, 2009b) June survey and from a map of England created by the of the Countryside Agency illustrating the average farm size according to Joint Character Area. Although, DEFRA (2014) now classify farm business by size accordingly to how much labour they require to run the farm (Standard Labour Requirement) an internet search could not find data applicable at a regional scale. Also, the output should be treated as indicative of the method rather than a specific basis for contemporary planning, as the underlying data derive from 2004. Figure 5.12 depicts the resulting intensive livestock landscape function map.

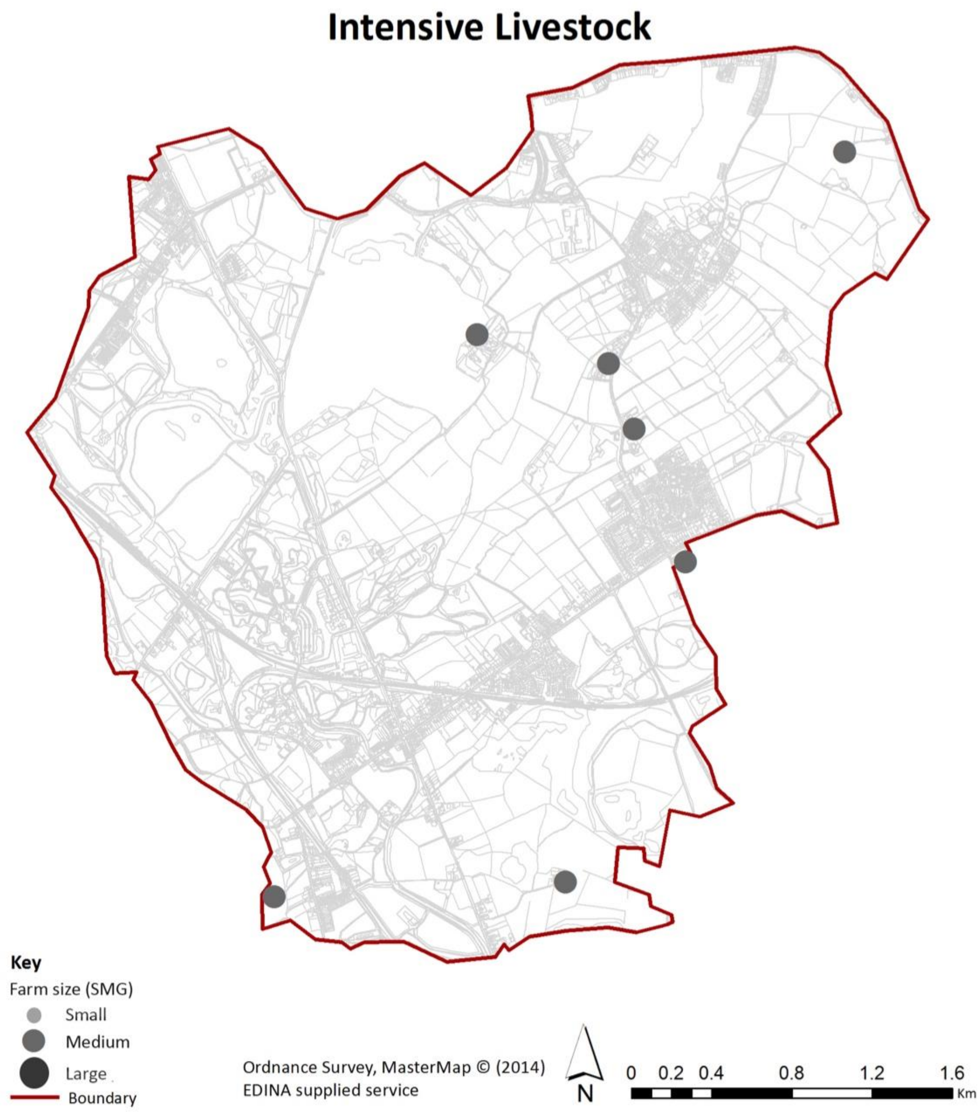


Figure 5.12. Intensive Livestock landscape function map.

Willemen et al. (2008) propose mapping the cultural heritage landscape function by spatially identifying conservation areas indicated by the Gelderse Vallei region's policy documents, and quantified by identifying the percentage of unchanged land-use within a 250 m radius. Conservation areas in the Netherlands are identified as areas that have a high historical and cultural value through certain qualities reflected in their spatial structures and configurations, and monuments or buildings (Willemen et al., 2012; Cultural Heritage Agency, 2016). In the UK landscape approach, landscape cultural qualities are assessed through the Landscape Character Assessment (LCA) (Natural England, 2013a; 2013b; 2014); and landscape heritage qualities are assessed by Historic Landscape Character (HLC) approach which focuses on analysing and identifying important historic qualities (natural and built) in the environment influenced by human activity and social attitudes that are present in the current landscape (Clark et al., 2004).

For this exploratory exercise, we proposed to spatially delineate this landscape function by identifying evidence of potential landscape heritage, through analysing Landscape Character Assessment (LCA) documents at different scales, such as the national scale East Midlands NCA published by Natural England (2013a; 2013b; 2014) and the local scale published by the Derbyshire County Council (2015) and by The National Forest Company (NFC, 2004). The analysis identified that the location of "piecemeal enclosures and ancient woodlands" was an appropriate spatial indicator that could inform potential cultural heritage landscape function in the region of Moira. To create this map, the study used the Historic Landscape Character Assessment database provided by the Leicestershire County Council. Because of the information provided by the LCA and HLC the produced map for the Moira project area will not correspond to a 'cultural heritage map', but to 'historical legibility map' as it analyses present evidence of past land use (Schofield, 2008).

Finally, this landscape function was quantified as the original study by Willemen et al. (2008) proposes calculating the percentage of unchanged land use. However, because of the difference of scale between the Gelderse Vallei and Moria regions (750 km2 and 12.97 km2 respectively), the percentage of unchanged land use was calculated through grids of 30 metres by 30 metres. Figure 5.13 illustrates the cultural heritage landscape function.

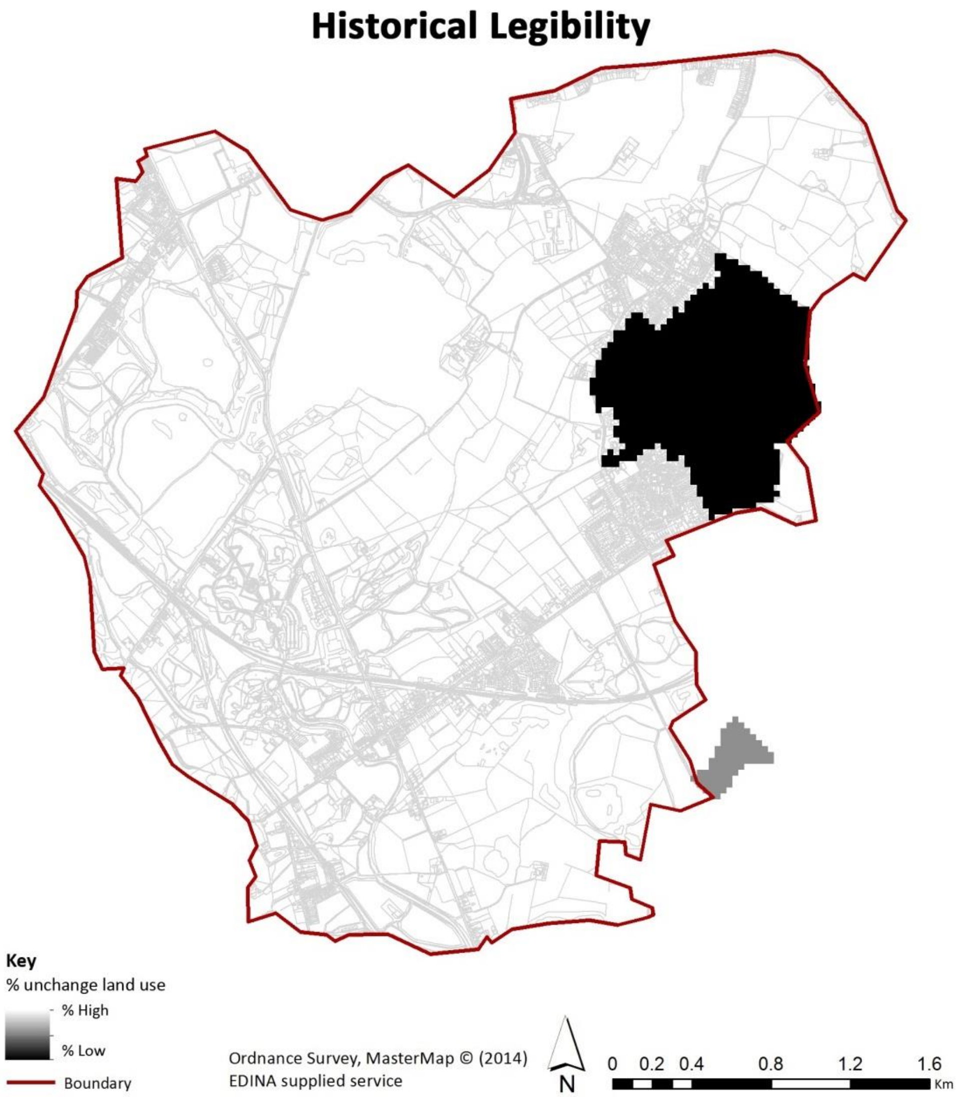


Figure 5.13. Historical legibility landscape function map.

The last proposed *delineated* function is that of drinking water. Willemen et al. (2008) proposed mapping this landscape function by locating water bodies such as reservoirs, rivers and aquifers where water is abstracted for human consumption, and then quantifying this landscape function by identifying the allowed extraction rate of water (m^3/year) for spatially identified zones of drinking water extraction. This exploratory exercise aimed to identify for the Moira region Drinking Water Protected Areas (DrWPAs) as nominated by the Environment Agency database (2015). However, there was no public domain information regarding the extraction of water per water body (water extracted by private water supply or by a licensed water company). As an alternative, local authorities, through the Water Framework Directive, classify private water consumption as large supplies (> 10m³/day or service to more than 50 people per day), small supplies (<10m³/day and service to < 50 people), supplies to single domestic property, and Private Distribution Networks (water distributed to industrial or country states and caravan parks). However, data were not accessible in the public domain. Because there was not a spatial reference or an appropriate quantifying indicator applicable to the case study region, it was not possible to map a drinking water landscape function. Table 5.5 illustrates a summary and comparison of the spatial references and indicators for the complete delineated landscape functions mapping exercise.

Table 5.5 Comparison of indicators and spatial references used in the Willemen et al. 2008 study and this thesis explorative exercise for the *Complete Delineated* Landscape Functions mapping method

	Willemen et al. 2008 Indicators - Proxy	**This thesis Indicators - Proxy**
Landscape function		
Residential		
Spatial delineation:	Residential areas-neighbourhoods	Housing polygons in OS MasterMap
Measure:	Number of residents per ha.	Number of residents per output area. Source: Census, 2001
Intensive livestock		
Spatial delineation:	Livestock farm zone	Farms features in OS MasterMap
Measure:	Farm size (economic units)	Standard Gross Margin (SGM: small, medium or large) DEFRA indicator, Regional scale. Source: Countryside Agency, 2009
Cultural Heritage		
Spatial delineation:	Conservation areas indicated by policy.	Evidence of piecemeal enclosures and ancient woodlands (LCA documents, Natural England, 2013a; 2013b; 2014; Derbyshire County Council, 2015; NFC, 2004) HLC GIS file provided by Leicestershire County

		Council, HLC report (Leicestershire County Council, 2010)
Measure:	% of unchanged land-use within a 250 m radius.	% of unchanged land-use in grids of 30 m. by 30 m.

5.3.2 Semi-delineated landscape functions

As explored before, the semi-delineated method for mapping landscape functions requires integrating several landscape components such as biophysical and socioeconomic factors and land cover information. The majority of the spatial indicators proposed by Willemen et al. (2008) were available and applicable to this thesis exploratory exercise; Table 5.6 illustrates a comparison between the indicators originally proposed by Willemen et al. (2008) and the indicators available for this exploratory exercise. This exercise of finding appropriate spatial indicators suitable for the region of Moira did not present any problem; however, this thesis could not complete the landscape function methodology because of sampling issues related to the required statistical analysis. The following paragraphs describe the problems encountered.

This semi-delineated method aims to identify and quantify landscape areas suitable for tourism. The method initially locates existing rural accommodation sites, and then their suitability is determined by indicators reflecting attractiveness, accessibility and recreation possibilities and components for tourism. Willemen et al. (2008) propose quantifying this function through a *stepwise logistic regression* analysis. This statistical analysis aims to *predict the probability of occurrence* through several independent variables and binary dependent variables (Pampel, 2000). In this case, the dependent variables are samples of presence (1) and absence (0) of rural accommodation; the independent variables are the indicators and described in Table 5.6. For the region of Moira, only four samples containing rural accommodation were located and, as recommended, another four absence samples were selected randomly. Thus, a total of 8 samples were analysed through an initial logistic regression model using the statistical package R 2.15.0. However, because the sample of dependent variables was too small in relation to the sample of independent variables (compared with 397 samples found in the Willemen et al. (2008) study, the statistical model could not estimate a significant alpha (<.05) coefficient to provide reliable beta coefficients which inform the probability of occurrence. Thus, this explorative exercise did not produce a tourism landscape function map.

In the case of mapping the landscape functions of plant habitat provision and arable production it was not possible to carry out the proposed statistical models to identify and quantify both landscape functions. The main reason was the lack of adequate variables for running such analyses. To map the landscape function of plant habitat provision, Willemen et al. (2008) had access to a biodiversity conservation value index (CV), together with biophysical indicators such as groundwater level, nutrient levels, soil type and land cover. Regarding these, they prosed to determine the possibility of occurrence through a *multiple linear regression* statistical analysis. This statistical modelling approach looks at the relation between a dependent variable - in the case of the Gelderse Vallei region the biodiversity conservation value - and explanatory or independent variables (biophysical and land cover indicators) (Schroeder et al., 1986). This exploratory exercise did not run the statistical model because no data existed on an equivalent dependent variable such as the biodiversity conservation value for the region of Moira; the other independent variables were identified and available except for nitrogen levels (Table 5.6).

Further, in the case of mapping and quantifying the arable production function, Willemen et al. (2008) proposed mapping this function by locating arable fields. However, it cannot be fully delineated by this approach because of rotation practices. Thus, the calculation of probable occurrence of this function looks at the relation between crop yield and landscape characteristics (groundwater levels, soil type and farm type). In this instance a model was used to calculate the probability of occurrence, where the dependent variable is the crop yield indicator. In the Gelderse Vallei, Willemen et al. had access on data of crop yield of Maize per postcode (ton/ha); however, this exploratory exercise could only access a single sample at a regional scale so, with a unique the value of yield/ha for the entire region as a dependent variable, it was not possible to run the *multiple linear regression.* Hence, this exploratory exercise did not produce a map for the arable production landscape function.

Table 5.6. Comparison of indicators and spatial references used in the Willemen et al. 2008 study and this thesis for the *Semi- Delineated* Landscape Functions mapping method

	Willemen et al. 2008 Indicators - Proxy	**This thesis Indicators - Proxy**
Landscape function		
Overnight tourism		
Spatial semi-delineation:	Presence and non-presence of rural accommodation.	Presence and non-presence of rural accommodation.
Measure:	% of agricultural land use (500m radius)	% of agricultural land use (250m radius) OS map and aerial photography evaluation.
	% of natural areas (500 m)	% of accessible woodlands (500 m) Database provided by National Forest C. Accessible woodlands was selected to avoid double counting or ambiguity defining “natural areas”
	% of clustered natural areas > $1km^2$ (5km radius)	% of accessible > $1km^2$ (5km radius)
	Openness of landscape (line of sight m.)	Line of sight (metres) from viewshed analysis using OS land form maps
	Distance to highway m – negative influence	Distance to highway m; OS map and aerial photography evaluation.
	% of industry or business parks (500 m radius) – negative influence	% of industry or business parks (500 m radius); OS map and aerial photography evaluation.
	Proximity to natural areas	Proximity to accessible woodlands
	Proximity to accessible natural areas	N/A, because all woodlands quantified are already accessible
	% of small roads (500m radius)	% of small roads (500m radius); OS map and aerial photography evaluation.
	Proximity to recreation facilities	Proximity to CONKERS visitor centre.
Plant habitat		
Spatial semi-delineation:	Point locations of species inventories	Wildlife sites; Database provided by Leicestershire County Council
Measure:	Biodiversity conservation value (dependent variable)	Not found
	Groundwater levels (cm below surface)	Groundwater levels (cm below surface); data obtained from British Geological

		Survey, online maps, scale: regional.
	Soil type	Soil type; data from Soilscapes online maps, scale: landscape.
	Distance to forests Distance to open nature	Distance to wildlife sites; Database provided by Leicestershire County Council
	Nitrogen availability	Not found
Arable production		
Spatial semi-delineation:	Arable production fields	
Measure:	Maize yield per post code (tonne/ha)	Several crop yield per region (tonne/ha) DEFRA
	Lowest groundwater level (cm below surface) Highest groundwater level (cm below surface)	Groundwater levels (cm below surface); data obtained from British Geological Survey, online maps, scale: regional.
	Soil type	Soil type; data from Soilscapes online maps, scale: landscape.
	Average farm size per postcode area	Farm size per district DEFRA
	Farms per postcode area	Farms per Output Area

5.3.3 Non-delineated landscape functions

The non-delineated landscape function method involves mapping the landscape functions through different spatial indicators and quantifying indicators and valuing thresholds based on literature references. In the particular instance of the capacity of the landscape to support cycling for leisure, Willemen et al. (2008) proposed mapping this function through different landscape characteristics. First it is necessary to locate residential areas, as leisure cycling occurs near these; then cycling facilities are identified as small roads within a 5 km buffer near the residential areas. However, areas of industry and motorways are excluded from the selection as these are associated with visual and noise disturbance. Finally, this landscape function is quantified via the potential population able to reach the cycling facilities. Willemen et al. (2008) excluded residential areas with a population of less than 10000 inhabitants. Based on this proposed indicators, this exploratory exercise was able to identify potential areas for leisure cycling by mapping small roads around residential locations in a 600 m radius contrary to the 5 km radius proposed by Willemen et al., reflecting the proportional difference of scale between the two study areas (Gelderse Vallei and Moira) and exclusion of polygons indicating land covers such as industry, motorways, and mining. The quantification was carried out as proposed by identifying the population of each census output area. Figure 5.14 illustrates the leisure cycling landscape function map derived from this explorative exercise; and Table 5.7 compares the indicators proposed by Willemen et al. (2008) and this thesis.

Table 5.7. Comparison of indicators and spatial references used in the Willemen et al. 2008 study and this thesis for the *Non-delineated* Landscape Functions mapping method

	Willemen et al. 2008 Indicators - Proxy	**This thesis Indicators - Proxy**
Landscape function		
Leisure cycling		
Spatial delineators:	Residential locations with a potential leisure cycling population > 10,000 people	All residential areas of the region of Moira
	Cycling facilities and small roads around residential locations within 5 km radius	Location of small roads around residential areas within a 600 m radius buffer
	Exclusion of industry, highways, business parks and waste dump.	Exclusion of industry, motorways and active and disused mining.
Measure:	Potential population for leisure cycling	Population of residential areas per output areas according Census 2001

Figure 5.14. Leisure cycling landscape function map.

5.4 Summary from the exploratory exercise

This research study places special attention on the term landscape functions because these refer to the social and ecological processes influencing the landscape's multifunctional properties. The purpose of mapping landscape functions is to illustrate the spatial distribution and dynamics of each landscape function; these maps in turn aim to support analyses and decision-making in landscape planning, management and design processes.

To date, the literature displays a wide range of approaches to mapping the stock and flow of ecosystem services, and a few which map landscape functions. Nevertheless, apart from the prevailing ambiguity between ecosystem services and landscape functions, both approaches fail to consider and advance on principal landscape multifunctionality properties such as: dynamism and interactivity, crossing multiple scales, participation and trans-disciplinarily. Thus as discussed before, this research project considered it appropriate to carry out an explorative exercise of two distinctive approaches to landscape function mapping in order to inform and advance on an approach to landscape function mapping and understanding landscape multifunctionality.

The Mersey Forest proposes a qualitative approach to landscape function mapping. This study is described as a non-quantitative GIS approach because it does not involve any statistical or quantitative analyses; in this case GIS supports the creation of maps to inform through visualisation (Pavlovskaya, 2009). The Mersey Forest approach comprises identifying green infrastructure assets and assigning functions to each asset, then analysing the benefits and needs of the project area. This approach addresses an analysis of actual landscape functionality through spatial analysis of land cover and land use, supported by fieldwork, surveys and local experience. The results of this approach comprise 22 individual landscape function maps and one multifunctionality map. Through this exploratory exercise, a number of issues were identified, primarily concerned with the limited capacity of analysis based on land cover to illustrate and support an understanding of relationships between landscape functions and their underlying dynamics. A detailed discussion of these issues is deferred until the Discussion Chapter (Chapter 8, section 8.2.1). Overall, however, the resultant maps suggest an equivalence in the distribution and capacity of each landscape function. Whilst the multifunctionality map suggests that landscape functions are equally compatible and interchangeable, which is not the case. However, the positive aspect of the Mersey Forest method is its practical and feasible application in the field, which has been demonstrated through its wide application particularly in the Merseyside region.

In contrast, Willemen et al.'s (2008) approach landscape function mapping involves a quantitative methodology. This approach is described as quantitative because it includes statistical analysis and quantitative GIS spatial analyses. Willemen et al. (2008) from the outset discusses the importance of addressing and analysing multifunctionality properties, in particular interactivity between landscape functions, and notes that interactivity may be negative, positive or compatible. The methodology comprises three different methods where it is necessary to identify drivers and components influencing the spatial location, quantity, quality and capacity of each landscape function; then, it calculates the potential occurrence of such landscape functions in determined spatial locations. Each landscape function is allocated to a particular method according to its different descriptive characteristics and the spatial data available. The Willemen et al.'s study explored only eight landscape functions; however, this thesis was able to re-produce only four landscape function maps. These limited results are attributed to the differences of scales between the regions of Moira and the Gelderse Vallei, and this difference restricted the identification of appropriate and available indicators and the number of samples to run certain statistical analyses; however, the main discussion of this exploratory exercise is central to the low feasibility of the method to be practised in the field (see Chapter 8, section 8.2.2). Nevertheless, this method facilitated understanding of how observable landscape components can be identified, referenced, used and linked to provide a spatially explicit illustration of intrinsic processes of individual landscape function systems. The findings from this exploratory exercise contributed to inform a landscape function mapping approach proposed in section 5.5 of this chapter.

5.5 Systems approach: *landscape function systems mapping*

The objective of this chapter was to explore two relevant published approaches to landscape function mapping, in order to gain an understanding of advances and limitations to ways of mapping the processes, influences and relationships between landscape functions. The results from the previous exploratory exercises (sections 5.2 and 5.3) supported a comprehensive exploration of available and accessible spatial databases for the National Forest project area, and they illustrated limitations of different spatial scales to provide adequate samples and indicators, corroborated the limitations of analysing landscape functions through land cover analysis, and revealed the potential inaccessibility of statistical analysis. However, in particular, Willemen et al.'s (2008) method for mapping "non-delineated landscape functions" (section 5.3.3) was taken as the basis for proposing an approach to landscape function mapping. Willemen et al.'s approach to non-delineated functions comprised identifying from existing literature, spatial elements and thresholds that together could map and quantify the capacity of the landscape to provide ecosystem services.

Thus, drawing upon the previous literature review and experimentation, this thesis developed an approach to landscape function mapping based on analysis of landscape function processes, components and thresholds that are susceptible to spatial identification, followed by the generation of process-oriented landscape function maps. This was achieved by interpreting spatial database elements according to a system-oriented understanding of each landscape function. This proposed approach was applied to the total area of the National Forest (Figure 5.15). The GIS software used to create the maps is ESRI ArcMap 10.1. The exercise entailed a total six landscape function systems: *provision, hydrological cycle support, atmospheric, biodiversity, information and carrier and community systems* as identified previously in Chapter 4. The following sections will explore and discuss the proposed spatial components and processes selected to interpret and illustrate each landscape function system.

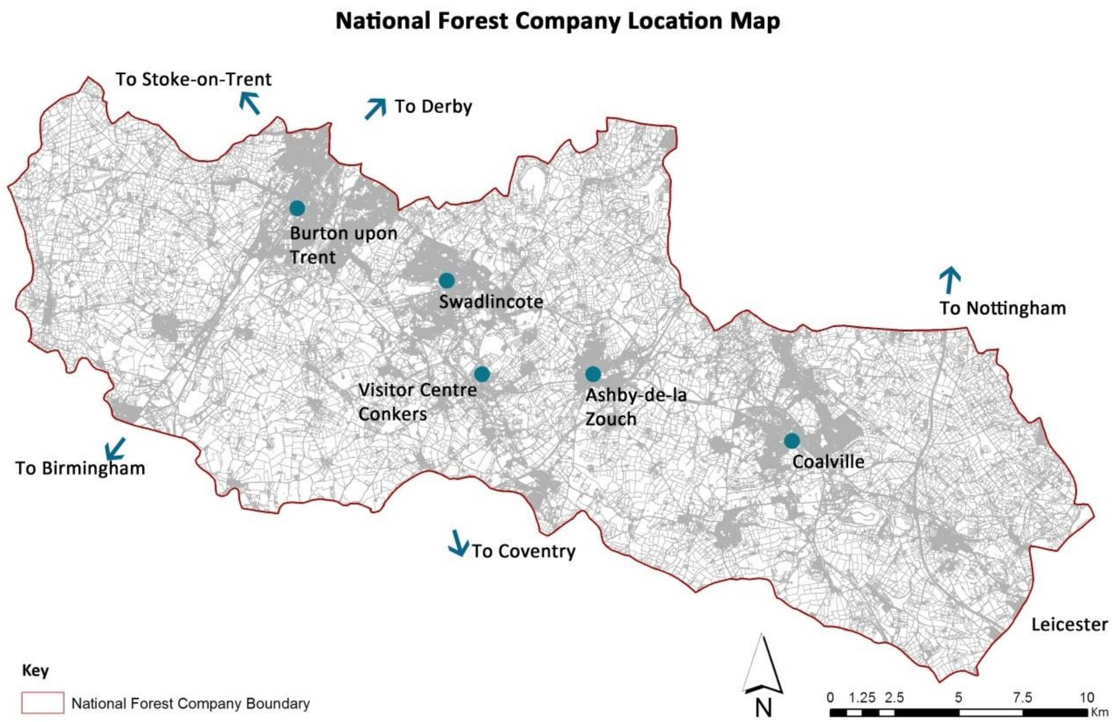


Figure 5.15. The National Forest project area map.

5.5.1 Provision system

The provision system supports the transformation processes of converting inputs of energy, nutrients and water to plant growth and the subsequent production of a wide range of biomass. Within the provision system, the production of biomass is orientated to food, raw materials and resources for energy purposes (de Groot et al., 2002; de Groot, 2006). This thesis uses the Agricultural Land Classification framework (ALC) to spatially represent the provision system. The ALC framework was developed to provide a land classification of suitability and limitations of land for agricultural use in order to inform planning applications (Natural England, 2012b). The ALC takes into consideration the land's biophysical constrains such as temperature, rainfall and aspect (climate); gradient and flood risk (site characteristics); and soil properties (texture, structure and chemical properties). Furthermore, the ALC also considers the interactions between those properties; these dynamics influence soil wetness and drought, which in turn affect crop choice and yields (Ministry of Agriculture, Fisheries and Food, 1988). The ALC classifies the land in 5 grades (1 to 5). The optimal grades which potentially could allow growing a wider range of crops with low input requirements are Grade 1, 2, and 3a (Grade 3 is subdivided in 3a and 3b) (Natural England, 2012b).

The spatial data set is available in the public domain, and is provided at a national scale. There are two versions of this dataset; the first version comprises a strategic and provisional map of the ALC which does not contain the grade 3 subdivisions; the second version is known as "ALC post-1988" and comprises the field surveys following current ALC guidance as published by Ministry of Agriculture, Fisheries and Food in 1988. The mapping process comprised identifying, extracting and re-drawing all the polygons illustrating grades 1,2 and 3a within the National Forest boundary. Figure 5.16 illustrates the provision function map generated. One limitation on using this spatial database is that it not includes urban areas, and so disregards urban agriculture. The ALC is only provided at national and regional scales, lacking detailed site context and information, although Natural England (2012b) suggests the ALC framework can be applied at different spatial scales.

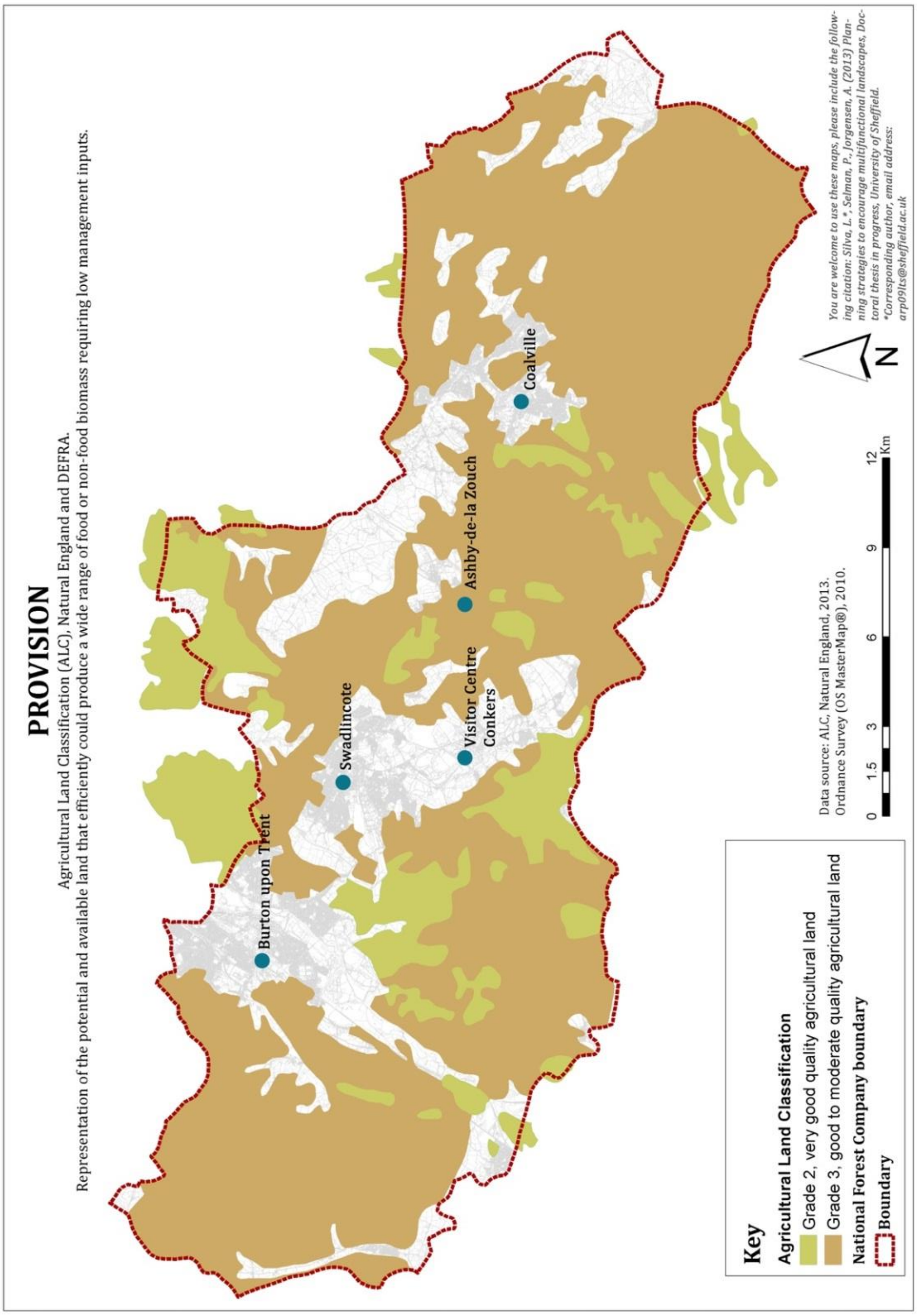


Figure 5.16. Provision system map

5.5.2 Hydrological cycle support system

This landscape function refers to the role of the landscape's elements and influences on the hydrological cycle as previously noted: vegetation intercepts a certain amount of rainfall; the soil infiltrates overland flow; overland flow and anthropogenic drivers have an impact on water quality; and the landscape has capacity to storage and conduct overland flow for water consumption (Anderson et al., 1976; Kübeck et al., 2009; Wheater and Evans, 2003; de Jong and Jetten (2007); Johnson et al., 2010; Ryan et al., 2010).

On hydrological modelling, three main components determine the volume and intensity of overland flow, namely, land use, land cover and soil type (Whitford et al. (2011); Gill et al. (2007); Xiao and McPherson, 2002). Based on these and the description of the landscape function in chapter 4, this study proposes to spatially represent the components having a role within the hydrological cycle, specifically, land cover, soil drainage capacity and location of water bodies.

Tall vegetation has a bigger capacity to intercept rainfall than low vegetation, therefore areas with tall vegetation such trees and shrubs have a higher potential to intercept and briefly retain rainfall (Nisbet, 2005). As an indicator of tall vegetation and based on available spatial data, the land cover of *woodlands* has been mapped. Water bodies comprise rivers, streams, lakes, ponds and reservoirs, and spatial land cover information on these has been collected from different sources: NFC's woodlands dataset, OS MasterMap, 25m OS Raster map, and Centre for Ecology and Hydrology land cover maps from 1990. Soil drainage capacity spatial data was accessed from the Soilscapes database developed by Cranfield University's National Soil Resource Institute; soils described as freely draining and slightly impeded drainage were mapped. Figure 5.17 illustrates the hydrological cycle support system map.

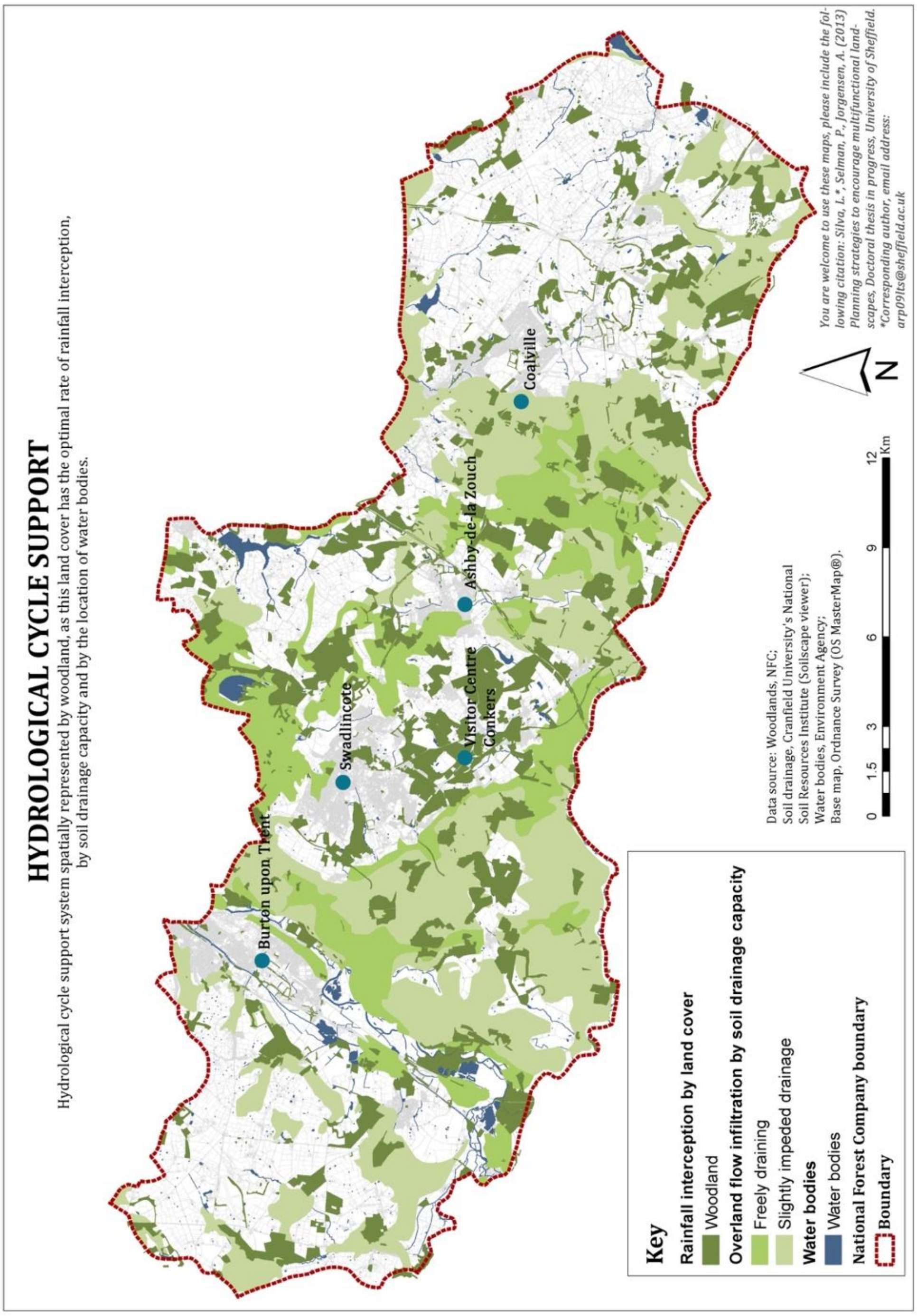


Figure 5.17. Hydrological cycle support system map

5.5.3 Atmospheric system

This landscape function relates to the capacity of the landscape to influence the quality and the temperature of the air, and as well its supporting role to climate change mitigation. The literature review (Chapter 4, section 4.4) identified tree cover as a landscape component also to support the interception and filtration of pollutants suspended in the atmosphere (Beckett et al., 2000; Donovan, 2005; Nowak et al.,2006). Moreover, trees have the capacity to reduce air temperature through transpiration and shading from canopies (Akbari et al., 2001; Gill et al., 2007). Finally, through photosynthesis, trees can absorb CO_2 that is subsequently stored as carbon in foliage and branches (above ground sequestration and storage) (Nowak and Crane, 2002; Balis, 2006).

Thus, this mapping exercise spatially identified tree cover in order to indicate the role of trees in air quality, air temperature and climate change mitigation. The spatial databases used to identify tree cover within the NF project area are: OS MasterMap and the Centre for Ecology and Hydrology land cover map of Great Britain from 1990. The tree covers identified and mapped are: woodland, scattered trees and orchards. Figure 5.18 illustrates the atmospheric landscape function system.

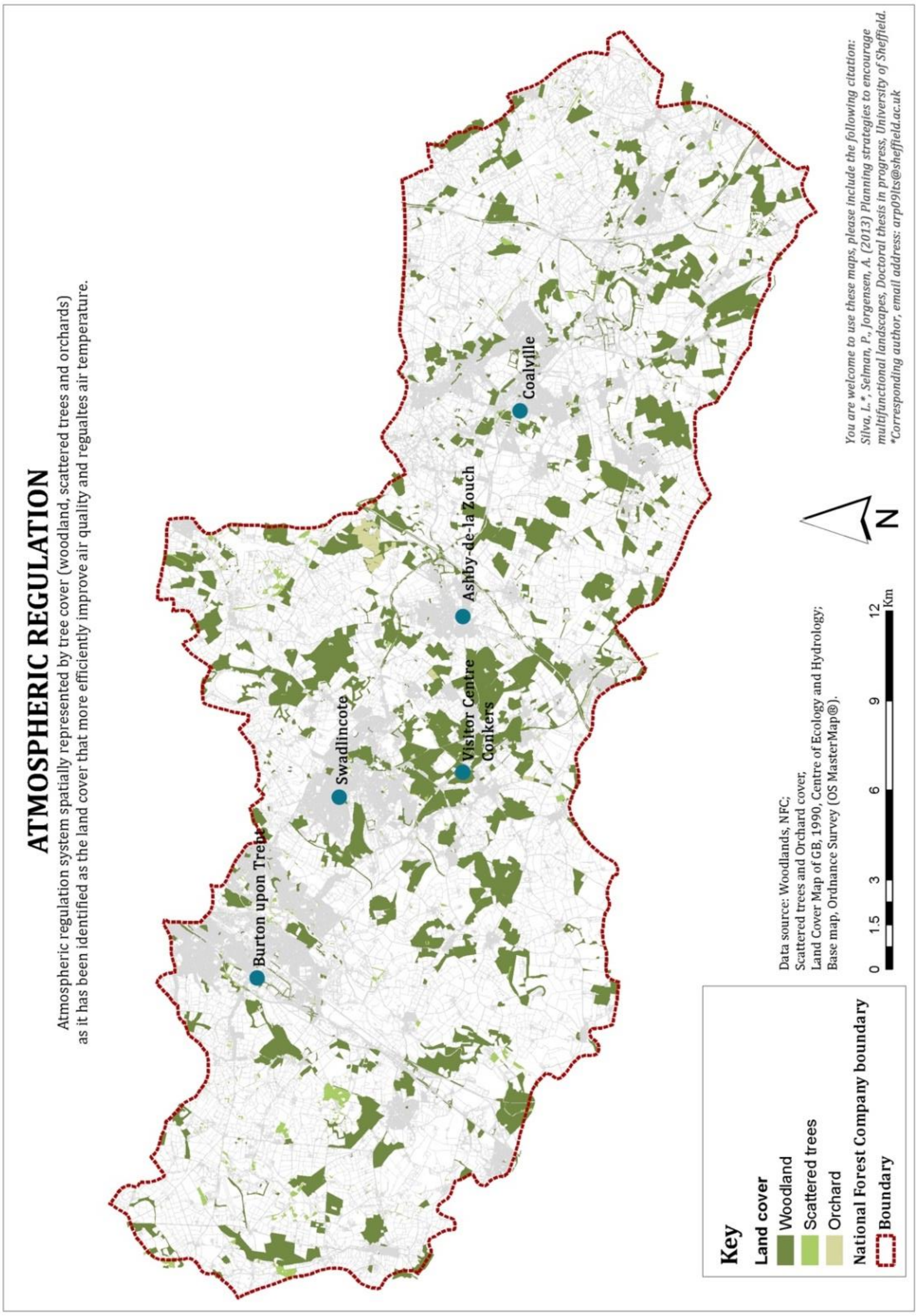


Figure 5.18. Atmospheric regulation system map

5.5.4 Biodiversity system

As explored in Chapter 4, this landscape function system has the capacity to support biodiversity by providing high quality habitats and an ecological network where species can move, transform energy, and find resources and cover.

Landscape connectivity is the measure that defines the extent to which landscapes support or hinder species movement (Tischendorf and Fahrig, 2000; Taylor et al., 1993). There are numerous research studies that concentrate on the quantification and representation of habitat connectivity. All of them vary in scale and scope, for example: the study of a specific species movement, the study of how many steps a species moves to find a new habitat or the quantity of individuals migrating to new habitats (Tischendorf and Fahrig, 2000). Although, for the purposes of mapping the capacity of the landscape to perform this function, the chosen spatial model should have a clear understanding of the distinction between structural landscape connectivity and functional landscape connectivity (Tischendorf and Fahrig, 2000). *Structural* landscape connectivity refers to the physical and spatial connection of habitat patches by the use of linear landscape elements, for example, corridors. On the other hand, *functional* landscape connectivity is about species' movement response to the landscape elements (habitat quality, patches, linear corridors and the wider landscape matrix); for example, habitat patches might be structurally connected but do not necessarily provide functional connectivity, as the habitats might not be appropriate for the species' movement patterns (Tischendorf and Fahrig, 2000). Therefore, for the representation and quantification of the capacity of the landscape to support biodiversity, the model should aim to explore functional habitat connectivity.

For the purpose of representing the functional connectivity, this case study has selected the habitat connectivity model developed by the NFC. The NFC developed a GIS model where key habitats (woodland, grasslands, heathland, and mire/bog/fen) are identified and given a *permeability* value based on research published by Natural England, and then analysed in terms of the dynamics between habitats. The model aims to identify groups of habitats connected and the final output is a map illustrating potential ecological networks (personal e-mail communication NFC officer; Ordnance Survey, 2015). The continued development of the NFC GIS model has evolved to illustrate different levels of interconnectivity, from large areas to isolated patches (Ordnance Survey, 2015).

Furthermore, this study research complemented the NFC's habitat connectivity model by integrating information provided by a pollinator model developed by Osborne et al. (2008b) and looking at potential density of bumble bees in different rural land covers. As explored in the literature review, the pollinator support function was added to the biodiversity support system because of the pollinator's role to enhance biodiversity by reproducing and dispersing plant species.

The main constraint for mapping the pollinator support function is the wider range of pollinator species and their different traits. From all pollinator species (e.g. honeybees, bumblebees, solitary bees, wasps, hover flies, beetles and birds) research has identified that bees are the predominant and most economically important group of all pollinator species (Barmaz et al., 2010; Batáry et al., 2010). Bumblebees' traits are essential for flora and crop pollinations, yet bumblebee species have been severely affected by agricultural intensification (Rundlöf et al., 2008).

As discussed previously, for mapping potential the pollinator support function, this study chose to map potential nest densities of bumblebees through different land covers. Osborne et al. (2008a) carried out a nest survey of bumblebees on different countryside land covers, in England and Wales, which then allow them to calculate nest densities per type of land cover. To the habitat connectivity map, we added three specific land covers: garden, grassland and woodland, subsequently adding the following density values:

- Garden: 36 nest per ha^{-1}
- Grasslands > 10 cm sward: 15 nest per ha^{-1}
- Woodland: 11 nest per ha^{-1}

The spatial datasets used to identify land cover polygons are: Ordnance Survey MasterMap, NFC's woodlands dataset and Land Cover Map of Great Britain 1990 at 25 m (Centre for Ecology and Hydrology) resolution.

Limitations on land cover characterisation were encountered delineating grasslands where cutting leaved a swards of more than 10 cm. Polygons identified as *rough grassland* from the OS Master Map dataset and *semi-natural swards* and *grass heath* from the 1990 Land Cover dataset were merged to create a more comprehensive grassland cover layer. Osborne et al. (2008b) discuss significant limitations of their study, namely, nest information does not provide information on nest survival after June-July, so there is no information regarding pollinator survival, and the nest survey was collected by non-expert surveyors. However, the proposed nest density values support an understanding of different land covers that have the capacity to support pollinators. The resulting biodiversity and pollinator support map is illustrated in Figure 5.19.

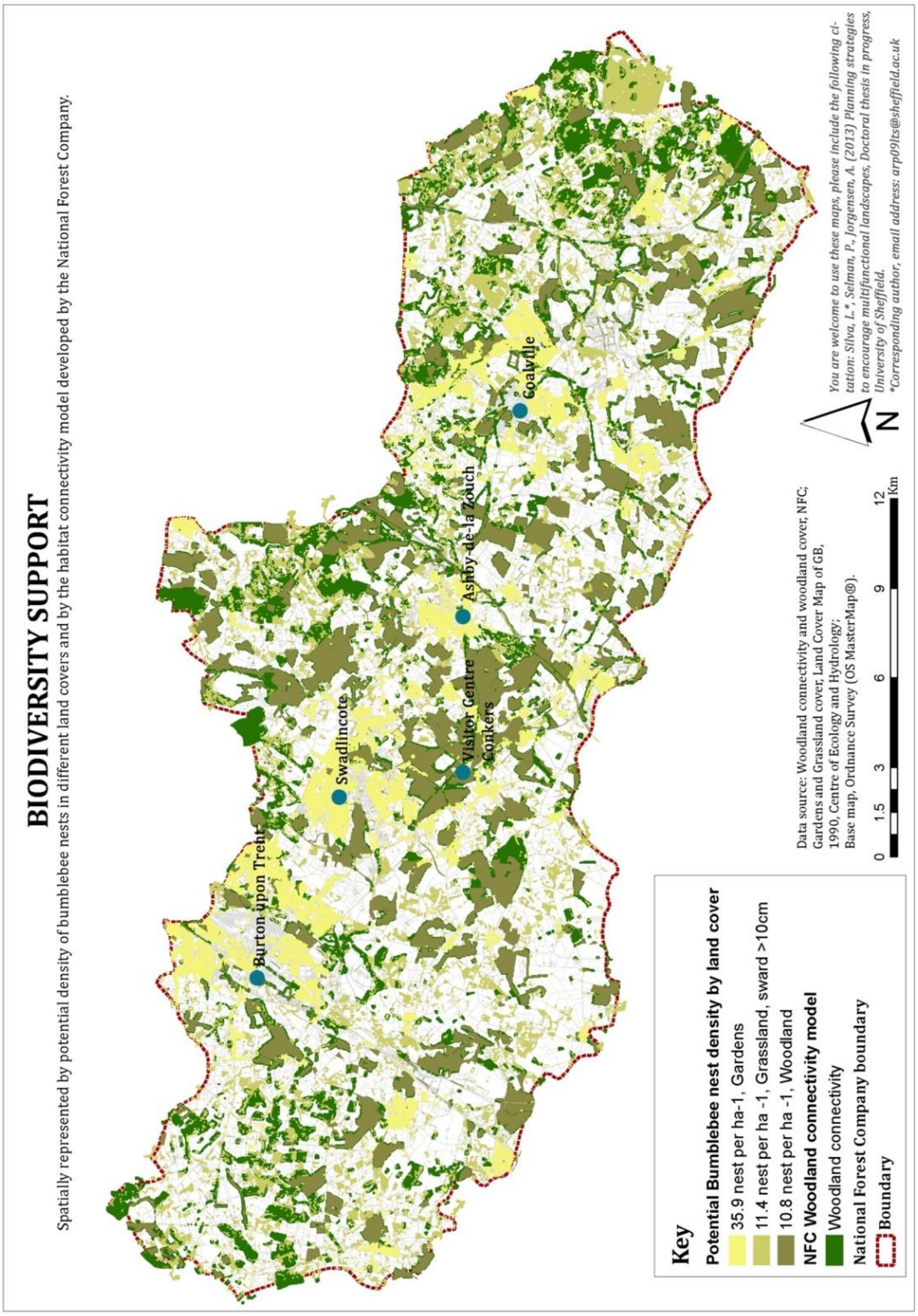


Figure 5.19. Biodiversity support system map

5.5.5 Information and Carrier systems

The information and carrier landscape functions comprise different processes and components that lead to different landscape dynamics. Nevertheless, they have one common feature, as they both trigger relationships between people and the landscape, in particular when people are directly involved in and experience the landscape. Thus, this study proposes a joint spatial representation of the information and carrier systems.

The landscape function's processes involved for the information systems are information exchange and cognitive processes that lead to opportunities to reflect, learn and inspire; and, for the carrier landscape function, a meaningful spatial configuration between spaces and places, for example functional connections from house to transport nodes or to workplaces, shops and recreation sites, these encourage people to actively engage and move through the landscape. Based on such landscape processes and components, this study sought to map two potential indicators where people can engage and move directly within the landscape. The first spatial indicators used are the formally designated spaces and places where people could potentially carry out an activity. The mapping of such polygons was generated from the *accessible woodland* and *attractions* databases generated by NFC. The second spatial indicator refers to supporting movement through the landscape, so this study spatially identified walking groups and routes recommended by local authorities or other organization (Dobson, 2011). For mapping walking routes, this study used the following databases: i) national forest walks developed by NFC, and ii) walking for health routes, accessed through Natural England GIS Digital Boundary Datasets. Figure 5.20 presents the resulting information and carrier systems map.

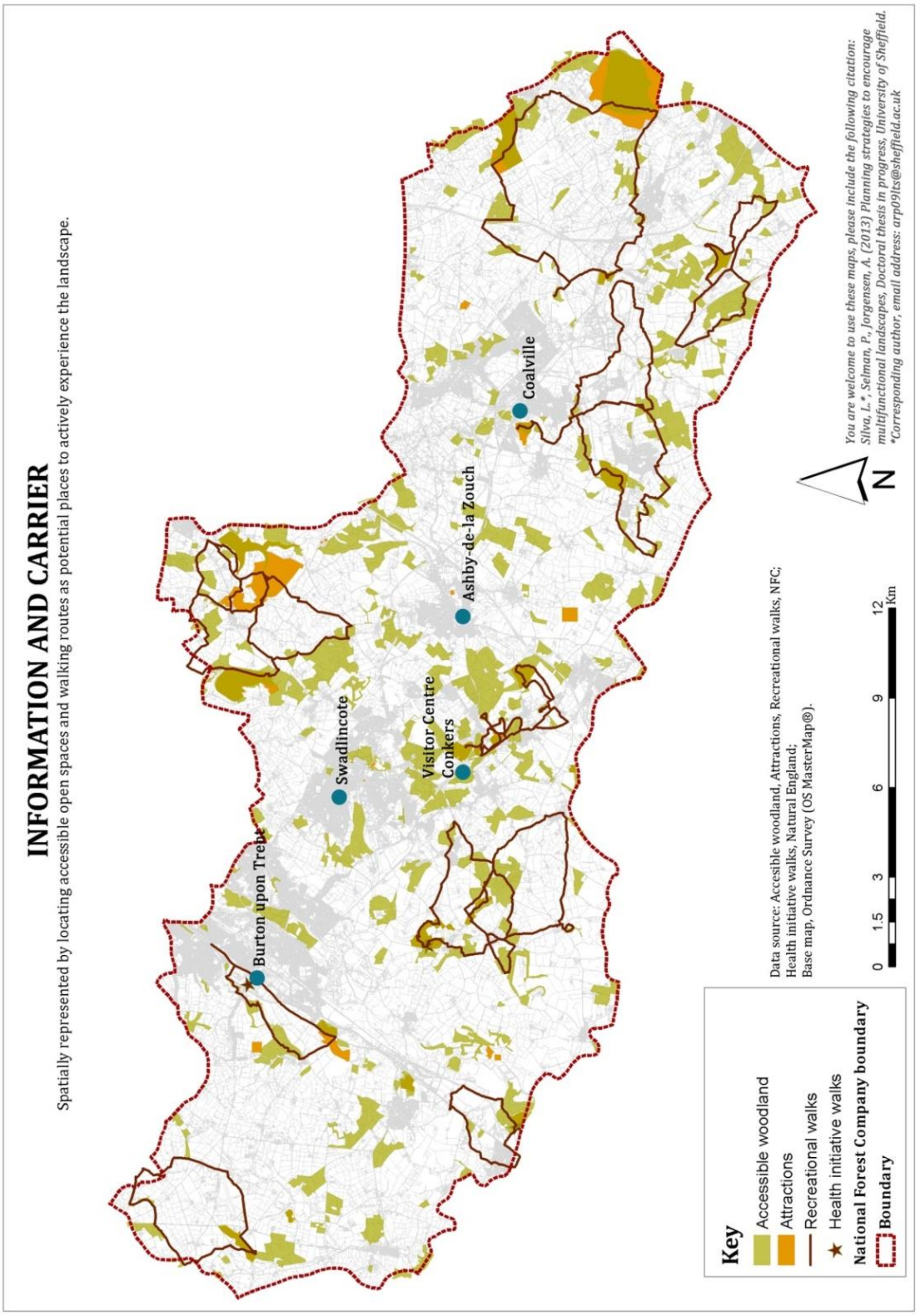


Figure 5.20. Information and Carrier landscape function systems.

5.5.6 Community system

As explored in the landscape function systems literature review (Chapter 4, section 4.8), this research study defines the community landscape function system as the processes and relationships between people that occur within the landscape. The effects of these processes are the encouragement of cooperation and collaboration between community members, which in turn support beneficial social processes such as social learning, social capital and local economic capacity. For the mapping exercise we identified community and volunteering groups such as 'Friends of…" or "maintenance volunteering of…", which have qualities reflecting active landscape involvement, and potentially have a positive effect on the development of *place* qualities and the quality of the landscape through management and maintenance volunteering. Figure 5.21 shows the geographical location of 'Friends of…" or "maintenance volunteering of…" groups. Such groups were identified through searching local authority web pages within the NF project area.

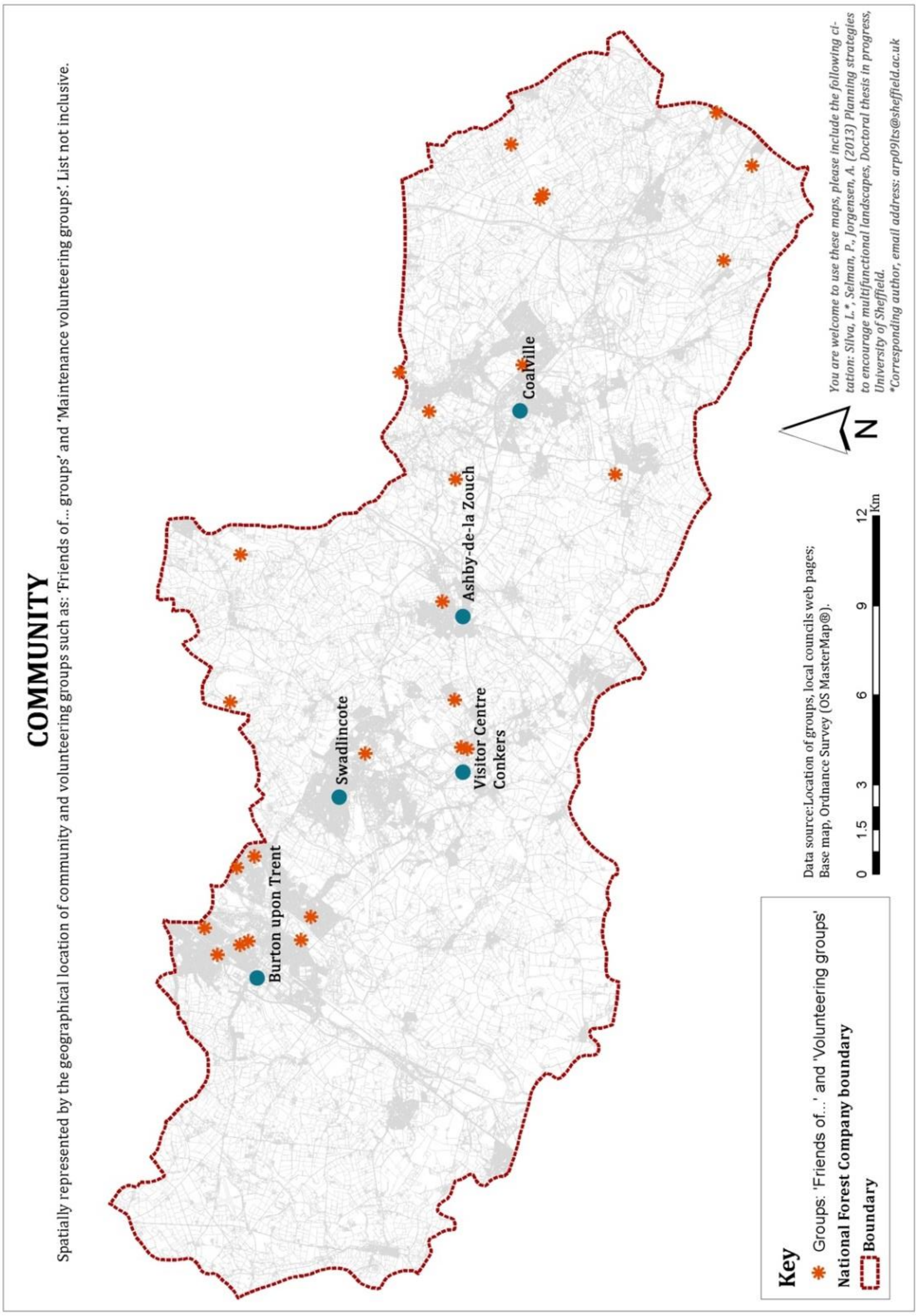


Figure 5.21. Community landscape function system.

5.6 Conclusion

This chapter has described the exploratory exercise carried out to build on existing approaches to landscape function mapping. Three approaches to landscape function mapping were explored and applied to the National Forest case study area. The first approach was developed by The Mersey Forest in 2009, described as a qualitative approach that assigns landscape functions to different green infrastructure assets. Overall, the approach was successfully applied to the Moira district, but the exploratory exercise concluded that this approach has a limited capacity for analysing dynamics and relationships between landscape function systems. Louise Willemen et al. (2008) developed the second approach explored in this exploratory exercise, which, by contrast, is characterised as a quantitative approach to landscape function mapping through statistical quantification of the potential occurrence of each landscape function. Its exploration and application to the region of Moira was not successful because only four of the eight proposed landscape functions were mapped. This was attributable to the differences of spatial scales between the original case study and the Moira district. A third approach was explored and applied to the total area of the NF. This was influenced by Willemen et al.'s approach to *non-delineated* landscape functions, which comprised identifying spatial indicators and desirable process thresholds that potentially describe the occurrence of the landscape function under consideration. This final approach differs from others because it aims to illustrate the landscape through interpreting spatial datasets by understanding processes and components of each landscape function system. However, the latter mapping approach too, has limitations, associated with fully illustrating all the landscape functions processes, components and their extent of occurrence; it is also limited by the quality and accessibility of spatial databases in terms of spatial and temporal scales. Nevertheless, it appears that there is a recent, continuing improvement of the quality and accessibility of spatial datasets.

Chapter 6 | Soft Systems Methodology

6.1 Introduction

Landscapes are complex systems that have the capacity to support multiple social and ecological processes. These processes are referred as landscape functions. Dynamism and interactions between landscape functions determine the capacity of the landscape to provide ecosystem services; but most importantly they trigger emergent and highly desirable landscape properties such as *multifunctionality,* landscape character and resilience. Landscape multifunctionality is an approach that aims to understand and explore the underlying dynamics of landscapes, in order to be able to identify how to intervene purposefully, to then to encourage desirable properties and change.

This research study explores landscape multifunctionality as a system, in particular as a social- ecological system, to support an understanding of its dynamics by looking at the relationships between landscape functions and placing people as integral part of the system. Thus the main aim of this thesis is to explore and apply a systems thinking approach that permits a comprehensive illustration of landscape function dynamics. After exploring landscape functions as social and ecological systems, first theoretically (Chapter 4) and then spatially (Chapter 5), the next challenge is to analyse the dynamics between landscape function systems. The objective of this chapter is to apply and explore Soft Systems Methodology (SSM) as a system thinking approach to help landscape professionals and stakeholders to explore together dynamics between social and ecological systems.

SSM is a methodological approach that through social learning aims to understand complex situations by applying three considerations: i) it takes into account multiple perceptions and perspectives from different people involved, ii) it recognises that people tend to act purposefully to confront any situation, and iii) it provides rigour and transparency to the analysing and discursive processes (Checkland and Poulter, 2010). This approach will be explored and applied to the National Forest case study area. SSM comprises four stages. The first is a *finding out* stage of data collection and the researcher builds a comprehensive overview of the problematic situation (section 6.2). The second stage relates to identifying and defining relevant systems through several proposed analyses (section 6.3).

Subsequently, the aim of the third stage is to develop conceptual models of the previously identified systems (section 6.4). The final stage uses the previously developed conceptual models to organise and discuss the situation and considers how it could be improved (section 6.5).

6.2 Stage 1: *finding out*

The purpose of this stage is to start the inquiry process by collecting information and carrying out thinking exercises that will illustrate to the practitioner and others a comprehensive overview of the *situation* under consideration. *Situation* is a term used within SSM to refer to any query under review, *e.g.* problems, issues, initiatives and programs; however, SSM guidance proposes this term in particular to avoid thinking in terms of “solutions” and, rather, to learn about the situation.

At this first stage, the information to be collected involves a compilation of stakeholders’ perspectives, insights, roles, values, issues and concerns. As previously explored, SSM is described as a collaborative method (Checkland, 1999; Checkland and Poulter, 2010). Information collection at this stage provides an early opportunity to encourage active stakeholder participation within the SSM process. Through stakeholder discussions, participation at the beginning of the methodological framework aims to set goals and objectives (Opdam et al., 2008; Henningsson et al. 2014). The information collected is then explored by three different methods, and subsequently presented through a *rich picture* diagram. These steps do not necessarily occur sequentially, but rather simultaneously.

This thesis starts from the academic debate about landscape multifunctionality as a framework for identifying the dynamic relationships between multiple ecological and social landscape function systems (Lovell and Taylor, 2013; Selman, 2009; 2012). As previously discussed, this thesis seeks to understand multifunctionality properties by analysing the underlying process of functions (social and ecological) to identify points of feasible intervention that could accelerate the emergence of multifunctional, resilient and distinctive landscapes.

6.2.1 *Data collection*

Although this research study had an established collaboration with the NFC, it was recognised that opportunities to actively engage with stakeholders were going to be limited by their time availability and resources available to the researcher. SSM practical guidance by Peter Checkland discusses opportunities to achieve a high degree of interactive participation at this through either collectively creating a *rich picture* diagram or by collectively providing feedback and improving an existing *rich picture* diagram.

Reviewing existing SSM studies exploring environmental *situations* (e.g. Dobson et al., 2014; Habron et al., 2004), it was found that information collected through stakeholder participation, at this first stage, was characterised by a low degree of interactive participation. Another study by Bunch (2003) collected data throughout workshops, yet the information collection exercise comprised answering questions individually. In these cases, stakeholder participation was limited to gathering information through structured and semi-structured interviews, achieving only *one-way* communication (Patel et al., 2007). It is important to note that this thesis does not aim to assess the appropriateness of these methods, but aims to analyse when and how within the SSM stages the researcher's limited resources could achieve and encourage a more interactive and fruitful stakeholder participation. Based on this, it was decided to conserve the resources and opportunities until the later fourth SSM stage, which will be described in section 6.5.

Nevertheless, to inform this thesis *situation*, information was primarily collected through an analysis of existing literature scoping the context of multifunctional landscapes (see Chapter 2). However, this information collection was widened by the opportunity to meet informally with NFC's stakeholders. Two meetings took place, first with a senior landscape adviser of Natural England and then with the NFC landscape advisory group. Prior to both meetings, we sent an email containing a short discussion paper discussing the context and purpose of this research. During each meeting, the stakeholders kindly discussed their perspectives and thoughts on landscape functions and landscape multifunctionality.

6.2.2 *Thinking exercise*

SSM guidance by Checkland proposes three different thinking processes - *Analysis I, II and III* - that aim to analyse and structure the collected stakeholder's perspectives and concerns. *Analysis I* aims to identify who is involved, interested in or affected by the *situation;* in particular, to identify who is the client requesting the query process, who is going to carry out the query process (for example, the practitioner or an analyst), and who is going to be affected. The purpose of *Analysis II* is to identify the roles, behaviour and values of the people identified previously. Finally, *analysis III* is concerned with the *politics* of the *situation*, by analysing who has the *powers* to use and direct resources and how final decisions and actions are taken (Checkland and Scholes, 1999; Checkland, 1999; Checkland and Poulter, 2010).

After carrying such analyses, then the *situation* is illustrated by the creation of a *rich picture diagram.* Checkland recommends representing complexity graphically, because as the *situation* starts to build up, it is more difficult to achieve appropriate, accurate and easy to comprehend textual manuscripts describing the *situation* under consideration. The creation of *rich picture diagrams* mirrors the analogy of forming a *mental picture* in the richest form possible (showing a comprehensive and holistic view of the *situation* under consideration). Through *rich picture* diagrams, existing structures, relationships, people involved and stakeholders' points of view are illustrated through simple and symbolic graphics.

After collecting and analysing data regarding landscape multifunctionality and the National Forest, a rich picture diagram was developed (Figure 6.1). The main components of this *rich picture diagram* are The National Forest as a project area and central point of the *situation*, and the ecological and social factors influencing the project area. In this study, the role of this *rich* picture has been to inform the subsequent SSM stages by providing specific information regarding the social and cultural components of the NF, in particular identifying people and organisations involved.

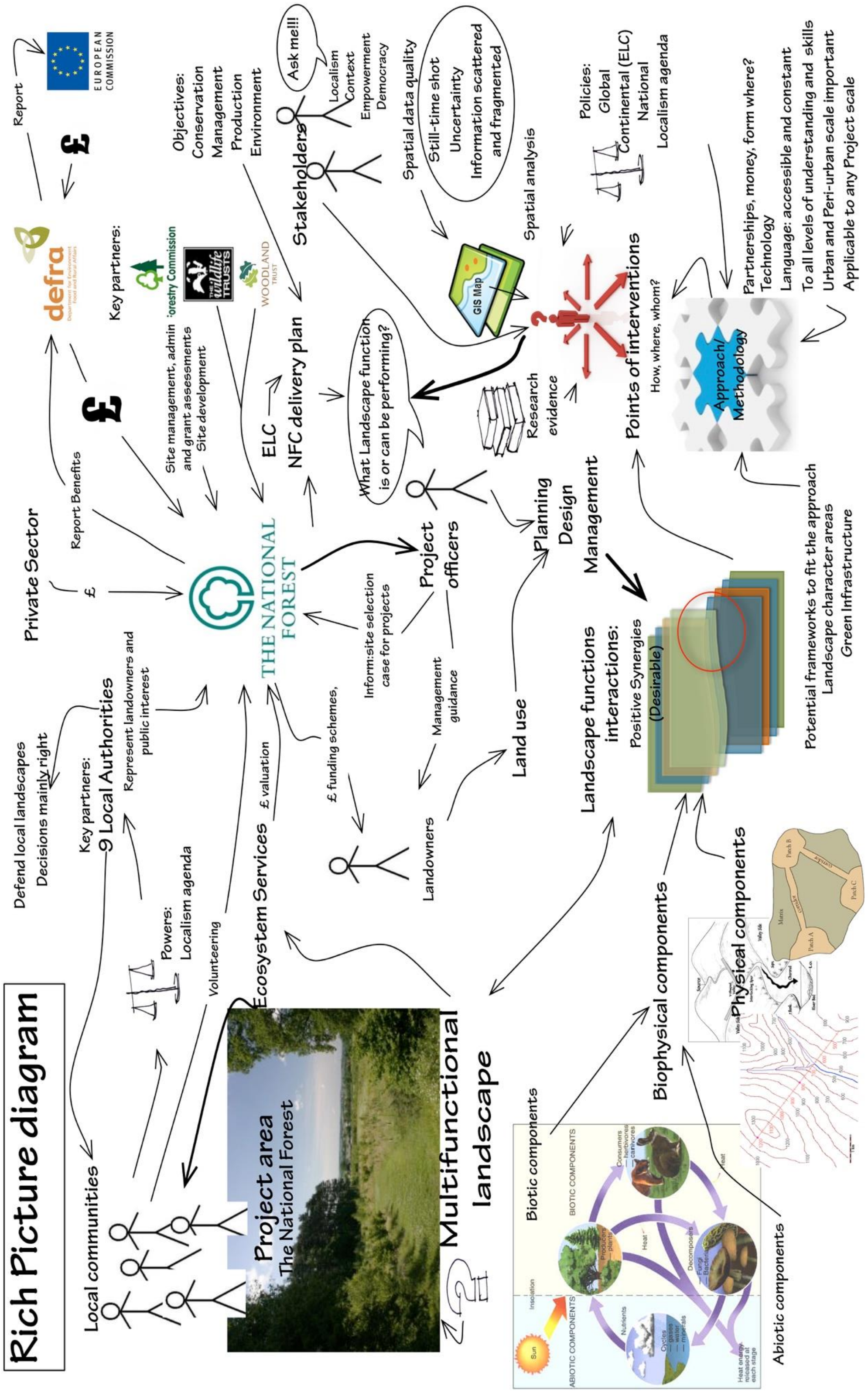


Figure 6.1. Rich Picture diagram

6.3 Stage 2: *idetifying and defining relevant systems*

The aim of this stage is to identify and create a clear definition of the relevant systems to be modelled in the next SSM stage 3 (section 6.4). In SSM terms, this definition is called *root definition*. A *root definition* is short written statement describing a *purposeful activity.* A *purposeful activity* is described as a *transformation* process that involves doing something to achieve something else. A *root definition* requires the investigator to express the particular point of view that the models will adopt, which provides the reason or justification to carry out the transformation process; for this, SSM uses the term *worldview* or *weltanschauung.* There are always several *worldviews* that can be suitable for any single system. To summarise, the *root definition* requires clarification of the system's components throughout the transformation process, the particular *point of view* or *worldview* taken, and the main people involved.

Recent SSM guidance by Checkland and Poulter (2010) proposes carrying out five different thinking processes that aim to identify relevant information about the systems, which in turn will help the analyst to build a comprehensive *root definition*. The five thinking processes are as follows:

i) *PQR* formula,
ii) *Root definition* statement
iii) *CATWOE*
iv) *3 E's*
v) To identify purpose of *root definition*: *primary task vs. issue based*

The following paragraphs will describe the application of such analyses to this research study.

6.3.1 Worldview and Relevant Systems.

This research study focuses on exploring **multifunctional landscapes** as a *complex social-ecological system* where its emergent properties (multifunctionality, resilience and distinctiveness) depend on the dynamic relationships between its underlying and interconnected social and ecological **landscape functions** (*the sub-systems*). Synergetic relationships between landscape's natural and cultural functions can potentially stimulate the emergence of new, distinctive, characterful and resilient landscapes; this desirable condition will deliver a desired range of ecosystem services and will become a *place* for local communities to identify with (Selman, 2012). For this research study, we identify multifunctional landscapes and their landscape functions as the relevant systems to be modelled. Through SSM we aim to learn about those systems in order to inform *action to be taken* or purposeful and planned interventions that will create opportunities to stimulate synergies between the environment, society and economy.

The literature explored in Chapter 2, section 2.4 identified a total of 29 landscape functions. As noted previously, SSM guidelines suggest considering only between seven and nine *systems*. After, the initial 29 landscape functions were analysed, it was concluded that they could be clustered in seven landscape functions systems. Hence, this study uses seven landscape function systems plus an eighth- landscape multifunctionality as the wider system embracing all their interactions. Table 6.1 shows the identified relevant systems and their corresponding cluster of landscape functions.

Table 6.1. Identified relevant systems and landscape function cluster.

Wider System	
1. *Multifunctionality*	
Systems	**Landscape function cluster**
2. *Provision*	• Provision of Food and Raw materials • Energy conversion of non-fossil sources • Soil stabilisation
3. *Hydrological Cycle Support*	• Interception and infiltration of rainfall • Filtration of overland flow • Water storage
4. *Atmospheric regulation*	• Air pollution filtration • Carbon sequestration • Microclimate regulation
5. *Biodiversity support*	• Habitat provision • Habitat connectivity • Pollinator support
6. *Information*	• Aesthetic experience • Heritage interpretation • Outdoor learning experience • Health and well-being encouragement
7. *Community*	• Institutional thickness • Economic
8. *Carrier*	• Recreation opportunities • Sustainable transport opportunities

6.3.2 PQR analysis and Root Definition

As explored previously, the first thinking approach that supports the creation of a *root definition* is referred as the *PQR* formula. This acronym helps to provide an initial structure to the root definition by answering What? How? and Why? The PQR initials are used to remember to describe: *do P, by Q* (this is the transformation process), *in order to achieve R.* For this thesis, we identified *P* as: *the promotion of multifunctionality in the NF project area;* Q: *by intervening appropriately to encourage synergies between landscape functions;* R: *to create distinctive, resilient and characterful new landscapes.* Following these statements an initial *root definition* draft was written:

Root definition**:** *A system that promotes landscape multifunctionality in the National Forest by appropriate stakeholder intervention to catalyse synergies between landscape functions, in order to enable a distinctive, resilient and multifunctional new landscape to emerge.*

6.3.3 CATWOE analysis

The initial *root definition* requires to be complemented by applying a series of steps known by the mnemonic *CATWOE*. This helps the analyst to further define the system's components that will inform the conceptual models, in particular identifying and defining the main people involved in the system. For this analysis, the *rich picture diagram* (Figure, 6.1) was particular relevant. Table 6.2 illustrates the definitions of CATWOE and its application in the multifunctional landscape system.

Table 6.2. CATWOE components according to Checkland and Poulter (2010) and its application to this thesis.

CATWOE	Definitions for this research
C*lients* or customers of the system that are benefited or affected by the transformation process	Residents, workers, visitors, wildlife
A*ctors*, who would perform the necessary activities to achieve the transformation	Project officers, landowners, farmers, forest officers, local communities, local authorities
T*ransformation*, the change that takes place throughout a purposeful activity	Planned, designed and managed activities that stimulate the emergence of distinctive, resilient and multifunctional landscapes.
W*eltanshauung* (**w**orldview) a particular point of view that provides purpose to the system analysed	Multifunctional landscape properties emerge from positive and synergetic relationships of its interconnected landscape functions
O*wner,* who is the authority to stop or make changes to the system	Private and public landowners
E*nvironment*, restrictions that could enhance or affect the system	Funding, objectives of funding institution, information supporting the decisions, policies, ecological processes that will occur despite human action.

6.3.4 3 E's analysis

This thinking approach encourages reflecting on how the *transformation process* could, in the future, be measured, assessed and monitored. Checkland and Poulter (2010) identify three different potential measures: a) *Efficacy,* the *transformation process* is producing the desirable result; b) *Efficiency,* the *transformation process* is being achieved in respect of resources, often related to costs; and c) *Effectiveness,* the *transformation process* accomplish a *long-term* aim. This thesis proposes that landscape multifunctionality can be assessed and monitored by its *efficacy* and *effectiveness* to achieve distinctive and resilient landscapes. It can potentially be evaluated through community perceptions and well being, but, as the rich picture illustrates (Fig. 6.1) approaches and initiatives need to be justified and assessed in terms of resource *efficiency* through ecosystem services delivery.

6.3.5 Task-Based or Issue-Based Models

The final analysis refers to the identification of the system's boundaries. SSM guidance identifies two types of *root definitions* that in turn will produce a *task-based* or an *issue-*

based model. These terms describe the institutional boundaries that the models will consider. *Task-based* models are limited to studying *purposeful activities* occurring within existing departments' or organisations' boundaries. On the other hand, *issue-based* models explore *purposeful activities* without considering organisational boundaries. Checkland and Poulter (2010) evaluated through experience that *issues-based root definitions* and their consequent *conceptual models* stimulate more dialogue at the discussion stage (SSM stage 4, section 6.5) because they promote questions about existing and potential roles and structures beyond institutionalised boundaries. However, they also found that within the SSM thinking and learning process, further modelling and analysis could benefit from considering both types of definition and consequently the creation of two different conceptual models.

In relation to this research study, landscape multifunctionality is an approach where its underlying processes and dynamics have an effect across different spatial, organisational and temporal frames (Cash et al., 2006; Selman, 2009; Folke et al., 2010; Lovell and Taylor, 2013; Mastrangelo et al., 2014). Thus, we consider the *root definition* of a multifunctional landscape system as an *issue-based* definition.

To summarise, the landscape multifunctionality system is described by a ***transformation process*** that involves stakeholders who *intervene appropriately through planned, designed and managed landscape interventions*. The National Forest stakeholders comprise: *project officers, landowners, farmers, forest officers, local communities and local authorities*. The ***worldview*** taken is that *synergetic dynamics and relationships between landscape functions accelerate the emergence of multifunctionality*. It is proposed that the system and sub-systems will be evaluated and monitored in terms of *community perceptions and delivery of ecosystem services*. Finally, the following conceptual models can be described as ***issue-based*** models as landscape multifunctionality tends to cross multiple organisational and spatial boundaries.

This reviewed *root definition* corresponds to the landscape multifunctionality system, but also provides the basis for the landscape function system's root definitions, in particular the CATWOE mnemonic components, the three E's and the *issue/task-based* analyses. However, it was important to identify and clarify the *transformation process* of each landscape function sub-system. The PQR analysis was particularly helpful in defining the transformation processes for each landscape function system; Table 6.3 identifies these transformation processes.

Table 6.3. Sub-systems to be modelled and *transformation processes*

Landscape Function Systems	*Transformation Process*
Provision	The capacity of the landscape through the soil to sustain biomass productivity and support renewable energy
Hydrological Cycle Support	Contribution of landscape elements to complete the hydrological cycle.
Atmospheric regulation	Improvement of air quality and microclimate through trees.
Biodiversity support	Provision of appropriate and spatially connected habitats for species to thrive and adapt to disturbances.
Information	Human experiences and perceptions of landscape attributes that encourage positive cognitive associations, providing scope for learning, aesthetics, sense of place and restoration experiences.
Community	The landscape as spatial framework or object that contributes to community collaboration and economy.
Carrier	Provision of place, connectivity and space suitable for human physical movement.

The completion of stage 2 achieves the formal analysis and formulation of the situation under consideration. The analyses carried out previously gave structure to the thinking process by exploring in particular the human roles within the multifunctional landscape system. The following stage aims to model the relevant systems based on the *root definitions.*

6.4 Stage 3: *modelling landscape systems*

The third stage of the SSM learning cycle is concerned with the development of conceptual models for each system. Conceptual modelling is achieved by illustrating graphically the system's *transformation process* components (social and natural) and their dynamics, all from a particular *worldview.* The purpose of the conceptual models is to be used as tools and support materials to frame and encourage dialogue between stakeholders in the following SSM stage (section 6.5).

SSM guidance describes the conceptual model building approach as a continuous exercise of root definition analyses (QPR formula, CATWOE, 3Es and boundaries); followed by assembling, noting down and linking with arrows the activities and components required to represent a transforming process (Checkland and Poulter, 2010).

Nevertheless, studies applying SSM have approached conceptual model building in different ways. For example, Morris et al. (2006) applied casual loop diagram conventions to build conceptual models exploring sustainability approaches to land use in Herefordshire; Selman and Knight (2006a) explored the application of multiple cause diagrams to study "virtuosity" between human activity and the environment which were then developed further into sign diagrams; and Mendoza and Prabhu (2006) in their study of sustainable forest management explored the application of cognitive mapping for conceptual modelling.

Furthermore, Selman and Knight (2006a) and Mendoza and Prabhu (2006) assessed the opportunity to further develop the conceptual models into formal qualitative and quantitative models. Specifically, this becomes possible, when information, data, knowledge and expertise are available, with the intention of pursuing deeper analysis of non-linear relationships and feedbacks, including thresholds, trade-offs, indicators and scenario evaluation. Because of the continuing discussions regarding the limitations of data, in terms of quality and suitability to analyse the landscape and environment complexity (Bastian et al., 2012; Potschin and Haines-Young et al., 2013; Mastrangelo et al., 2014), emerging studies are aiming to develop more appropriate data, which includes the importance of "non-expert" empirical knowledge and observations. Subsequently new data and knowledge should become more accessible and appropriate, and will then potentially fill in quantitative, qualitative, non-linear and multiple-scale (time and space) variables in complex systems analyses. Although there is a clear flexibility on how to approach SSM conceptual modelling, it is important to consider that all approaches share the important characteristic that make conceptual models standout against hard/mathematical models, such as accessibility to a different range of skills.

After considering the important qualities of conceptual models and their potential and desirable subsequent formal analysis, a *systems dynamics* approach was chosen as a potential framework for conceptual modelling. Systems dynamics is a discipline that, through modelling, aims to understand the dynamics of complex systems (Coyle, 2000, Wolstenholme, 1999, White, 2011). Systems dynamics also forms part of systems thinking approaches. The difference between systems dynamics and SSM, is that systems dynamics aims to represent non-linear qualities of complex systems by identifying feedback loops, stocks and flows; however, unlike SSM it is not characterised as a participatory approach and a structured learning cycle process.

Systems dynamics comprise both qualitative and quantitative modelling approaches. The qualitative approach starts by modelling systems through influence diagrams. These diagrams aim to describe the causalities between system components by connecting their relationships either positively or negatively (Mendoza and Prabhu, 2006). Then, these influence diagrams are further developed into more complex qualitative mapping methods such as sign diagrams and fuzzy cognitive mapping (for example: Mendoza and Prabhu, 2006); then depending on data and knowledge available, models are further modelled into quantitative models throughout Fuzzy and Bayesian modelling methods (Mendoza and Prabhu, 2006). Based on current research agendas, this thesis adopts influence diagram guidelines as suggested by systems dynamics to construct conceptual models, permitting SSM analysis of landscape multifunctionality and offering the opportunity for further, deeper and quantitative analyses if required.

6.4.1 Landscape Function Systems conceptual models

Conceptual models of landscape function systems were constructed following *influence diagram* guidelines. As explored previously, the purpose of creating influence diagrams is to offer the possibility of using the conceptual models as a basis for further quantitative modelling through *systems dynamics* approaches.

As explored in section 6.3.1 of this chapter, *Landscape Multifunctionality* and seven *landscape function systems clusters* were identified as appropriate for modelling. In total, eight landscape function systems conceptual models were constructed:

1. Provision
2. Hydrological Cycle Support
3. Atmospheric regulation
4. Biodiversity support
5. Information

6. Community
7. Carrier
8. Landscape multifunctionality, *Master model*

These conceptual models were constructed using the diagraming software *OmniGraffle* version 5.4.4. The models were developed individually through four main phases. The first phase involved identifying each landscape function system's components. This information was compiled from two sources: the literature review presented in Chapter 4; and the analysis carried out in the SSM stages 1 and 2. The literature review had the objective to compile, describe and critically analyse the nature of landscape function systems from a process-oriented point of view. The literature review contributed to identifying the components of each system, in particular, biophysical and management process drivers and their derived ecosystem services. The systems components identified from the literature review are characterised for their general application to a non-specific case study context. SSM stages 1 and 2 informed conceptual modelling regarding the systems' social and cultural components in the particular context of the NFC.

Each landscape function system literature review was read twice, simultaneously noting down a list of components. This analysis was carried out through answering the question: what are the components, activities and actors necessary for the *transformation process* to occur? As well answering this question, it was required to continuously review the previously identified *transformation process* of each system and the *worldview* taken (tables 6.2 and 6.3 illustrate the CATWOE and each system transformation process respectively).

The second phase comprised re-reading each landscape function system review, and the list of components created from it, but this time writing down the components in a logical sequence and drawing their connections, relationships and influences. This analysis aimed to answer: how do elements influence each other for the *transformation process* to occur? Influences were identified according to type and strength. There are two types of influences and relationships between components: positive influences (reinforcing the system) and negative influences (breaking down, degrading the system). Also, influences are described according to the significance of influence between each component system (strength).

In this conceptual modelling step, it was particularly helpful to annotate on the diagram the title of the system and its *transformation process*, as well as having to hand the *root definition* analyses. These elements (in particular the *transformation process and worldview*) prevent the analyst modelling the existing condition of the systems under review, which, according to Checkland and Poulter (2010) could constrain and limit the analysis and discussion of the conceptual models in the subsequent SSM stage.

The third phase consisted of reviewing the resultant *rich picture* (see figure 6.1) and re-visiting the *root definition* analyses (sections 6.2 and 6.3, SSM stages 1 and 2 respectively). A second conceptual model draft was produced by adding and modifying components and influences as necessary.

Finally, the fourth phase involved improving the graphic representation of the conceptual models. To improve their legibility, it was found necessary to add a starting point to follow the *transformation process*. Secondly, a symbology legend was created to explain graphically the differences between positive (continuous line) and negative (dashed line) influences; the direction of the influence is represented through an arrow, and strength of influence is illustrated by increasing line thickness. Bolder fonts highlight the relevant model's components. Additionally, some models' components were moved around the canvas aiming to avoid, as far as possible, influences becoming confused with others. Finally, it emerged that certain system components have a key role on other landscape functions systems' models, and then these were colour coded according to the different systems which they affect. The following pages comprise a brief description of the conceptual models and their associated illustrations.

6.4.2 Landscape Function System: ***P r o v i s i o n***

The *provision system* conceptual model aims to illustrate the relationships, interactions and dynamics occurring when the landscape is supporting biomass productivity for food, raw materials and energy crops. For this model, the chosen starting point component to begin working through the model is: *soil properties.* The landscape functions literature review (Chapter 2) identified the soil as the medium where biophysical and chemical processes take place in order to support plant growth and the subsequent production of a wide range of biomass; however, the productivity and suitability rate are determined by soil properties, agricultural practices, climate and water availability. Important relationships identified relate to the hydrological cycle support function affecting water availability and quality, and energy crops influencing positively air quality. The model illustrates dynamics occurring beyond direct provision; for example, food production might also influence resource conservation techniques and rural and urban agriculture's contribution to community and information functions. Figure 6.2 illustrates the proposed conceptual model for the provision system.

6.4.3 Landscape Function System: *Hydrological cycle support*

For this landscape function system, the model intends to illustrate the processes occurring within the landscape that contribute to the hydrological cycle support. The initial point for reading the model is the starting point of the hydrological cycle itself - rainfall -, followed by processes such as vegetation interception and filtration, soil drainage capacity and water movement, and the influence of water availability for human, wildlife consumption and vegetation uptake. It is important to notice how this function beyond water yield is affected by the information function through education and attitudes; and how water yield influences health and well-being and the landscape character of the area through supporting local flora and fauna. Figure 6.3 shows the suggested hydrological cycle support system.

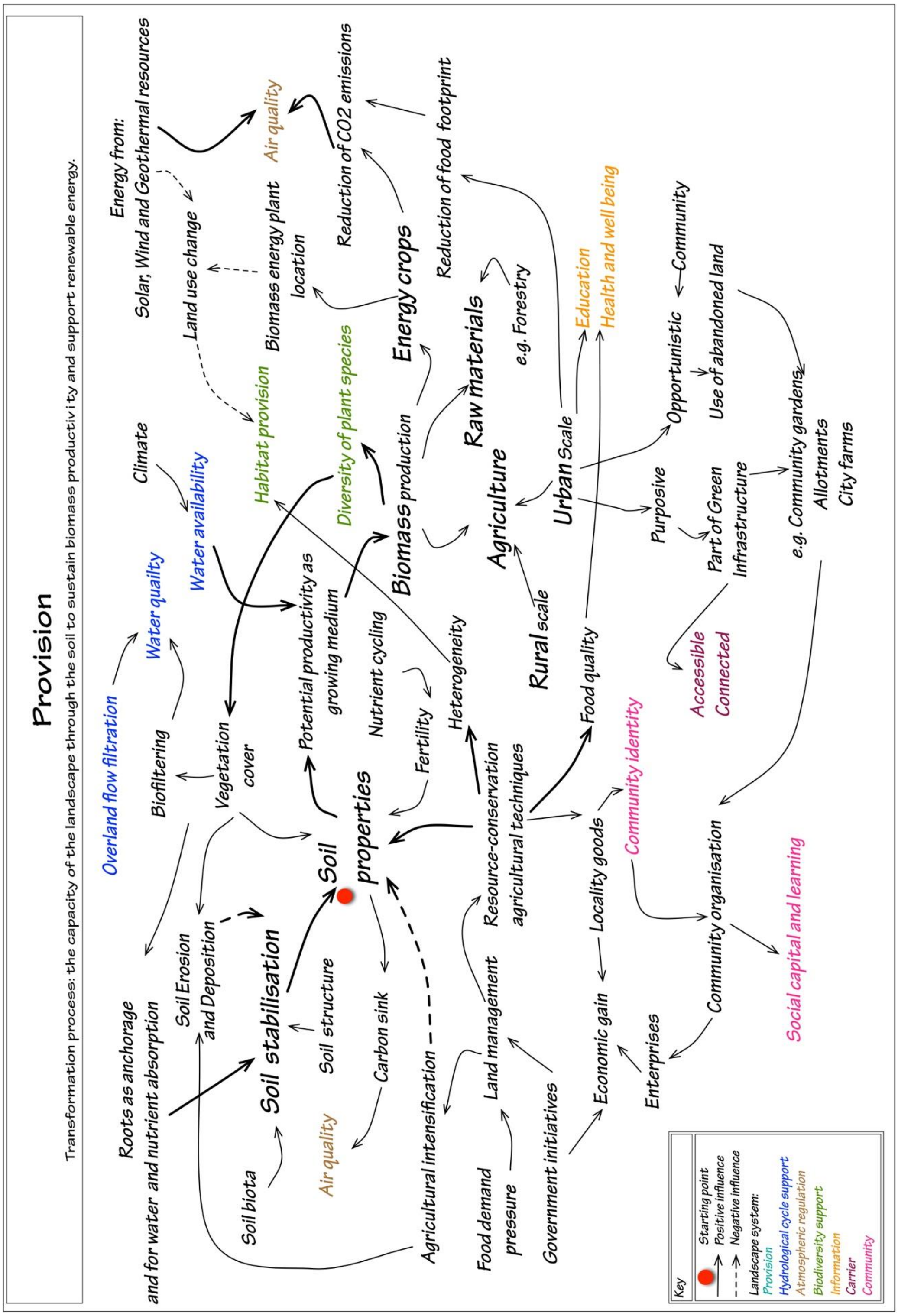


Figure 6.2. Provision landscape system conceptual model

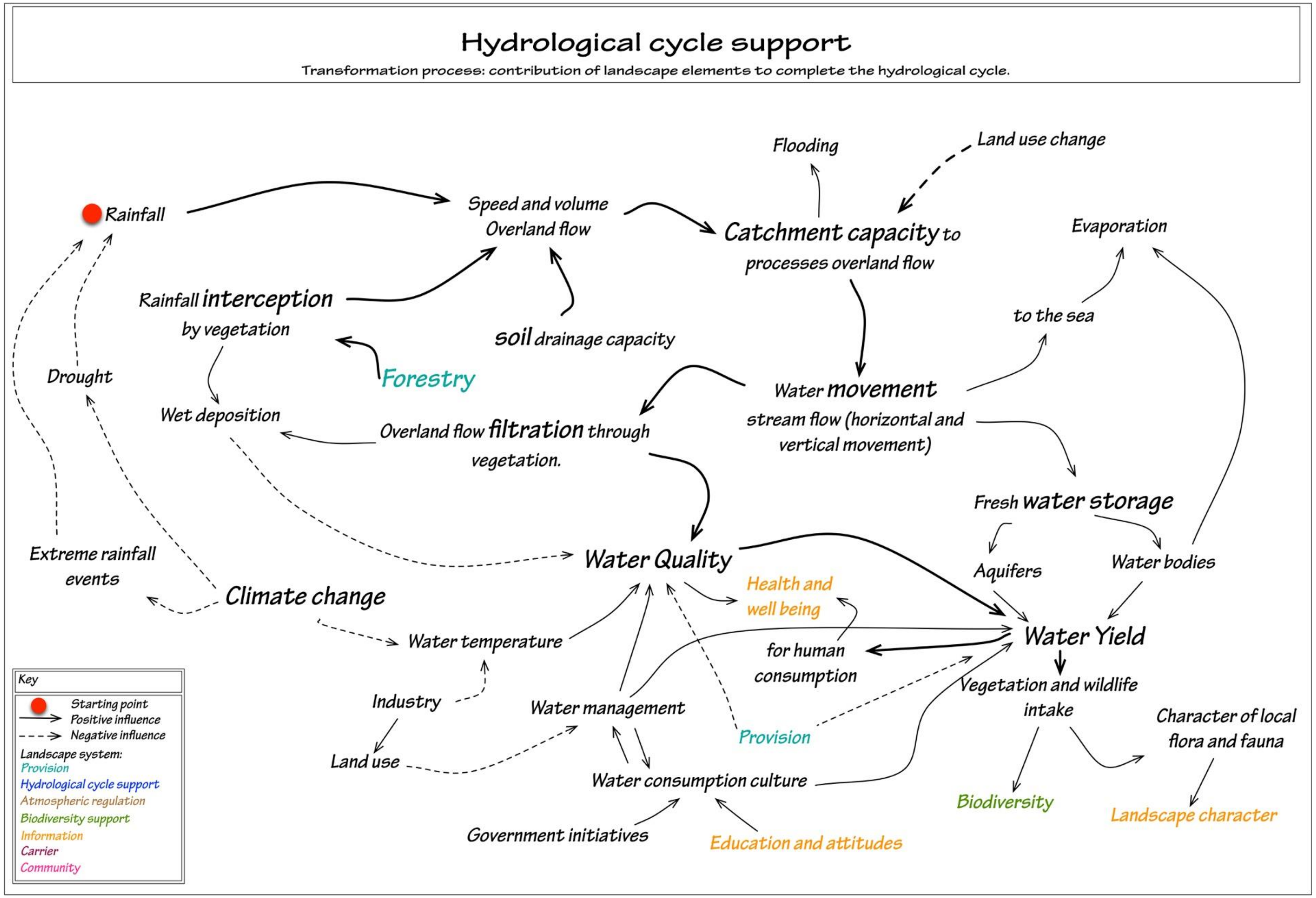


Figure 6.3. Hydrological cycle support landscape system conceptual model

6.4.4 Landscape Function System: ***Atmospheric regulation***

The transformation process established for this landscape system relates to the capacity of the landscape to influence air quality and the temperature of the air. The landscape function literature review recognised that tree cover is the most important landscape component in this transformation process. This landscape system also has strong effects on the health and well-being function. If this landscape function is considered alongside hydrological cycle support, the resources these systems provide (water and air) have multiple dynamics (influences and effects) with all the others landscape systems, from the influence of active transport to biodiversity support through tree cover. Figure 6.4 presents this system.

6.4.5 Landscape Function System: ***Biodiversity support***

The biodiversity support system transformation process relates to the capacity of the landscape to provide appropriate and spatially connected habitats for species to thrive and adapt to disturbance. In this landscape system model the initial point is the habitats itself, and the capacity of the landscape to support this system is illustrated by the importance and strong influence of biomass production (provision system), and the influence of landscape management approaches. The model illustrates that, although habitats are an important component providing resources, biodiversity is mainly influenced by landscape permeability providing connectivity for species to move. Other dynamics occurring in this system potentially influence positively the information and community landscape function systems. Figure 6.5 illustrates the biodiversity support landscape function.

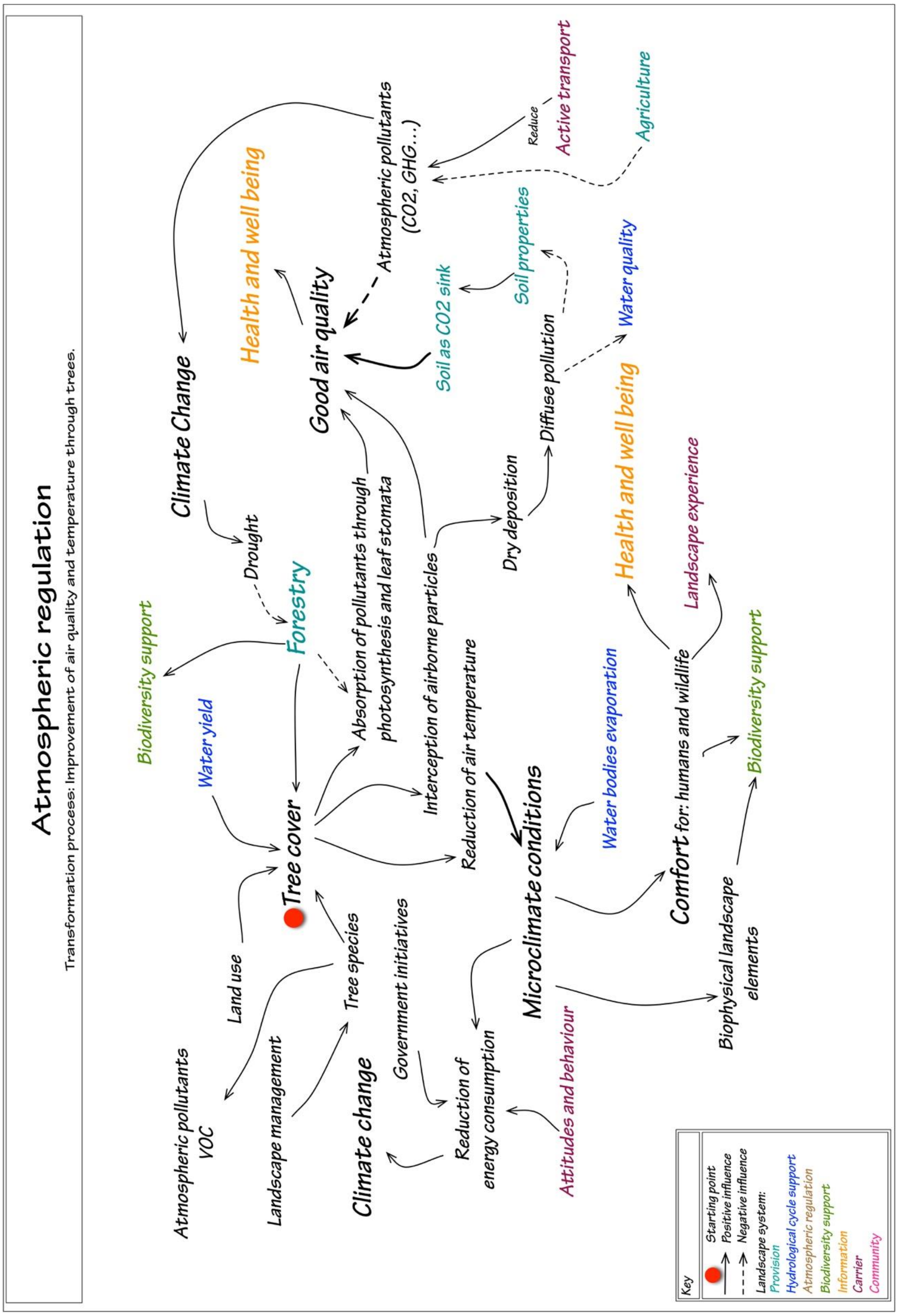


Figure 6.4. Atmospheric regulation landscape system conceptual model

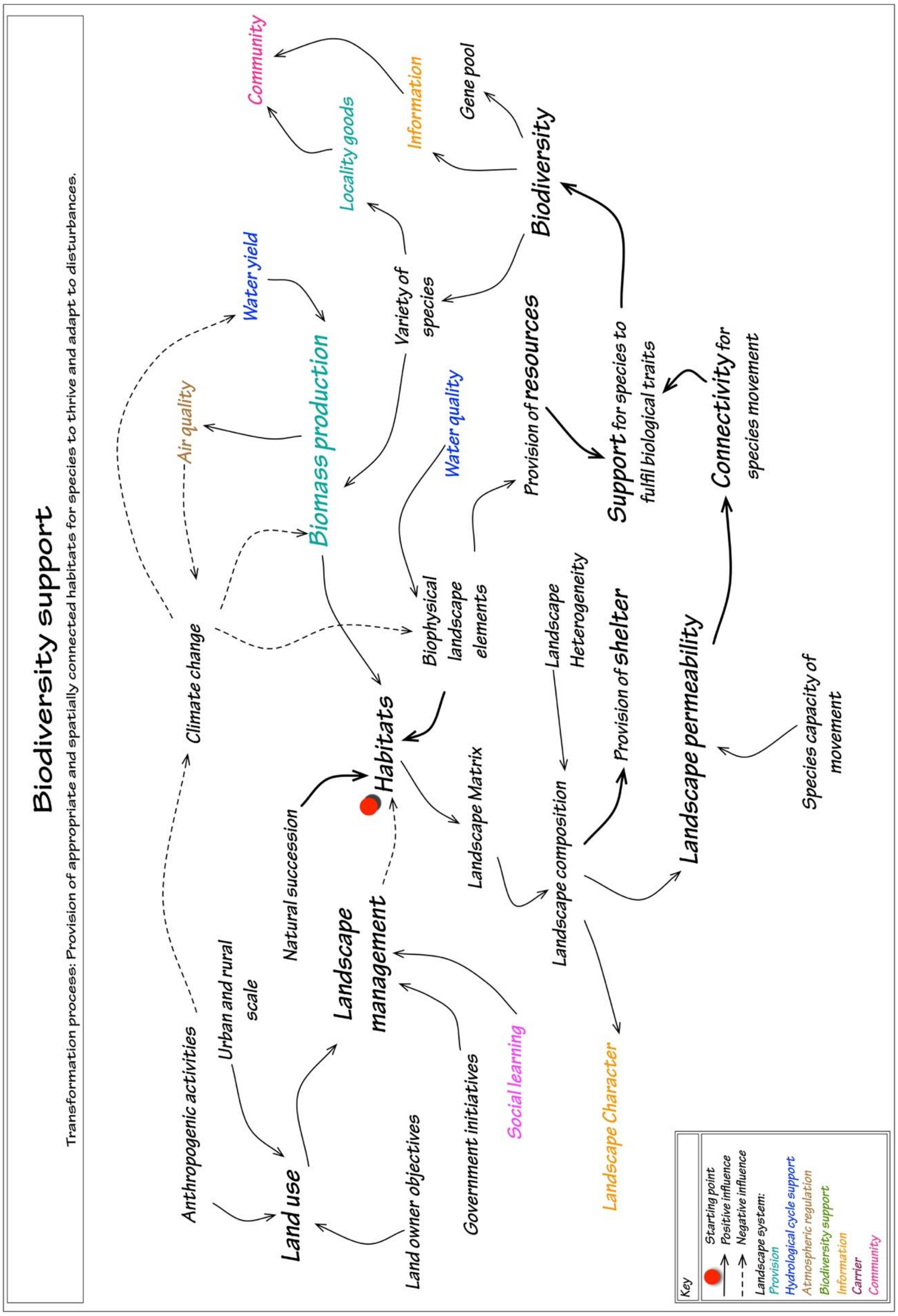


Figure 6.5. Biodiversity support system conceptual model

6.4.6 Landscape Function System: ***I n f o r m a t i o n***

The transformation process identified for this system relates to the capacity of the landscape to support human experiences and perceptions of different components and attributes that encourage positive cognitive associations that enhance learning, aesthetics, sense of place and restoration experiences. The starting point proposed for reading this conceptual model is the potential formal and informal positive experiences within the landscape; this component is mainly influenced by the carrier systems landscape physical qualities, which, in conjunction with information abstracted from the landscape, leads to learning, health and well-being, and restorative benefits. Relationships from this system with others illustrate processes not usually explored in ecosystem service studies, including social capital, social learning and potential common ground for multi-ethnic communities. Figure 6.6 shows this landscape function system.

6.4.7 Landscape Function System: ***C a r r i e r***

This landscape function system transformation process relates to the capacity of the landscape to provide places, connectivity and spaces suitable for people's physical movement. The conceptual model aims to illustrate the dynamics involved to provide adequate spaces and meaningful connections for encouraging human movement through the landscape, which in turn potentially, impacts on positive landscape experiences and the development of a sense of place. Apart from illustrating influences to socially related functions (information and community systems), this conceptual model explores the positive effect of this system on the atmospheric landscape system. The figure 6.7 presents this system.

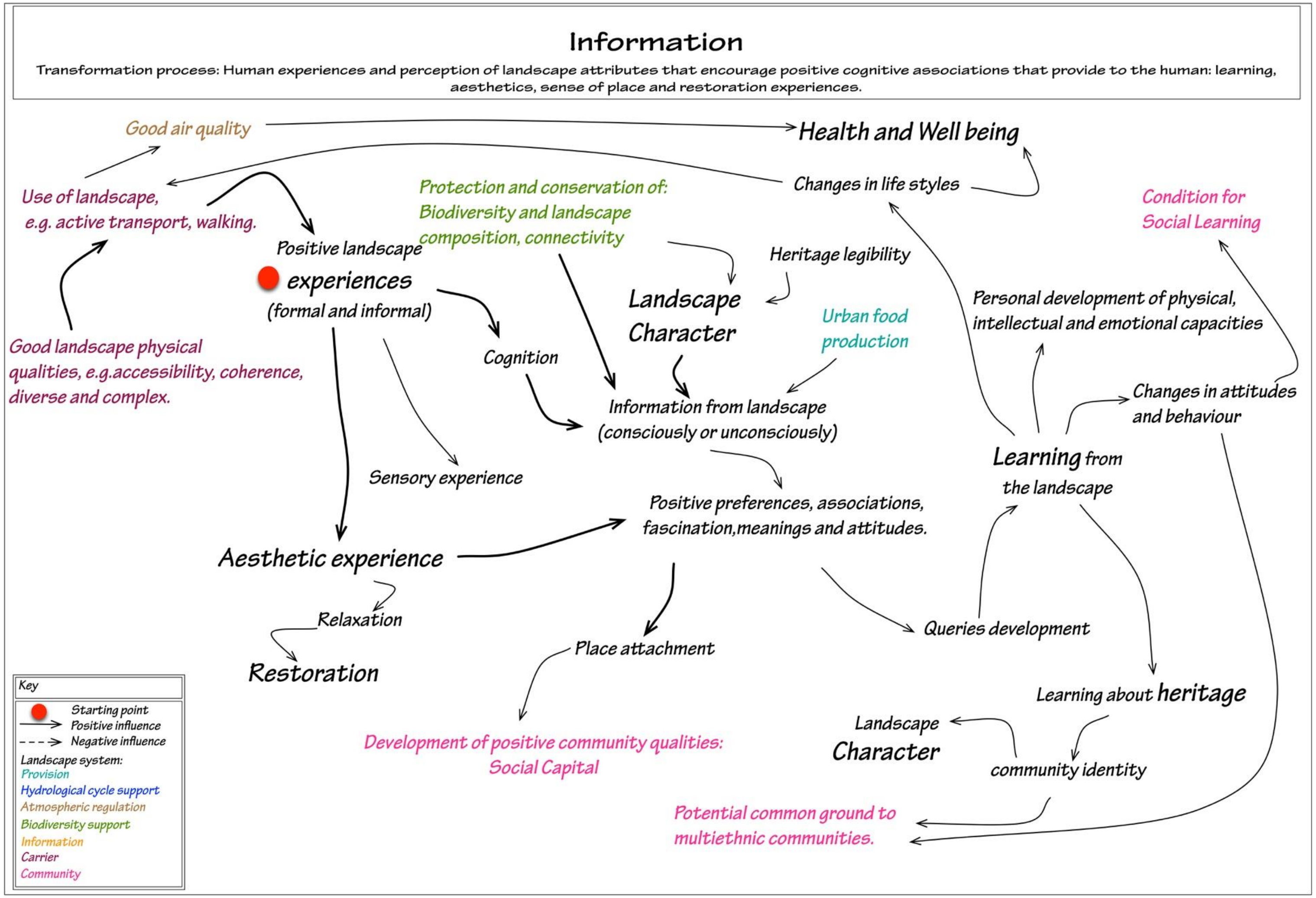


Figure 6.6. Information landscape system conceptual model

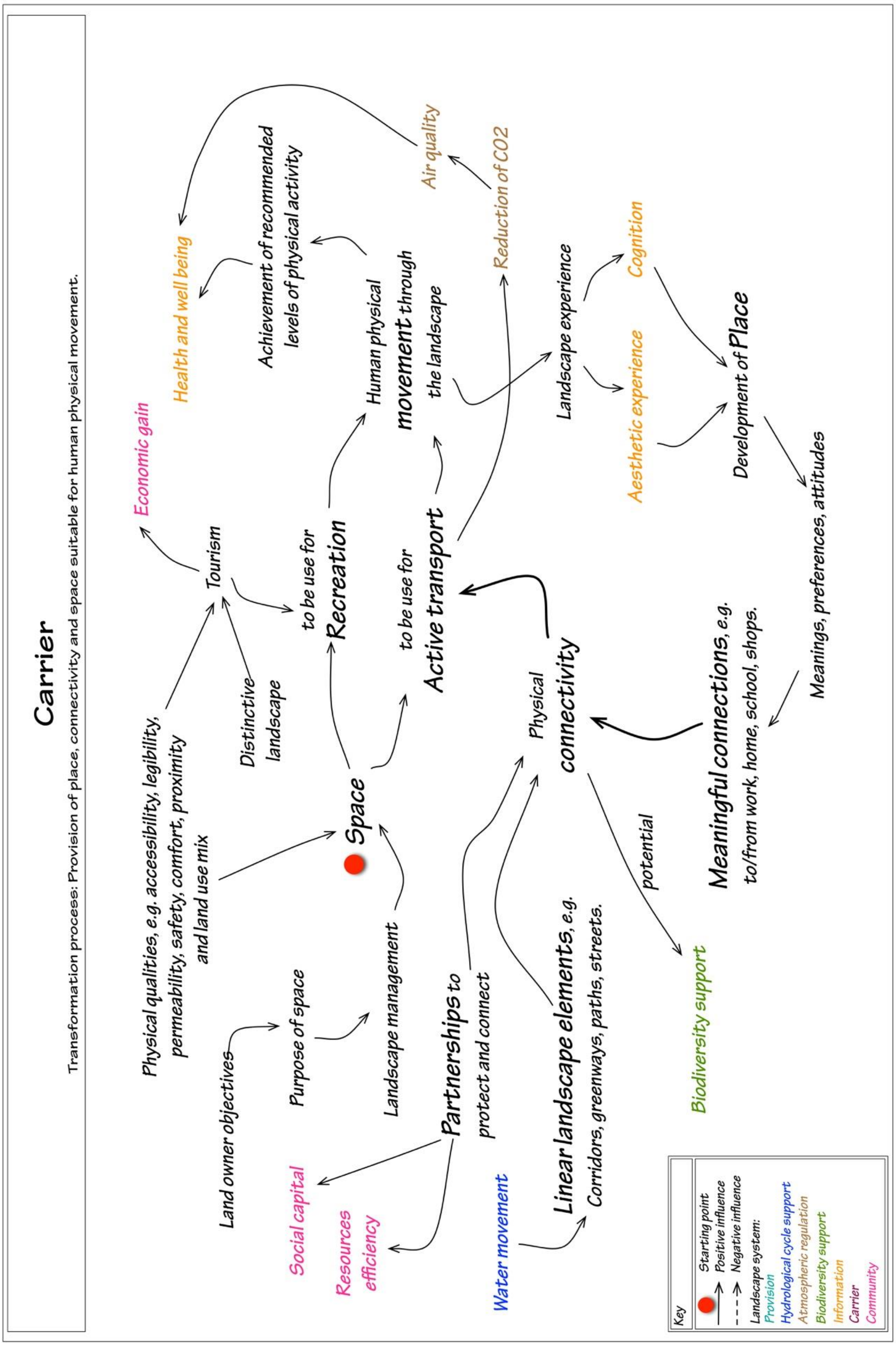


Figure 6.7. Carrier landscape system conceptual model

6.4.8 Landscape Function System: ***Community***

In this landscape community system, the model centres on people as the main element for the landscape function to occur, and aims to describe the landscape as the setting or the object that contributes to community collaboration and the local economy. Thus the starting point for this conceptual model is the component of people living, interacting and influencing the landscape; then through the formation of communities, social processes such as social capital and social learning could potentially occur. This landscape function also supports biophysical landscape systems such as provision and biodiversity through the involvement of partnerships in landscape management. The figure showing this landscape function model is 6.8.

6.4.9 Landscape Function System: ***Landscape multifunctionality***

Finally, the landscape system of multifunctionality was modelled with the purpose of trying if possible to draw all the landscape function systems together. The transformation processes described for this system relates to the initial root definition for the wider system and describes a system in the National Forest that, through its stakeholder interventions aimed at catalysing local opportunities, could enable multifunctional, resilient and distinctive new landscapes to emerge. The proposed initial point for this conceptual model is the landscape component of biomass; this component was selected because it not only represents the accumulation of living organisms, but also comprises the beginning and end points of the cycle of provision of energy to support species and their eventual transformation to carbon (Vitousek et al., 1986). Figure 6.9 illustrates this conceptual model.

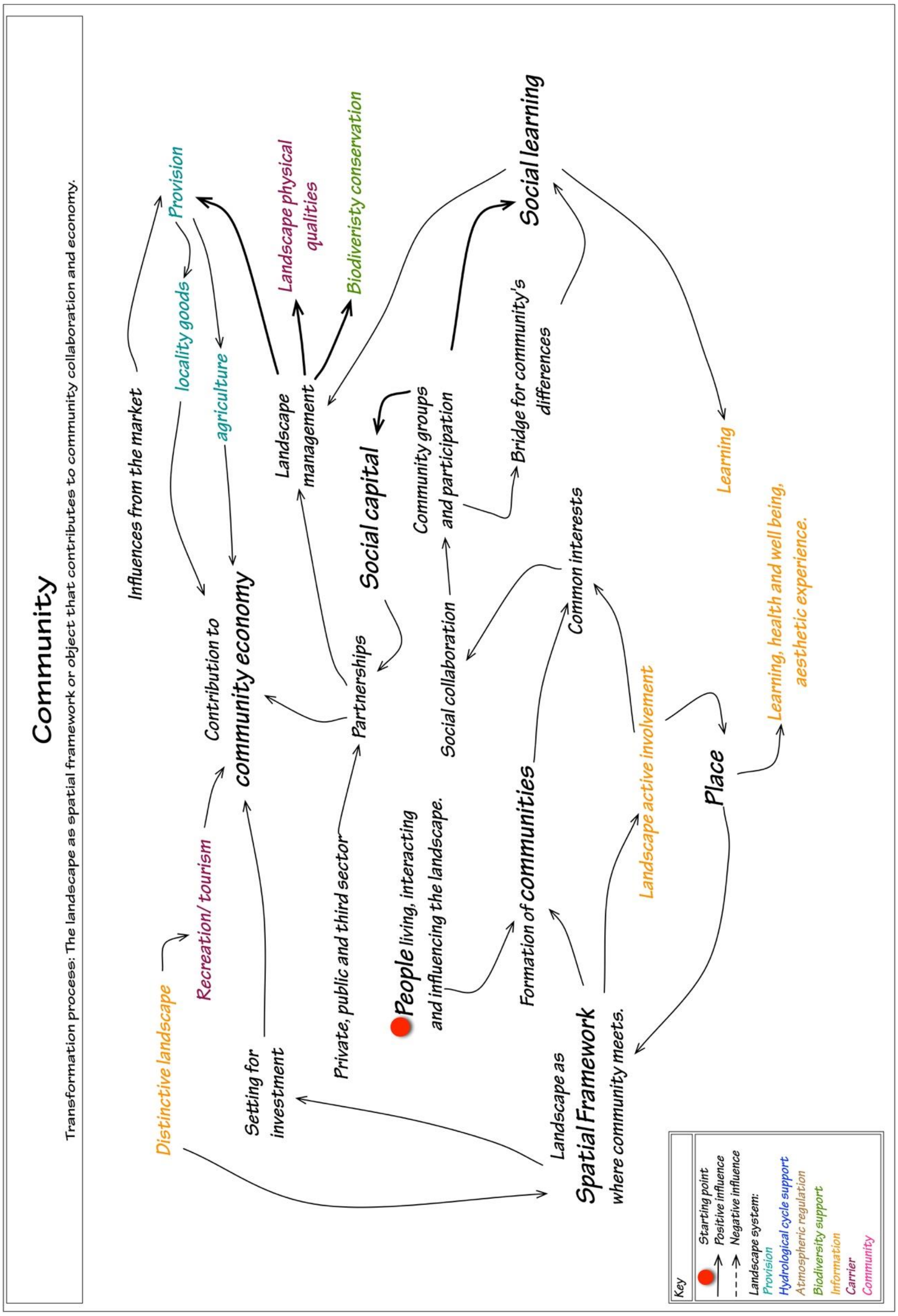


Figure 6.8. Community landscape system conceptual model

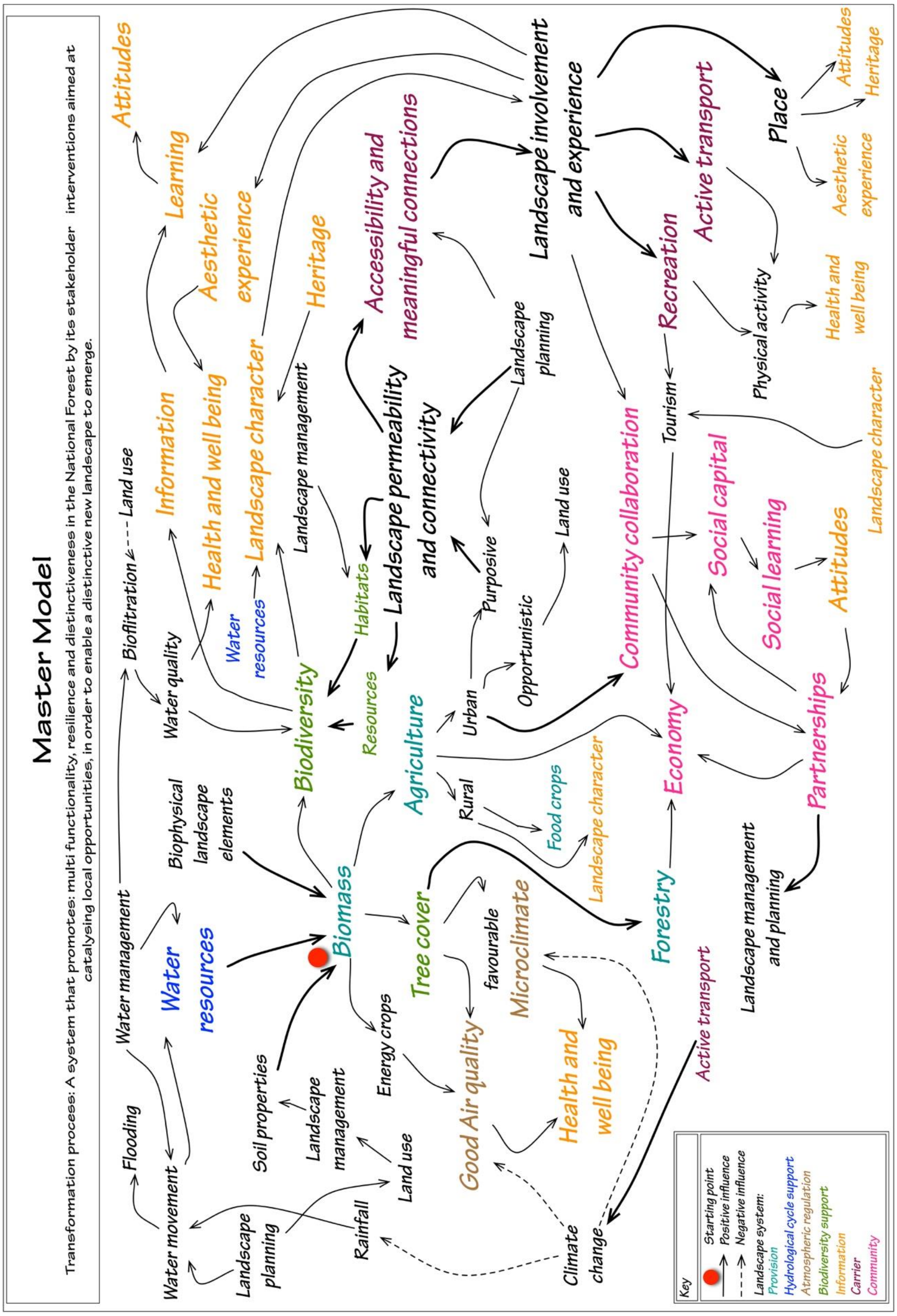


Figure 6.9. Landscape multifunctionality system conceptual model

6.5 Stage 4: *Using Models to Structure Discussion About Landscape Multifunctionality*

Throughout stages 1,2 and 3 we began to construct a comprehensive picture of landscape multifunctionality and landscape function systems as socio-ecological systems within the NF project area; to achieve this, we drew a rich picture diagram and carried out several analyses that led to the identification and definition of relevant systems and their components. Then, we proceeded to build conceptual models, whose objective is to represent the relevant transformation processes and components of each landscape function system, from a landscape multifunctionality perspective. Stage 4 now proposed to identify how the problematic situation could change throughout a structured discussion between the system's actors or stakeholders. There are three different types of potential change to be identified through dialogue, these are: changes to the system structure, to procedures or processes, and/or changes in attitudes (Checkland, 1981; Patching, 1990; Checkland and Poulter, 2010). The structure of this discussion is based on the conceptual models previously built.

The importance of structuring the discussion is to avoid negative experiences which have been observed in debates amongst people with different *worldviews*, understandings, skills, agendas, attitudes, personalities etc. Often this appears to result in poor group dynamics, reflected in lack of clarity and objectivity of discussion limited learning (Reed, 2008). Thus SSM proposes to use the conceptual models as a reference to generate questions regarding the situation, such as: what are the system's activities, who carries out the activity, how does the activity occur, and are there other possible options of how this activity can take place? Another type of question suggested by Checkland and Poulter (2010) refers to *"measures of performance"* and, although they acknowledge that this question is difficult to address, they argue it can help consider and identify thresholds and monitoring schemes that could inform the system's capacity to be efficient and effective. According to Checkland and Poulter (2010), in practice, these discussions had additional outcomes such as pointing out and stimulating thinking about situations and activities usually taken for granted, identification of other potential systems, and attracting attention to other *worldviews*.

This SSM stage offers another opportunity to address participatory qualities within landscape multifunctionality, prioritising land users and land owners as a fundamental part of the systems – not as part of the fundamental system components, but rather as an agency for collaborative knowledge generation, learning and contributing to decision-making. As discussed above and in the literature review (Chapter 2), stakeholder participation can be obstructed by barriers such as communication, objectivity and inclusion (Luz et al., 2000; Reed, 2008; van Asselt Marjolein and Rijkens-Klomp, 2002); nevertheless, if achieved satisfactorily, the potential social learning generated can be a driver for a system's stakeholders to legitimize and support changes and decisions (Schroth, 2007). In SSM terms, this stage aims to oppose arbitrary decision-making in order to arrive at a general arrangement between the system's actors to accept or tolerate courses of action which improve the situation under review (Checkland and Poulter, 2010).

Throughout the development of SSM guidance there are number of ways of approaching this stage. Checkland and Poulter (2010) have identified that three main practices have dominated SSM practice. The first one is described as informal discussions about the conceptual models as a background for later debate or as a source of detailed questions. The second approach requires interrogating a *matrix chart* with one column containing the activities, issues and relationships identified from models and the others column containing the specific questions. Finally, the third approach comprises creating and comparing *narratives* or *scenarios* based on the conceptual models and other people's background and knowledge. Nevertheless, Checkland (1981) and Patching (1990) commented that although the methods can be flexible enough to support specific needs for dialogue, they recommend the application of a proposed technique to deliver a purposeful and sound discussion stage.

Bunch (2003) and Habron et al. (2004) provide examples of SSM applied to environmental situations that specifically aim to achieve collaborative and participative processes. The studies carried out this stage framed through discussions conducted in workshops and focus groups respectively. Literature on stakeholder participation suggests that although existing approaches tend to be flexible to accommodate different resources, the selection of a participatory approach has an impact on the "size, quality and diversity" of participation (Patel et al., 2007). Regarding the desirable impact of participation, Sevenant and Antrop (2010) explain that the ELC (Council of Europe, 2000) encourages *substantive* and *instrumental* participation, according to Stirling's (2006) ranks of levels of participation, which refer to *"substantive"* participation when participation processes integrate analyses, aimed at collecting multiple perspectives and "local-context" information, and to *"instrumental"* as participation that aims to increase "credibility" and "trust" by looking at how to apply, justify and legitimate the decisions reached. Furthermore, another important aspect to consider when selecting a method for participation is the type of communication desired: either '*one-way'* or *'two-way'* communication processes (Patel et al., 2007).

Thus, this research study will approach this SSM discussion stage as a participatory process. This exercise is a theoretical exploration of SSM in the NF context; however, we also propose to use this stakeholder engagement opportunity to evaluate SSM approaches to landscape multifunctionality. This research conducted this stage through a series of workshops, where the conceptual models provided the material to be discussed through pre-established questions. We structured and organised the workshop to specifically achieve a *"substantive"* participation through *'two-way'* communication techniques. The following sections explore the workshop preparations and the methods used to analyse the data resulting from the workshops.

6.5.1 Materials and methods

As explored in the previous section, this discussion stage is approached as a participative process. We carried out workshops as settings to conduct two structured discussion exercises. Workshops are participatory approaches for presenting and learning through actively involving participants on discussions and hands-on exercises. Although workshops are characterised as informal settings, they offer opportunities to encourage discussion, dialogue and intense-learning opportunities, and thus require a well planned structure in time-limited frames (Community Tool Box, 2015). The following section will explore the workshop procedures and organisation.

6.5.1.1 *Workshop aim and objectives*

The purpose of the workshops was to accomplish SSM stage 4 by discussing with stakeholders the proposed landscape function systems and appropriateness of the SSM models to assess landscape multifunctionality properties and facilitate the emergence of multifunctional landscapes.

In order to structure and organise the workshop's activities and discussions two objectives were outlined:

1) To review and assess model capacity depicting: a) the processes, components and dynamics of landscape functions; b) positive interactions with other landscape functions that accelerate the emergence of landscape distinctiveness; and c) influences, linkages and/or points of intervention that enhance or hinder the landscape function.

2) To discuss the usefulness of SSM and landscape function models to support the landscape multifunctionality approach in terms of: a) usability; b) feasibility; c) credibility; and d) relevance and impact of decisions facilitated by the models.

6.5.1.2 *Workshop participants*

As noted in the literature review, stakeholders are individuals and groups that share an interest in influencing knowledge and decisions in the context of a geographical area; the understanding and agreement reached will have an effect on them or on others (van Asselt Marjolein and Rijkens-Klomp; 2002; Reed, 2008; Palacios-Agundez, et al., 2014).

In the National Forest context, workshops participant identification was supported by the rich picture and CATWOE analyses (sections 6.1.2 and 6.3.3 respectively), and through a discussion with supervisors. Then, specific organisations were identified by reviewing the NFC web page in their stakeholders and partner's section (NFC, 2015); potential participants' contact details were collected from their organisations' or groups' web pages. We aimed to invite NFC stakeholders representing different organisations and individuals related to landscape planning, design and management, for example: local authorities, non-governmental organisations, volunteering groups and advisory groups.

In agreement with the NFC and with their support, potential participants were approached and invited to take part in the workshop through an email sent by the researcher. The email included a covering letter containing an invitation to participate in the proposed workshops; it also included information regarding the purpose of the research study and briefly explained where the workshop would take place and what activities would be involved. This invitation email included a consent form reviewed and approved by the the

University of Sheffield Landscape Department research ethics committee (Appendix 1). We aimed to achieve an attendance of 9 to 12 participants according to workshop preparation guidance (Community Tool Box, 2015)

6.5.1.3 *Workshop preparations*

An initial response was received from eleven potential participants. In order to improve the efficiency of the workshop by having a more less equal understanding of the study context among participants, we prepared, produced and posted prior to the workshops a briefing paper containing a synthesis of this study background, aim, objectives and methodology, as well as a detailed proposed schedule for the workshop. Further, in this briefing paper we asked the participants to "*think*" or to "*have in mind*" a case study of an open space with which they were involved or acquainted; this information was asked because we wanted that their evaluations and discussions to benefit from their personal, every-day work and hands-on experiences (Community Tool Box, 2015). Appendix 2 contains a copy of the briefing paper.

The researcher took the role of facilitator. Based on the proposed workshop structure to be explored in the following section, a facilitator script was developed comprising which a detailed outline of the structure, main messages and information important to run the activities in each part of the workshop. Further, this script included a list of the equipment, supporting materials, stationery and refreshments required in each part of the workshop.

Supporting material prepared in advance included A3 size prints of the GIS-landscape function maps of the National Forest (Chapter 5), a glossary of terms used in this study and within the models and, finally, detailed guidance on the workshop's objectives and discussion exercise aims (Appendix 3).

6.5.1.4 *Workshop structure*

The researcher structured and organised the workshops in two sessions, aiming for a workshop of three hours. Thus, the workshop was divided in Session A and B, including a lunch break in between. Each session aimed to address one of the two objectives of the workshop previously established.

The workshop was initiated by formally welcoming the participants; then the participants were asked to present themselves to the others participants. This was followed by an introductory talk given by the facilitator; this presentation aimed to review the research study background, but mostly focused on summarising key concepts, objectives, structure and proposed exercises of the workshop.

As explored previously, session A aimed to explore the model's capacity to depict: a) the processes, components and dynamics of landscape functions; b) positive interactions with other landscape functions; and c) influences, linkages and/or points of intervention that enhance or hinder the landscape function system. For this session, participants were allocated in pairs; then, each pair was assigned two landscape system models. The assignment of the models was based according to participants' expertise or area of interest. The exercise comprised discussing, annotating and modifying A1 size prints of the conceptual models, with the exercise and discussion being prompted by questions relating to the conceptual model's components, links, strength of influences and other aspects. Box 6.1 contains the questions used for reviewing and discussing the conceptual models in session A. Finally, the materials used to annotate the conceptual models included marker pens and post-it labels.

Box 6.1. Questions to answer when reviewing the landscape systems conceptual models.

Q1. Do you consider that the model correctly chooses the most appropriate entities and links, and represents them correctly?

Q2. Do the arrows have the right thickness in proportion to the level of the influence?

Q3. Are there any missing entities or arrows that you think have an important role to play in helping positive interactions to occur in the landscape?

The objective of Session B was to discuss the usefulness of the landscape function models and SSM to approach landscape multifunctionality in terms of a) usability, b) feasibility, c) credibility and d) relevance and impact facilitated by the models. In this session the participants continued to work in pairs and were asked to answer and discuss particular questions relating to benefits and limitations of the conceptual models and SSM among others (box 6.2). Participants were invited to use flip-chart sheets to write their comments.

Finally, the participants were requested to present to the other workshop participants their answers and thoughts. The facilitator allowed other participants to briefly interrupt a presentation in order to encourage discussion between the workshop attendees.

Box 6.2. Questions discussed by participants in session B.

Q1. What do you think are the benefits of using the conceptual models as a decision-support tool?

Q2. What do you think are the limitations of the conceptual models and their application in landscape planning and management?

Q3. Do you think that the information contained in the models is correct, credible and reliable as part of guidance to support your decisions?

Do you have any comments or recommendations concerning their credibility?

Q4. How easy was it to understand and untangle the different 'layers' and complexity of the landscape system models, such as: processes, drivers and services? Please, give an example to support your answer.

Q5. Do you think that the conceptual models represent the landscape system's processes and influences at an appropriate landscape scale? Why?

Q6. What is the potential of the models to influence decision-making among stakeholders?

6.5.2 Workshop 1

Workshop 1 was held at The National Forest Company premises in Swadlincote, South Derbyshire, on Friday 22nd March 2013. The workshop took place from 10.30 am to 2.00 pm. The workshop was structured in two sessions, each session lasting 60 minutes, and each session aimed to discuss one established objective (see, 6.5.1.4).

Because of severe weather conditions only six people from the initial eleven potential participants attended the workshop; however, they were joined by this thesis supervisors.

Participants included a representative of The National Forest Company, non-governmental organisations such as the Forestry Commission and Woodland Trust, representatives from two community volunteer groups (Burton Conservation Volunteers and Ramblers), and finally a representative from a local council.

For session A, as planned and organised, the participants worked in pairs exploring and reviewing the conceptual models, a total of four pairs were organised, and each pair reviewed two conceptual models. For session B, one attendee had to leave, there was a minor rearrangement to the discussion groups, and so participants were organised in one group of three people and two pairs. The discussion proceeded as planned and organised.

The arrangement of the meeting room was a round table, this was particularly helpful because it was able to accommodate all the participants and was appropriate to working in pair. Also, this setting allowed them to hear and exchange ideas with other pairs during both sessions.

6.5.3 Workshop 2

We were able to carry out another workshop with participants that were not able to attend workshop 1 due to weather conditions. This is identified as Workshop 2 and was held in Birmingham at The Priory Rooms, on Tuesday 23rd April 2013. The workshop took place from 12.00 pm to 3.30 pm. Four people took part in the workshop, they included two representatives of Natural England and were joined by this thesis supervisors. In the same manner as the previous workshop, Workshop 2 was structured in two sessions, each session lasting 60 minutes, and each session aimed to discuss one established objective (see, 6.5.1.4). However, because of the small number of participants, the discussion exercises for session A and B were carried out by the four participants, in a round table setting. In this case, for session A only two conceptual models were analysed; and for session B the discussion took place without following strictly the proposed questions to guide the discussion (Box 6.2).

6.5.4 Session A: data and analysis.

To summarise, Session A was organised in the following form: welcome and introductions of participants, introductory presentation of research context, conceptual models methodology and explanation of the session objective and the evaluation exercise. Within pairs, the evaluation exercises comprised a brief description of each participant's case study, then discussing, reviewing and annotating two conceptual models. During Workshop 2 everything took place as planned except the description of each participant's case study. In workshop 1 the conceptual models were allocated to participants according to their expertise and interest; eight conceptual models were reviewed. In Workshop 2 only two conceptual models were reviewed. Participants' discussion and review of models was assisted by supporting material, which included a glossary of terms and six maps generated by the mapping exercise carried out in Chapter 5. The exercise lasted 60 minutes, which was monitored in two 30-minute parts; in each part the pairs or the group were asked to change and review the other conceptual model.

6.5.4.1 *Session A data*

Data generated from session A during the workshops 1 and 2 has been collected and stored in two formats. Session A data in workshop 1 comprises physical material that includes the annotated A1 prints of the conceptual models and the audio recording of the session. Session A data in workshop 2 comprises text derived from researcher annotations during the workshop and the audio recording of the session.

6.5.4.2 *Session A data analysis*

The type of data collected from session A is verbal communication in the form of text through annotations and notes. The analysis of these data has been approached deductively through Content Analysis. This analysis method was selected because the objective and the exercises of session A were structured and focused according to particular questions applied to specific material (conceptual models). Through the content analysis, coding was approached in two ways. A first reading and analysis carried out an open coding approach, aiming to identify relevant codes and a second reading and analysis carried out a coding based on questions proposed to prompt the discussion (Hsieh and Shannon, 2005). The results from this analysis are presented in Chapter 7, section 7.2, and the discussion of the findings is presented in Chapter 8.

6.5.5 *Session B data and analyses.*

To summarise, session B was organised in the following form: a brief presentation of the session objective and the questions that aimed to structure the discussion (see box 6.2); this was followed by fifty-minute discussion exercise between participants. In workshop 1, the groups annotated their key points on flip-chart sheets and then one person per group presented their key reflections to the other participants. In workshop 2, there were no annotations or presentations as the discussion took place among all the participants.

6.5.5.1 *Session B data*

Data generated from session B during the workshops 1 and 2 was collected and analysed in two formats. Session B data in workshop 1 comprises physical material that includes annotated flip-chart sheets with key comments discussed by groups during session B and the transcript of the audio recording of the session. Session B data in workshop 2 comprises the transcript of the audio recording of the discussion; there were no annotations made by participants.

The transcript process comprised the following protocol: a) the audio record was played using a software called "Tempo" (Dragon BTV Apple App) which allowed control of the speed of the speech, then text was typed using a word processor (Microsoft Word); b) all the comments and questions made by the facilitator (researcher) had been included; c) speech errors were preserved; and d) sounds, non-audible behaviour and pauses were not transcribed.

6.5.5.2 *Session B data* analyses

The type of data collected from session B is verbal communication in the form of text, compiled by two different approaches: a) transcripts of the workshop discussions (workshop 1 and 2) and b) notes from workshop participants (workshop 1). Because of the nature of the data collected, it was analysed through qualitative methods (Hsieh and Shannon, 2005; Schutt, 2011), namely, grounded theory and content analysis. The data was inductively and then deductively analysed in order to minimise bias in the identification and analysis of valued findings (Hsieh and Shannon, 2005; Schutt, 2011); nevertheless, a direct content analysis (deductive) allowed building on or extending concepts already established through previous research (Hsieh and Shannon, 2005; Moretti et al., 2011).

6.5.5.3 *Grounded Theory*

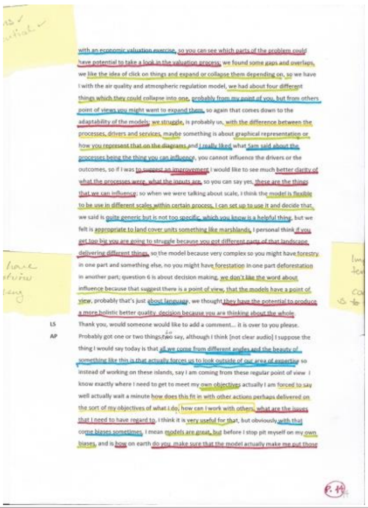
Grounded theory is a qualitative research method that has been used to identify *"theories"* through consistent data collection and data analysis processes; this method does not aim to test or to validate existing theories (Strauss and Corbin, 1998; Birks and Mills, 2011).

Data analysis through grounded theory methodology aims to identify and classify new insights in a particular *phenomenon* which potentially could complement existing understanding, by systematically identifying properties and dimensions of concepts relevant to the phenomenon under consideration and potential areas for *future* research (Strauss and Corbin, 1998).

In the case of this research study, data was analysed through grounded theory aiming to identify insights regarding the use of SSM to approach landscape multifunctionality. Notes and transcripts generated from session B (section 6.5.4.1) comprise the material analysed, which was approached in an inductive manner through Grounded Theory. This method comprised three stages: 1) open coding, 2) axial coding, and 3) selective coding.

Open coding refers to the identification of concepts or insights; these are "coded" by giving them a name which will represent the concepts identified. Such concepts will relate to the context and background of the research topic and the researcher's knowledge. Identified ideas or insights that share the same meaning with others will be given the same code; this process is called "classification". Open coding will not contribute to new understandings of the concepts; it is a systematic process to break down and organise data for further analysis. This thesis data (notes and transcripts) were open coded through reading, highlighting and writing codes in post-it® notes (see Figure 6.10). As part of the methodology, diagrams were drawn, each diagram corresponding to a code or category; these diagrams illustrate insights, references or definitions developed throughout the process of open and axial coding to support the final stage of analysis (Strauss and Corbin, 1998; Birks and Mills, 2011). These diagrams were consistently recorded and referenced by date, headings relevant to their content and included references to raw data (page and paragraph).

a)



with an economic valuation exercise, so you can see which parts of the problem could have potential to take a look in the valuation process; we found some gaps and overlaps, we like the idea of click on things and expand or collapse them depending on, so we have I with the air quality and atmospheric regulation model, we had about four different things which they could collapse into one, probably from my point of you, but from others point of views you might want to expand them, so again that comes down to the adaptability of the models; we struggle, is probably us, with the difference between the processes, drivers and services, maybe something is about graphical representation or how you represent that on the diagrams and I really liked what Sam said about the processes being the thing you can influence, you cannot influence the drivers or the outcomes, so if I was to suggest an improvement I would like to see much better clarity of what the processes were, what the inputs are, so you can say yes, these are the things that we can influence; so when we were talking about scale, I think the model is flexible to be use in different scales within certain process, I can set up to use it and decide that, we said is quite generic but is not too specific, which you know is a helpful thing, but we felt is appropriate to land cover units something like marshlands, I personal think if you get too big you are going to struggle because you got different parts of that landscape delivering different things, so the model because very complex so you might have forestry in one part and something else, no you might have forestation in one part deforestation in another part; question 6 is about decision making, we don't like the word about influence because that suggest there is a point of view, that the models have a point of view, probably that's just about language, we thought they have the potential to produce a more holistic better quality decision because you are thinking about the whole

LS Thank you, would someone would like to add a comment... it is over to you please.

AP Probably got one or two things two say, although I think [not clear audio] I suppose the thing I would say today is that all we come from different angles and the beauty of something like this is that actually forces us to look outside of our area of expertise so instead of working on these islands, say I am coming from these regular point of view I know exactly where I need to get to meet my own objectives actually I am forced to say well actually wait a minute how does this fit in with other actions perhaps delivered on the sort of my objectives of what I do, how can I work with others, what are the issues that I need to have regard to, I think it is very useful for that, but obviously with that come biases sometimes, I mean models are great, but before I stop pit myself on my own biases, and is how on earth do you make sure that the model actually make me put those

b)

c)

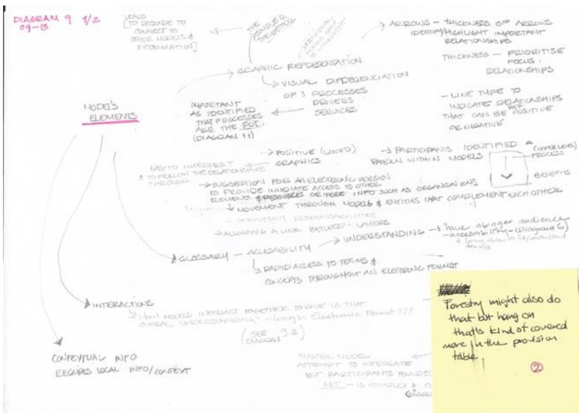


Figure 6.10. Grounded theory open and axial coding methods, a) Colour coding of transcripts; b) Concepts initial organisation; c) Diagrams used to organise concepts into categories and subcategories.

As concepts are identified, the researcher starts to organise the "broken" data by grouping concepts into categories, which is the objective of axial coding. Categories can describe phenomena (ideas, issues, events, etc.). Therefore, axial coding is the process where the researcher analyses and relates categories and subcategories in order to illustrate a comprehensive understanding of the phenomena. Subcategories provide information which contributes to the explanation of the main category and answers questions such as: when, where, how and who? The initial statements that explore the relationships between categories, subcategories and concepts are called "hypotheses". Open and axial coding usually occurs at the same time; they are not necessarily sequential activities. Axial coding can be considered finished when there are no more concepts and information to be added to categories. Categories and subcategories found through open and axial coding are presented in table 7.3 (Chapter 7).

Selective coding is the process where the analysis carried out during the open and axial coding is integrated and explored through a central or core category. This can be different from existing identified categories, and when the central category has been identified the relationships between categories are integrated and explored through written statements. The results of this analysis are presented in Chapter 7, section 7.3.

6.5.5.4 *Content Analysis*

The objective of applying content analysis to the data collected in session B was to analyse the content of the discussion through a systematic classification of the text through previously identified concepts; this content analysis approach has been identified as "direct content analysis". Text is structured by coding into previously identified concepts from prior research literature, a deductive use of previous studies (Hsieh and Shannon, 2005; Schilling, 2006). Session B objective was to identify if workshop participants found the use of conceptual models and SSM as a useful, credible and feasible approach to promote multifunctional landscape properties such as dynamics, participation, multi-scale and trans-disciplinarity.

Before the content analysis process is established, it is important to define the "unit of analysis" (Weber, 1990; Schilling, 2006); the unit refers to the extent (how much) of text can be understood without the need of context, and yet has the property to represent an *idea* or *information* (Weber, 1990, Schilling, 2006, Moretti, et al., 2011). Units can be a minimum of a single word or a maximum of a complete piece of text (Weber, 1990). In this particular case, a unit of analysis was selected within a range of of a word (minimum text component) and a sentence (maximum text component); these ranges were allocated to codes as long as they represented by themselves an idea or information (Schilling, 2006; Moretti, et al., 2011).

Data was structured and analysed through the following processes:

1) A first reading was carried out and all text that gave a first impression of relevant information was highlighted.
2) The reading order of the material analysed was: all text from workshop 1, then all text from workshop 2.
3) All highlighted text was coded through predetermined codes; text that could not be classified into the proposed codes was given a different code. The proposed initial codes were determined by the previous literature review (Chapter 2) on landscape multifunctionality properties and current assessments.
4) Results had been organised in a *coding agenda* (Mayring, 2000) which contains the previously identified codes, results and the text analysed, see Appendix 4. The results are presented in Chapter 7, section 7.3.

6.6 Conclusions

Within SSM, the workshops sought to specifically identify the required changes to improve the *situation*. Checkland and Poulter (2010) explore three types of changes: to *structures,* to *processes* and to *attitudes.* The findings of these stages might require re-running the SSM cycle through the new and improved *situation.* For the particular case of this research study, the SSM learning cycle finished on the discussion stage (stage 4), as it focused on exploring SSM as an approach to encourage landscape multifunctionality, and not looking for *particular actions to be taken*. The results generated from the application of SSM in the context of the National Forest are presented in the next chapter (Chapter 7), followed by the discussion of findings, implications and contribution of SSM (Chapter 8).

Chapter 7| Results: *Discussing Landscape Multifunctionality*

7.1 Introduction

This research aimed to explore the application of SSM as a way of helping landscape practitioners to understand the dynamics of landscape systems. Especially with the aim of promoting appropriate “initial conditions” to speed up the emergence of multifunctional, resilient and distinctive landscapes (Selman, 2012; Lovell and Taylor, 2013; Folke et al., 2010; Moore et al., 2014). Furthermore, understanding of the dynamics of landscape functions could enable practitioners to inform their decision-making by identifying purposive planning interventions for potential, desirable and feasible cultural changes (Folke et al., 2010; Moore et al., 2014).

The objective of this chapter is to present the findings from two workshops held as part of the SSM methodology. The aim of the workshops was to test the utility of the conceptual models as a supporting tool in the particular context of landscape multifunctionality. The workshops were structured in two main sections. Session A’s objective was to work through the conceptual models and evaluate whether they successfully depicted elements, interactions and points of intervention in landscape function systems. Session B’s objective was to discuss how useful, credible, feasible and relevant the conceptual models could be to support decisions and landscape multifunctionality. Within this chapter, findings will be presented in the same form as workshops were organised.

The first main section comprises Session A results. Raw data consist of collected annotations made by workshop participants on the A1 size conceptual models (section 6.5.4.1), followed by their interpretation through a direct content analysis approach (section 6.5.4.2). The second main section consists of results from the discussion between workshop participants in Session B; the two discussions’ transcripts (workshop1 and 2) had been analysed by grounded theory (section 6.5.5.3) and direct content analysis (section 6.5.5.4). Sections 7.2 and 7.3 summarise data analysis approaches and explore the workshop results through the categories identified by the coding processes of grounded theory and content analysis as appropriate.

7.2 Session A, evaluation of conceptual models: *data analysis and results*

7.2.1 Data and analysis approach

This session was organised to allow the participants to work on and analyse the conceptual models, to evaluate whether they successfully depicted elements, interactions and points of interventions in landscape function systems. During workshop one the eight people that took part were organised in pairs, four in total. Two conceptual models were allocated to each pair according to expertise and interest, so far as possible, (Table 7.1). During workshop two, the evaluation and discussion of the conceptual models occurred between all four participants. In workshop two, participants were given the choice of which conceptual models to review, and selected the Information and the Master Model.

Table 7.1. Allocation of conceptual models to participant pairs during workshop 1.

Participant organisations	Landscape systems conceptual models
Woodland Trust The National Forest Company	Biodiversity support Hydrological cycle support
Ramblers University of Sheffield	Provision Carrier
Forestry Commission University of Sheffield	Atmospheric regulation Information
Local authority representative Burton Conservation Volunteers	Community Master model

During both workshops, the exercise required them to analyse, discuss and annotate the conceptual models. The models were printed on A1 size paper. Their discussion was prompted by the questions discussed in section 6.5.1.4, and by the case study which they were asked to bring to the workshop (section 6.5.1.3). In workshop one, the conceptual models were annotated by marker pens and post-it labels. At the beginning of the exercise, each pair introduced their case study to each other, in a time frame of no more than five minutes; then the participants discussed and evaluated each model for twenty minutes; and session A lasted 60 minutes in total. The meeting room was arranged as a round table, allowing participants to work in pairs and to hear and interact with other working pairs (see Figure 7.1).

In the case of workshop two, there was no presentation of participants' case studies; and although the material provided was the same as in workshop one, the participants did not annotate the models as they were more involved in discussing the model elements (components and directions) than annotating. Thus the discussion was documented through researcher notes, which were complemented by notes on what comments referring to the models were actually referring to, for example, in the case of comments such as: *"this should link that"*. The audio record was analysed shortly after the workshop. The data collected was analysed using a direct content analysis approach (section, 6.5.4.2). It was decided to analyse data deductively because the aim of the session A exercise was very structured and focused by particular questions applied to specific material (conceptual models).

Figure 7.1. Workshop one at The National Forest Company, pairs working during session A.

The themes emerging from the open coding analysis of participant's annotations and discussion included 'vocabulary and terms used', 'missing components and positive and negative influences/links between components', 'potential double influences', 'appropriateness of strength and level of influence', and 'other additional comments to components'. Also, themes emerging from the direct coding analysis included 'appropriate use and location of components', 'appropriate use of links' and 'missing components'. Figures 7.2 and 7.3 are examples of annotated conceptual models produced in session A.

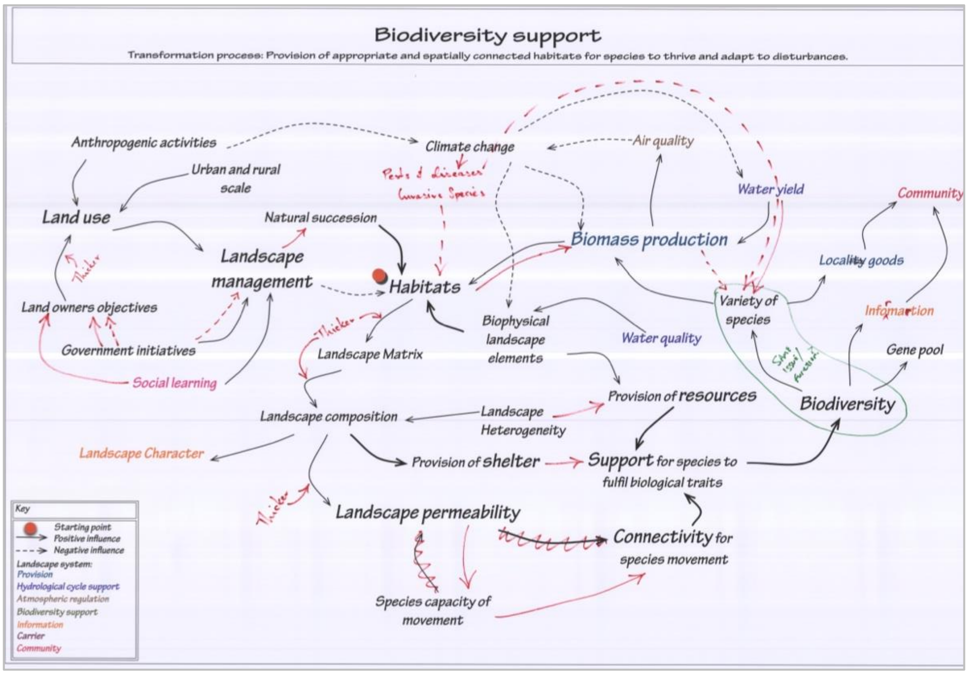


Figure 7.2. Example of the biodiversity support conceptual model annotated after session "A" exercise.

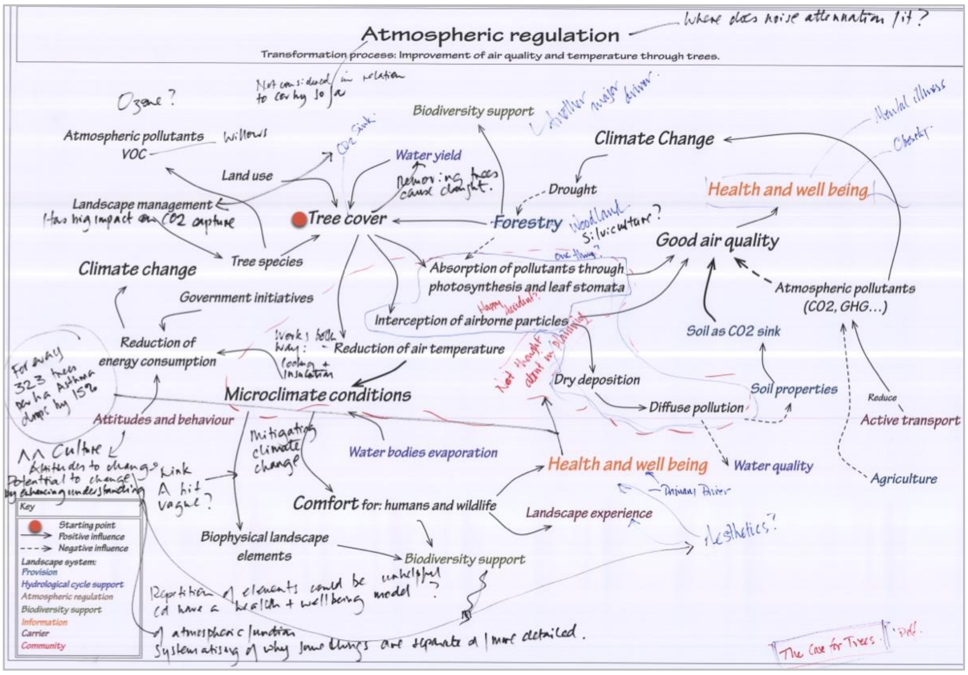


Figure 7.3. Example of the atmospheric regulation conceptual model annotated after session "A" exercise.

7.2.2 Results: *the components of the conceptual models*

Regarding the evaluation of each model's components, the participants' annotations and suggestions included the identification of missing components, notes about particular terms and vocabulary used, and the graphical location of key components aimed at improving the legibility of the conceptual models.

Some missing components identified refer to being more specific about detailing the scale of occurrence of the component. For example, in the provision conceptual model, participants suggested showing the level of government initiatives, for example local as against nationwide initiatives. Another case concerned was participants feeling that components located in different conceptual models, were also relevant to their own model: in effect, the identification of such 'missing' elements exemplified participants identifying inter-connection between different systems. For example, in the case of the atmospheric system model, it was noted that *Culture* was a missing component in this model, and the note went on to point out how *Culture* influences *Attributes and behaviour.* Other missing components were concerned with complementing and extending the processes under consideration. In the case of the atmospheric system model the participants commented that the *Reduction of air temperature* process also should include the components of *cooling and insulation*, which in turn beneficially influences *Microclimate conditions.*

Throughout the annotations and discussions, an important emerging theme was the evaluation of vocabulary and terms used in the conceptual models. The comments were mainly concerned with the appropriateness of certain terms used. For example, in the atmospheric systems model one comment suggested using the terms *Woodland* and/or *Silviculture* instead of *Forestry*, whilst another comment proposed that the elements *Absorption of pollutants* and *Interception of particles* are the same process and should be combined. Another key example was found in the 'biodiversity support system', where participants recommended merging *variety of species* and *biodiversity*, because for them both terms represent the same *"issue or function".* In workshop two, during the evaluation of the 'Master' model, and after following a hesitant start, the discussion focussed primarily on the appropriateness and suitability of the component of *Biomass* as a starting point to describe the system of landscape multifunctionality. Here, the participants were concerned that using *Biomass* as a starting point might lead to an overemphasis on the biological part of the landscape, limiting the exploration of the social and cultural processes.

Finally, another key type of annotation found was the potential re-location and thickness of the text of key components, in order to improve the legibility of the conceptual model and highlight components' relevance within the model. For example, in discussion of the 'information system' model during both workshops, it was suggested that the key component *experiences* should be located at the centre of the conceptual model, because this position highlights and gives importance to understanding how we experience landscapes *"beyond the view".*

7.2.3 Results: *influences*

Another theme emerging from the evaluation of the conceptual models is the appropriateness of relationships and influences between components. Participants' annotations and discussions suggested different missing positive and negative influences within each model. For instance, in the hydrological cycle system model, it was suggested that a positive influence be added between *Forestry* and *Overland flow filtration, Soil drainage capacity* and *Rainfall*; and *Biodiversity and Character of local flora and fauna*.

Furthermore, the participants noted potential changes to the thickness of lines depicting particular influences to reflect their relative impact on other components. Another modification suggested by participants was to change the direction of certain influences. For example, in the 'biodiversity support' system, the participants proposed changing the direction of influence between *landscape permeability* and *species' capacity of movement* so that *species' capacity of movement* is seen to influence *connectivity* positively.

Furthermore, the participants recognised that a third type of influence could be added to the models namely "two-way" influences that can be either positive or negative, depending on circumstances. For example, in the 'hydrological cycle' support model, *government initiatives* may have either a positive or negative influence on *Water consumption culture*, depending on their nature.

7.2.4 Results: ***points of intervention***

Session A analyses identified the emerging theme of *points of intervention*. This theme refers to participants' comments concerned with specific potential transformations and actions applicable within the National Forest project area. For instance, in the 'provision system' model, participants observed that in the NF, *raw materials* from forest waste and local gardens can be used as peat substitutes as part of a NFC soil amelioration strategy.

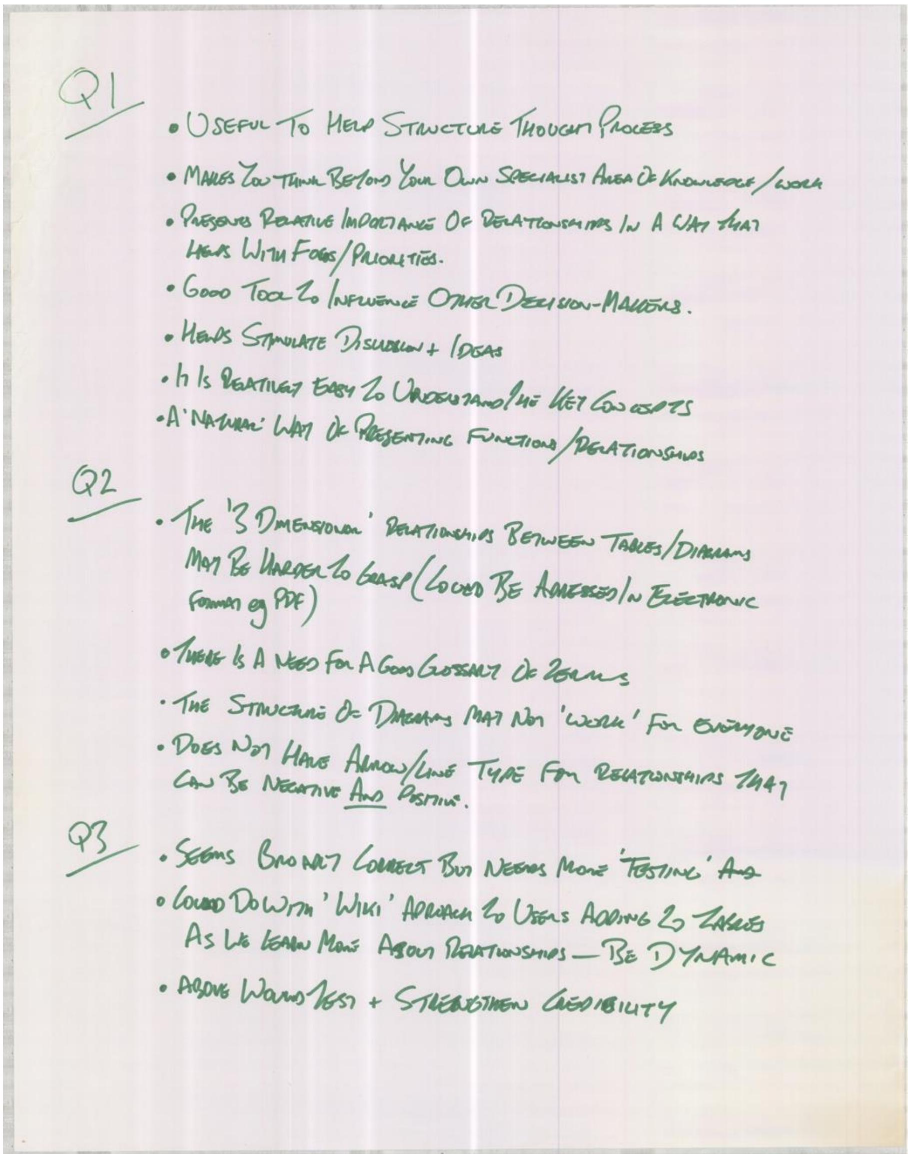
Another example occurred during workshop 2, when it was pointed out that it is not only positive experiences that have positive impacts on the system: even negative experiences (e.g. natural disasters such as flooding) can lead to learning opportunities, by leading people to reflect and learn about relationships between natural processes, people and ecosystem services.

Other annotations were concerned with specific physical qualities and events, for example the way in which, for 'Ramblers', topography is an element of interest; or the potential consideration of *"walking festivals".* Also, in the element of *Tourism* in the 'community system', one annotation indicated the importance of the *strategic* location of *cafes and shops*. Nevertheless, several participants noted down the common dilemma of "*the chicken or the egg"*, referring to what is required first… the visitors or the services?

7.3 Session B results approaching landscape multifunctionality: ***data analyses and results***

7.3.1 Data and analysis approach

After the participants had had the opportunity to interact and work with the conceptual models (session A), the aim of this session B was to discuss with participants the utility, credibility, feasibility and relevance of the conceptual models to support decision-making for landscape multifunctionality approaches. Session B was planned and carried out in the same manner in the two workshops, participants would discuss their opinions with their group partner guided by questions proposed by this study (see Box 6.2, Chapter 6), then they could present their thoughts to all the workshop participants. During workshop one, three groups were formed as one participant had to leave the workshop after session A; participants engaged on the discussion and annotated their answers on flip chart sheets (Figure 7.4). The discussion lasted 50 minutes and, after this, each group presented to the others a summary of their views on the use of conceptual models. However, during workshop two, the discussion occurred in a less structured way, the discussion being led by the representatives of Natural England, giving direct feedback to the researcher and supervisors regarding their experience during session A. This discussion was 50 minutes.


Q1
• USEFUL TO HELP STRUCTURE THOUGHT PROCESS
• MAKES YOU THINK BEYOND YOUR OWN SPECIALIST AREA OF KNOWLEDGE / WORK
• PRESENTS RELATIVE IMPORTANCE OF RELATIONSHIPS IN A WAY THAT HELPS WITH FOCUS/PRIORITIES.
• GOOD TOOL TO INFLUENCE OTHER DECISION-MAKERS.
• HELPS STIMULATE DISCUSSION + IDEAS
• IT IS RELATIVELY EASY TO UNDERSTAND THE KEY CONCEPTS
• A 'NATURAL' WAY OF PRESENTING FUNCTIONS/RELATIONSHIPS

Q2
• THE '3 DIMENSIONAL' RELATIONSHIPS BETWEEN TABLES/DIAGRAMS MAY BE HARDER TO GRASP (COULD BE ADDRESSED IN ELECTRONIC FORMAT eg PDF)
• THERE IS A NEED FOR A GOOD GLOSSARY OF TERMS
• THE STRUCTURE OF DIAGRAMS MAY NOT 'WORK' FOR EVERYONE
• DOES NOT HAVE ARROW/LINE TYPE FOR RELATIONSHIPS THAT CAN BE NEGATIVE AND POSITIVE.

Q3
• SEEMS BROADLY CORRECT BUT NEEDS MORE 'TESTING' AND
• COULD DO WITH 'WIKI' APPROACH TO USERS ADDING TO TABLES AS WE LEARN MORE ABOUT RELATIONSHIPS — BE DYNAMIC
• ABOVE WOULD TEST + STRENGTHEN CREDIBILITY

Figure 7.4. Example of annotated flip chart sheet during session B discussions.

The data collected from the two workshops comprises: transcripts of session B of each workshop and the flip chart sheets annotated by participants during workshop 1. The data collected was qualitatively coded and analysed through two approaches: grounded theory and content analysis (section 6.5.5.2, Chapter 6). The intention was to analyse the data first in an inductive manner (grounded theory), then in a deductive (content analysis) manner to avoid introducing bias into the identification and analysis of valued findings (Hsieh and Shannon, 2005; Schutt, 2011). The analysis of session B's data through grounded theory was particularly useful for exploring, identifying and understanding new categories and data relationships. Particularly relevant topics included the role of GIS landscape function mapping on the overall methodology, and the potential role of SSM and the conceptual models on community and stakeholder participation. Nevertheless, data analysis through direct content analysis was particularly useful as a framework to structure the findings to be presented in the following sections of this chapter (Table 7.2).

Table 7.2. Concepts and categories identified through grounded theory and content analysis

Grounded Theory Categories	Chapter 7 Session B results structure	Direct Content Analysis Categories	
Purpose of conceptual models	7.3.2 Using conceptual models to approach landscape multifunctionality properties: *participation, inter- and trans-disciplinary, multiple-scale.*	Identification of changes to the landscape systems, potential changes, desirable changes and cultural changes	Categories from SSM stage 4 purpose, discussion about landscape multifunctionality
Using SSM to create local contextualised conceptual models		Understanding of landscape systems' dynamics	Categories from research aim
Using conceptual models to present ideas and to involve others	7.3.3 Conceptual models, elements to consider: complementary information, vocabulary and terms, practical aspects, users' preferences for learning and communication tools	Identification of interactions between landscape functions	Categories from workshop aim and objectives
Overall methodology		Spatial representation of landscape systems	
Practical implications		Identification of points of intervention	
Final outcome		Conceptual models' benefits	
Existing methodologies	7.3.4 Supporting understanding of landscape function dynamics	Conceptual models' limitations	
Role of GIS mapping		Information within the conceptual models to inform decision making	
Points of interventions	7.3.5 Conceptual models characteristics: flexible, credible and supportive	Recommendations to improve credibility	
Representation of interactivity		Effectiveness of conceptual models to understand landscape functions complexity	
Interactions between functions understanding	7.3.6 Spatial scale application	Spatial scale that landscape systems represent	
Relation between conceptual models		Potential of conceptual models to influence decision making	
Biases	7.3.7 The role of GIS landscape functions mapping		
Different disciplines			
Terms and vocabulary			
Improvement of conceptual models			
Conceptual models graphics and format			
Conceptual models flexibility			
Preferences of learning and communication methods and media			
Conceptual models' spatial scale application			
Conceptual models' accessibility			

7.3.2 Using conceptual models to approach landscape multifunctionality properties: ***participation, inter- and trans-disciplinarity, multiple-scale***

During both workshops, the participants commented on how useful and beneficial the conceptual models could be for stakeholder consultations and community engagement exercises. The participants came to this conclusion because they identified certain qualities that they thought were essential for community participation. One group of participants said that the conceptual models were *"good to stimulate discussion".* Another group found the conceptual models *"thought provoking"*. And, last but not least, they commented on how the conceptual models were useful and appropriate *"to present"* and *"to communicate with professionals"* and/or with others. They found that conceptual models can give an opportunity to all participants to share their *"opinions and perspectives",* as one participant during workshop 2 explained:

"…benefits of these conceptual models include the role they play in stakeholder and community engagement, the means for people to share their own perspectives on things, good way to share their perspectives and to draw out things that are relevant to individuals in a particular landscape…" (Natural England representative, Transcript 2, p. 1)

In addition, during workshop two the participants discussed the benefits of using the conceptual models to "present" to others how the landscape is functioning, for example: *"getting this partnership to accept that we are all working for the same thing" (Natural England representative, Transcript 2, p. 3).*

One other participant mentioned that each conceptual model represented *"a different discipline"* giving the chance to everyone to share their opinions on their expertise or interest topic:

"…I can see this things laid down in the table and people drawing in them and would help them to think through… some people will find they relate more to one than another and perhaps that leaves space for everyone to have an opinion or something so we looked at atmosphere and information [conceptual models] and I have a lot to say about atmosphere but not much to say about information but that's because is how I'm a professional engaged with it so that leave space for… to get a couple of words in…" (Forestry Commission representative, Transcript 1, p. 3)

Furthermore, another benefit identified by participants in relation to the representation of different disciplines was that they were able to identify issues "beyond their area of expertise". This would allow them to be aware of other organisations that could exert influence to help them achieve their objectives, as one participant said:

"…the beauty of something like this is that actually forces us to look outside of our area of expertise so instead of working on these islands. Say I am coming from these regular points of view, I know exactly where I need to get to meet my own objective. Actually I am forced to say, well, actually wait a minute. How does this fit in with other actions perhaps delivered on the sort of my objectives of what I do, how can I work with others, what are the issues that I need to have regard to…?" (Local Authority representative, Transcript 1, p. 5)

One other participant responded to the previous comment and said:

"I like what you were saying about it [conceptual models] helps you to see how you might help other organisations or other aspects, but I think it also enables you to see how other organisations or other aspects can actually help you to achieve your goals" (Woodland Trust representative, Transcript 1, p. 6)

Another benefit identified by participants during the discussion was the "*value"* of SSM as a *"thinking process"* to develop an *"understanding and thoughts",* in particular to understand how the landscape is functioning, or simply to help them to identify the range of ecosystem services a landscape could deliver. As one participant reported during workshop 2, following up on a comment made during workshop 1: *"ah! That's what we have been trying to do but actually we never thought of that" (University of Sheffield representative, Transcript 2, p. 1-2)*

During workshop 1, one group reported how they thought the use of the conceptual models and their concepts and terms could be applied *"universally"*, so that if used by different organisations they could help to minimise boundaries:

"…the beauty of a model like this is in some respects is universal whether I was a planner in East Staffordshire, Northwest Leicestershire or South Derbyshire it would ask the same questions, so it might actually allow me to join up our thinking with what is happening over the boundary and quite often we don't do that, we work in our administrative area and obviously if lots of organisations choose a model like this then it is

through asking the same questions that actually those links would possibly be better that what they are now, so from that point of view I think is very useful…" (Local authority representative, Transcript 1, p. 6),

Finally, participants identified that the conceptual models could potentially be used on other stages of planning, such as for tracking changes, monitoring or follow up stages, all because the conceptual models provide a certain "temporal dimension". Furthermore, another potential use identified by a participant was for the models to be used as part of economic valuation of ecosystem services, because he recognised that the "thinking process" could be helpful to identify priorities about where to focus and how to advance on the valuation process.

7.3.3 Conceptual models elements to consider

7.3.3.1 *Immediate access to complementary information*

One existing limitation that the workshop participants identified was the need to improve immediate access to information within the conceptual models. Participants refered to three different types of information to be accessed within the conceptual models: one, easy access to the other groups' conceptual models; two, the potential to access to information regarding organisations; and three, immediate access to the glossary.

Participants recognised that each conceptual model is related and/or complementary to other conceptual models; participants described the conceptual models as: *"almost to stack these in tri-dimension layers"* and *"… you need to look at them all"* (Transcript 2, p. 2). During workshop 1 one group of paticipants presented the issue with an useful example of why it is important to have access to all the conceptual models:

> *"…about the tri-dimensional thing of the relationship between the different [conceptual models] diagrams and tables, we found ourselves a couple of times thinking: yes but forestry might also do that, but hang on that's kind of covered more in the provision table…" (Transcript 1, p.1)*

The second type of information that could potentially be integrated was explored during workshop 1, where another group explored how aditional information on organisations, incuding their roles, might help to provide evidence for decision-making, noting that the conceptual models provide "good pointers" to organisations who could inform their functions:

"… we thought the information… provided very good pointers just to those overall organisations, those others functions, that would inform decision making, perhaps more information could be available underlying the models somewhere, about how we interact with those overall organisations, what the [their] functions are, what types of regimes underpin those. One of the things we talked about, things about the European Landscape Convention, is, like I am aware of it, but it's something that not necessarily informs my decision but actually it should do… quite often a lot of planning authorities we don't include that on decisions that we take, so I don't know whether there is room for the model to try to forcibly make the case. This is why you need to be looking at this because actually it helps you to fulfil your statutory responsibility…" (Transcript 1, p. 6)

Although the participants were provided with a printed glossary, they discussed the importantce of an easily accessible glossary of terms used through the conceptual models, as the representatives of the National Forest Company and Woodland Trust expressed:
"…and equally enough to be address … is having a good glossary because there were a couple of terms that I know I struggle with, and I think you can have a wider audience…" (Transcript 1, p.1)

Then participants discussed the possibility for immediate access to all the different conceptual models, complementary information concerning organisations, and the glossary through a digital version of the conceptual models. As one partcipant noted:

"… *being able to, I don't know what that is, click on it and the explanation comes up, might be much easier…and whether you can address that we were talking about an electronic version where actually you can click on Forestry and it will take you through to the right bit, so you don't try to cap everything in every single table…" (Trascript 1, p.1)*

Nevertheless, such a statement contradicts other participants' ideas of having the conceptual models *"on the table and stakeholders drawing on them"*; furthermore, during workshop 2 it was briefly explored how the use of digital media or computer modelling could affect the accesibility of the models, in terms of people's different skills and/or as an obstacle that could hinder the process of sharing ideas.

7.3.3.2 *Vocabulary and terms*

Participants througout the workshops raised questions about certain terms. During session A, in both workshops, questions were specific to the use of certain terms used in each model. However, during session B, particulary during workshop 1, participants explored in a broader sense why the vocabulary and terms used posed a significant issue. One aspect to consider is that they found some terms have the same meaning but are presented with two different words, which in their opinion adds complexity to the conceptual models. As expressed by two participants:

"…One of the things we found in the biodiversity model were a couple of times where almost the same concept is represented in two different blobs. An example we had was biodiversity represented separately from variety of species, whereas I think it is almost two different expressions of the same thing" (Transcript 1, p. 2)

"…so we had the air quality and atmospheric regulation model, we had about four different things which they could collapse into one, probably from my point of view, but from others' point of views you might want to expand them, so again that comes down to the adaptability of the models…" (Transcript 1, p. 4)

Nevertheless, the participants suggested that, in case it is required to have two different terms with the same meaning, then it might be helpful to represent those graphically in the same manner as if they are part of each other. Finally, participants identified that terms describing the proposed methodology and theoretical and local context requires clarification, to avoid ambiguity and to improve the understanding and focus of the exercise, as the Forestry Commission representative commented:

"Apart from vocabulary that might have the same meaning, the limitations regarding vocabulary or terms used and how they are pre-conceived by people, which raised questions about whether they were talking about planning or forestry?... or planning from a professional point of view?... when you are talking about interactions… interactions with the public? Are they interactions with different pieces of models?" (Transcript 1, p. 4)

The participant continued describing how this problem can be minimised if the conceptual models are developed from the outset through all the stages of SSM. In this way, the models could benefit from certain language flexibility as vocabulary could fit the context and purpose of the exercise. Nevertheless, it was interesting to note that throughout the grounded theory coding procedure participants used interchangable terms to describe, in particular, the relationships and components of/and between conceptual models. The terms various used were: diagrams, tables, mind maps, layers, different pages and conceptual diagrams, reflecting each participant's *worldview* on naming the conceptual models.

7.3.3.3 *Practical aspects*

Particularly during workshop 2, participants raised some questions regarding the practical application of the conceptual models. The main concern raised was about the practicality of the conceptual models on everyday landscape practice and how SSM could help to get *"more bang for your buck".* One of the questions raised for further reflection was the role of professionals within the method; in particular, they asked who would lead and put *"the package"* together, and how the decision would be made to: *"put together this partnership"* and get *"this partnership to accept that we are working for"*. Other concerns were raised about how to integrate local information and context.

Finally, the participants talked about clarifying what would be the "end-product" after carrying the conceptual models discussion exercise. One participant recognised the role and importance of GIS on everyday practice, and how this could be an important element of the end result in order to be accepted by professionals, recognising the constraints on the resources available for community engagement: *"[with GIS] there seems to be less emphasis on the people engagement side, it takes quite an investment to do that"*.

It was recognised by participants during both workshops that SSM and the conceptual models are accessible to different skills, for example through the use of rich pictures or by converting the conceptual diagrams to sign diagrams. However, they mentioned the potential need for guidance and training in order to: a) develop conceptual models, b) use already developed conceptual models, and c) clarify terms and vocabulary, which is an issue already explored.

Also, during workshop 1, the local authority representative identified biases as a practical issue that could potentially limit decision-making. He presented this issued by commenting:

"…I mean models are great, but how on earth do you make sure that the model actually makes me put [my biases] to one side and actually look at it, bringing wider issues

into the full process and decision making that we go through in my authority…" (Transcript 1, p. 5)

During workshop 2, without making a specific reference to biases, the participants made reference to potential bias when they discussed the importance of an appropriate mind-set. For example, a multifunctionality mind-set might help with establishing wider objectives from the outset, as opposed to starting with a single objective approach and then finding out what else the landscape is providing. For example, one "single objective" starting point the need to "meet" biodiversity targets by 2020, which instigated a potential bias.

7.3.3.4 *Users' preferences for learning and communication tools*

Participants expressed their views regarding people's preference of learning and communication methods. Participants discussed how these preferences might militate for or against the use of the conceptual models against popular check list formats or mathematical approaches. During workshop 1, the representatives of each group agreed they usually preferred checklists to diagrams; they also commented how they managed to focus on the conceptual models by "in their own thought process" removing different conceptual model elements such as the "text" or the "arrows"; despite their own preference, participants found the graphic representation of the conceptual models helpful, concurred that these were useful to represent graphically the functions and their relationships in a "natural way", especially if presented to others.

Similarly, during the workshop 2, participants expressed that although they are *"quite comfortable with Soft Systems ideas"*, they questioned how others might accept the proposed conceptual models, in particular disciplines that prefer hard systems or mathematical models. The discussion was followed by the exploration of how Soft Systems can be accessible at certain different stages: by the use of rich pictures or the development of conceptual models into sign graphics. Thus, participants concluded that a key aspect for the acceptance of the conceptual models was to be clear about the purpose and role of SSM and it associated models. Then, they identified that, after a collaborative dialogue of issues, other disciplines' representatives could investigate further the issues discussed in their preferred methodology.

7.3.4 Supporting the understanding of landscape function dynamics

Four conceptual model components were identified and widely included in the discussions, namely components or elements, drivers, processes and outputs. During workshop 1, two groups agreed that processes, within the conceptual models, are the elements where the stakeholders could intervene; specifically they identified that processes are the points of interventions. The group formed by the NFC and Woodland Trust representatives noted:

"…a process can be landscape management and the outcome of that is habitats, but the driver for that landscape management could be government initiatives…because we talk between ourselves [between groups] about the fact that we can't directly affect habitats. What we are affecting is the landscape management that delivers the output…" (Transcript 1, p.2)

Throughout the discussion, the representative of the Forestry Commission corroborated the previous statement, by identifying that they (as landscape professionals) cannot influence the drivers and the outputs; thus, it was suggested graphically distinguishing what the processes are within the conceptual model elements, so then it could be easy to identify *"the things that we can influence".* This comment complemented a remark made during Session A in workshop two when reviewing the master model, and the participants proposed graphically distinguishing components related to potential interventions against outcomes or ecosystem services.

Regarding information within the conceptual models that would allow practitioners to identify and understand landscape functions and their dynamics, the workshop participants acknowledged that the conceptual models were helpful for understanding complex "relationships". One group during workshop 1 said that it was very useful to have *"something on paper"* that required participants to work with, and encourage them to think about the processes and the *"…relationships that perhaps we ought to be considering but we often don't…" (Transcript 1, p. 5).*

During workshop 2, participants highlighted the importance of identifying "links" and "relationships", which would allow them to: *"understand how it is [the landscape works] together or not, that's when you start to build this idea of how landscape has evolved and how it is now" (Transcript 2, p.6)*. The participants continued exploring the importance of being aware of how the landscape is working, so as to understand landscape change, which they found essential to “move forward” and “extrapolate ideas”.

Regarding influences between the conceptual models, workshop participants identified that the arrows representing influences were effective not only to develop an understanding but, also the different arrows’ thickness was useful for them to identify important influences, which potentially, would allow them to prioritise and focus. Nevertheless, during workshop 1, participants recognised that a third “type of line” might be required, aiming to make visible various influences that can be either positive or negative. For example, noted:
“…for example government initiatives, the right government initiative can have a positive effect, the wrong one can have a negative effect [influence]…” (Transcript 1, p.)

During both workshops, participants expressed that the conceptual models were easy to interpret and represent graphically in “a natural way” to follow the relationships. However, the participants who reviewed the Master Model, found it too complex, commenting that the Master Model has many terms duplicated. Nevertheless, they felt that if they had reviewed another individual conceptual model (landscape system) before “hitting” the Master Model, they would probably have been able to “get used to the process”, which might then have made it easier for them to understand its complexity. In any case, participants of both workshops recommended that any of the conceptual models would benefit from simplicity.

7.3.5 Conceptual models characteristics: *flexible, credible* and *supportive*

In addition to previous topics discussed, participants identified and appreciated a certain degree of flexibility within the proposed conceptual models. They recognised that the conceptual models could be used and applied to different cases and situations; in addition, participants acknowledged that the conceptual models were open to different interpretations and that potential users would be able to set up their own issues and priorities, as required. However, participants agreed that if conceptual models were flexible enough to be modified, or in any case developed from the outset through SSM, it would allow the practitioners to include locality information; furthermore, problems encountered with terms and vocabulary could have been avoided as local context and background would have been included by the practitioner.

When participants were asked about the credibility of the conceptual models, they had a positive response and thought that the conceptual models were credible. Nevertheless, they recommended testing their validity, e.g. *"these"* workshops need to run with other people to *"test and challenge"*. An interesting proposal for increasing the credibility of the conceptual model was explored during workshop 1, where participants recommended that conceptual models should be able to evolve over time, by modifying them as necessary with relevant information *"learned"* by experiences and by allowing practitioners to collaborate and contribute to the "growth" of the conceptual models. They called this a *"wiki approach"*:

"…whether in the longer term to keep it dynamic, I might get this wrong but in a sort of wiki approach, where people come and edit it, to actually add things to it, so it doesn't become [a] snapshot of now but because we are constantly learning and new things come out and new lessons are learned that could be added to it, it can be built upon, so keeps growing organically …" (Transcript 1, p. 2).

Finally, during both workshop 1 and 2, participants had a very positive acceptance of the use of the conceptual models, describing the proposed methodology as a *"very strong"* tool for influencing decision-making. Reasons given by participants included:

"we thought they [conceptual models] have the potential to produce a more holistic better quality decision because you are thinking about the whole…" (Transcript 1, p.5)

"Universal application…it might allow me to join up our thinking with what is happening over the boundary" (Transcript 1, p.6)

"Helpful to wider thoughts within a planning processes" (Workshop 1, flipchart sheet transcript)

"I think there is definitely stuff here we would take…This is relevant in terms and thoughts around the whole systems science idea and gathering data… gathering information… very good benefits to start to build" (Transcript 2, p.)

7.3.6 Spatial scale application

During both workshops none of the participants, via their comments, agreed on a suitable spatial scale for the conceptual models. During workshop 1, the pair formed by the representatives of the NFC and Woodland Trust acknowledged that the application of the conceptual models is appropriate to landscape scale issues, because the conceptual models comprise and integrate issues complex enough to represent landscape scale, adding the it would be difficult to use the conceptual models at land cover units. Contrary to this comment, another group identified that the conceptual models were flexible enough to be used in different scales but only with *"certain processes";* they finally indicated that the conceptual models were more suitable to be applied to land cover units, mentioning *"marshlands"* as an example, because at a bigger scale the issues and conceptual models get very complex as the landscape delivers different *"things…for example, afforestation in one part and deforestation in another part"*. The final group in workshop 1 mentioned that they considered that the conceptual models were appropriate to *"represent change at landscape scale".*

During workshop 2, participants commented that the National Character Areas are *"too big"* as an appropriate spatial scale to analyse landscape multifunctionality; however, they recognised that to work with *"small locations"* is not appropriate for landscape approaches or landscape change. The discussion continued by highlighting that it is important that users of the conceptual models recognise the scale at which each landscape function and process operates.

7.3.7 The role of landscape functions mapping

During workshop 2, participants spent a considerable amount of time discussing the role, importance and contribution of mapping landscape functions through the use of spatial data and Geographical Information Systems (GIS). Participants identified three main functions of GIS landscape function mapping used in conjunction with the conceptual models. One function is an exercise to collect basic and contextual information about the landscape under review, with the purpose of gaining an understanding of what is happening, in terms of landscape functions and attributes. Participants mentioned four examples of information to be collected: historic data, interventions, locality knowledge and problem/specific data.

Although they supported landscape function mapping, the participants discussed and acknowledged existing limitations of this approach and the information it provides. The main limitation explored by participants was the limited capacity of spatial data to illustrate the interactions between landscape functions. Participants commented that if available spatial data is used directly (raw) or as proxies, landscape function mapping could be only *"two dimensional… crude…* or *…proxies are simplistic"*. The discussion continued by exploring existing approaches to landscape function mapping in the context of landscape multifunctionality. The researcher briefly talked about the both methodologies explored in Chapter 5 of this thesis: Willemen et al. (2008) and The Mersey Forest (2008 and 2013), as well as about the approach taken to map the pollinator support landscape function within the biodiversity support landscape system (section 5.5.4). After such exploration and reflection, the participants suggested what is required is *"better interpretative data"* rather then a collection of description of attributes. They explored how *"interpretative data"* and other information through collaboration can start to develop an understanding of how the landscape is functioning:

"… I would say we cannot get away because it is nothing else than the start of a process, and gathering some information, as you say, is probably showing some associations between the functions. Great, my lead is to start to think more definitely like the pollination stuff for example… To my mind then, this when you start applying this sort of information to test those associations and how the partnership looks over these particular systems within the particular focus area… could be a hot spot, a cold spot or somewhere you don't have information at all, it doesn't really matter… but you started off with something which showed you something in terms of associations… and you go out and test it and you start to get under the skin of what is happening in that particular physical location. I think that's where these are coming together and that's when partnerships will be looking at the information. Now, you look to a small area, well it says there is an information layer here, how is that associated to other elements, the initial GIS suggests this, is that right? And by looking then at this you can say, well, what other parts of landscape experience is it that people are gathering in this particular area, is information feeding into that?, is there a healthy walk, sustainable cycling routes? And you start to put a picture together; that's when you start to understand how the interactions might be occurring, this the bit we really haven't got to it at the moment in a lot of places…" (Transcript 2, p.8).

The second role of "GIS mapping" discussed by the participants was the role and importance of spatially identifying hot and cold spots within a larger area. The participants acknowledged that hot/cold spots are useful to identify where to focus and prioritise *"further investigation".* However contrary to academic discussion of hot and cold spots, the participants referred to hot/cold spot mapping as a simple overlay of functions:

"…So that's what shows overlapping some of the functions, here you have 12 overlapping rather than just 3 over there. Therefore, do we look at that area with hot spots, with more layers, then apply this [conceptual model] to understand how the functions are interacting together?... again you have to bring the historic elements, interventions to understand how that hot spot is working, the interactivity which is the core of what we are after, which hasn't looked at interactions in many places…" (Transcript 2, p.5)

The participants also discussed the limitations of hot/cold spots. In the discussion, the researcher contradicted the opinion of some representatives about the value of hot/cold spot mapping, by exploring how a simple overlay of landscape functions spatially identified by descriptive data does not necessary demonstrate landscape multifunctionality. Furthermore, another participant explored the importance of *"being aware"* of some potential landscape functions and the scale at which operate:

"…you might get a hot spot where a lot of things appear to be happening in one place but actually they refer to much wider areas which do not necessary coincide…" (Transcript 2, p.6).

After the discussion, participants agreed that is still valuable to identify hot/cold spots because these can help to start collecting information and to develop an understanding of the landscape under consideration:

"…You don't necessarily have to, you know, the mapping you have done with the National Forest that shows the hotspots [exploratory exercises], you can actually have somewhere which seems to indicate nothing but intuitively we know that field that it is not showing anything will have functions. It is functioning no matter what you think and it just happens that you don't have any data. Or you might say, there is a community here that really wants to do something with the material. There's all sort of ways you can use that material but at least you've got something, you've done something to try and gather a basic understanding of how a landscape is functioning. And if you said it's pretty two-dimensional, it is not telling you a lot, maybe, but where else do you start? If that modelling and mapping isn't any use at all, you can say, well in that case here is a community, we want to work with them, forget about the mapping lets go straight into this [SSM models]; would that work? I suspect it probably would…"

Finally, the third potential role of the "GIS mapping" was briefly explored by questioning whether could be useful, practical and necessary to *"map back"* results from the conceptual models exercise, by spatially locating *"interventions, partnerships and stuff together".*

7.3.8 Overall methodology

The discussion during workshop 2 in particular started with a general concern about how to use the conceptual models, what would be their implications and what would be the final end product. However, as the discussion progressed, ideas between the participants were reflected and clarified; then, throughout the discussion, participants identified four elements necessary to approach landscape multifunctionality.

The first element identified by participants is the need to have an appropriate *"mind-set"* from the outset of any project at the landscape scale. They recognised that is important to start approaching SSM with a *"wider"* range of objectives, instead of considering individual goals and then reviewing what other benefits are being provided. They cited the following example:

"…it is actually putting it on the table and presenting it, which starts to get people thinking… but actually here is an area we want to increase the number of red kites in this particular area and that's all we worry about for a large geographical area, and others will [say] well, hold on, why are you doing that… don't you realise that you could benefit from this stuff and from the other? It is almost the mind-set to start rather than starting from a single point of interest…, Yes, red kites might actually be of interest, but there are so many more benefits you can have by intervention and by partnerships in a particular area. We haven't got there yet, but everything we are talking about is this idea of integration of multiple benefits joined up…"(Transcript 2, p.3)

The participants briefly explored the aims of Nature Improvement Areas and the role of National Character Assessment. But in their opinion, although good approaches, these are not able to *"put things together"* and they are not answering *"how are they [the landscape functions elements] interacting?"*.

The second element to be considering within an overall methodology is the role of GIS mapping - not only as explored previously regarding the importance of GIS in current landscape practice - but as an initial exercise to start gathering data and understanding the landscape under consideration (section 7.3.7). The participants explored the following example:

"*…to begin with you need to have that [GIS], even if it is very basic GIS pointing out where these functions are occurring to our best knowledge - and that knowledge is not very perfect - but then you can start to home in with the potential partners of a particular area. They would have a very basic understanding of how this landscape has evolved and how it is now, and until you've got that you can't extrapolate forwards at all…" (Transcript 2, p.6.)*

The third element is the exploration of the conceptual diagrams illustrating the landscape systems. These can then be used to *"unpack"* and to follow all the potential interactions occurring, in collaboration with the project area's stakeholders, and then identify what interventions are possible and desirable. As one participant stated:

"…these conceptual models come into play to start to understand the interactivity between those layers [landscape functions]. I think that's when you start to get a better understanding of how the landscape has evolved, how it is now… and therefore what interventions do you want to do now so it is functioning better in the future… (Transcript 2, p. 5)"

The fourth and final element is the clarification of what is the *"end product"* from using SSM and the proposed conceptual models. The participants identified that the outcome of the exercise is about meeting with potential partners and sharing ideas. Participants explored the idea arising from the workshop that we approach "*does not give a specific answer, it is about collaboration and dialogue"*; thus the process of sharing ideas between the landscape's stakeholders is more important than a specific "solution".

7.4 Chapter summary

This chapter presents and describes the results from the analysis of the discussions which took place in two workshops with NF stakeholders as part of SSM. Together, these results provide important insights into the evaluation of SSM as a systems thinking approach to support the illustration of landscape function dynamics and landscape multifunctionality properties. The themes emerged from the analyses which explored in detail the components and relationship of landscape function systems; as well as describing the capacities and qualities of SSM and the conceptual models to approach landscape multifunctionality properties. These properties comprised dynamics and relationships between landscape functions, participation, trans-disciplinarity and multiple-scale awareness. In addition, the participants evaluated implications and barriers to SSM within landscape practice and planning spheres. Finally, the results presented the potential role of landscape function mapping within SSM. The next chapter moves on to discuss the findings of these results in conjunction with the results from the literature review on landscape function systems (Chapter 4) and the exploratory exercise on landscape function mapping (Chapter 5).

Chapter 8| D i s c u s s i o n

8.1 Introduction

Landscape multifunctionality affords a framework through which to promote landscape's emergent properties of resilience, distinctiveness and interactivity through purposive planning and management interventions to encourage desirable landscape change, whilst supporting an adequate delivery of ecosystems services. To date, methods and decision-support tools struggle to address fully the attributes of landscape multifunctionality, namely, dynamism, participation, multiple-scale occurrence and trans-disciplinarity. These properties refer to complex relationships and interactions between 'natural' and 'cultural' processes, where people are central to those processes and landscape is central to people's well-being. Furthermore, landscape processes, tend to occur over different time frames and spatial and organisational scales, and their analysis draws upon a wide range of disciplines and empirical knowledge.

This research study's approach to landscape multifunctionality has been underpinned by two fundamental points. First, it considered landscapes as a socio-ecological system to assess complexity through process-based and systems theory approaches (Selman and Knight, 2006a; Haines-Young, 2011; Potschin and Haines-Young, 2013). Second, it explored particularly landscape functions as systems that support the landscape's underlying and mutually interacting ecological and social processes (Kienast et al., 2009; Selman, 2012; Willemen et al., 2008).

The aim of this research study was to explore and to apply a systems thinking approach to support the comprehensive planning of landscape function dynamics and landscape multifunctionality properties. This overall aim was achieved through the pursuit of the following research objectives:

1. To critically disambiguate and establish the current state of knowledge and theory with regard to the range and nature of landscape functions as landscape systems.

2. To develop an approach to landscape function mapping in order to spatially identify and reflect the extent and direction of landscape systems.

3. To explore Soft Systems Methodology as a Systems Thinking approach to understand and address landscape multifunctionality properties in order to inform potential applications of this framework in landscape practice in future.

The fulfilment of these three objectives was supported by a methodological framework comprising a diverse range of methods underpinned by systems theory (see Chapter 3). Supporting objective one, a literature review was carried out to study and explore the range and nature of landscape function systems (Chapter 4). Then, objective two was approached through an explorative exercise looking at three different landscape function mapping approaches (Chapter 5). Finally, as part of objective three, this thesis explored and applied SSM to identify landscape multifunctionality dynamics and attributes (Chapter 6). Overall, these methods individually aimed to approach and resolve an individual objective of this thesis; nevertheless, the outputs of each objective form a collective framework assessment to landscape multifunctionality complexity. The proposed methodological framework was applied to a specific case study: The National Forest (NF) project area in tandem with its supporting organisation the National Forest Company (NFC). The NF project area was selected as a relevant case study because it is an exemplar of landscape regeneration that aims to deliver a wide range of socio-ecological objectives (Potschin and Haines-Young, 2006; DEFRA, 2013; NFC, 2014a). From its establishment in 1991 to date, the NF's strategies, objectives and actions comprise opportunities for the creation of multifunctional landscapes (Chapter 3).

This discussion chapter explores the key findings of the thesis. Section 8.1 describes findings from the literature review concluded with the aim of achieving a better description of landscape function systems' elements. Section 8.2 explores the lessons learned from the exploration of existing methodologies for landscape function mapping. Section 8.3 discusses key findings from the evaluation of SSM to support an understanding of complex dynamics between natural and social systems. Finally, a summary of key findings and implications is presented in section 8.4.

8.2 Landscape Function Systems

Landscape functions refer to the underlying processes and activities that define landscape emergent properties and the delivery of ecosystems services. This study has approached landscape multifunctionality by focusing on landscape functions, thereby differing from most current research which looks at the delivery and valuation of ecosystem services. Within ecosystems services debates, the term landscape function is generally associated with looking at a broader range of processes including people, as well as acknowledging their occurrence at landscape scale (Hermann et al., 2011). This study's emphasis on landscape functions comes from framing and studying landscapes as socio-ecological systems. Thus, through an understanding of the underlying landscape processes and the identification of adequate purposeful actions the system's dynamics can be directed towards synergetic paths of feedbacks between processes and activities encouraging desirable landscape change and emergent properties (Moore et al., 2014).

Research recognises that an important element of landscape multifunctionality assessments is a clear definition and description of landscape functions (de Groot, 2006; de Groot et al., 2010). Yet, there is a continuing debate regarding terms and classifications defining and differentiating landscape functions from ecosystem services (Hermann et al., 2011; Krováková et al., 2015). Most importantly we identified a limited body of information describing what is entailed by each landscape function, particularly concerning the underlying processes and activities that support the emergence of landscapes. In response to this issue, the first objective of this research focused on compiling a comprehensive description of the range and nature landscape functions as a landscape system. This was achieved through a literature review of existing peer-reviewed publications on key landscape functions associated with socio-ecological systems; Chapter 3 describes the literature review methods and material; and Chapter 4 presents the literature results.

Several research studies have identified a wide range of landscape functions together with ecosystem services and approaches to their classification (e.g. Millennium Ecosystem Assessment, 2005; de Groot et al., 2002). These studies tend to classify functions or services -these terms being used interchangeably- as *provisioning, regulating, supporting and cultural*. Through an initial analysis of existing literature, this thesis identified a total of 24 landscape functions and their respective ecosystem services. The identification of landscape functions as opposed to ecosystems services was based on the widely applied framework proposed by Haines-Young and Potschin (2010) analysing the relationships and distinctions between functions-services-benefits through a *"cascade model"* (see Chapter 2, section 2.5).

In comparison with other classifications, this thesis proposed a classification acknowledging landscape functions as systems and clustered those according to their relevant underlying processes. Contrary to discussions emphasising the need for uniform classifications of functions and ecosystems (for example, Wallace, 2007) this study aimed to feed specifically into Soft Systems Methodology by limiting the number of systems to be analysed. In accordance with guidance from Checkland and Poulter (2010), based on cognitive processes between five to seven systems and components were sought. Equally, the classification and review are not constrained according to available data, as for example Willemen et al. (2008 and 2010).

The literature review illustrates, describes and synthesises processes, components and conditions involved in each landscape system. This compilation of information provides a useful baseline in contrast to previous reviews of ecosystem services, because it not only describes widely studied ecological and social processes such as the hydrological cycle or development of place attachment, but also explores the role of landscape components within the overall system. It considers the performance and roles of such components, their effects on each landscape system and process over different scales and time frames. Overall this information started to provide a comprehensive picture of dynamics occurring between landscape function components.

Furthermore, the literature review had two significant inputs at different stages. First, exploratory exercises looked at landscape function mapping approaches. In particular, the literature review supported the identification of spatial landscape attributes that might be used to map landscape function systems (Chapter 5). For instance, the *Community system* was mapped by spatially locating community and volunteering groups such as: *Friends of…* or *maintenance volunteers of…,* as the literature suggests that these community groups influence, generally positively, the development and continuity of good quality landscapes and encourage community cohesion (Mathers et al. 2015; Leibovitz, 2003). Secondly, this literature review informed the conceptual modelling stage of Soft Systems Methodology,

by providing information on relevant landscape components and the strength and direction of relationships and influences between the system's components (Chapter 6).
Because the literature review of landscape functions supported directly the construction of conceptual models, this study found that supported various themes from the literature review. First, participants determined that the conceptual models and information content is credible and that components and influences in the models are adequate for representing landscape function systems. Participants did not identify key missing components, although they questioned the use of certain terms and vocabulary. A possible explanation is that their comments on vocabulary, terms and influences reflect their own *worldview* within their area of expertise, which is different to the researcher's *worldview* developed by the literature review on landscape functions. The identifications of differences between worldviews is a desirable SSM outcome, and is one of the key elements to encourage dialogue (Checkland and Poulter, 2010).

A second potential quality identified is that the literature review supports a multi-disciplinary perspective. During the evaluation of the conceptual models, the workshop participants agreed that they provided information from different disciplines; this in turn increased the credibility of conceptual models and encouraged people with different expertise to share their knowledge. Again, this reinforces the above issue regarding people's different *worldviews*. Findings from other studies discuss the importance of integrating multiple disciplines as an essential quality to address socio-ecological systems (e.g. Hermann et al., 2011; Potschin and Haines-Young, 2013). The integration of multiple disciplines can occur at different levels - from "multidisciplinary" where information is collected from different disciplines to "interdisciplinary" where different disciplines have a common goal of crossing disciplinary boundaries, to "trans-disciplinary" which involves the integration of multiple disciplines and non-academic knowledge to create new knowledge (Tress et al., 2006). As explored throughout this thesis, one landscape multifunctionality attribute is trans- disciplinarity, although, because of the nature of the literature review methodology only the level of multi-disciplinarity can be achieved.

8.3 Approaches to landscape function systems mapping

Another significant element to any multifunctional landscape or ecosystem services assessment is the spatial definition and visualisation of landscape functions, often carried out through the application of Geographic Information Systems. Within multifunctional landscape assessment, landscape function mapping is important as a way of illustrating to others (stakeholders and decision-makers) the spatial distribution, quality and the capacity of landscape functions to deliver ecosystem services (Kienast et al. 2009, Hermann et al. 2011, Wiggering et al. 2006). There is a growing body of evidence on spatial assessments; however, this generally focused on the spatial relationship of stocks and flows of ecosystems services. Thus, de Groot et al. (2010) and Hermann et al. (2011) are still addressing the research question of "how can landscape functions be mapped?"

Throughout the literature review and in relation to its emphasis on landscape functions, this thesis identified that many of the data and methodological limitations encountered in other mapping assessments will be continue to be faced, mainly because of the complexity involved in integrating landscape dynamics and landscape multifunctionality properties, such as crossing multiple scales (time, space and organizational). Nevertheless, regarding its second objective, aiming to increase an understanding of the range and nature of landscape function systems, this study sought to advance existing mapping approaches by exploring landscape functions as social and ecological systems. This objective involved carrying out an exploratory exercise on two relevant methodologies: a) landscape functionality mapping approach proposed by The Mersey Forest (2009); and b) landscape functionality quantification and mapping methodology by Willemen et al. (2008 and 2010).

Both approaches answered research questions different to this PhD research; however, they were distinguished from other studies because they addressed, applied and explored concepts such as landscape functions instead of ecosystem services. This exploratory exercise applied both methodologies to the former mining village of Moira, located at the centre of the National Forest project area. The results from this exercise informed a subsequent approach focused on the spatial representation of landscape function systems. The following sections 8.2.1 and 8.2.2 discuss the results from the exploration of the Mersey Forest and Willemen et al. methodologies; and section 8.2.3 discusses the proposed approach based on mapping landscape functions as social-ecological systems.

8.3.1 Mapping landscape functions, The Mersey Forest approach (2009)

The Mersey Forest methodology aims to present evidence-based information to support a green infrastructure intervention plan. This methodology was relevant because it focused on landscape functions in order to improve green infrastructure multifunctionality in urban and peri-urban areas. This approach comprises first, the creation of a green infrastructure typology map; second, the assignation of landscape functions to each green infrastructure type; and third, an evaluation of benefits and needs.

After applying the Mersey Forest approach to the Moira area, it was possible to create a green infrastructure map, twenty-two landscape function maps and one multifunctionality map (Chapter 5, section 5.2). The exploration of this methodology has been important for understanding the qualities of a practical and accessible approach; it permitted an exploration of detailed spatial databases, a spatial analysis of Moira's green infrastructure, and an assessment of the limitations of landscape function mapping approaches based on land cover analysis.

Previous research has debated the limitations of analysing landscape functions and related services through the spatial analysis of land cover/use; researchers have acknowledged that relationships between landscape spatial elements, processes, scale, spatial arrangement and intensity of land use, cannot be recognised from land cover/use descriptions only (Willemen et al. 2008; Verburg et al., 2009; Eigenbrod et al., 2010; Rounsevell et al., 2012). The results from this exploratory exercise corroborated such discussion. The resulting maps have a monotonic description of the landscape functions; the maps represent a single time-shot of the process, and unsuccessfully illustrate the quality and capacity of any landscape function. The maps for Moira lack reference to the extent of which a landscape function is happening, and the ways in which biophysical and social-economic drivers influence the capacity of landscape functions. For instance, the Mersey Forest study proposes that *"woodlands"* always should be considered as providing timber and bio- fuel; yet the capacity of this provisioning function is subject to the purpose and management of the "*woodland*", such that management objectives may focus on biodiversity conservation and accessibility (Woodland Trust, 2015).

After individual landscape function maps were created, these were juxtaposed leading to the production of a multifunctionality map for the Moira district. This multifunctionality map provides a general picture of where the landscape could support functions; unfortunately, the map implies that all co-located landscape functions are equally compatible, which is not the case (de Groot et al., 2010; Willemen et al., 2010). Nevertheless, The Mersey Forest acknowledges these limitations of multifunctionality mapping, and recommends using the individual landscape function maps only to inform an intervention plan. Yet the individual maps, as previously noted, provide very limited information in terms of biophysical and social context to support landscape dynamics and multifunctionality attributes. The findings from this exploratory exercise, informed the mapping approach proposed in section 8.3.3 of this chapter, in two ways. Firstly, it allowed the identification of a wide range of spatial data available and relevant to the NFC project area. Secondly, it clarified the limitations of single land cover/use approaches, primarily the lack of reference to different temporal scales. For, although the Mersey Forest approach has important qualities that are practical and accessible, it does not illustrate and interpret how biophysical and social influences can hinder or enhance the capacities and qualities of landscape multifunctionality.

8.3.2 Mapping and quantifying landscape functions, The Willemen et al. approach (2008)

Willemen et al. (2008) proposed a quantitative approach to spatially represent and quantify landscape functions. This study measured and analysed multifunctionality by identifying and looking at interactions between landscape functions. Willemen et al.'s proposed framework comprised three steps. First, they mapped and quantified landscape functions; then, they undertook a multifunctionality assessment, identifying types of interaction and the way these affected individual functions' capacity to provide ecosystem services; finally, they sought to map hot and cold spots.

The Willemen et al. approach for mapping comprised three different methods. An initial analysis allocated a particular method to each landscape function according to its different characteristics and the spatial data available. These methods correspond to: a) functions *completely delineated* by land cover spatial information; b) landscape functions *semi-delineated* by land cover spatial information, but also quantified by biophysical and socioeconomic indicators; c) *non-delineated* landscape functions, i.e. those lacking specific spatial references, but having various elements and indicators drawn from existing literature and policies.

Willemen et al.'s study mapped and quantified eight landscape functions in total: residential, intensive livestock, cultural heritage, drinking water, overnight tourism, plant habitat, arable production and leisure cycling. However, the exploratory exercise in this thesis, applied to the project area of Moira, only managed to map and quantify four functions: residential, intensive livestock, cultural heritage (*completely delineated functions*) and leisure cycling (*non-delineated functions*) (Chapter 5, section 5.3). Since it was not possible to map and quantify the majority of the proposed landscape functions by Willemen et al. (2008), the subsequent stages of multifunctionality analysis and hot/cold spot mapping could not be completed.

The results from this exploratory exercise were also limited by the differences in scale between the two studies (12.97 km^2 as against 750 Km^2). The difference of scales reflected itself in the suitability of available indicators to be applied at urban and peri-urban scales, and the suitability of the proposed statistical models for the quantification of *semi-delineated* landscape functions. In the case of the indicators, the equivalent indicators applicable to England were only to be found at a regional scale (*e.g.* East Midlands, Yorkshire and the Humber and North East), so when applied to Moira could only be represented as a single value, without a specific spatial reference. For example, in the case of the *Drinking Water* landscape function (a *completely delineated function*), apart from not being able to locate spatially Drinking Water Protected Areas (DrWPAs) within the Moira project area, the study had to utilise water extraction rates which were provided at regional scales only (Environment Agency, 2015). Similarly, the *Arable production* function, a *semi-delineated* function, is calculated via a multiple linear regression model, providing an estimated crop yield based on existing crop yield data and landscape elements (soil, groundwater levels and farm size); the dependent variable to be used is the indicator which reports *crops yield ha/year,* which in England was available only at regional scale, giving the dependent variable a single value and precluding the use of a statistical model.

The difference of scales was also reflected on the suitability of the proposed statistical models for quantifying the probability of occurrence of some landscape functions. For instance, the overnight tourism function could not be quantified through a logistic regression model, as the sample of the dependent variable was too small in relation to the sample of independent variables, so the statistical model could not estimate a significant alpha (.05) coefficient to provide reliable beta coefficients which inform the probability of occurrence. The Willemen et al. study registered 397 cells containing overnight tourism accommodation, against 5 overnight tourism accommodation cells located in the Moira project area. These findings suggest that this approach is not equally applicable at different spatial scales, in particular the urban and peri-urban scale. It could be transferable to another regional scale, but a considerable amount of research and skills would be required in order to identify appropriate indicators and to run the proposed statistical models. This has implications for who might use the approach.

The exploration of this methodology was important for understanding what elements intervene on different landscape functions (e.g. heterogeneity, soil type, landscape management, groundwater levels, accessibility) and how these might influence (negatively, positively or neutrally) the potential interactions between landscape functions, which in turn determine the capacity of the landscape to provide ecosystem services. Also, it shed light on the way in which observable landscape elements can be used and linked to provide spatially explicit insight on the intrinsic processes of each individual landscape function system. The findings from this exploratory exercise informed the landscape function mapping approach explored in the following section. The *complete delineated* and *non-delineated* methods were particularly helpful because their application proved to be flexible, practical and accessible. Although these methods depend on land cover data, it is possible to integrate biophysical and socio-economic indicators, supported by existing literature, which spatially illustrate the processes involved in different landscape function systems.

8.3.3 Proposing an approach for mapping Landscape Functions Systems

As discussed before, the spatial representation of landscape functions is an important element of any multifunctionality assessment (de Groot et al., 2010). The purpose of landscape function mapping is to inform and support decision making by illustrating the distribution, quality, capacity and context of landscape functions. There a growing body of work on spatial assessments, for example, the InVEST (Natural Capital Project, 2015) and ARIES (Villa et al., 2014) models; however, these focus on ecosystem services assessment. Thus, the question of how landscape functions can be mapped still requires further exploration (de Groot et al. 2010, Hermann et al. 2011), specially aiming to represent influences and relationships between system elements and the spatial and temporal scale at which these occur (Hermann et al., 2011).

Results from the methodologies explored in sections 8.3.1 and 8.3.2 showed that a methodological framework based only on GIS spatial analysis does not provide sufficient information on landscape dynamics. This is because spatial data (land cover/use databases, indicators and proxies) limit the spatial representation of the complexity and multifunctionality of landscape functions (dynamism, participation, multiple-scale and trans-disciplinarity). An awareness of these limitations informed an approach that identifies elements and conditions which could indicate the possibility of occurrence of a specific landscape function. The final aim was to produce process–oriented maps that would help practitioners to see the landscape in terms of its systems components and processes.

The proposed approach was applied to the total NF project area. Six landscape function systems were mapped: *provision, hydrological cycle support, atmospheric regulation, biodiversity support, information and carrier, and community* (Chapter 5, section 5.5). The results were relevant in two ways: regarding information used to represent landscape function systems; and exploring the contribution of the maps to address landscape multifunctionality. The resultant maps are different from the existing spatial analysis as they do not represent values (high to low), but instead depict elements that play a role within a landscape function system. For example, *the hydrological cycle support* function system has been represented by three elements: woodland land cover, as this land cover has the optimal rate of rainfall interception (Nisbet, 2005); soil drainage capacity (freely draining and slightly impeded drainage), as these categories determine an optimal rate of rainfall infiltration to the ground (Whitford et al., 2011; Gill et al., 2007); and location of water bodies, which within the hydrological cycle provides movement and storage of water that will evaporate and complete the cycle (Anderson et al., 1976; Kübeck et al., 2009; Wheaterhead and Howden, 2009; de Jong and Jetten, 2007; Johnson et al., 2010; Ryan et al., 2010). Some of the spatial elements chosen do not represent the core components of each system; but the rationale behind their selection was the availability and quality of spatial datasets appropriate to the National Forest project area. The proposed approach does not resolve the problem of landscape function quantification, relevant to inform high level policy makers (de Groot et al., 2010; Willemen et al., 2010). Furthermore, this approach does not identify areas of synergy, as spatial data within the proposed landscape function maps fail to illustrate multifunctional dynamics, for instance, influences of systems on another system. As found in other studies (*e.g.* Willemen et al., 2008) spatial data availability considerably limits landscape function mapping approaches.

The second relevant finding is that despite the above constraints, the resulting maps effectively illustrate spatial landscape elements that could communicate to stakeholders the essential multifunctionality processes within the landscape. Yet, the findings suggest that the proposed maps are only an initial reference to the system under consideration; they require a sound understanding of spatial and temporal scale at which the processes operate, and the information within the maps needs to be amplified by local knowledge and site-specific context. The resulting maps were used as support information during a series of workshops (Chapter 6, section 6.5). Through the discussion, the workshop participants discussed and supported the use of the proposed landscape function system maps as part of an integrated assessment framework. During the discussion, the participants identified three roles of landscape function system maps. These findings differ from the typical aims within ecosystem services methodologies, going beyond the spatial distribution and capacity of ecosystem services (*e.g.* Hermann et al., 2011) to their wider role informing decision-making.

The first role discussed by the workshop participants was to conduct a landscape function systems mapping exercise to collect information about the project area. Then, they discussed and explored the maps with specific local-place context information, in particular, community priorities and values. This result is consistent with an analysis made by Potschin and Haines-Young (2013) when they explored the importance of local knowledge/context within *place-based* approaches in comparison with *systems-based* or *habitat-based* approaches. Potschin and Haines-Young (2013) argue that the inclusion of local knowledge/context improves the relationship and understanding of environment and people, and it also introduces a *temporal* dimension by including *past change* and *future visions*.

The second proposed function of GIS mapping within the landscape multifunctionality framework was to spatially identify opportunity areas where synergy might be promoted. Existing literature refers to these areas as hot/cold spots, described as areas with several landscape function systems occurring simultaneously and enhancing or hindering each other's capacity to deliver ecosystem services (Gimona and van der Horst, 2007; Egoh et al., 2008; Willemen et al., 2010). The workshop participants considered whether identifying these *spots* could indicate potential areas for focusing further research or exploration. Some existing studies identify hot/cold spots through quantitative and statistical models, but these approaches are found to be limited by spatial data quality, uncertainty and highly specialized methods (Hermann et al., 2011).

Finally, the third potential role of landscape function maps was to spatially represent the results from a stakeholder engagement exercise, for example, agreed interventions and partnerships amongst stakeholders and decision-makers. This step is relevant within a decision-support framework, as it could illustrate potential results within the project area for further analysis; also, it could provide continuous communication of interventions between stakeholders, and might potentially be used as a monitoring stage. Many SSM studies include stages which aim to accomplish such elements.

8.4 Soft Systems Methodology

This thesis aimed to explore and to apply a systems thinking approach to support and to provide a comprehensive illustration of landscape function dynamics and landscape multifunctionality properties. This aim emerged in response to current limitations failing to look comprehensively and holistically at landscape multifunctionality properties: synergistic dynamics, multiple-scale crossing, participation and trans-disciplinarity (de Groot et al., 2010; Hermann et al., 2011; Bollinger et al., 2011; Bastian et al., 2012; Selman, 2012; Lovell and Taylor, 2013; Potschin and Haines-Young et al., 2013; Mastrangelo et al., 2014). Landscape multifunctionality is an emergent property resulting from the dynamics occurring between several social and ecological processes, which in turn lead to the emergence of other desirable landscape attributes such as landscape character, distinctiveness, time-depth, place and resilience; furthermore, landscape multifunctionality as a basis for planning provides a way of understanding how the whole landscape evolves in association with its underlying biophysical processes, components and local land managers and communities (Lovell and Johnston, 2009; Ling *et al. 2007*; Selman, 2009; Lovell and Taylor, 2013).

This aim of this research study has been addressed through three objectives. As discussed in previous sections, the first two objectives refer to the identification, definition and mapping of the processes and components of landscape function systems. The final objective is concerned with applying Soft Systems Methodology as a *Systems Thinking* approach for identifying dynamics and interactions occurring between landscape functions systems. Throughout the literature review (Chapter 2), Soft Systems Methodology (SSM) was identified as a potential framework that could support the identification of points of intervention that would allow landscape practitioners, in conjunction with the local landscape managers and community, to channel the directions of landscape dynamics towards desirable change.

Soft Systems Methodology was applied to the National Forest project area as a case study (Chapter 3, section 3.4). Through four SSM stages, this thesis conducted a systemic inquiry into landscape multifunctionality and landscape function systems (Chapter 6). This study "found out" and created a "rich picture" of landscape multifunctionality within the National Forest (section, 6.2); then we clarified and specified relevant multifunctionality and landscape function systems components (section, 6.3). These analyses were followed by constructing eight qualitative conceptual models (section 6.4), and, finally, concluding two workshops with NF's stakeholders in order to discuss and to evaluate SSM as a suitable framework. The results from these workshops are presented in Chapter 7. The key findings from the NF's stakeholder workshops are reviewed below, namely, the evaluation of conceptual models for depicting dynamics between landscape function systems, and SSM as a supporting framework to address landscape multifunctionality attributes.

8.4.1 Conceptual models for: *understanding landscape function systems dynamics*

In systems theory, complex systems are studied through the construction of analytical models. In this context, models are *constructs* of the real world through different contexts and views (Pickett et al., 2004); the purpose is to develop an understanding of a situation and its system's components, boundaries, interactions and dynamics. Though the SSM process, eight qualitative models were created: *Provision, Hydrological cycle support, Atmospheric regulation, Biodiversity support, Information, Carrier, Community, and a Master model.* These models were constructed throughout a particular *worldview*: landscape dynamics support landscape's systemic and emergent properties, as explored in chapter 6. Each conceptual model aimed to represent a *transformation processes* including the relationships and influences between landscape systems' components.

The key finding from the evaluation of the conceptual models was their capacity to illustrate and make aware to others the landscape function dynamics and potential points of intervention for landscape practitioners. Landscape dynamics are defined as the interactions and relationships between processes, patterns, structures and functions through space and time, and the results from such interactions are reflected in the character, condition and properties of the landscape (Wood and Handley, 2001). During the analyses of the results, we identified that the conceptual models successfully represent qualitative relationships and interactions between landscape function systems components, including ecosystem and social processes. Another type of dynamic identified through the exploration of the conceptual models was the relationship and interconnectedness between all the eight function systems and, as well as *hints or pointers* of information aiming to illustrate the *wider* system. Within systems thinking this type of understanding is referred as *holistic thinking* (The Open University, 2013), and aims to understand a system as a *whole* even through it is part of larger relationships with others systems which in turn give it context and significance (Oreszczyn, 2000; Bosch et al., 2007; Cabrera et al., 2008; The Open University, 2013).

Furthermore, the conceptual models made the participants discuss and be aware of the different *spatial, temporal and organisational* scales at which each component, process, influence and service occur within each function system. As explored in the literature review, this particular issue is referred as to *multi-scale* feedbacks (Cash et al., 2006; Selman, 2009; Folke et al., 2010; Lovell and Taylor, 2013; Mastrangelo et al., 2014). The relevance of this landscape multifunctionality attribute resonates with the awareness of the consequences that interventions had, have or could have on others system components at different spatial, temporal and organisational scales (at different times: past, present and future) (Cash et al. 2006; Brace and Geoghegan, 2010; Willemen et al. 2012).

The other key finding from the evaluation of conceptual models relates to their capacity to inform about potential points of interventions. The identified potential points of interventions were not specific and spatially referenced project areas, but involved the identification of specific system *processes* and potential actions where stakeholders, through discussion, recognised they might influence positively the system or conduct further investigation. A specific example explored in the workshops was how certain stakeholders have the capacity to change *management actions* that in turn will influence a habitat's distribution, qualities and attributes. Within social-ecological systems, a point of intervention which is well informed by landscape multifunctionality attributes can intensify synergetic paths and feedbacks between processes, functions and services in order to support desirable landscape change and other emergent properties (Wood and Handley, 2001; Moore et al., 2014).

One SSM attribute is that, through dialogue, promoted and structured by conceptual models, different worldviews and perspectives are recognised and accommodated when apprising *actions to be taken* (Checkland and Poulter, 2010). In the case of this research study, different *worldviews* amongst the workshop participants were primarily reflected in feedback regarding terms and vocabulary used for each landscape function system. Ambiguity of terms within landscape multifunctionality and ecosystem services concepts is an ongoing topic discussed by several authors within the literature. Fisher et al. (2009) argued that it would be difficult to reach a consensus of terms, as these relate primarily to the context in which the terms are being used in different studies. Our participants recognised that if the conceptual models are going to be used as pre-developed supporting material, more testing and further evaluation of each model by potential users and experts would increase the acceptability of the terms used, as it would integrate a wider range of perspectives, points of view and *worldviews*. Further, the participants recognised that the conceptual models would require clarification of the context within which they were applied. According to the workshop findings, context can potentially be provided in two ways: through the provision of support material such as a glossary and landscape function systems maps, provided these are accessible; and by involving stakeholders at early stages of SSM. The involvement of stakeholders at early stages is encouraged because their particular roles, concerns, values and attitudes can be integrated at the problem formulation stages, and then illustrated in the conceptual models (Checkland and Poulter, 2010). In the case of using the conceptual models as prior supporting material, they would require to have a certain level of inbuilt flexibility and accessibility, as it is important to accommodate expert feedback from continuing evaluations and newly emerging knowledge.

These findings contrast usefully with existing multifunctionality assessments because they support the importance of elements, notably dynamics and participation, that other studies fail to address. This study affirms the capacity of conceptual models to illustrate how landscape dynamics emerge from SSM analysis. First, it places people at the centre of the system by acknowledging and identifying the existence of different perspectives and worldviews, and as well by supporting active engagement by encouraging participation and social learning. Second, the analyst applying the SSM methodology is helped to think holistically and to address interconnections within and beyond the system; then, in conjunction with others, the analyst can learn about the logic of the system (The Open University, 2013).

8.4.2. Evaluation of SSM as a framework supporting landscape multifunctionality

As explored above, the concepts underpinning SSM closely relate to landscape multifunctionality attributes. This section will reflect on results from the evaluation of SSM as a framework supporting landscape multifunctionality. Results show that SSM, through its systemic thinking exercises, allows participants to compile a comprehensive picture of system as a whole. In the particular case of this thesis, SSM allowed stakeholders to understand and learn about the social and ecological processes and dynamics occurring on each landscape function system. Also, it supported the integration and consideration of local contextual understanding including the identification of ecosystem services provided by the region, community priorities and issues, the organisations involved (e.g. institutions, governance, policies) and the awareness of processes and the potential implications of interventions at different scales in time and space.

The second SSM quality is the opportunity to actively engage with the system's stakeholders. Stakeholder engagement and participation processes are limited by the study resources available (Reed, 2008). This research study was able to engage with stakeholders on a couple of occasions. The first occasion occurred informally and its main role within SSM was to provide information relevant to the formation of a rich picture of landscape multifunctionality in the NF project area. The second opportunity occurred formally through two structured workshops, which provided the results of evaluation. In comparison with other multifunctionality assessments, the application of SSM achieved *"substantive"* stakeholder participation; as described by Stirling (2006) this type of stakeholder engagement seeks to integrate a participation process with another type of analysis, so as to collect multiple perspectives and *"local-context"* information for a complete and extensive description of needs and values. The participation process approached by this study followed SSM guidance on using conceptual models to structure a discussion exercise between stakeholders. The results explore positive qualities derived from such activity. For example, the discussion exercise encouraged interdisciplinary knowledge to be exchanged - NF's stakeholders identified that throughout exploring the conceptual models with others they were able to identify, discuss and understand different disciplines and people perspectives. Also, they found it appropriate and encouraging to have a hands-on approach and to work on and with the conceptual models in order to explore, learn and unpack landscape dynamics. Finally, the participants identified that SSM is an approach flexible enough to generate new knowledge to accommodate different priorities, needs, data and skills.

Apart from the positive findings previously discussed, our results illustrated several queries regarding the practical implementation of SSM in landscape practice. The first question discussed for further exploration concerned the establishment and agreement of objectives among key stakeholders. Results are consistent with other research studies, which discuss the role and influence of objectives on stakeholder participation and decision-making (Henningsson et al., 2014). In particular, findings suggest that multifunctionality approaches need to contemplate broader social and ecological targets from the outset, contrary to strongly sector-oriented perspectives, such as conservation planning and ecosystems service delivery. In relation to participation, the multifunctionality perspective contributes to the collection, exposition and analysis of multiple social-ecological aims from a wide range of stakeholders (Selman, 2004; van Berkel and Verburg, 2012; Harden et al., 2013). The second issue not explored here, but raised by the workshop participants, is the definition and implementation of actions to be taken and follow up stages. Findings suggest that up to the comparison and evaluation stage, the main outcome is the achievement of sharing ideas, dialogue and collaboration between stakeholders. SSM guidance by Checkland and Poulter (2010) acknowledge that SSM does not seek to provide specific results; it is an inquiry processes enabling through learning, action to be taken to change a *problematic situation* (Checkland and Poulter, 2010) rather than pursuing a specific solution to solve a problem. SSM comprises a final stage where interventions can be identified and evaluated, or the learning cycle can begin again to look at the new and potentially improved situation (Checkland and Poulter, 2010).

However, this research study recognises that it is still necessary to clarify how to define and evaluate specific desirable and achievable interventions in the context of landscape multifunctionality; and to explore the consequences of such decisions and actions taken. The results discussed above had been identified as opportunities for future research, and are discussed in the Conclusion chapter. The following section reflects on a key lesson learned after the application and analysis of SSM.

8.5 Approaching landscape multifunctionality

This research study proposed exploring landscape dynamics and approaching the complexity of landscape multifunctionality through Systems Thinking theory, in particular exploring the application of Soft Systems Methodology developed by Peter Checkland and colleagues from the 1990's. Throughout the development of this thesis a key lesson was learned: in order to approach landscape dynamics to properly inform the direction of actions, policies and strategies for landscape re-generation (Selman, 2002; Lovell and Taylor, 2013), it is necessary to address landscape multifunctionality through an integrated assessment. Based on this thesis findings, the proposed type of assessment could integrate and use GIS to represent and present to others the spatial distribution, quality, local context and the capacity of landscape functions at the landscape scale (Kienast et al. 2009, Hermann et al. 2011, Wiggering et al. 2006). Then, the application of SSM as framework would be used develop an understanding between stakeholders regarding landscape function dynamics, and intervention points and priorities. This would be followed by further detailed analyses and monitoring to improve and support the understanding and impact of specific actions on the existing ecological, social and economic systems.

Chapter 9 | C o n c l u s i o n s

9.1 Introduction

Encouraging the emergence of multifunctional landscapes requires an understanding of how the landscape evolves in association with its underlying processes, local land managers and community. Multifunctional landscapes are associated with positive emergent properties such as resilience and distinctiveness developed fortuitously and over a long period of time (Selman, 2009). Landscape multifunctionality is a phenomenon that displays four attributes: interactivity between landscape functions, stakeholder participation, multiple scales and trans-disciplinarity. Current landscape practice, planning and policy frameworks seek to address the complexity associated with multifunctional landscapes. As discussed in Chapters 1 and 2, many current methods for planning, designing or evaluating multifunctional landscapes are limited in their treatment of key attributes of multifunctionality, notably landscape function dynamics (complexity) and stakeholder participation (public active engagement). This thesis aimed to explore and to apply a systems thinking approach to support and provide a comprehensive illustration of landscape function dynamics. In response to this research aim, this research study framed landscapes as socio-ecological systems and explored the causal relationships of its interconnected *landscape function systems*, to facilitate the identification of points of purposive landscape intervention to set appropriate ‘initial conditions’ to speed up the emergence of multifunctional, resilient and distinctive landscapes. In particular, this study applied and evaluated Soft Systems Methodology (SSM) as a suitable framework for addressing complexity, public engagement and co-production in planning for multifunctional landscapes.

This research followed an integrative approach combining different qualitative methods applied to a specific case study, the National Forest Company in the East Midlands, United Kingdom (Chapter 3). This concluding chapter outlines this study’s contribution, limitations, implications for practice and the potential future research actions which flow from these aspects.

9.2 Supporting information

Before exploring SSM as a decision support tool, it was necessary to achieve two objectives. The first objective was to critically disambiguate and establish the current state of knowledge and theory with regard to the range and nature of landscape functions as landscape systems. The output was a literature review describing the processes and components of each selected landscape function. The second objective was to develop an approach to landscape function mapping in order to spatially identify and reflect the extent and direction of landscape systems. This led to the development of an approach based on spatial definition and visualisation of landscape function systems. The findings from these two objectives had a supporting role, informing the application of SSM. Yet, they also had specific contributions and implications as individual pieces of research. These contributions will be explored in the following sections.

9.2.1 Landscape function systems: *description.*

This research has focused on the particular concept of landscape functions. Within existing literature, landscape functions are associated with the underlying and dynamic social and ecological process that support landscape properties and ecosystem service delivery. Existing research studies which identify and describe landscape functions are carried out from a service-benefits flow perspective, leading to a limited understanding of the processes and components involved in each landscape function. This prompted the need to compile a comprehensive description of each individual landscape function system. Chapter 4 contains an analysis of seven proposed clusters of landscape function systems, namely: *Provision, Hydrological Cycle Support, Atmospheric Regulation, Biodiversity Support, Information, Community and Carrier.* The key role of this literature review, particularly in the present context, was to provide a comprehensive description of the processes, components and roles of each system. This analysis then informed the approach proposed for landscape function systems mapping (Chapter 5, section 5.5), as well as supporting the development of the conceptual models (Chapter 6, section 6.5).

The literature-based analysis was assessed through an evaluation of the conceptual models (Chapter 7, section 7.2). This evaluation was carried out by NFC stakeholders through two workshops, which assessed whether the components and influences contained within the models were appropriate for illustrating the processes involved and the dynamics occurring within each proposed landscape function system. The findings suggest that the information in each conceptual model is adequate, although improvements could be made. The workshop participants identified missing components and influences, suggesting that the conceptual models should be reviewed to accommodate knowledge from additional experts and stakeholders. However, an important finding is that any analysis and information base supporting such conceptual models requires a degree of flexibility, to allow growth and to accommodate local context and new empirical knowledge. Also it should support and reflect the input of different disciplines, at a multidisciplinary level; findings show that allowing different experts to advance their opinions in their own area of expertise, in turn allows others to learn and to understand different perspectives.

This literature review, as an individual piece of research, contributes to existing landscape multifunctionality research disambiguating and describing the components of landscape functions. Its multidisciplinary process-oriented perspective contrasts with other assessments which identified flows of benefits and quantifiable indicators or proxies for ecosystem service valuations. This literature analysis provides a compilation of existing research knowledge and theories from different disciplines, as a basis for understanding the general principles of ecological and social processes, which then can be enriched through the lenses of local empirical knowledge.

9.2.2 Landscape function systems: *spatial representation*

As part of any landscape multifunctionality assessment, the spatial representation of landscape functions aims to illustrate the spatial distribution and capacity of potential landscape functions to provide ecosystem services at a landscape scale. Yet despite the wide range of published spatial assessments, there is no general consensus that this task has been successfully achieved (Hermann et al., 2011), particularly in research studies analysing landscape function dynamics. Chapter 5 presents an exploration of two spatial analysis methods, relevant to landscape multifunctionality (section 5.3 and 5.2). Findings from this exercise suggested that land cover based analyses help our understanding of accessibility and efficiency, but do not reflect the dynamics occurring between landscape functions; instead they illustrate these as interchangeable or compatible. The findings from the quantitative analysis showed that although aspects of dynamics between landscape functions have been considered in land use and ecosystem service analyses, they are constrained by spatial data quality and availability. Furthermore, this quantitative approach is not equally applicable at different spatial scales and requires highly specialised technical skills to implement and interpret.

Building on this exploratory exercise, this thesis proposed a landscape function system mapping approach (section 5.5). Based on the existing literature this approach identifies spatial elements and conditions that indicate the possibility and potential degree of occurrence of different landscape function systems. Six landscape function systems maps were created: *Provision, Hydrological Cycle Support, Atmospheric Regulation, Biodiversity Support, Information and Carrier, and Community.* The resulting maps are different to existing spatial analyses because they do not aim to illustrate quantitative values; rather, through interpretative data, the maps aim to present components that have a role and a potential degree (threshold) of occurrence within each landscape system, for example, soil drainage capacity to infiltrate overland flow. However, as in the case of existing spatial analysis, these results were also limited by spatial data quality and public domain availability.

The exploratory exercise corroborated the intrinsic limitations of spatial data and mapping approaches to address landscape function dynamics, complexity and other multifunctionality attributes; in turn, it supported the aim of pursuing a systems thinking approach through the application of SSM. However, despite the limitations encountered, the output maps were also used as supporting information during the evaluation of the conceptual models and SSM (Chapter 6, section 6.5).

Although the landscape function systems maps were not specifically evaluated in terms of their content, the maps generated discussion regarding their role within SSM. Three purposes were identified. First, they played a role as contextual information, in particular collecting, combining and presenting the components of spatial landscape function processes in a local context and at a landscape scale. In turn, they could potentially reveal *place based* qualities in any decision support approach. The second purpose was to present spatially the results and potential actions derived from the application of a decision-support approach, in order to improve continued communication and monitoring. Finally, the third purpose of mapping landscape functions is to help to explore, analyse and spatially represent any areas of opportunity, for example helping to identify hot/cold spots, as defined in Chapter 2, section 2.6.1.2. The two final roles (second and third) were not initially considered and explored in this thesis but emerged as concepts during the workshop analyses; as these topics emerged later, they are considered as future academic research opportunities (section 9.6 of this chapter).

Thus, the findings from the exploration of existing spatial analysis methods provided additional evidence regarding the uncertainties and limitations inherent in existing approaches in terms of their ability to successfully account for landscape multifunctionality attributes and complexity. This thesis proposed a landscape function mapping approach, primarily following Willemen et al. (2008), to non-delineated functions, which comprises mapping and quantifying landscape function thresholds on the basis of existing literature. However, in this thesis, the approach differs from Willemen et al. (2008) in terms of looking at landscape functions as systems rather than focusing on the delivery of ecosystem services. Thus, this study approach contributes to existing research by pursuing a qualitative approach and, through interpreting raw spatial data, aims to identify and analyse the components of landscape function systems to support decision making and landscape multifunctionality attributes.

9.3 Soft Systems Methodology: *approaching landscape multifunctionality*

This thesis explored and applied SSM aiming to help the public, landscape practitioners, managers and policy makers to understand and identify the dynamics occurring between natural and cultural landscape functions. In turn, this would enable them to identify how and where to purposefully intervene to encourage the emergence of landscape multifunctionality. SSM was used to approach landscape multifunctionality complexity and dynamics from a systems thinking perspective. The application of SSM has been assessed in terms of its contribution for approaching landscape multifunctionality attributes and its potential for supporting decisions.

9.3.1 Soft Systems Methodology: *for structuring and analysing landscape multifunctionality*

Landscape multifunctionality dynamics are characterised by complexity and uncertainty. These qualities are derived from the interactions between natural and social landscape function systems. An effective and practical assessment of landscape multifunctionality remains a challenge because existing practice and studies have had limited success in addressing complexity by accounting for environmental, social and community drivers, needs and values and their interactions. This thesis explored SSM as a method to approach landscape multifunctionality attributes by addressing a comprehensive analysis of the dynamics occurring in multifunctional landscapes.

The findings from this exploration illustrate that SSM can successfully provide a structure to help engage with the complexity of landscape multifunctionality. It was approached by addressing the SSM stages proposed by Checkland (1999), Checkland and Scholes (1999) and Checkland and Poulter (2010). These stages aim to look at a problematic situation by systemic thinking, i.e. thinking holistically about systems which are part of wider systems. Stage one and two (Chapter 6, sections 6.2 and 6.3) started the enquiry process by exploring the situation, formulating a *problematic statement,* identifying a *transformation process* as well as the main people/organisations involved in each landscape function system. The problematic situation for this thesis was developed by analysing current discussions on landscape practice (planning, design and management), aiming to approach broader ecological and social objectives and to identify the necessary conditions that will allow multifunctional, distinctive and resilient landscapes to emerge. The *transformation process*es were identified by analysing the processes involved in each landscape function system, compiled and described thorough the literature review in Chapter 4. In contrast with other existing SSM studies and SSM guidance, this research did not involve close consultation with stakeholders in these particular stages (1 and 2) regarding their concerns, issues and points of view; rather, this study approached NFC's stakeholders informally, and this is a limitation discussed in section 9.3 of this chapter.

The following stage comprised modelling the complexity of multifunctionality. This stage was approached graphically, through the development of conceptual models. In this particular study, each conceptual model aimed to represent, qualitatively and graphically, the dynamics occurring between landscape function components (Chapter 6, section 6.4). For each landscape function system identified, a conceptual model was created, resulting in seven conceptual models: *Provision, Hydrological Cycle Support, Atmospheric Regulation, Biodiversity Support, Information, Community, Carrier*. A final additional conceptual model was also developed, which illustrated and integrated all landscape function systems, representing landscape multifunctionality.

Subsequently, there is a discussion stage within SSM methodology (Chapter 6, section 6.5). In this stage the conceptual models' purpose was to encourage discussion. In the context of this thesis the discussion was structured for exploring landscape function relationships and evaluating SSM approaches to landscape multifunctionality. The discussion occurred throughout two NFC stakeholder workshops. Results from the workshops concluded that the conceptual models had an important role in approaching and understanding complexity and interconnections between landscape functions. Consequently, from this discussion, participants were able to identify and analyse the following information:

a) Interactions and influences occurring between different landscape function components and processes.
b) Awareness of multi-scale feedbacks between different spatial, temporal or organisational scales. Participants identified information regarding points a) and b) when they studied the conceptual models and started to discuss and evaluate their contents.
c) Links and correspondences between other landscape function systems; but also with ecosystem services, organisations and policies. Participants noted that when they were exploring a conceptual model they felt the need to start connecting with and looking at the other conceptual models.
d) Points of interventions where the workshop participants felt able to influence the dynamics of the system: specifically, participants identified that components referring to processes were the points at which they could directly intervene.

These results contribute to existing landscape multifunctionality research in two ways. First, this thesis explored a contrasting qualitative approach that accounted for and gave structure to multifunctionality complexity and its attributes; this in turn, through active dialogue between stakeholders, potentially helps to improve our understanding of social and ecological landscape function interactions at a landscape scale. Secondly, in comparison with other multifunctionality assessments (e.g. Willemen et al., 2010; The Mersey Forest, 2013; Lovell and Taylor, 2013) the information that stakeholders were able to discuss corresponds to landscape multifunctionality qualities and attributes such as multiple-scale awareness and trans-disciplinarity. For example, apart from identifying that positive and negative interactions between landscape function systems were occurring, participants recognised how the different landscape functions interacted together simultaneously, in a three-dimensional way (linking function systems 'vertically and horizontally' and through different time frames). Also, there was a co-existence of different spheres and disciplines, and the integration of a multi-disciplinary perspective can potentially develop new trans-disciplinary/ co-produced knowledge. Furthermore, instead of analysing a set of spatially fixed and static representations in the maps, SSM facilitated active discussion of the potential interventions through different time frames (past, present and future) and scales (spatial and organisational) of interventions. Finally, through SSM, people had a central role within and during the discussion of landscape dynamics and multifunctionality through the involvement of potential systems actors and their roles, and by facilitating active stakeholder engagement.

9.3.2 Soft Systems Methodology: ***supporting decisions***

As part of the challenge of exploring and understanding the dynamics between landscape function systems, this thesis evaluated the role of SSM as methodology in supporting decision-making. Results from such evaluations were analysed in two ways: SSM as a part of a decision-support approach, and SSM as part of an integrated assessment framework.

Compared with existing multifunctionality assessments, this thesis identifies three SSM qualities that support better decision-making. First, SSM successfully involves stakeholders and encourages collaborative and active public engagement, by encouraging communication, dialogue and perspective sharing. This allows decision making to be generated on the basis of developing a common understanding and agreement of objectives between stakeholders (Reed, 2008). In this thesis, communication and dialogue took place at the SSM *discussion stage*. Findings illustrate that SSM allows the generation of *"substantive"* participation (Stirling, 2006), which integrates participation with an additional type of analysis, aiming to collect multiple perspectives and *"local-context"* information for a complete and extensive description of needs and values. Secondly, SSM has proved to be a flexible approach that allows for the creation of new and continuously evolving empirical knowledge, as well as accounting for different skills between stakeholders. Third, SSM addressed multidisciplinary exchange of knowledge through the conceptual models; however, through stakeholder discussions, interdisciplinary was also achieved. These findings are consistent with other SSM studies applied in other environmental contexts; however, this thesis contributes significantly to current research by applying SSM in the context of landscape multifunctionality, in contrast to the current tendency towards quantitative modelling assessments, where stakeholders' involvement is not clearly defined or taken into account during and after modelling.

Finally, this study has suggested specific roles for landscape function system mapping and SSM within a larger integrated assessment framework. As explored before, the application of SSM can beneficially be preceded by a spatial assessment of a landscape function system, aiming to present and provide a spatial context for landscape function system components at a landscape scale. Then within an integrated assessment framework, two potential roles for SSM can be identified. First, SSM includes stakeholder participation and active engagement at the centre of a transparent and systemic reflection process that gives structure to complexity. Secondly, SSM improves the understanding of landscape function dynamics, accounting for uncertainty and the implications of decisions at different spatial, time and social scales. Subsequently, within an integrated assessment framework, the potential agreements and actions identified and generated from SSM can be followed by producing a specific evidence base through, for example, quantitative modelling, trade off analysis, multiple scenario analysis or monetary valuations of ecosystem services delivery. Nevertheless, all are based on the co-created framework of multifunctionality understanding and attributes.

9.4 Limitations

There are some limitations to this research study that need to be acknowledged, particularly regarding the composition and size of the workshops. The workshops were only one part of the research and were limited by available resources and other practicalities. Within a single case study context, they were sufficient to inform development, and to explore key issues, of the SSM approach. However, their limited scale means that this stage of the research was exploratory rather than comprehensive, and so future research could usefully expand on this aspect.

First, the workshop outputs achieved an acceptable degree of insight and refinement within the current research context, because the participants comprised a balanced representation of potential stakeholders, for example, local authorities, governmental organisations, community representatives, conservation organisations and academics. However, because of external factors and research limited resources, the number of participation opportunities and the number of participants in the workshops were limited.

Specifically, it was not possible to organise a greater number of workshops to ensure a large number with a wider range of participants on; and would have extended to purposefully involvement of stakeholders at the problem formulation, transformation process stages as suggested by other studies and SSM guidelines. This would have permitted greater generalisation in the refinement and evaluation of conceptual models. It may also have informed a fuller inclusion of certain process elements, such as negative aspects and influences of landscape functions.

Therefore, the inclusion of more stakeholders would have provided a better balanced range of skills and knowledge (local, scientific, practical), and may have enhanced the validation of key research findings (Reed, 2008). With regard to the current research context, it might have benefited the application and evaluation of conceptual models and SSM as a participative and learning approach to landscape multifunctionality (Watkin et al., 2012).

Second, further consideration might have been given to stakeholders' background and their influence on others participants' thoughts and actions (Reed, 2008). For this particular research study, the allocation of two explicit conceptual models according to participants' and pairs' interests or skills allowed each member of the pair to contribute their expertise accordingly. As observed in the Discussion chapter, participants felt that this workshop exercise allowed them to contribute their expertise when required but to learn about a process not in the range of their own skills or expertise. Further, due to the same external factors noted above, it proved necessary to involve the thesis supervisors in the workshops. Their participation had a supportive role during session A only (where pairs discussed and analysed the elements of the conceptual models) by completing the proposed working pairs. A preferable situation may have been to involve only impartial participants who were distanced from the research project; it is possible that their background knowledge on this research topic and own biases could have unintentionally influenced others participants' thoughts and actions.

This thesis was applied specifically to the project area of the NFC. As explored in the methodology chapter (p. 49) a single case study approach has certain limitations in terms of extrapolating research findings to other situations because triangulation and cross-cases comparison of different contextual situations is not possible. Nevertheless, recognising the pros and cons of single case study approach this thesis limited itself to exploring a particular planning objective or intervention that could provide a more specific focus to the discussion and evaluation. In consequence, this limited the results from the evaluation and the identification of potential future interventions in specific problematical situations.

9.5 Implications for landscape multifunctionality planning practice

This thesis makes a clear distinction between multifunctionality and ecosystem service approaches. It demonstrates that landscape multifunctionality adopts a holistic outlook on a complex system that requires a comprehensive understanding of interactions and feedbacks between cultural and natural function systems, which was achieved through a systemic thinking and participative process.

This study developed an integrated decision support framework, comprised primarily of landscape function systems mapping and SSM, with the potential to be followed by quantitative modelling. However, the separate elements of the proposed framework - in particular, landscape function systems mapping, conceptual models and SSM - can be used individually to address landscape multifunctionality properties. Nevertheless, it is necessary to be aware of their limitations as individual supporting approaches.

9.5.1 Landscape Function Systems mapping

The proposed spatial elements for landscape function systems mapping are transferable to other landscape scale project areas; however, the resulting maps will depend on spatial data quality and availability.

9.5.2 Conceptual models

The conceptual models developed in this thesis, although not corrected and tested further, can potentially be used as a basis for future development, for example by including additional information pertinent to the local context. Nevertheless, for the development of conceptual models it is important to follow the SSM enquiry cycle, which comprises essential steps towards a systemic thinking process necessary to unpack complexity.

9.5.3 Soft Systems Methodology

This research study contributes to decision-making in landscape planning practice by presenting insights gained from the exploration of SSM as means of promoting landscape multifunctionality. SSM has not been applied in this context before but the findings illustrated that SSM offers key qualities for efficient decision making. Central to this approach is stakeholder participation. This study's results could be of interest to the wider landscape community including the public, landscape planning practitioners, landscape managers, local authorities, governmental organisations, community groups, policy makers and academics. The application of SSM is suitable to support decision-making and is compatible with current environmental policies and planning frameworks aiming to address a wide range of natural and social objectives.

Throughout its different stages and processes, SSM supports communication, dialogue and sharing knowledge. In addition, it was found to be sufficiently flexible to adapt to the resources available, particularly in relation to stakeholder participation, as it can be approached in different ways. Stakeholders can also be included at different stages of SSM: at the beginning, defining issues concerning a problematic situation and providing local context knowledge; and at the discussion stage, aiming to identify where and how landscape practitioners could purposefully take action to encourage synergetic feedbacks or procure additional enquires. SSM supports and values equally the learning, sharing and knowledge generation process in relation to the identification of specific interventions. The findings of this thesis corroborate that the use of the entire SSM stages process (formulating, root definition, concept modelling and comparison) achieves a rigorous, transparent and explicit reflective and participatory process that unpacks and explain complex and unstructured problematic situations. In specific contexts, SSM could support the establishment and monitoring of for example NIAs, landscape character assessments, environment and landscape impact assessment, green infrastructure planning, the European Landscape Convention, ecosystem services valuation assessments, and participatory approaches in landscape planning. SSM limitations in landscape planning practice relate to available resources to collect good data quality and accommodate dialogue opportunities; also participants' attitudes and biases may cause suspicion towards a 'soft' approach, where they have typically been accustomed to quantitative analyses of landscape multifunctionality and ecosystem services.

9.6 Future academic research

Further academic research can be undertaken aiming to increase the credibility and acceptance of SSM in respect of landscape multifunctionality planning approaches. Firstly, if the conceptual models are going to be used in an "off-the-peg" manner, then it is necessary to revise and validate their development. Integrating expertise and knowledge, and further evaluation of the conceptual models through stakeholder involvement, can increase their credibility. There is potential to explore the use of conceptual models in a digital format, aiming to enable instant access between all the proposed landscape function conceptual models and supporting material such as a glossary, landscape function maps and information about potential stakeholder organisations and frameworks. This would include evaluating how conceptual models in a digital format could affect or enhance stakeholder dialogue and interactions with the material.

Further research might explore and evaluate the results from SSM application with different levels of stakeholder involvement, such as stakeholder participation at the *problem formulation* stage, at the *comparison stage,* and at both stages. In addition, future research should examine the follow up or monitoring stages, especially exploring the impact of new co-produced knowledge, and the resonance, responses and actions taken within the wider landscape community, and any further assessments undertaken after SSM inquiry and application. Future research should integrate and assess the contribution or limitations throughout a larger number of stakeholders and wider range of skills and expertise.

This study has shown that landscape multifunctionality properties are important for approaching landscape dynamics complexity in order to encourage and direct desirable landscape qualities including resilience and distinctiveness. Furthermore, this thesis has identified that landscape multifunctionality analysis through SSM is a viable approach to support current landscape practice and policy challenges, especially where these address complex social and natural objectives and interrelationships. They hold particular promise in relation to active engagement and dialogue between the public, scientists, practitioners and policy makers, as well as the potential development of new co-produced understandings, information and knowledge.

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Appendix 1

A1. Initial and preliminary landscape function list before landscape function systems literature review (Chapter 4) and landscape function systems mapping (Chapter 5).

Landscape Function	**Processes or components**	**Ecosystem service**	**State indicator** *How much is present* *(suggested by de Groot et al., 2010)*	**Performance indicator** *How much provides in a sustainable way* *(suggested by de Groot et al., 2010)*
Regulation functions **Regeneration processes**	*The capacity to regulate ecological processes and life support systems* *de Groot, 2006* *Cycling and filtration processes (air, water, waste)* *Daily, 1997*			
Air quality regulation *Millennium Ecosystem Assessment, 2005* *de Groot et al., 2010*	Air filtering *Bolund and Hunhammar, 1999*	Good air quality	85% air filtering in parks 70% with street trees *Bolund and Hunhammar, 1999*	Filtering capacity increases with more leaf areas; coniferous trees have a larger filtering capacity than deciduous trees *Bolund and Hunhammar, 1999*
Gas regulation (regulation of atmospheric chemical composition) *Constanza et al., 1997*	Bio-geochemical cycle: CO2/O2 balance, O3 for UVB protection *Constanza et al., 1997* Carbon sequestration *Whitford et al., 2001*	Climate change mitigation *Constanza et al., 1997; The Mersey Forest, 2009*	Carbon storage (tonnes ha)-1 =1.063 x %tree cover Carbon sequestration (tonnes ha-1 per year) =8.275 x %tree cover *Whitford et al., 2001*	Vegetation types according to their carbon storage potential: Low to none (desert); medium (grasslands); high (forest) *Egoh et al., 2008*
Climate regulation *Constanza et al., 1997;*	Regulation of	Climate		Tree

Millennium Ecosystem Assessment, 2005; de Groot et al., 2010	temperature and other climatic processes at local and global scale *Constanza et al., 1997* Micro-climate regulation at street and city level *Bolund and Hunhammar, 1999*; *Albon et al., 2011* Partial stabilization of climate *Daily, 1997* Absorption of cool air, wind break, decrease of radiation, compensation in temperature *Niemann,1986* Energy exchange *Whitford et al., 2001*	change adaptation, and evaporative cooling *The Mersey Forest, 2009*		transpiration 450 lts of water per day, consuming 1000 MJ of heat energy *Bolund and Hunhammar, 1999*
Natural Hazard mitigation *de Groot et al., 2010* Disturbance prevention *Costanza et al., 1997 ; de Groot, 2006*	Coastal and river channel stability *Daily, 1997* Rainwater drainage *Bolund and Hunhammar, 1999* Damping and response to rainfall *Costanza et al., 1997* Natural soil drainage capacity *McHarg, 1971* Interception of rain and water	Flood alleviation, flood control, storm protection *Millennium Ecosystem Assessment, 2005* Moderation of weather extremes *Daily, 1997*	No-vegetated urban areas 60% approx. Of rainwater is led off to storm water drainage *Bolund and Hunhammar, 1999*	Vegetated ground retains 5-15% of runoff *Bolund and Hunhammar, 1999* Soil drainage capacity *Ryan et al., 2010*

	infiltration *Whitford et al., 2001*			
Water regulation *Constanza et al., 1997 Millennium Ecosystem Assessment, 2005; de Groot et al., 2010*	Regulation of hydrological cycle *Daily, 1997* Regulation of hydrological flows *Constanza et al., 1997* Water cycling, water purification *Millennium Ecosystem Assessment, 2005* Filtration Gradual release of water Evaporation of water *Whitford et al., 2001*	Good water quality, fresh water *Millennium Ecosystem Assessment, 2005*	Ecological quality status, Chemical status *European Water Framework Directive (WFD) Environment Agency*	
Water supply *Constanza et al., 1997; de Groot, 2006*	Retention and storage of fresh water *Constanza et al., 1997* Groundwater recharge *Meyer and Grabaum, 2008*	Water supply, provision of water for agriculture, industry, transport, human consumption *Constanza et al., 1997*	Water consumption rate *Willemen et al., 2008*	The volume of water produced by area *Egoh et al., 2008*
Waste treatment *Constanza et al., 1997*	Biota and abiotic processes in removal or breakdown of organic matter Nitrogen reduction *Bolund and Hunhammar, 1999*	Pollution control, detoxification *Constanza et al., 1997*	-	-
Erosion control and sediment retention *Constanza et al., 1997* Erosion regulation *Millennium Ecosystem*	Soil retention *Constanza et al., 1997; de Groot, 2006* Vegetation and biota in soil retention	Erosion protection *de Groot et al., 2010* Prevention of loss of soil by wind or runoff	Vegetation type and their ability to curb erosion *Egoh et al., 2008*	30% vegetation cover slightly reduce 70% significantly reduce

Assessment, 2005	Soil (dust) sedimentation *Niemann,1986*	*Constanza et al., 1997*		*Egoh et al., 2008*
Soil formation *Constanza et al., 1997; Millennium Ecosystem Assessment, 2005; de Groot et al., 2010 ; Albon et al., 2011*	Soil formation process, microbial processes to decompose organic material and mineral nutrient cycle *Harvey et al., 1994; Wienhold et al., 2004*	Growing medium and nutrients provision for root and plant growth *Harvey et al., 1994; Wienhold et al., 2004*	Soil depth and leaf litter 0.4 mm depth and 30% litter cover 0.8mm depth and 70 % litter cover *Egoh et al., 2008*	
Pollination *Constanza et al., 1997; Albon et al., 2011 ; Millennium Ecosystem Assessment, 2005; de Groot et al., 2010*	Translocation processes, dispersal of seeds *Daily, 1997* Movement of global gametes *Constanza et al., 1997*	Abundance and effectiveness of pollinators		Nest density *Osborne et al., 2008b*
Biological regulation/control Disease and pest regulation *Constanza et al., 1997; Albon et al., 2011*	Control of pest populations *Constanza et al., 1997; Daily, 1997*	Human disease regulation *Millennium Ecosystem Assessment, 2005*		
Nutrient regulation *de Groot, 2006*	Nutrient cycling *Constanza et al., 1997; Millennium Ecosystem Assessment, 2005; Albon et al., 2011*	Support of biomass growth		
Habitat function	Capacity to support habitats for wildlife *de Groot, 2006*			
Refugium functions *Constanza et al., 1997; de Groot, 2006*	Living, breeding, feeding and resting space and conditions for species *Constanza et al., 1997; de Groot, 2006*	Provision of habitat *Millennium Ecosystem Assessment, 2005*	Soil type Groundwater level Nitrogen availability Land cover *Willemen et al., 2008*	
Genepool protection	Ecological balance and evolutionary processes Evolutionary processes and wild species diversity	Genetic resources *Constanza et al., 1997 Daily, 1999 Millennium Ecosystem Assessment, 2005*	Priority species in a Biodiversity Action Plan *Gimona and van der Horst, 2007*	

	Albon et al., 2011	*de Groot et al., 2010*		
Production function	Capacity of a landscape to provide natural products *de Groot, 2006*			
Food production *Constanza et al., 1997* Production of goods *Daily, 1997* Provisioning services *Millennium Ecosystem Assessment, 2005; de Groot et al., 2010*	Soils properties, climate and water availability to support processes of: seed germination, root growth and nutrient and water take to produce biomass *Natural England, 2009; Muller et al., 2010* Photosynthesis, *Millennium Ecosystem Assessment, 2005*	*Edible plants and animals* *Arable production* *Livestock* *Constanza et al., 1997* *Daily, 1997* *Millennium Ecosystem Assessment, 2005* *de Groot et al., 2010* *Portion of primary production used as food* *Constanza et al., 1997;* *Millennium Ecosystem Assessment, 2005* *Raw materials* *Constanza et al., 1997* *de Groot et al., 2010* *Natural fibre, timber* *Daily, 1997* *Millennium Ecosystem Assessment, 2005* *Biochemical resources* *Biomass fuel* *Daily, 1997* *Millennium Ecosystem Assessment, 2005* *de Groot et al., 2010*	Production in ton per ha Soil type Groundwater level (summer and winter) Farm characteristics (location and quantity) Farm size (economic units *Willemen et al., 2008*	
Information functions	The capacity to provide cognitive development (non-commodities) *de Groot, 2006*			
Aesthetic *Natural England, 2009b; de Groot et al., 2010;* *Church et al., 2011*	Aesthetic quality of the landscape *de Groot et al., 2010* Experiencing and interacting with the landscape for cognitive processes and information	Aesthetic beauty, Serenity, Spiritual inspiration *Daily, 1997; Millennium Ecosystem Assessment, 2005*	Landscape designations *de Groot et al., 2010* Negative associations *King, 2012*	-

	exchange, *de Groot et al., 2002; de Groot, 2006; King, 2012* Sensory experience *Gobster et al., 2007* Cultural and artistic information *de Groot, 2006*	Inspiration for art and design *de Groot et al., 2010* Emotional responses, place attachment *Bjørn et al., 2002* Change attitudes *Jorgensen, 2011*		
Recreation *Constanza et al., 1999 ; Bolund and Hunhammar, 1999; de Groot et al., 2010*	Opportunities for recreational activities *Constanza et al., 1999; de Groot et al., 2010* Using the landscape for exercising, escapism, calm *Natural England, 2009b*	Recreation Health and well-being, sense of place *Millennium Ecosystem Assessment, 2005*	Potential visitors *Gimona and Dan van der Horst, 2007* Distance to residence areas Visual and Noise disturbance Cycling facilities *Willemen et al., 2008*	Living space, green open space *de Groot, 2006* Population, residential areas *Willemen et al., 2008*
Cultural heritage *Millennium Ecosystem Assessment, 2005; de Groot et al., 2010*	Sense of History *Natural England, 2009b* Historical legibility Provision of information about history, past generations *Antrop, 2005*	Sense of place *Millennium Ecosystem Assessment, 2005* Place attachment Social learning *Antrop, 2005*	Historic Landscape Characterisatio n Landscape Character Assessment	-
Education and science *de Groot et al., 2010*	Outdoor learning experience *Fjørtoft and Sageie, 2000*	Cultural, intellectual inspiration, scientific discovery *Daily, 1997* Knowledge systems *Millennium Ecosystem Assessment, 2005*	Educational frameworks	
Carrier function	Capacity to provide sustainable medium for human activities			

	de Groot, 2006			
Space for *de Groot, 2006*	Housing Energy Conversion facilities Cultivation *de Groot, 2006*	Providing substrate and space for human activities *de Groot, 2006*		Living space, green open space *de Groot, 2006* Population, residential areas *Willemen et al., 2008*
Transportation *de Groot, 2006*	Green travel routes *The Mersey Forest, 2009* Active transport *Cerin et al., 2007*	Health and well-being	Distance to residence areas Cycling facilities *Willemen et al., 2008*	
Tourism	Opportunities for tourism *de Groot et al., 2010*	Eco-tourism *Kienast et al., 2009*	Facilities and attractions *Willemen et al., 2008*	
Economic function	Capacity to provide marketable opportunities or create wealth *Ling et al., 2007*			
	Support sectors of economy *Benedict and McMahon, 2006* Protection of working land as business Investment attraction	More resources for maintaining Provision of goods	-	-
Community function	Capacity to support social activity *Ling et al., 2007*			
	Connection of communities *Benedict and McMahon, 2006* Building cooperation and collaboration *Selman, 2006*	Social Learning Social Capital	-	-

Potential Databases
1. Defra – Statistics at Defra
2. Environment Agency - Local environmental data and maps
3. Forestry Commission - GIS data download, Statistics
4. Land information systems - Soilscapes
5. MAGIC – GIS database
6. Natural England - GIS dataset
7. Office for National Statistics
8. National Heritage List for England – Designation GIS data
9. SUSTRANS
10. Campaign to Protect Rural England - Maps

A p p e n d i x 2

A1. SSM stage 4 workshop's invitation email

Dear xxxx,

I am writing to invite you to take part in a **stakeholder workshop about Planning Strategies to Encourage Multifunctional Landscapes**. The workshop will take place on **22nd March 2012** in **The National Forest Company premises** located in **Moira, Swadlincote, DE12 6BA.** Your contribution to the workshop would be valuable because of your role and involvement in the shaping of the National Forest.

I am a PhD student in the Department of Landscape at the University of Sheffield working in collaboration with the National Forest Company. As part of my PhD research, I am developing a decision support tool that aims to promote multifunctionality as a basis for encouraging the emergence of new distinctive, resilient and self-sustaining landscapes. The tool includes a series of models that illustrate how landscape functions and processes interact with each other in the National Forest. The **aims of the workshop are:**

- To review the models, by evaluating their success in depicting interactions between landscape functions.
- To evaluate the usefulness of the models as a decision support tool.

The workshop is planned to last about three hours. It will involve a brief presentation and explanation of the models under discussion, and an interactive exercise followed by reflection and feedback. A full program and briefing paper will be posted to participants on 4th March 2012. The proposed workshop agenda is:

Draft Agenda	
10.30	Coffee, welcome and introduction
11.00 -12.00	Session 1 Brief presentation of PhD research and introduction to workshop exercise. Interactive exercise.
12.00 - 12.30	Break - Lunch
12.30 - 1.45	Session 2 Continuation of interactive exercise Discussion and Feedback.
1.45 - 2.00	Summary and coffee

Furthermore, if you know someone else within your organisation that might be interested in attending this workshop, please feel free to approach them directly, or advise me of their contact details so I can invite them. It would be interesting to hear different perspectives from the same organisation, if possible; all are very welcome to attend.

One more thing, to help me to review the workshop, I would like to digitally audio record it, and to retain or photograph any written and visual material produced. The audio records will be kept secure in a password protected computer, and deleted after completion of the thesis. I would like to use and reproduce the written and visual material in my PhD thesis and other publications, providing acknowledgements where appropriate. If on the other hand you prefer to remain anonymous I will ensure that your name and organisation are not referred to in the thesis or any other publications.

Taking part in the research is entirely voluntary and you are free to withdraw at any time. If you accept this invitation, I will ask you to give your formal consent by completing and signing the attached consent form at the start of the workshop. You may wish to read the form in advance.

Finally, this project has been approved through the University of Sheffield Landscape Department ethics review procedure. If you want more information or if you become concerned about any aspect of the research please do not hesitate to contact me (arp09lts@sheffield.ac.uk) or my supervisor, Dr. Anna Jorgensen (a.jorgensen@sheffield.ac.uk).

Your participation in the workshop would be very much appreciated. Many thanks in advance for your collaboration.

Kind Regards
Laura Silva

A2. Ethics consent form

Project:
Planning Strategies to Encourage Multifunctional Landscapes

Name of the Researcher:
Laura Silva

Please initial box

1. I confirm that I have read and understand the invitation email sent in February 2013 and I have had the opportunity to ask questions about the project. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐

3. I understand that the workshop will be audio recorded and the audio files will be kept securely and deleted after completition of this PhD thesis. ☐

4. I agree that any written and visual material produced during the workshop may be used in any report and publications. ☐

5a. I agree to being referred to by my name and organisation in any report and publications. ☐

OR

5b. I would prefer to remain anonymous in any report and publications. ☐

Name of Participant	Date	Signature
Researcher	Date	Signature

Appendix 3

A1. Workshop's briefing paper

Planning Strategies to Encourage Multifunctional Landscapes

Workshop Briefing Paper

22nd March 2013

The National Forest Company, Moira, Swadlincote, DE12 6BA.

1 Introduction.

This workshop, which you have kindly agreed to attend, is being carried out as part of my PhD research. The aim of the workshop is to obtain practitioners' feedback on the accuracy and usefulness of a proposed decision-support tool for multifunctional landscape planning. This briefing paper provides you with some background information in advance of the workshop, and additional information and guidance will be supplied on the day.

I would like to thank the National Forest Company for their collaboration facilitating this workshop and for the provision of datasets used in the production of landscape function maps.

2 Research context and background information.

The main purpose of my PhD research is to examine how certain highly valued landscape characteristics, such as resilience and distinctiveness, can be assisted by various types of planning. Usually, these qualities are 'emergent', and they happen fortuitously over a long period of time. Is there any way that planning agencies can facilitate and hasten their emergence? If so, this would be especially useful in project areas where agencies are trying to create good quality new landscapes fairly rapidly. The literature suggests that, by focusing on 'multifunctionality' we can increase the likelihood of beneficial interactions occurring, in ways that speed up the emergence of a mature and diverse landscape.

Some other important concepts of a similar nature, such as ecosystem services and economic valuation, already exist. However, they usually only consider individual flows of benefits from landscapes, and do not necessarily consider how a whole landscape evolves in association with its local land managers and communities. So, the idea of multifunctionality goes beyond looking at the simple presence or co-location of different landscape functions or services, and looks at ways that functions interact. It is this type of simultaneous interaction that results in fortunate accidents and synergies, in turn promoting the emergence of elusive landscape qualities such as character, distinctiveness, time-depth and resilience.

In order to encourage practitioners to seek opportunities to promote multifunctionality, I have been developing a method that allows people to explore potential interactions between landscape functions. This method includes the development of conceptual models. These conceptual models are intended to be complex enough to capture the numerous physical and social functions of landscape, but also simple, accessible and user friendly.

The workshop will work through some examples of my proposed method to see which aspects of it are most useful, and whether some elements of it would benefit from further development or simplification.

The research methodology

The method is based on an application of Soft Systems Methodology. This enables each key landscape function to be represented as a simple system, so that users can trace the feedbacks and interactions that occur within it. Hopefully, it will help the identification of opportunities to stimulate multifunctionality.

These conceptual models have so far been developed on the basis of existing evidence in the research literature. It is important now that I gain the views of experienced practitioners on how useful the approach might be, and whether there are particular strategic and detailed tasks for which it might be most suited.

Case study: The National Forest Company

The research rationale and methodology has been applied to a specific case study: the area covered by The National Forest Company (NFC). This is an ideal area on which to test a multifunctional approach: it is an area of rapid landscape change; the forest strategy has a wide range of objectives (protect, restore, enhance and conserve); there are several existing partnerships; and it has a comprehensive spatial database.

Spatial representation of Landscape Functions

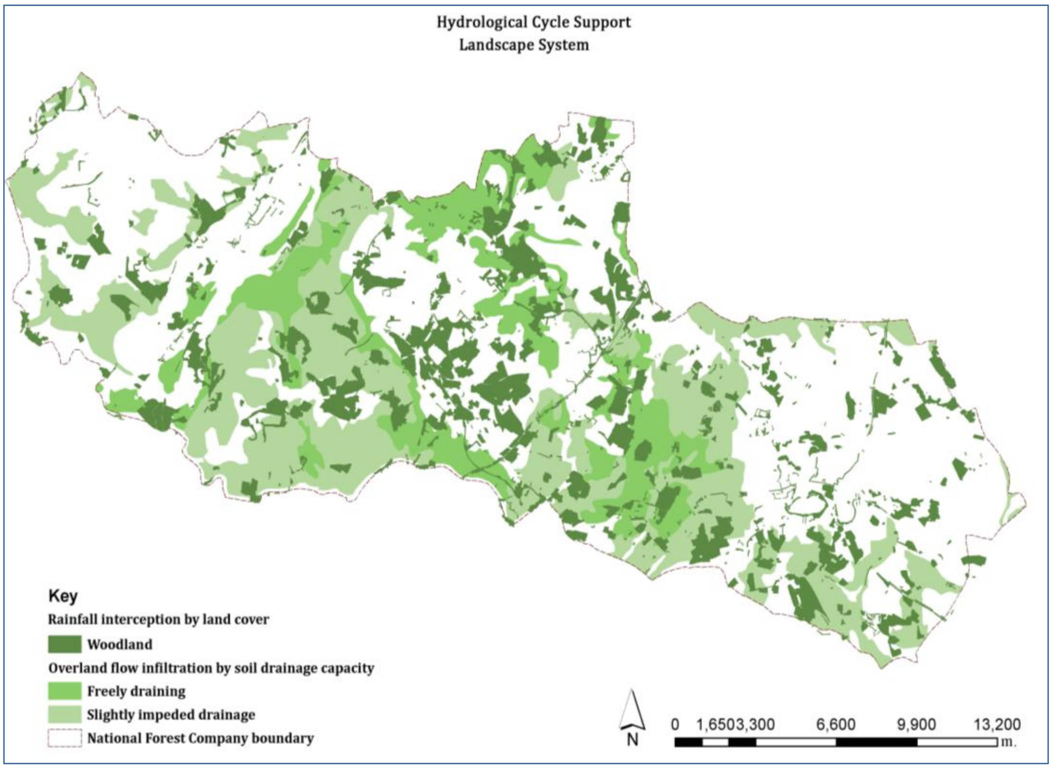
In order to develop the method, I have analysed a range of key landscape systems. Each system corresponds to a landscape function cluster. This landscape system and function list is based on a review and analysis of the literature. The following table lists the landscape systems and functional clusters which have been modelled.

Landscape system and function classification.

Landscape Systems	Landscape Function Cluster
1. Provision	• Provision of food and raw materials • Energy conversion of non-fossil sources • Soil stabilisation
2. Hydrological cycle support	• Interception and infiltration of rainfall • Filtration of overland flow • Water storage
3. Atmospheric regulation	• Air pollution filtration • Carbon sequestration • Microclimate regulation
4. Biodiversity support	• Habitat provision • Habitat connectivity • Pollinator support
5. Information	• Aesthetic experience • Heritage interpretation • Outdoor learning experience • Health and well-being encouragement
6. Community	• Institutional thickness • Economic
7. Carrier	• Recreation opportunities

	• Sustainable transport opportunities
8. Master Model	• Multifunctionality

Then, I developed spatial representations of these different landscape systems to help landscape planners see the landscape and its functions in new ways, and to form the basis for the Soft Systems Methodology conceptual models. An example of the spatial representation of the hydrological support function is given below:



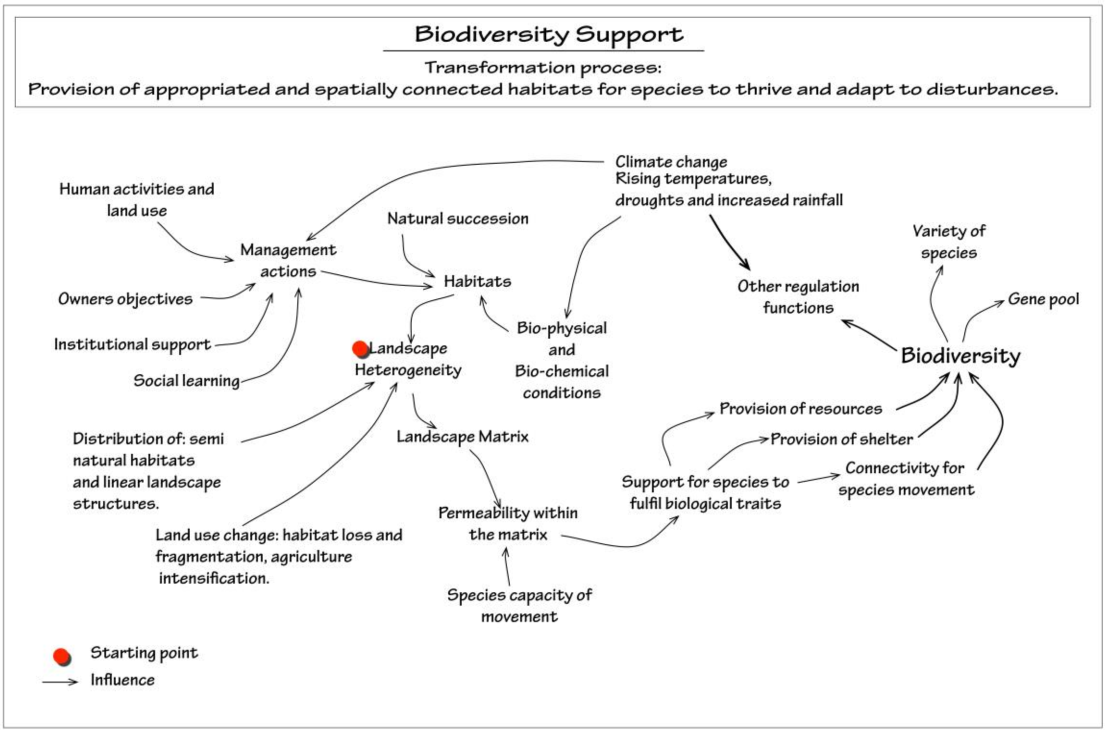
Hydrological cycle support system spatially represented by woodland, as this land cover has the optimal rate of rainfall interception, and by soil drainage capacity. Databases used: NFC, Natural England, Ordnance Survey (OS MasterMap®) and Cranfield University's National Soil Resources Institute (Soilscape viewer).

Soft Systems Methodology

Finally, I applied the Soft Systems Methodology (page 5 contains a table that summarise the methodology stages) to construct the conceptual models. The purpose of building conceptual models is to identify: the activities and elements required within a transformation process, and the feedbacks between human activity and ecological systems, i.e. the dynamics underlying landscape processes and points of intervention.

Apart from the seven landscape systems identified, a further conceptual model has been developed that integrates the 7 landscape systems, which has been named: Master Model.

I constructed the conceptual models using 'influence diagrams'. The elements and drivers, i.e. the inputs of each system, were identified through a review and analysis of the literature. The conceptual models are formed by ***entities*** that represent the landscape function elements and drivers, e.g. process, activities, natural elements, etc.; and the ***arrows*** represent the flows of influences between the entities. For example, an illustration of the *biodiversity support* system model is given below.



Draft conceptual model of the Biodiversity support system

Soft Systems Methodology Stages.

SSM Stage:	Purpose of stage:	Application of this stage to research and case study:
1 Problem Expression	To start the inquiry process, by defining the nature and scope of the problem.	**Problem:** • An area where landscape character and functions have been damaged and where the aim is to accelerate the conditions that will permit multifunctional, distinctive and resilient landscapes to emerge. **Systems to analyse:** • Landscape functions
2 Root Definition	To structure and formally express the system to be explored through the conceptual models. The formal expression is call root definition: this is a written statement describing a *transformation process* (to do X by Y to achieve Z) of the system to be analysed, from a specific point of view or perspective.	**Root definition:** • A system that promotes: multifunctionality, resilience and distinctiveness in the National Forest (NF) by its stakeholders' interventions aimed at catalysing local opportunities, in order to enable a distinctive new landscape to emerge. **Perspective:** • Multifunctionality and its attributes to encourage the emergence of a distinctive and valued new landscape.
3 Systems Models	To build a conceptual model that illustrates and identifies the ideal and necessary activities and components needed to accomplish the transformation described in the root definition.	• Models were developed following **influence diagram** conventions. • **8 systems** were modelled, representing a cluster of related landscape functions. • Each conceptual model was based on an analysis of literature.
4 Comparison of conceptual models vs. reality	To gain insights through a structured discussion using the models to identify desirable changes and culturally feasible changes	**Stakeholder Workshop,** discussion objectives: • Analysis and evaluation of accuracy of models and points of intervention.

	to the system.	• Evaluation of efficiency of models as decision-support tools.
5 Results: points of intervention and recommendations.	To analyse and evaluate the possible interventions and their feasibility	**Next steps:** • Content analysis of workshop results to obtain recommendations regarding: the models and its efficiency as a decision-support tool.

3 Workshop.

The aim of the workshop is to discuss and evaluate the conceptual landscape function models and their potential use as a decision support tool. You will be given copies of models at the workshop and asked to annotate and comment on them.

Workshop objectives.

In order to structure the proposed discussion we have two main objectives:

1. To review the models, by evaluating their internal validity and their success in depicting interactions between landscape functions.

2. To evaluate the usefulness of the models as decision support tools.

Consequently, the workshop is being organised in two sessions, each focused on one of the above objectives.

Participants' case study.

As a final favour, we would like to ask you to bring a case study or an example of a particular landscape in which you have been involved, and which displays actual or potential multifunctionality. If possible, this should be located within the National Forest boundary. On the day of the workshop, please bring the following information about your case study (2 sides of A4 maximum):

- **A general plan**
- **Location**
- **Approximate size (hectares or sq km.)**
- **Brief physical description: land use, habitats, topography, etc.**
- **Brief explanation of: situation, assets, problems, land use change, etc.**

Nevertheless, if you cannot bring a case study, please do not worry, as is not essential for the workshop. Furthermore, at the end of the workshop and with your permission I would like to keep the case study information.

The following page contains the workshop programme.

4 Workshop programme.

Time	Activity description	Duration
10.30 Welcome		
	Coffee and tea. Welcome to participants. Signing of consent form. Handing out workshop material and exercise guidance.	20 min
Session A		
10.50	Formal introduction of research team and participants.	10 min
	Presentation of research context, aims and methods and workshop purpose and objectives.	10 min
11.10	Introduction to: Session A Exercise	5 min
11.15	Review and evaluation of landscape function models	60 min
12.15 Lunch		
Session B		
12.45	Introduction to: Session B Discussion	5 min.
12.50	Group discussion: Models as a decision support tool	55 min.
1.45	Debriefing and coffee and tea	15 min.
2.00 Finish		

Appendix 4

Workshop's supporting material

A1 Glossary

Note: Some of the following definitions are taken from existing texts, but in order to create a readable document, we have not included references in this document. A fully referenced version of the glossary can be provided on request.

Aesthetic experience	The arousing of emotions, associations, preferences, attitudes and meanings towards the landscape through landscape perception.
Active transport	To travel by undertaking a physical activity such as: walking and cycling.
Anthropogenic activities	Human activities that have impact or effects on environmental processes.
Biodiversity	Diversity of plant and animal life in ecosystems, habitats and species.
Biophysical landscape elements	Biotic and abiotic factors that influence species' capacity to inhabit a particular environment; e.g.: temperature, light, humidity, soil nutrients, etc.
Carrier function	The spatial capacity of the landscape to allow and encourage human movement throughout it.
Catchment area	The area from which rainfall is distributed into components of the hydrological cycle.
Climate change	The change in global climate patterns attributed to increased levels of atmospheric carbon dioxide.
Cognition	Mental processes that influence preferences (distinct from affect or emotion); e.g.: attention, memory, learning and decision-making.
Corridors	Linear patches that connect other patches together.
Deposition	The placement in new areas of transported sand, mud, dust, stones and silt by wind, water flow and human activities.
Habitat	An area that is inhabited by particular species of animal and plants.
Heritage legibility	Evidence of natural and cultural heritage in the landscape.
Information function	The encouragement of positive cognitive processes through landscape experiences and perceptions.
Land use	The designation of human use of the land.
Landscape character	"A distinct, recognizable and consistent pattern of elements in landscape that makes one landscape different from another, rather than better or worse".
Landscape connectivity	The degree to which landscapes aid or hinder species movement.
Landscape composition	Number, variety and abundance of patch types in a landscape.
Landscape experience	Active or passive interaction with the landscape.
Landscape heterogeneity	Uneven distribution, diversity, density and species richness of patches and elements within a landscape.
Landscape management	Ongoing purposive human action to shape and maintain the land.
Landscape matrix	The most dominant and connected landscape element in

	ecological systems: the 'background' landscape in which patches and corridors are situated.
Landscape permeability	Physical connections and quality of patches that enables species movement through the landscape.
Leaf stomata	A pore in the epidermis of leaves and stems that controls gas exchange.
Locality goods	Goods directly linked (by a specific semi-natural habitat or by a specific production) to a particular landscape and community.
Microclimate	The highly specific weather and growth conditions of a limited area, influenced by local geographic and atmospheric factors.
Natural succession	The development of an ecological community from pioneer species to complex communities over time.
Surface runoff	Water flow that occurs when the soil is infiltrated to full capacity and excess water from rain flows over the land.
Patch	Non-linear areas or units of habitat that are different from their surroundings.
Place	The characteristics attributed by people to a specific location
Place attachment	The development of positive preferences, associations, meanings and attitudes towards a place.
Photosynthesis	The process by which plants use sunlight to synthesize nutrients from carbon dioxide and water.
Rainfall	The total precipitation occurring in an area; includes: rain, snow, hail and sleet.
Semi-natural habitats	A habitat largely formed by native plant and animal species but influenced by human use and management.
Social capital	Benefits derived from networks of trust and common interest groups within a particular community.
Social learning	The result of combining 'expert' knowledge and local 'experience'.
Space	A specific area or location often set apart from its surroundings by its physical characteristics.
Stream flow	The flow of water in streams, rivers and other channels.
Water management	The careful and systematic control and use of available surface and groundwater for human purposes, e.g. agriculture.

A2. Guidelines for exercise in Session A

Review and evaluation of landscape function models

1 Session A objectives

The ***objective*** for this session is to review the models by evaluating their success in depicting:

- **a.** The processes, elements and dynamics of landscape functions.
- **b.** Positive interactions with other landscape functions that accelerate the emergence of landscape distinctiveness.
- **c.** Influences, linkages and/or points of intervention that enhance or hinder the landscape function.

2 Landscape function models

The models have been developed following a ***Soft Systems Methodology*** framework and ***influence diagrams***. The models comprise ***entities*** that represent the landscape functions, e.g. elements, processes, activities, etc.. The ***arrows*** represent the flows of influences between the entities.

The different colours of the entities represent different landscape systems e.g. elements of the 'hydrological cycle support system' are represented with blue colour. The thickness of the arrows represents different types and/or strength of the influences, e.g. dotted arrows refers to negative influences. To read and analyse the models please start at the entities marked by a red circle, then follow the arrows as necessary.

3 Exercise

Groups

You will be allocated to a small group. Each group will be assigned a selection of the seven landscape system models (provisioning, hydrological cycle support, atmospheric regulation, biodiversity support, information, and community) and an overall master model.

Analysis

Please, with your own case study in mind, could you identify, discuss and modify as necessary the conceptual models, using marker pens and post-it labels. We are particularly interested in your views on the following questions:

Q1. Do you consider that the model correctly chooses the most appropriate entities and links, and represents them correctly?

Q2. Do the arrows have the right thickness in proportion to the level of the influence?

Q3. Are there any missing entities or arrows that you think have an important role to play in helping positive interactions to occur in the landscape?

A3. Guidelines for discussion in session B

Models as a decision support tool

1 Session B objectives

The ***objective*** for this session is to discuss the ***usefulness*** of the landscape function models as decision support tool in terms of:

- **a.** Usability
- **b.** Feasibility
- **c.** Credibility
- **d.** Relevance and impact of the decisions facilitated by the models.

2 Discussion Guide

This research study proposes the use of Soft Systems Methodology and conceptual models as a framework and decision-support tool for the understanding and encouragement of landscape multifunctionality. We would like to hear your thoughts, experiences and perceptions on the usefulness of the conceptual models and Soft Systems Methodology as a decision-support tool.

Within your groups, please comment on and discuss the following questions. Use the flip-chart sheets to write your comments. After you have done this, we will ask someone from your group to present a summary of your group discussion to all the workshop participants.

Questions:

Q1. What do you think are the benefits of using the conceptual models as a decision-support tool?

Q2. What do you think are the limitations of the conceptual models and their application in landscape planning and management?

Q3. Do you think that the information contained in the models is correct, credible and reliable as part of guidance to support your decisions?
Do you have any comments or recommendations concerning their credibility?

Q4. How easy was it to understand and untangle the different 'layers' and complexity of the landscape system models, such as: processes, drivers and services? Please, give an example to support your answer.

Q5. Do you think that the conceptual models represent the landscape system's processes and influences at an appropriate landscape scale? Why?

Q6. What is the potential of the models to influence decision-making among stakeholders?

Appendix 5

A1. Analysis coding agenda

Codes	Results/findings	Citations
Codes from purpose of SSM stage 4, comparison of conceptual models		
Identification of changes to the landscape systems		
Potential changes:		*"a process can be landscape management and the outcome of that is habitats, but the driver for that landscape management could be government initiatives, so you can be because we talk between ourselves about the fact that we can't directly affect habitats what we are affecting is the landscape management that delivers the output"(Transcript 1, p. 2)*
Desirable changes		
Cultural changes		
Codes from research question		
Understanding of landscape systems dynamics	[conceptual models] a natural way to present and follow them [landscape functions] through	
Identification of interactions between landscape functions	Identification of interactions with potential either positive and negative influences, depending on, for example the right government initiative	*"sort of processes that happen positive or negative influences, for example government initiatives, the right government initiative can have a positive effect, the wrong one can have a negative effect and so maybe having a third type of line, that is almost depending on that process, might be something to consider in the diagram" (Transcript 1, p. 2)*
Use of conceptual models for decision making		
Use of conceptual models to foster landscape multifunctionality		
Spatial representation of landscape systems		
Identification of points of interventions		
Codes from workshop aim and objectives, in terms of decision support tool analysis		
Conceptual models	Presenting to other	*"…benefits of these conceptual*

benefits	people, particularly to be used in "stakeholder and community engagement"	*models is the role they play in stakeholder and community engagement, the means for people to share their own perspectives on things, good way to share their perspectives and to draw out things that are relevant to individuals in a particular landscape…"(Transcript 2, p. 1)*
	Identification of issues beyond area of expertise	*"…the beauty of something like this is that actually forces us to look outside of our area of expertise so instead of working on these islands, say I am coming from these regular point of view I know exactly where I need to get to meet my own objectives actually I am forced to say well actually wait a minute how does this fit in with other actions perhaps delivered on the sort of my objectives of what I do, how can I work with others, what are the issues that I need to have regard to…"(Transcript 1, p. 5)*
	Good to stimulate discussion	
	Conceptual models to be used as "check list" to identify the range of landscape services that the landscape could be delivering	*almost could be a check list for the range of services that you would like to get form a landscape so you don't want to be too strict oh we haven't got that, but it helps you think through other of the things could come out through this landscape. (Transcript 1, p. 3)*
	Valuable to be used as a "disciplinary way of thinking", being important the process of developing an	*"so you don't have to put your penny on and see what comes out, is not about the outcome, is about the disciplinary way of looking at things, for that it is*

	understanding and thoughts developed.	*very useful" (Transcript 1, p. 3)*
	The benefit of the certain flexibility that SSM offers on how to use it and/or develop the conceptual models; which could develop of sense of ownership	*"… so its own by the person is using it so it is not something done to you…" (Transcript 1, p. 3)*
	Thought provoking	
	The use of conceptual models as potentially useful on "collaborative planning exercise" as a way to help people to develop an understanding. Because participants identified that the use of conceptual models seems appropriate to help to communicate with other professionals.	*"…I can see these things [conceptual models] laid down in the table and people drawing in them and would help them to think through if we use the maps [conceptual models] as it is, is another way to help people to think perhaps…" (Transcript 1, p. 3),*
	Helpful to encourage inter-disciplinary sharing of ideas, as each landscape system conceptual models represent different disciplines and offers an opportunity for people engage in different disciplines to express their knowledge and expertise	*"…with kind of different disciplines almost, some people will find they relate more to one than another and perhaps that leaves space for everyone to have an opinion or something…"(Transcript 1, p. 3),*
	The flexibility that SSM as discipline could offer the opportunity to change the links or elements to adapt to different situations. Another reflection of flexibility regarded the use of SSM from the outset was the opportunity to be more clear and use more appropriate vocabulary and terms according to context.	
	The conceptual models and SSM seem	

	appropriate to use on other stages of planning, giving a "temporal dimension", for example to be used to track changes and monitoring or follow up stages. Another potential use identified was to be used as part of an economic valuation exercise, as to identify priorities or where to focus to "take a look in the valuation process"	
	Flexibility about the use of the models and their purpose	
	Participants recognised that the use of models could be "universally" applied, allowing different for example local government to ask the same questions and potentially "join up our thinking"	*"…the beauty of a model like this is in some respects is universal whether I was a planner in East Staffordshire, Northwest Leicestershire or South Derbyshire it would ask the same questions, so it might actually allow me to join up our thinking with what is happening over the boundary and quite often we don't do that, we work in our administrative area and obviously if lots of organisations choose a model like this then is asking the same questions that actually those links would possibly be better that what they are now, so from that point of view I think is very useful…" (Transcript 1, p. 6),*
Conceptual models limitations	Lack of immediate accessibility to conceptual models elements, that link to others and are important for understanding	
	Having a good glossary Researcher comment: It is	

	not clear if the participant didn't realise of the glossary given, of perhaps the glossary was not good enough, or refers to the need of immediate accessibility to it.	
	People different forms of learning, and how this might support or not the use of diagrams against the preference of using for example lists, Apart from specific comments the participants made regarding the preference of list against diagrams, they shared what was their mechanism that help them to focus on the conceptual models	*LO"…and we also thought that like AP as a planner saw the planning process and that's put easier, that was useful for him to wider that out, whereas, my point of view I think took all the arrows away, that was my thought processes to allow me to focus…* *DB..You see mine was the opposite take the text away"*
	We are quite comfortable with soft systems ideas and conceptual models, but I wonder how natural scientist might feel about this conceptual and this kind of stuff. *One of the nice things about soft systems is that you can take it in two directions, a simple direction if you like with rich pictures for people that don't get into mathematical stuff at all with a very accessible level, the other direction you might quantify these with sign graphs and mathematical to describe the systems. It was certainly inacceptable for some natural scientist*	

	(check audio) *Probably it needs to clarify what is the purpose of these models for example to start dialogue* *I think that's the key* *Then to explore the complexity and what to review from that dialogue* *In collaboration* *Then perhaps the scientist can go* *And do the maths* *transcript 2, p. 9*	
	Vocabulary and terms used within models require to be reviewed, as some of them have different terms but have same meaning, however if there is a reason to have two different terms a suggestion to represent them graphically as they part of each other. Apart from vocabulary that might have the same meaning, the limitations regarding vocabulary or terms used and how they are "pre-conceive" by people, which raised questions about "…are talking about planning or forestry?... or planning from a professional point of view?... when you are talking about interactions… interactions with the public? Are they interactions with different pieces of models?" (Transcript 1, p. 4) This came issue came	*"One of the things we found in the biodiversity model there were a couple of times where almost the same concept is represented in two different blobs an example we had was biodiversity represented separately from variety of species, whereas I think it is almost two different expressions of the same thing" (Transcript 1, p. 2)* *"…so the model because very complex so you might have forestry in one part and something else, no you might have forestation in one part deforestation in another*

	more clear as it was identified how participants interchangeable used different terms to describe the conceptual models, for example: “different pages”, Another example of vocabulary issue as the same participant corrects himself:	*part..” (Transcript 1, p. 5)*
	Within the conceptual models it was found some overlaps and gaps, and explored the idea of conceptual landscape elements being able to expand or collapse according with context or interests. Would an electronic version could give this flexibility and adaptability required?	*“…so we have I with the air quality and atmospheric regulation model, we had about four different things which they could collapse into one, probably from my point of you, but from others point of views you might want to expand them, so again that comes down to the adaptability of the models…”(Transcript 1, p. 4)*
	Difficult to identify and differentiate what are processes, drivers and outcomes. And the importance to being able to notice the difference is because participants agreed (Sam and David) that processes are the points of interventions to carry out the necessary changes.	
	Potential users’ biases that affect people decisions For example, during workshop two when	*“…but before I stop pit myself on my own biases, and is how on earth do you make sure that the model actually make me put those to one side and actually look at it, bringing wider issues into the full process and decision making that we go through on my authority…”(Transcript 1, p. 5)* *“We still need to me the targets set up of biodiversity*

	discussing the importance to have the right mind-set from the beginning, which is start from wider objectives instead the objective of single species, this comment highlighted the biases and compromises that organisations have to achieve.	*by 2020" (Transcript 2, p. 3)*
	Planning authority recognise as well as o use and understand the models	
	The use of models requires some guidance to be used and understood properly, which participants proposed to use "spoke training" or a "drop down list" which refer as well as preferred method for learning/understanding.	
	One particular group discussed the "real" purpose of the exercise outcome, and identified that perhaps was more useful for better decision making or an "environmental management tool"	
Information within the conceptual models to inform decision making	Identification of elements: processes, outcomes and drivers, because participants identified that processes are the elements that they can influence to lead a better result, so from this derived the recommendation to differentiate those elements graphically.	*"we can't directly affect habitats what we are affecting is the landscape management that delivers the output and whether that's something needs to be or could be presented as you could see this is the result but this is the process that lead us to it… so yes that's where we need to influence things because that would lead to a better result here and if that could help" (Transcript 1, p. 2)*
	The links and relationships (interactions) were	

	important to develop an understanding	
Limitation to check	Through the use of the models, participants identified that models provide information or "pointers" to organisations and their functions that could inform decision making, and then suggesting that if possible that conceptual models contain more information about the organisations regarding their functions, and how they could interact	*"… one of the things we talk about things about the European Landscape Convention, is like I am aware of it but is something that not necessarily informs my decision but actually it should do, ________ (to check audio) quite often a lot of planning authorities we don't _____decisions that we take, so I don't know whether there is room for the model to try forcedly make the case this is why you need to be looking at this because actually it help you to fulfil you statutory responsibility…" (Transcript 1, p. 6)* *"…it helps you to see how you might help other organisations or other aspects, but I think it also enables you to see how other organisations or other aspects can actually help you to achieve your goals…"(Transcript 1, p. 6)*
Recommendations to improve credibility	Importance of glossary to address a wider audience	
	Opportunities to have conceptual models in an electronic version, allowing the users to click on models' elements and glossary and have immediate access to their content.	
	Requires more exercises such as "this" workshops, to work with other people and to test and challenge the models	
	How people could contribute to the "growth" and improvement of the models through the years to including lessons learned, to grow	*"whether in the longer term to keep it dynamic, I might get this wrong but in a sort of wiki approach, were people come an edit it, to actually add things to it, so doesn't become this is the snapshot of now but*

	"organically effective"	*because we are constantly learning and new things come out and new lessons are learned it could be add to it, it can be built upon, so keeps growing organically effectively" (transcript 1, p.2)*
Effectiveness of conceptual models to understand landscape functions complexity	Importance of the relationships between the different layers [conceptual models] and importance to access to them "simultaneously"	
	Very useful, to have "something in paper" that required participants to work with, and prompted to make them think about the processes and interactions between landscape functions, then going through the process was very helpful to perceive relationships and concepts that perhaps wouldn't be identified before	*"…it help us understand the information that we don't know, the relationships that perhaps we ought to be considering but often we don't…"(Transcript 1, p. 5)*
	Opinions regarding the graphic presentation of the systems were positive, but participant again wonder how other people acceptance of the conceptual models depending on their learning style	
	The group that reviewed the master model during workshop 1 identified that the Master model found it too complex, with many terms duplicated, but mentioned that did have the chance to "get use to the process", suggesting that perhaps going throughout another individual conceptual model before focusing on the master models could	

	be more helpful to understand its complexity	
	This proposed methodology does not give an specific answer and requires that the objective of the models to be very clear, is about collaboration and dialogue.	
Spatial scale that landscape systems represent	From the perspective of conservation charity representative and national park representative, they agreed that the application of these conceptual models is appropriated to landscape scale issues, because the identification and integration of issues is complex enough to represent the landscape scale, which would be difficult to apply to a landscape unit.	
	Identification of conceptual models flexibility to be used in different spatial scales, but contradicts previous comment as they recognise that use of the conceptual models within land cover units, arguing that at a bigger scale, it is very complex with parts of the landscape delivering forestry and something else somewhere else .	
	During workshop 2, discussion landscape scale ranged from National character areas to small landscape scale Another point of view regarding the spatial scale application of the conceptual models was	*"…to the natural character areas which ______ all the attributes of the landscape but looking at how those attributes are self-supporting each other, or not as the case might be, that sort of scale might be to big or to difficult to deal, may be with small*

	that they thought that the models are appropriate for landscape scale application. During workshop two it was highlighted the importance of landscape scale, however they recognised that the same principles could be applied to a smaller scale	*locations this is when it stops to be real…" (Transcript 2, p. 4)*
Potential of conceptual models to influence decision making	Positive acceptance and very strong. *Yeah, the whole issue of interactivity we having struggling for a while (check audio) unpack all the information to back it up, systems and soft modelling is better than say Andy and I think, you got something to back that up, so yeah absolutely, but again you need think how to place these through, next steps, next points is how practical this is, the practical use in the ground the way we are going, with much more focus on the local areas and how you connect people, that is coming back strongly, this the type of information to validate or apply in the local (check audio), how the national character areas descriptions, how theses systems will be identified in a fair large scale, how do then use*	*" broadly seems really good process" (transcript 1, p.2)* *"…we thought they [conceptual models] have the potential to produce a more holistic better quality decision because you are thinking about the whole…" (Transcript 1, p. 5)*

	that with the locals to engage (check audio) local landscape (check audio), there is room for, hopefully space for us to go back to them and say OK you have identify all the attributes but how they are interacting together, is there really a full understanding of how the landscape works and then how to communicate that to a community is ______ different until______ how to communicate *Transcript 2, p. 10*	
	Another practical implication participants found essential is the appropriate "mind-set" required to truly achieve landscape multifunctionality, which they recommend to start from a wider point of view rather and a single point of view Recognising that is necessary to have a "package" together that represents true multifunctionality with its multiple benefits Participants criticised Natural Improvement Areas, which their objective is about "interaction and integration" , but still there is lacking something that is putting things together and still are not answering: how are they interacting? Projects are still missing to have true multifunctionality from the outset, by looking at	*"... this idea of how the outcomes, might be at the bottom of the page, how we actually get to look the upper levels of that, how they could interact to increase the multiple benefit... Sorry is almost by design that you aiming for this multiple benefits and that's the position that we want to get to, we want to be designing the landscape which will create more benefits..." (transcript 2, p.3)*

	the "upper levels " where the processes and elements are, But this relates how this objective is presented to the landscape partners.	*"…In many ways it is a presentation level, is putting the functions and services, it is almost to getting this partnership to accept that we are all working for the same thing, what you said before… is very interesting about different partners picking different aspects of the model but somebody has to be overall above that if you like, putting it together, how does this collectively?*
	The thing to "show" and "demonstrate" in order for this proposed methodology to be used is: "to show the positive interactions in a n area and how it works together"	
	to being with you need to have that [GIS], even if it is very basic GIS pointing out where this functions are occurring to our best knowledge and that knowledge is not very perfect but then you can start to home in with the potential partners of a particular area, they would have a very basic understanding of how this landscape function, now we need to understand how it is working together or not, and that's when you start to build this idea of how landscape has evolve and it is now, and until you got that you can't extrapolate forward at all	

	p.6 *Does the national forest, do they indicated that they will continue to work with them? To look the application of these? Is there a particular work stop because stakeholder input feeding to_______________* *They have same question as you as well, what is the end product?* *Is there something that they might apply? or* *There was positive interest , they said they could see the usefulness and that they intend them to use them* *But that's not part of your specific PhD* *Check audio … it needs reflection* *I think it could be a post doc grant to developed further to a point of an app or commercially usable thing* *Check audio,* *I think models need to be more tested to be more valid* *I think there is definitely stuff here we would take (check)* *Yeah, certainly there is* *In terms of ideas, check audio, about interactivity,* *This is relevant in terms and thoughts around the whole systems science idea and gathering data for people (check audio) gathering information (check audio) very good benefits to start to built transcript 2, p. 9*	
New codes		
Practical application / implication	How to consider or avoid or minimise "Biases" and	*"… I mean models are great, but before I stop pit myself on*

	"Attitudes towards decision making tools (Transcript 1, p. 5)"	*my own biases, and is how on earth do you make sure that the model actually make me put those to one side and actually look at it, bringing wider issues into the full process and decision making that we go through…"(Transcript 1, p. 5)* *We still need to meet the targets set up of biodiversity by 2020 (Transcript 2, p.3)*
	On workshop 2 participants didn't found at the begging of the discussion what could be the final outcome and how to represent it and how would make to a better decision, however the discussion gave room for participants to think and that came to a better idea of what the outcome is: about sharing ideas and communication	
	During the workshop 2 participants devoted a considerable amount of time to discuss the role, relationship and importance of spatially represent: **The landscape functions** **Hot and cold spots** **The outcome of the analysis of the conceptual models,** this topic raised the following questions: How to represent the results spatially? Is this necessary?; after the stakeholder participation	
	How the use of technology, computer modelling could affect	

	the accessibility of the models?	
Overall methods	The discussion during workshop two, started with a general concern of how to use the conceptual models and what implications are in practice and reality, and what would be the end product, nevertheless, as the discussion progressed ideas between the participants were clarified by the discussion and they came to the conclusion of the following proposed framework: 1. The adequate mindset from the outset of any project at landscape scale *"… is almost by design that you aiming for this multiple benefits and that's the position that we want to get to…" Transcript 2, p. 3* 2. GIS landscape functions, locate where the landscape functions might be occurring, then you identify hot or cold spots, where landscape functions seem to be overlapping Localisation of hot and cold spots could help to prioritise and have focus to do research or data collection into the area	*"… How do you use it? ..." (Transcript 2, p. 3)* *"…but is the way we presenting the outcome to get more bangs from your buck rather than start from a single focal point of view, so where all this help in all of that?" (Transcript 2, p.4.)* *it is useful to have the GIS, to my mind is indicating where an area within a large area which is worth the further investigation where you can then bring these conceptual models into play to start to understand the interactivity between those layers, I think that's when you start to get a better understanding of how the landscape has evolve, how it is now and therefore what interventions do you want to do now so it is functioning better in the future (Transcript 2, p. 5)* *"…and that's when to start getting down together discussing with stakeholders to view things, but then the whole issue of how to communicate is different to professionals, so the idea of using conceptual models is I think is absolutely appropriate..." (Transcript 2, p. 2)*

	3. Conceptual "diagrams", to be used to "unpack" and follow all the potential interactions occurring as illustrated in the GIS mapping. Each conceptual model is related to other conceptual model, as one participant from workshop two describes them: "almost to stack this in tri-dimension in layers", coming to the conclusion that you require all the conceptual models to be looked at. 3 End product: exploratory exercise with site's stakeholder, being the processes of sharing the ideas of what can be done One of the supervisors of this thesis, as being able to be present at both workshops, mention her perspective on how during workshop one how to be focus on a particular situation (in that case was the participants' own case of study) give focus and context and some practical implications were easier to "appreciate" What is the outcome comparing the analysis of the conceptual models in cases when there is not an specific are where to focus or in cases when a	*"… it is actually of putting it in the table and presenting it, which starts to get people think but actually here is an area we want to increase the number of red kites in this particular area and that's all we worry about for a large geographical area and others will come out well hold on why are you doing that don't you realise that you could benefit from this stuff and from the other, it is almost the mind set to start rather than starting from a single point of interest that you going to lets broader that out, yes, red kites might actually be interest but there are some many more benefits you can have by intervention and by partnerships in a particular area, we haven't got there yet, but everything we are talking about is this idea of integration of multiple benefits joined out…" (Transcript 2, p. 3)*

	particular area has been already identified	
	Analysis and review from one participant regarding the overall methodology: *"… the mapping you have done with the National Forest that shows the hotspots you can actually have somewhere which seems to indicate nothing but intuitively we know that field that it is not showing anything will have functions, it is functioning no matter what you think and just happens that you don't have any data or you might say there is a community here that really want to do something with the material, there is all sort of ways you can use that material but at least got something, it is done something to try and gather a basic understanding of how a landscape is functioning, and I you said is pretty two-dimensional, it is not telling you a lot maybe but where else do you start? If that modelling and mapping isn't any use at all, you can say, well in that case here is a community, we want to work with them, forget about the mapping lets got straight into this [SSM models] would that work? I suspect it probably would, why have that functional mapping to begin with?..." p. 6* Research came to the	

	conclusion that GIS mapping did not illustrate relationships	
	GIS with interpretative date is on the contrary more helpful: *I would agree, I would say we cannot get away because is nothing else than the start of a process and is gathering some information as you say is probably showing some associations between the functions, great, my lead is to start to think more definitely like the pollination stuff for example, which my mind then, this when you start applying this sort of information to test those associations and how the partnership look over these particular systems within the particular focus area could be a hot spot, a cold spot or somewhere you don't have information at all, it doesn't really matter, but you started of with something which show you something in terms of associations or not and you go out and test it and you start to get into the skin of what is happening in that particular physical location I think that's where these are coming together and that's when partnerships will be looking at the information now, you look to a small area, well it says there is an information layer here, how is that associated to other elements, the initial GIS suggest this, is that*	

	right?, and by looking then at this you can say, well, what other parts of landscape experience is that people gathering in this particular area, is information feeding into that?, is there a healthy walk, sustainable cycling routes? , and you start to put a picture together, that's when you start to understand how the interactions might be occurring, this the bit we really haven't got to it at the moment in a lot of places, there is still something niggling in terms of, in almost what did you say Andy, map back how all come together in a master map, which start to find out various points of interventions, partnerships and stuff together, but then some organisations _____ this is how I try to simplified in my mind, I don't know if that works or not_________ transcript 2, p. 8	
Current projects looking at multifunctionality?		*"…Still how this come to together to show the positive interactions in an area and how it works together, that's thing to show and demonstrate, I don't know if the actual functioning mapping, if you like, the function analysis of places is actually happening yet, I mean as far as I am aware, you guys might think different, but is there any physical project that has actually look at the present functions of that landscape, how is functioning now? And than taking that*

		looking at the various attributes that might or might not work together, but this how we want the landscape to function in the future…" (Transcript 2, p. 4)
	ELC areas contains information regarding: "…functions, systems, things happening but how they work togetheror how they should work together and how do we foster that to work together so they do support each other" transcript 2, p. 4	
	and I haven't seen any project that has come back to me and say this is truly multifunctional understanding how the landscape is really working and more important back to the whole talk that we are doing here is how they interact together, negatively or positively, and I think this is fundamental to what you are doing .p. 6	
GIS	Participants described existing data to map landscape functions is limited and crude, practicioners regonise that proxies are simplistic and you cannot rely on them; but how to demonstrate that attributes are: "working together" The GIS role:	*"… yes we have all these attribute out there, all this functions, systems, things happen but how do they work together or how they should work together and how do we foster that to work together so they to do support each other…" (Transcript 2, p.4.)* *As I was saying before is to help you to identify somewhere where you might be focusing on a little bit more, where you can apply this a bit more, acting as a direction of where you should perhaps look at, because it is only giving you that almost*

	Conceptual models and information such as: historic elements and interventions, because Hot spots does not mean positive interactions are occurring	*two-dimensional, these where things are or located, we don't know actually ________, is this the initial mapping where to look at and apply this in more detail? What could this [maps] telling us?* *…So it is just indicating something, in terms of where we want to go in this sort of discussions it is indicating the direction of where we should focus on more* *… As suppose, some people say start with what you got and that sort of hotspot mapping gives you the best spots if you want to take some drivers*
	Important of GIS as an end product, in current landscape practice, although practicioners are recognising the limitations of functions mapping	*"My question about GIS map because I thought this should lead to an end result, I think we can only have soft systems element only to be successful **check audio** we are in a world were the GIS mapping seems to rule, you know, and seems to be less emphasis on the people engagement side, it takes quite an investment to do that" (Transcript 2, p.5)*
	During workshop participants asked if GIS mapping was the ultimate goal of the method, and it was explained is more "in terms of thought process" *But even that's changing though, even now colleagues recognise that*	*My question about GIS map because I thought this should lead to an end result, I think we can only have soft systems element only to be successful **check audio** we are in a world were the GIS mapping seems to rule, you know, and seems to be less emphasis on the people engagement side, it takes quite an investment to*

	proxies are sort of simplistic *Yes, you cannot rely on them* *Transcript 2, p. 5*	*do that Transcript5, p. 5*
	Participants interpretation of **hotspots:** *"…As I was saying before is to help you to identify somewhere where you might be focusing on a little bit more, where you can apply this a bit more, acting as a direction of where you should perhaps look at, because it is only giving you that almost two-dimensional, these where things are or located, we don't know actually _______, is this the initial mapping where to look at and apply this in more detail? What could this [maps] telling us?..." Transcript 2, p. 4 and 5* *"…So it is just indicating something, in terms of where we want to go in this sort of discussions it is indicating the direction of where we should focus on more…" Transcript 2, p.5* *It is identifying some of the layers? So that's what shows overlapping some of the functions, here you got 12 overlapping rather than just 3 over there, therefore do we look at that area with hot spots with more layers then apply this to understand how does functions are*	

	interacting together which again you have to bring the historic elements, interventions to understand how that hot spot is working, the interactivity which is the core what we are after, which hasn't been look at interactions in many places *Transcript 2, p.5* *, it is useful to have the GIS, to my mind is indicating where an area within a large area which is worth the further investigation where you can then bring these conceptual models into play to start to understand the interactivity between those layers, I think that's when you start to get a better understanding of how the landscape has evolve, how it is now and therefore what interventions do you want to do now so it is functioning better in the future p. 5* *I am not sure the value of starting from hot spots, in a way I would say this layers are always potentially present whatever you look and is just the case of being aware of them, and I think if you are going to take a step forward in mapping it would be to understand the different scales of which things operate so you might get a hot spot where a lot of*	

	things appear to be happening in one place but actually they refer to much wider areas which not necessary go insidep.6	
	Discussion about existing methodologies and data available to map landscape functions and their interactions, Data in both cases: willemen and Mersey is from same nature, but analysed different, stadistically: showing associations and not causing connections	
	Discussion about existing data: *So we are not collecting the right data, our data is more attributes, rather than processes?* *Sorry, who's data?* *Any data, in terms of features and attributes* *Probably, just describing, but sometimes if you want to identify the process, you have to identify what happen beyond the attribute or description.* *Is there any interpretive data? Were there any layers which you didn't just take a raw dataset, that you actually model, in that fact? P. 7* They questioned if any existing mapping has been done interpretively, it was exaplain the pollinator support example, *So the support is kind of you need more systems*	

	science crowd sourcing type data Better interpretive data p. 7	