IMPACTS AND PERSPECTIVES OF WOODLAND CREATION IN UPLAND CUMBRIA, UK

by

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University of Lancaster

This thesis is submitted in partial fulfilment of the requirement for a degree of Doctor of Philosophy

DECLARATION

I declare that this thesis is my own work and has not been submitted for a degree at any other university. Any section of the thesis that has been published has been clearly identified.

ABSTRACT

Title: Impacts and perspectives of woodland creation in the uplands of Cumbria, UK
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Upland regions in the UK are increasingly under consideration as potential areas for the creation of woodlands. This is driven by a combination of factors, including the aims of UK forestry policy to increase woodland cover, changes in current upland land-use and management, agro-environment schemes in national and international policy and an increasing public awareness of the ecosystem service benefits landscapes can deliver for society. Creating new woodlands in upland areas is challenging, partly due to concerns of the potential impacts from a change in land use and also due to stakeholder perspectives. This research carries out a rapid TESSA ecosystem services assessment of a 250km^2 grass dominated and sheep grazed Cumbrian (England) upland landscape and applies plausible alternative woodland creation scenarios of woodland cover percentages. The assessment focusses on changes these scenarios will deliver in terms of key ecosystem goods and services, which are identified by stakeholders to be of high importance to the study area. The results indicate that, under lower woodland percentage scenarios, no drawbacks and only benefits on all indicators are expected. However, a more complex outcome would be expected from the higher percentage woodland scenarios. The research furthermore adds a qualitative element to the overall understanding, by carrying out a Q-methodology investigation of stakeholder perspectives of upland woodland creation. The findings suggest that stakeholder perspectives are a powerful influence in upland woodland creation. The two components of research methods applied to the study complement each other and offer a greater understanding of this complex topic and identify barriers and opportunities for woodland creation in the uplands of Cumbria.

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TABLE OF CONTENT

DECLARATION **2**

ABSTRACT **3**

ACKNOWLEDGEMENTS **4**

LIST OF FIGURES **9**

LIST OF TABLES **10**

LIST OF ACRONYMS **11**

1. INTRODUCTION **13**

1.1 Project development influences 16
1.2 Aims & Objectives 17
1.3 Thesis outline 20

2. LITERATURE REVIEW **22**

2.1 United Kingdom's woodlands 22
2.1.1 History of The United Kingdom's woodlands *24*
2.1.2 Woodlands in the uplands of Cumbria *29*
2.2 Woodland creation in England 31
2.2.1 The future of Woodland creation *33*
2.2.2 Woodland creation in the uplands of Cumbria *37*
2.3 Woodlands and Ecosystem Services 42
2.3.1 Woodlands and climate regulation services *45*
2.3.2 Woodlands and water-related services *50*
2.3.3 Woodlands and nature–based recreational services *56*
2.3.4 Cultivated goods as a provisioning service *62*
2.4 Assessing ecosystem services 71
2.4.1 Strengths and weaknesses of ecosystem services assessment tools *72*
2.4.2 Contextualising ecosystem service assessment approaches *75*
2.4.3 Toolkit for Ecosystem Service Site-based Assessment (TESSA) *76*
2.5 Perspectives Of Woodland Creation 80
2.5.1 Cumbrian perspectives *81*
2.5.2 Identification of motivators and woodland creation typologies *81*
2.5.3 The need for interdisciplinary research *83*
2.5.4 The importance of feelings and emotions *85*
2.5.5 Introducing Q-methodology *86*

3. SCOPING STUDY **92**

3.1 Developing research question and scoping study 93
3.2 What kind of woodland creation? 95
3.3 Introducing the study site – a typical Cumbrian upland landscape 98
3.3.1 Howgill Fells NCA & ecosystem services *103*
3.3.2 Future drivers of change in the Howgill Fells NCA *108*

4. IMPACTS OF WOODLAND CREATION 110

4.1. INTRODUCTION 110

4.2 METHODOLOGY 115

4.2.1 Defining current and alternative scenarios *115*
4.2.2 Rapid ecosystem services assessment *117*
4.2.3 Climate regulated services *119*
4.2.4 Water-related services *137*
4.2.5 Nature-based recreation *145*
4.2.6 Cultivated goods *153*

4.3 RESULTS 157

4.3.1 Climate-regulation *157*
4.3.2 Water-related services *167*
4.3.3 Nature-based recreational tourism *173*
4.3.4 Cultivated goods *177*
4.3.5 Overall impacts of woodland creation on ecosystem services in the Howgill Fells NCA *179*

4.4 DISCUSSION & CONCLUSION 182

4.4.1 Climate regulating services *185*
4.4.2 Water-related services *190*
4.4.3 Nature-based recreation *196*
4.4.4 Cultivated goods *201*
4.4.5 Summary *204*

5. PERSPECTIVES OF WOODLAND CREATION 207

5.1. INTRODUCTION 207

5.2. METHODOLOGY 210

5.2.1 Development of a Q-set *211*
5.2.2 Execution of Q-set *215*

5.3 RESULTS 222

5.3.1 Interpretation *227*
Factor 1 .... *229*
Factor 2 .... *233*
Factor 3 .... *237*
5.3.2 Summary *241*

5.4 DISCUSSION & CONCLUSION 242

5.4.1 Participants *242*
5.4.2 Perspectives and feelings *244*
5.4.3 Personal against public perspectives *246*
5.4.4 Is economics important? *248*
5.4.3 Future opportunities *249*

6. THESIS DISCUSSION & CONCLUSION 252

6.1.1 The importance of recognising emotions *256*
6.1.2 The importance of ecosystem services *258*
6.1.3 Concerns for changes ahead *259*
6.1.4 Stakeholder engagement and participatory processes *260*
6.1.5 Interrelation and interdisciplinary approaches *261*
6.1.6 Implementation of results *263*

6.1.7 Additional considerations....263
6.1.8 Future research....264
6.2 Summary....266

7. REFERENCES....268

APPENDIX I – SCOPING STUDY PARTICIPANT LIST....285

APPENDIX II – EQUATIONS USED IN CHAPTER 4....286

APPENDIX III – Q METHODOLOGY TERMINOLOGY....288

APPENDIX IV – NATURE-BASED RECREATIONAL TOURISM QUESTIONNAIRE....289

APPENDIX V – Q PARTICIPANT LIST....290

APPENDIX VI – Q-SET....292

APPENDIX VII – Q RESULTS....293

APPENDIX VIII – EXTRACTION CRITERIA & OTHER EQUATIONS USED IN CHAPTER 5....295

APPENDIX IX – CRIB SHEET FOR INTERPRETATION....299

APPENDIX X – RESEARCH TIMELINE....300

LIST OF FIGURES

FIGURE 1 – SCHEMATIC DIAGRAM OF OUTLINE OF THESIS 21
FIGURE 2 – HISTORY OF THE DEVELOPMENT OF WOODLAND IN THE UK 28
FIGURE 3 – UK NATIONAL ENVIRONMENTAL ASSESSMENT HABITAT CATEGORIES 44
FIGURE 4 – AVERAGE UK HABITAT CATEGORY T/C/HA 47
FIGURE 5 – MEAN SOIL INFILTRATION RATES IN WOODLAND SHELTERBELTS 55
FIGURE 6 – UK DESIGNATED 'LESS FAVOURED AREAS' AND 'SEVERELY DISADVANTAGED AREAS' 60
FIGURE 7 – CUMBRIA COMMON LAND AREAS 67
FIGURE 8 – FARM BUSINESS INCOME EXAMPLES 70
FIGURE 9 – DIFFERENCE BETWEEN MODELLED AND OBSERVATIONAL DATA 74
FIGURE 10 – Q – METHODOLOGY GRID 87
FIGURE 11 – MANUAL EXECUTION OF A Q SORT 88
FIGURE 12 – NORTH-WEST ENGLAND UPLAND AREAS 98
FIGURE 13 – STUDY AREA – HOWGILL FELLS NCA MAP 101
FIGURE 14 – STUDY AREA – HOWGILL FELLS NCA PHOTO 102
FIGURE 15 – STATEMENT OF ENVIRONMENTAL OPPORTUNITY (SEO) 104
FIGURE 16 – LUNE CATCHMENT 106
FIGURE 17 – MILLENNIUM ECOSYSTEM ASSESSMENT 111
FIGURE 18 – TESSA ECOSYSTEM SERVICE ASSESSMENT OUTLINE 114
FIGURE 19 – ABOVE-GROUND CARBON STOCK ASSESSMENT SURVEY PLOTS 124
FIGURE 20 – WATERWORLD MODELLING EXAMPLE 144
FIGURE 21 – WATERWORLD DATA OUTPUT EXAMPLE 144
FIGURE 22 – MANIPULATED PHOTOS OF HOWGILL FELLS NCA 149
FIGURE 23 – NATURE-BASED RECREATION VISITOR NUMBER CALCULATIONS 153
FIGURE 24 – ABOVE AND BELOW-GROUND CARBON STOCKS IN T/C/HA IN HABITAT CATEGORIES 159
FIGURE 25 – TOTAL AMOUNT OF CARBON STORED UNDER CURRENT AND ALTERNATIVES STATES 160
FIGURE 26 – TOTAL CARBON SEQUESTRATION IN T/CO_2/YR 164
FIGURE 27 – TOTAL CO_2 EMISSIONS AND SEQUESTRATION 165
FIGURE 28 – TOTAL GHG FLUX SUMMARY 166
FIGURE 29 – WATERWORLD MODELLED OUTPUTS OF NCA 170
FIGURE 30 – WATERWORLD TOTAL CURRENT AND ALTERNATIVE STATES OUTPUTS IN M^3/YR........ 171
FIGURE 31 – WATERWORLD TOTAL CURRENT AND ALTERNATIVE STATES OUTPUTS IN PERCENTAGE 172
FIGURE 32 – PROBABILITY PERCENTAGE OF VISITOR RETURNS 174
FIGURE 33 – MONETARY VALUE OF NATURE-BASED RECREATION IN THE NCA 175
FIGURE 34 – LU & ECONOMIC VALUE OF CULTIVATED GOODS IN THE NCA 178
FIGURE 35 – SUMMARY OF PROPORTIONAL DIFFERENCES OF ES INDICATORS 181
FIGURE 36 – Q METHODOLOGY RESEARCH STRUCTURE 210
FIGURE 37 – FACTOR 1 VISUAL FACTOR ARRAY 229
FIGURE 38 - FACTOR 2 VISUAL FACTOR ARRAY 233
FIGURE 39 - FACTOR 3 VISUAL FACTOR ARRAY 237

LIST OF TABLES

TABLE 1 – INTERNATIONAL FOREST AREAS 23
TABLE 2 – INTERNATIONAL ANNUAL CHANGES IN FOREST AREAS 23
TABLE 3 – YEARLY NEW TREE PLANTING CATEGORIES IN THE UK SINCE 2007 24
TABLE 4 – LU VALUES OF UK BREEDS 39
TABLE 5 – AVERAGE CARBON STOCK ESTIMATES IN SOIL AND VEGETATION 47
TABLE 6 – GRASSLAND MANAGEMENT AND CARBON ESTIMATES 48
TABLE 7 – WOODLAND PLANTERS TYPOLOGIES BY EVES *ET AL.* (2013) 84
TABLE 8 – HABITAT AREA SIZE IN EACH WOODLAND SCENARIO 121
TABLE 9 – GRASSLAND SURVEY SAMPLES & CALCULATIONS 125
TABLE 10 – ORGANIC SOIL ADJUSTMENT OF AREA SIZE 134
TABLE 11 – GRASSLAND AREA, LU AND SHEEP NUMBERS UNDER EACH SCENARIO 156
TABLE 12 – MEAN T/C/HA IN EACH WOODLAND PLOT SURVEYED 158
TABLE 13 – TOTAL ABOVE AND BELOW-GROUND CARBON STORAGE IN EACH HABITAT CATEGORY 159
TABLE 14 - TOTAL ABOVE AND BELOW-GROUND CARBON STORAGE IN EACH HABITAT CATEGORY 160
TABLE 15 – CO^2 SEQUESTRATION IN BROADLEAVED WOODLAND PLOTS 162
TABLE 16 - CO^2 SEQUESTRATION IN CONIFEROUS WOODLAND PLOTS 163
TABLE 17 – CO^2 SEQUESTRATION IN THE CURRENT STATE OF NCA 163
TABLE 18 – MONETARY VALUE OF CARBON TRADING VALUE 164
TABLE 19 – WATERWORLD EXAMPLE OF OUTPUTS WITH 50 % FOG INPUTS QUERY 172
TABLE 20 – MONETARY VALUE OF NATURE-BASED RECREATION IN NCA 176
TABLE 21 – CENTROID/PCA ANALYSIS EXAMPLES 217
TABLE 22 – CORRELATION MATRIX 219
TABLE 23 – RETENTION SUPPORT OF FACTORS FOR ANALYSIS 220
TABLE 24 – FACTOR ARRAY & Z-SCORES 224
TABLE 25 – TOP 10 CONSENSUS STATEMENTS 225
TABLE 26 – TOP 10 DISAGREEMENT STATEMENTS 226
TABLE 27 – FACTOR ARRAY IN THEMATIC THEMES 228

LIST OF ACRONYMS

AET	Evapotranspiration
APE	Annual Probability Event
CAP	Common Agriculture Payments
CFA	Centroid Factor Analysis
CH_4	Methane
CO_2	Carbon Dioxide
CS	Countryside Stewardship
EGSW	English Woodland Grant Scheme
ES	Ecosystem Service
ESC	Ecological Site Classification
ET	Evapotranspiration
FC	Forestry Commission
GHG	Greenhouse Gas
GIS	Geographic Information System
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LAI	Lost Area Index
LFA	Less Favoured Areas
NAEI	National Atmospheric Emissions Inventory
NCA	Natural Character Area
NE	Natural England
NGO	Non-Governmental Organisation

N_2O	Nitrous Oxide
PCA	Principle Component Analysis
PSS	Policy Support System
PET	Potential Evapotranspiration
REDD	Reducing Emissions from Deforestation and forest Degradation
SAB	Sycamore, Ash, Birch
SDA	Severely Disadvantaged Area
SEO	State of Environmental Opportunity
TESSA	Toolkit for Ecosystem Service Site-specific Assessment
UKFS	UK Forestry Standard
WCF	Woodland Carbon Fund
WCC	Woodland Carbon Code
WT	Woodland Trust
ZOI	Zone Of Interest

1. INTRODUCTION

This thesis assesses ecosystem services and goods impacts and stakeholder perspectives on new woodlands in the uplands of Cumbria, UK. It is a complex topic, combining multiple strands of scientific fields and paradigms. The research is driven by forestry policy and the need to create an increasing amount of woodland in the United Kingdom (UK). Today, woodland cover in the UK stands at 13%, which is well below the European average of 37% Research (2017). UK policy has acknowledged the benefits woodlands can provide to the country's economy, environment and society and has consequently settled on a target of woodland expansion to 15% by 2050 (DEFRA 2017). Central to this policy is the need for new suitable areas to plant and the uplands[1] have been identified as one potential area where planting could be carried out with multiple benefits to society and nature. The upland landscape is, however, managed with multiple stakeholder aims and objectives and valued by many for its current appearance (Reed *et al.* 2009a; Bunce *et al.* 2014). Planting trees in such a landscape could potentially alter its appearance and function, depending on how and where such planting is carried out. Further to this, the uplands also have a strong cultural identity and values, which are connected to the landscape and a history of livestock farming (Mansfield 2012; Convery *et al.* 2014).

How the uplands are managed in the UK has, in recent years, become a highly discussed topic (Nijnik & Mather 2008; Reed *et al.* 2009a; Curry *et al.* 2013; Curtis *et al.* 2014), with debates surrounding land-use, cultural heritage, management, entitlement and nature conservation (Reed *et al.* 2009a; Broadmeadow & Nisbet 2010b; Curtis *et al.* 2014; Jerrentrup *et al.* 2014; Huq & Stubbings 2015). Additionally, the uplands also provide society with vital services, such

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[1] Upland Cumbria is defined as land above 300 m as per Burton *et al*. (2005). More detail on the definition of the study area will be presented in chapter 3.

as agricultural production, climate change mitigation, water provision, recreation and biodiversity (Gimona & van der Horst 2007; de Groot *et al.* 2012). Changing the land use in the uplands from predominantly grazed grassland to woodland will therefore have impacts on not only the appearance and function of the uplands, but also on local communities and identities. Stakeholders have differing opinions on what impacts planting would have, and as a result, creating new woodlands in the uplands is currently perceived as difficult and a highly conflicted topic.

Previous research has highlighted some of the social and ecological impacts associated with upland tree planting (Reed *et al.* 2009a; Broadmeadow & Nisbet 2010b; Bunce *et al.* 2014). The impact of woodlands and management approaches on ecosystem services are investigated in detail (Clarke *et al.* 2015; Baral *et al.* 2016; Brockerhoff *et al.* 2017; Sing *et al.* 2017), but are often very generalised (Peh *et al.* 2013) without much appreciation of regional differences, site-specific circumstances and impacts on local communities in a landscape with a strong cultural heritage. Moreover, research emphasises the need to understand a wide range of opinions and attitudes to such proposed changes in land use, as these have been identified as a major barrier in achieving woodland creation targets (Buijs & Lawrence 2013; Lawrence & Dandy 2014). Previous research has examined this, but typically takes either a very broad approach (Urquhart *et al.* 2012; Bell 2014) or focusses on one particular element, such as financial incentives (Madsen 2003; Church & Ravenscroft 2008), regulation (Sorice *et al.* 2014; Ruseva *et al.* 2015) or employment impacts (Crabtree *et al.* 2001). Such research often draws multiple conclusions (Thomas *et al*. 2015) and highlights a need for more in-depth understanding of what the impacts of tree planting would have on both the landscape and people equally (Thomas *et al.* 2015; Nijnik *et al.* 2017). Further to this, stakeholder emotions and feelings as a potential barrier to woodland creation have been identified by Buijs & Lawrence (2013) as an underrepresented area of research. Lawrence *et al.* (2014) review of attitudes to woodland creation concluded that some stakeholder groups are neglected in the evidence, such as agents, managers, community woodland groups and local authorities.

In recent years the UK has experienced extreme weather events, such as severe flooding, with devastating effects to society (Stratford *et al.* 2017; Chandler *et al.* 2018). This has led to an increased focus on the role landscapes can play in mitigating the outcomes of extreme weather events (Locatelli *et al.* 2015; Norton *et al.* 2015; Hunsberger *et al.* 2017). Assessing the natural world and ecosystems and how they benefit society is topical, especially in the sphere of natural capital accounting and ecosystem service assessment (Guerry *et al.* 2015; Zank *et al.* 2016; Costanza *et al.* 2017). There is increased political focus by governments to initiate and implement natural resource management policies to improve the environment, mitigate climate change and protect biodiversity (Holden *et al.* 2017; Stratford *et al.* 2017). Creating new woodlands and increasing woodland cover in upland areas has been suggested to be beneficial for improving ecosystem services, such as climate change mitigation (Read *et al.* 2009;; Holden *et al*. 2017; Stratford *et al*. 2017), flood protection and water quality (Broadmeadow & Nisbet 2010a).

This thesis will show that with a study such as this, exploring any of the abovementioned elements of woodland creation in the uplands of Cumbria singularly will lead to the other elements being drawn into the topic. Establishing barriers and opportunities to woodland creation in these areas cannot be done without an inter-disciplinary approach, which brings together considerations towards both the quantifiable (impact assessment) part and the qualitative (perspectives) part. Conclusions reached on either of these alone would leave the topic inconclusive. The next section will explain how this study came about and the aims and objectives of the project. Onwards from there, a thesis outline will explained the twin-tracked approach this thesis takes, in order to try and provide a holistic view to the topic.

1.1 Project development influences

This study originated within the two departments of The National School of Forestry and The Department of Wildlife Conservation at the University of Cumbria and became a joint effort with further funding, support, curiosity and enthusiasm from a second partner - The Forestry Commission England. The study was deemed necessary to enable greater understanding for why upland woodland planting is perceived as being difficult. Furthermore, the research addresses the need for more site or area specific information and, with the use of a case study, explores impacts and perspectives on woodland creation in the uplands of Cumbria. There was an objective for the study to be inter-disciplinary and with a strong element of social science, as this was regarded as being important by the initial proposers of the study, but with a slight hesitation as to the value of the qualitative science part from the second partner. The overarching aim was to provide a deeper understanding of the barriers and opportunities that exist for future woodland creation projects. The author of the thesis came onboard at a later stage and took all the above into consideration when developing the methodology. The author was allowed to creatively and independently develop the methodology, which was done in collaboration with a large amount of input from external advisors. The methodology developed with inspiration from the preliminary interviews (chapter 3) held in the beginning of the project, conferences, meetings and multi-disciplinary literature, especially literature around the topic of conflict in landscape governance, landscape ecology and stakeholder engagement and participatory processes. One particular IALE Landscape ecology conference presentation on conflict in African community fisheries at Glasgow University inspired the initial idea of using Q-methodology, which was then further developed with the help and support from the international Q-methodology community and psychology academics at University of Reading and Glasgow University. The choice of Q-methodology for the qualitative part of the study was particularly well received amongst the Forestry Commission team, due to the statistical element of the data analysis, which was perceived as adding validity to a social science approach. TESSA was first introduced during a workshop on participatory processes and this sparked the beginning of the idea to use TESSA in this study. The author had a growing sense of there being conflict and a need for stronger stakeholder engagement as part of the topic of planting woodland in upland Cumbria. This was particularly informed by the strong sense of conflict and feelings from stakeholders during the preliminary interviews. The methodology behind TESSA enabled such considerations, as well as being able to assess impacts caused by changes on a landscape scale caused by woodland planting and therefore seemed to be an interesting approach, although still in its developmental phase.

The research assesses how increasing woodland cover by different percentage levels can impact what are identified by local stakeholders as important ecosystem services and goods that the Cumbrian upland landscape provides to society. Further to this, stakeholders' opinions and perspectives are also explored, which together with an ecosystem service assessment provides a much richer understanding for the topic.

1.2 Aims & Objectives

This research explores impacts and perspectives of planting new woodlands in an upland area of Cumbria. This is carried out by a case study approach, using a upland Natural Character Area (NCA) in Cumbria: The Howgill Fells. The study aims to provide a 'twin-track' rounded insight in how woodland planting in this particular NCA could affect the area, in terms of changes to ecosystem services and goods that the area currently provides and which are identified as being important by stakeholders. Further to this, the research aims to assess stakeholder perspectives on the topic of woodland planting in Cumbria. This will aid understanding for the interrelated nature of stakeholder perspectives on the topic and impacts woodland planting has on services and goods the landscape provides on a local scale. Combined, this will aid understanding for the reasons for and against woodland planting in the uplands of Cumbria and offer advice on how to overcome any barriers.

Aim 1:

To assess ecosystem services impacts caused by woodland creation in a Cumbrian upland landscape

Objectives:

1.1. To identify a suitable and typical Cumbrian upland landscape study site for assessment as a case study

1.2. To identify, via stakeholder consultation, four ecosystem services which are of importance to the Cumbrian uplands and which will be used as indicators for the assessment

1.3. Develop scenarios of alternative states (levels of increased woodland creation) within the study area

1.4. Carry out data collection for each of the four chosen indicators by the use of the TESSA toolkit:

i) **Climate regulation**

   (1) Carbon storage in tonnes

   (2) Annual flux of GHG in tonnes of 'carbon dioxide equivalents'

ii) **Water related services**

   (1) Above-surface water balance in m^2

iii) **Nature-based recreation**

   (1) Estimate the number of visits for nature-based recreation

   (2) Estimate the economic value of nature-based recreation

iv) **Cultivated goods**

   (1) Estimate the economic value of cultivated goods

1.5. Compare changes between the chosen ecosystem service indicators between current and alternative states

1.6. Develop recommendations on what impacts woodland creation can have on ecosystem services in a Cumbrian upland landscape, based on the findings of the study

Aim 2:

To assess stakeholder perspectives on woodland creation in a Cumbrian upland landscape.

Objectives:

2.1 To identify stakeholders relevant to the case study of creating new woodlands in an upland Cumbrian landscape

2.2 Explore perspectives that relate to woodland creation in a Cumbrian upland landscape by a Q -methodology study of stakeholders

2.3 Explore opportunities and barriers to woodland creation in a Cumbrian upland landscape based on the findings of the study

2.4 Develop recommendations on future approaches to upland woodland creation based on the findings of the study

1.3 Thesis outline

The outline of this thesis is divided into two main sections, reflecting the interdisciplinary approach of the study and it is illustrated in figure 1. A full research timeline is found in appendix X. The thesis follows a structure beginning with an overall thesis introduction in chapter 1, which is then followed by a literature review in chapter 2. Chapter 3 is a preliminary scoping study, which aided the development of the research questions. Chapter 3 also introduces the study site and the case study. Thereafter, the study divides into two 'twin-track' sections of different research paradigms. Chapter 4 is the quantitative focus on the impacts of woodland creation. This chapter is an ecosystem services assessment, following the methodology of the Toolkit for Ecosystem Service Site-based Assessment (TESSA). Following this chapter is the next part of the thesis, which brings a qualitative aspect to the study by focussing on perspectives on woodland creation via a subjectivity factor analysis using Q-methodology in chapter 5. Finally, chapter 6 brings the two divisions of the thesis together in a discussion and conclusion with recommendations for future research, barriers and opportunities for woodland creation in the uplands of Cumbria.

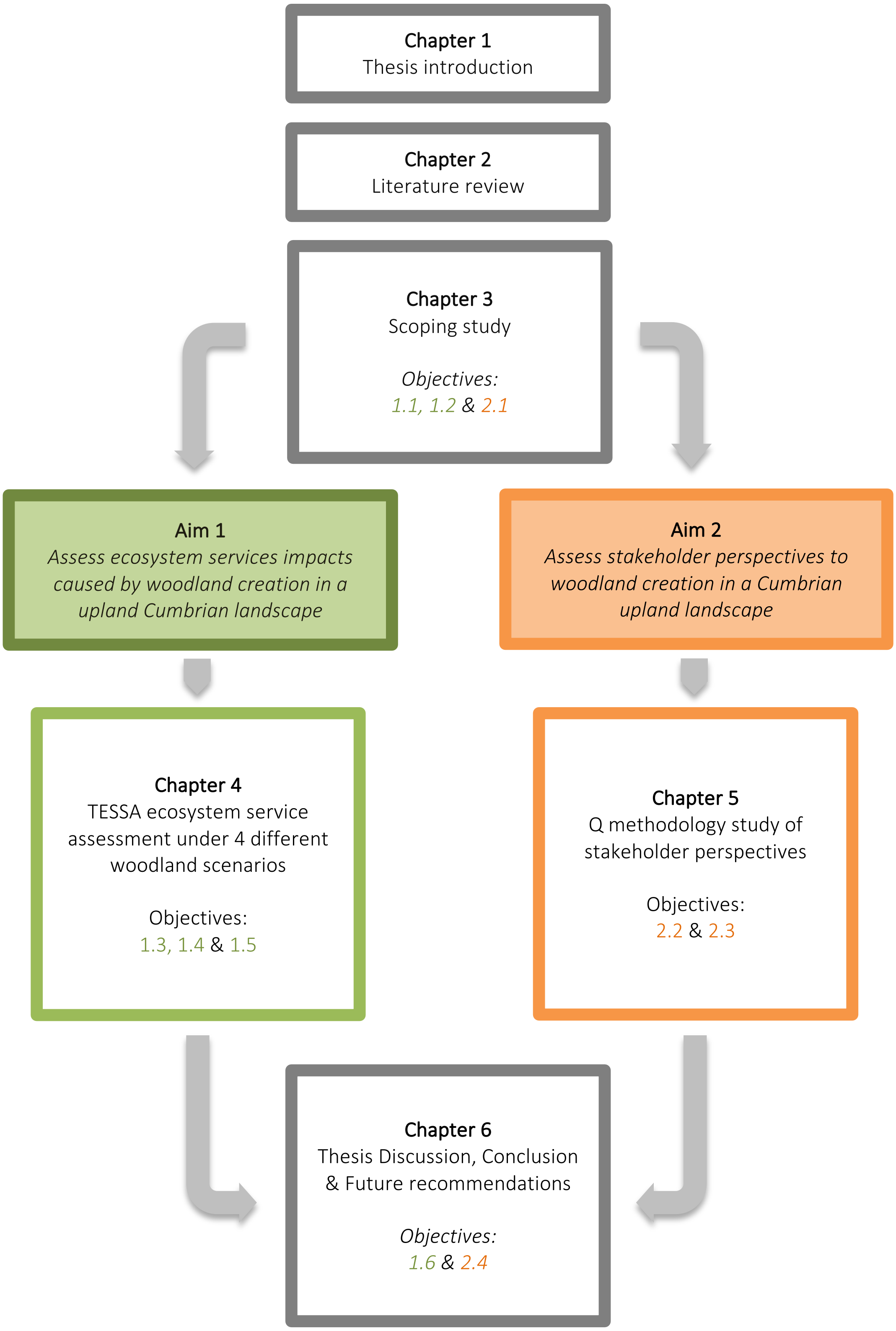

Figure 1 - The figure shows a schematic diagram showing the outline of the thesis structure and which sections are covering the stated objectives.

2. LITERATURE REVIEW

This literature review will explore and discuss the literature behind the topic of woodland creation in the uplands of Cumbria. This will be done in the format of first focussing on presenting the woodlands of the UK and Cumbria specifically (section 2.1). Thereafter, woodland creation approaches are explored with a focus on the specific challenges of creating new woodlands in upland areas (section 2.2). From there, the review changes direction and focusses on one of the two main directions of this research - potential impacts on key ecosystem goods and services caused by woodland creation in the upland landscape (section 2.3) and assessment methods (section 2.4). Finally, the other main direction of our study - perspectives on woodland creation is reviewed in the final section (section 2.5).

2.1 United Kingdom's woodlands

In the United Kingdom (UK), 13% of land cover is woodland[3] and trees – table 1 - of which two-thirds are broadleaved and one-third conifers. Internationally, the UK has one of the lowest levels of woodland cover, but the area is increasing with a small (0.3-0.6%) percentage yearly – table 2 - with higher rates of broadleaved trees being planted compared to conifers – table 3. Although the woodland area is increasing in the UK and the European Union (EU) as a whole, since 1990 woodland areas have decreased internationally. This is mainly attributed to large areas being deforested in South America and Africa – table 2. 72% of all woodlands in the UK are owned by the private sector (Commission 2017b). As such, a large majority of woodlands

[3] The National Forest Inventory for Great Britain defines woodland as: "Areas with a canopy cover of 20% or more (or the potential to achieve this), a minimum area of 0.5ha and a minimum width of 20m. Areas of less than 0.5ha of open space within woodland are included as part of total woodland area, being considered as an integral part of the woodland ecosystem" (Commission 2018b). Further definition of woodland for purpose of this study is detailed in chapter 3.

are in private hands which is of significant interest in terms of woodland creation and management.

Table 1 – Forest area in million ha. In (column 2), the total land area in million ha. (column 3) and the percentage of land area with forest (column 4) within the UK and other European and worldwide countries (Europe & Unece 2015).

Country	Forest area (million ha)	Total land area (million ha)	Forest as % of land area
Europe			
United Kingdom	3	24	13
Finland	22	30	73
France	17	55	31
Germany	11	35	33
Italy	9	29	32
Spain	18	50	37
Sweden	28	41	68
Other EU	52	159	32
Total EU	**161**	**424**	**38**
Russian Federation	815	1,638	50
Total Europe	**1,015**	**2,214**	**46**
Africa	624	2,987	21
Asia	593	3,118	19
North & Central America	751	2,134	35
Oceania	174	850	20
South America	842	1,747	48
World	**3,999**	**13,049**	**31**

Table 2 – International comparisons in annual changes in forest area from 1999 to 2015 (Europe & Unece 2015).

Region	1990-2000		2000-2010		2010-2015	
	(000 ha)	(%)	(000 ha)	(%)	(000 ha)	(%)
UK	18	0.6	11	0.3	17	0.5
EU	681	0.5	450	0.3	369	0.2
Total Europe	803	0.1	1,127	0.1	382	0.0
Africa	-3,537	-0.5	-3,209	-0.5	-2,836	-0.4
Asia	-221	0.0	2,349	0.4	791	0.1
North & Central America	-394	-0.1	172	0.0	75	0.0
Oceania	82	0.0	-564	-0.3	304	0.2
South America	-4,000	-0.4	-3,868	-0.4	-2,024	-0.2
World	-7,267	-0.2	-3,993	-0.1	-3,308	-0.1

Table 3 – Yearly new planting of conifers and broadleaved species carried out every year since 2007 in thousands of ha. in the UK (Commission 2017b).

Year	Conifers	Broadleaved	Total
2007	2.1	8.5	10.7
2008	0.9	6.7	7.5
2009	1.2	5.2	6.4
2010	0.5	4.9	5.4
2011	1.5	6.6	8.2
2012	3.5	9.2	12.7
2013	1.9	8.9	10.8
2014	2.2	10.7	12.9
2015	2.6	7.7	10.3
2016	1.9	3.7	5.6
2017	3.5	3.0	6.5

2.1.1 History of The United Kingdom's woodlands

The shaping of the UK woodlands has been ongoing since the Neolithic revolution approximately 4,000 BC when domestication of animals and arable farming began (Rackham 2012). The decline in woodland has always had a strong correlation with human development and the need for resources. At around 2,000 BC woodland cover was reduced to about half the area of England and the remaining wildwoods were managed more actively. By 410 AD the Romans had brought greater infrastructure and agriculture greatly increased with the result of further forest clearance (Davies & Watson 2007). Between 410 - 1086, the so-called Dark Ages, there are suggestions that woodland might have increased slightly, but by 1086 woodland cover was down to 15% due to an expanding population and further woodland clearing. By 1349, this was more than halved to 7%. The Black Death in 1349 halted this development, due to a dramatically reduced population, which continued to be low through to 1500. During the sixteenth and seventeenth centuries, the demand for wood increased due to a variety of factors including colder winters, an increasing demand from industry and agricultural improvements which resulted in further woodland clearing.

During this post-1500 period, many woodlands were taken by the Crown from monasteries and became a much valued resource to the royalty as hunting grounds (Winchester 2005). In fact, some of the large English woodlands, such as the Forest of Dean, the New Forest and Sherwood are all preserved as having been old royal hunting grounds. On a local scale, Borrowdale in Cumbria, known to be the most wooded part of The Lake District, had some areas under royal ownership before being donated to the National Trust (NT 2015).

An increasing population and a growing navy with the need for timber resulted in a 5.2% forest land-cover by 1905, which is the lowest ever woodland cover on the British Isles. During the First World War Britain's timber imports were restricted and the highest quality domestic stands were felled, leaving little behind (Oosthoek 2000). The end of the First World War marked a beginning for UK afforestation and a steady increase in woodland has emerged since. Forestry became a national priority after the Acland Committee Report (1918) recommendation and the Forestry Commission (FC) was established in 1919 with the aim of creating a sustainable strategic national reserve of timber (Oesthoek 2000; Jones 2015). The report advised an increase of 60,000ha to be planted by the state and 20,000ha to be planted by private landowners with state assistance. The Acland report was influential and was at the core of British forest policy until 1957 (Oosthoek 2000). 1957 marked a changing point in forestry priorities and was driven by the Zuckerman Report, which advocated a need for forestry to become more commercial as opposed to strictly prioritizing the need for building timber reserves for state affairs. The argument was that times had changed - particularly with the arrival of nuclear technologies and warfare. A review was carried out based on the Zuckerman Report with the outcome of a change in direction for British forestry. The economic value and commercialisation of forests was now the priority (Oesthoek 2000). As a result, short rotation species were planted and the operational direction was aimed at forest products to end-users. This change in direction had a landscape-scale impact as woodland products required processing and single species planting on a large scale in order to fulfil a fast evolving market need. By the 1960s, 35,000ha were planted annually[4]. Scotland and the north of England in particular were targeted for forestry operations as their upland areas were identified as low value for agriculture (Oesthoek 2000). In Cumbria, the first Forestry Commission forest was acquired in 1919 at Whinlatter in Cumbria, soon to be followed by Ennerdale, Dunnerdale and Grizedale (Wyatt 2004). This was not without controversy, as the change in landscape and use had a great impact on local communities and people (Jones 2015). Pre-1960s, there were strong arguments made that many of the remoter uplands regions would see an increased migration of people moving from the rural areas to towns, with the decline of local communities. It was therefore argued that the increase in productive woodlands would provide employment and sustainability to the remote areas (Oesthoek 2000). Forestry activity did, for a short spell, provide valuable employment to rural areas. In 1924 a 'forest holding scheme' was set up by the FC whereby houses were built close to forest operations, with 10 acres of farm land incorporated. Local people could occupy these with the promise of 150 days' work a year in the forest with the rest of the year to work their own land or holding. From 1924-1931 the FC forest holding scheme was very successful, but participation decreased during WWII. Post-war policy by the FC took a different strategy and in some areas whole 'forest villages' were built by the FC. These houses were different and did not incorporate farm land, but they did, for a short spell, provide a stable labour force and development to local communities, some of which increased markedly in population size (Ooesthoek 2000). This was, however, a temporary development and by the 1960s the number of houses and occupants started to decrease, presumably due an increase in modernisation of machinery for forest operations

[4] This is a very high level compared to the current 5000ha annually policy planting target.

(Oosthoek 2000). This decline had a strong impact on some communities in areas of Scotland and the north of England. Large scale plantations had been planted, but local councils felt that the promise of forestry employment by the Government, had not been fulfilled (Oosthoek 2000). This argument of promised large scale employment by the forestry sector is still heard today and still targets the north. It is, however, acknowledged that this increase in employment will be mainly found in the processing industry and not in the woodland itself. The woodland provides good employment opportunities until it reaches maturity. From then onwards employment numbers decrease (Bell 2014). The homogenous large blocks of plantations planted during this time did meet strong opposition from the public, due to the detrimental effect it had on the landscape (Wyatt 2004). As the years have passed the forest policy has slowly changed and accepted a compromise between productivity, aesthetics and nature conservation. In Cumbria this compromise has at times been difficult due to the high aesthetic value of the landscape and the need for agricultural production. The next section will expand on this.

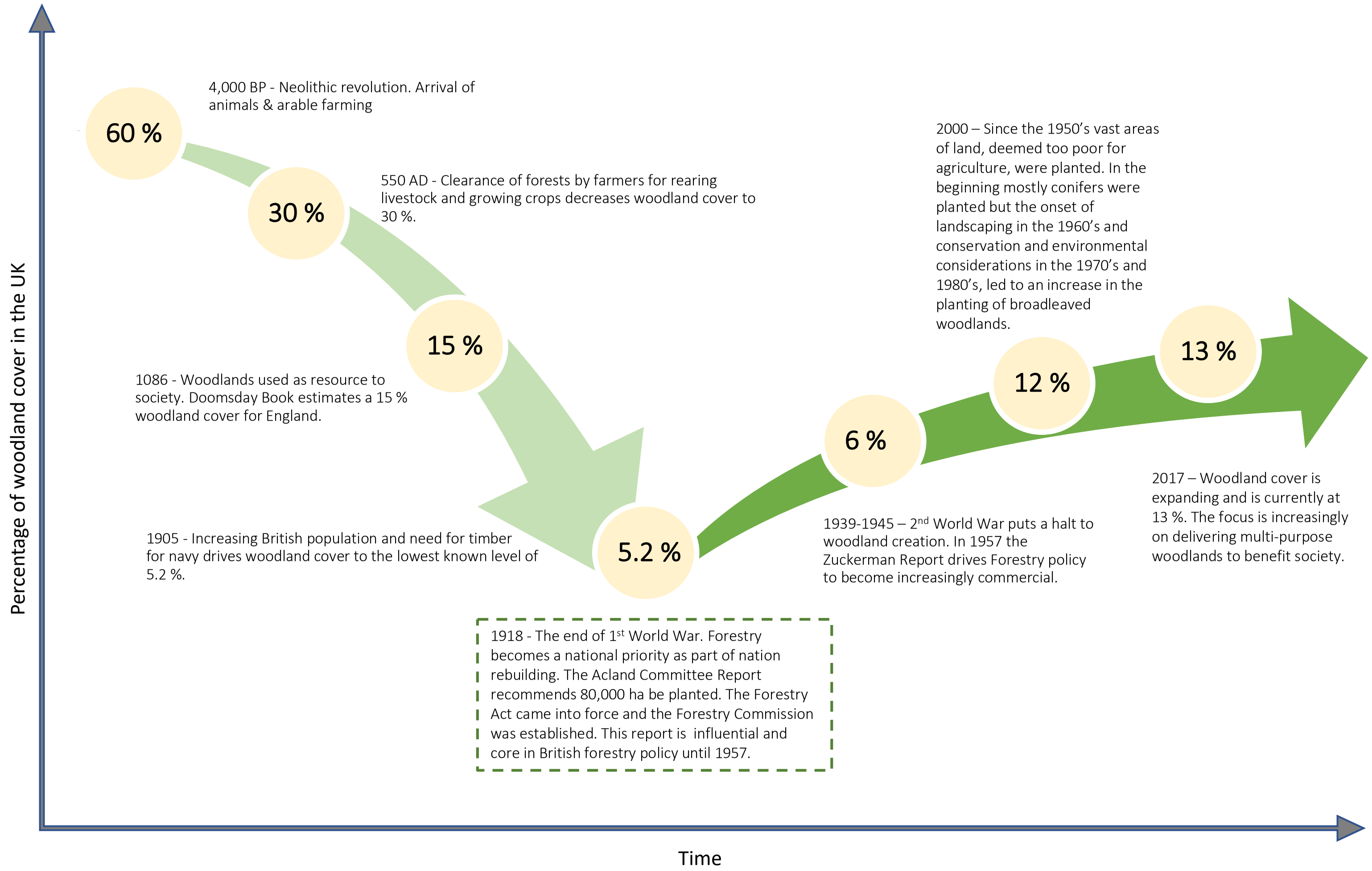

Figure 2 – History of the development of woodland cover within the UK from the arrival of the Neolithic revolution to 2017. The yellow circles indicate the level of woodland cover in percentages. The figure is created from references by (Winchester 2005; Davies & Watson 2007; Brockerhoff *et al.* 2017; Commission 2018a).

2.1.2 Woodlands in the uplands of Cumbria

Cumbria is one of the least wooded counties in England with 9.9% of the land area being woodland (country range 6-53%) (Woodlands 2015). Within the county, the Lake District National Park contains a higher percentage of woodland at 12% and the southern part of the county has 18% woodland cover (Woodlands 2015). These woodlands are a combination of broadleaved woodlands and conifers, especially within large Forestry Commission (FC) plantations, such as Whinlatter, Ennerdale, Dunnerdale and Grizedale (Wyatt 2004). During the establishment of the large blocks of plantations, there was strong opposition from the public due to the perceived detrimental effect it had on the landscape (Wyatt 2004). Oosthoek (2000) argued, however, that an increase in productive woodlands can provide employment and sustainability to remote upland areas that have experienced a decline of local communities and, as such, be beneficial to areas such as Cumbria. This increase in employment is, as found in other parts of the country, exists in the processing industry and not in the woodland itself. It could therefore be argued, as put forward by Bell (2014), that woodland only provides good employment opportunities up until it reaches maturity, whereby from then onwards employment numbers decrease, as less management is needed . As an example of the influence of the processing industry, several processing and sawmill facilities are now found within Cumbria.

The type and structure of the woodlands in Cumbria is influenced by the activity of people and is eloquently expressed by Wordsworth:

"*Formerly the whole country must have been covered with wood to a great height up the mountains; where native Scotch firs must have grown in great profusion, as they do in northern Scotland to this day. But not one of these old inhabitants has existed, perhaps, for some hundreds of years; the beautiful traces yet survive in the native coppice woods, that have been* *protected by enclosures, and also in the forest trees and hollies, which, though disappearing fast, are yet scattered both over the enclosed and unenclosed parts of the mountains".*

The practice of 'coppicing' has been very influential in providing food, shelter, building material and fuel to the county and for the making of charcoal, in particular as a smelting agent for the production of iron, copper, lead and as a constituent of gunpowder (Rackham 1990). Between the 18th century and towards the beginning of the 20th century, local businesses used coppiced woodlands for products such as brush and basket making (Wyatt 2012). The woodland structure in Cumbria is therefore a mixture of many different species and often shows signs of coppicing practice (Woodlands 2015).

This history of woodlands as a resource to the local community and industry in Cumbria has since declined, and Cumbria's woodlands now play an important role by providing services and goods in different ways. Section 2.3 of this review will expand on this, but first a review of how woodlands are created in England, and Cumbria specifically, will aid the understanding for how and why reaching a national planting policy target is difficult. Planting new woodlands within the Cumbrian landscape and context are deeply embedded in both EU and UK public subsidy schemes.

2.2 Woodland creation in England

The creation of new woodlands in England is mainly funded from the public purse (Jones, K. 2015, Personal Communication, 2 March 2015) and it is estimated that 99% of all planting that has been carried out over the past 10 years has been funded via grant schemes (Harrison, C. 2015, Personal Communication, 7 May). The Forestry Commission's (FC) woodland creation grant scheme began in 1919. Over the years since, the grant schemes have gradually changed format, direction and priorities (Commission 2017a). The management, support and creation of woodlands and tree planting has traditionally been carried out mainly by the FC, but Natural England has also been able to plant smaller woodlands and trees via various agri-environmental schemes, such as the Environmental Stewardship (replaced by the Countryside Stewardship) and Higher Level Stewardship (HLS) agreements. These schemes are embedded in EU environmental and agricultural policies and have changed regularly as modifications have been applied. Such modifications have, particularly over the last 40 years, changed every 10 years and can result in practical changes and confusion where applied to landowners, farm advisors and project officers in management and advisory roles on the ground (Arkle, P. 2016, personal communication, 11 February).

Between 2004 and 2014 tree planting was carried out by way of two approaches:

- The English Woodland Grant Scheme (EGWS), administrated by the FC. Principal requirements are: area size over 2ha, a strict planting density and species composition and a specific required management plan. The grant pay-out consisted of three elements: a capital starter grant, followed by a yearly pay-out per hectare planted and a capital payment after 15 years if the survival rate of trees was >80% (Fox P. 2015, personal communications).
- Environmental Stewardship tree planting scheme, administrated by Natural England. Farmers or landowners could utilise these as part of HLS agreements. The area

> requirements for the creation of woodlands both inside and outside severely disadvantaged areas was a size of <1ha and not exceeding 3ha overall. Woodlands had to be native species, but with allowance for the creation of successional scrub, farm woodlands and orchards (NE 2015).

A new modification to the EU policy has, from 2015, set a new direction for woodland creation and tree planting in England. The scheme of Environmental Stewardship (ES) (2004-2014) has been replaced by the Countryside Stewardship (CS) scheme (2015-2025). This new scheme approach is important in terms of woodland creation, as it replaces the ESWG and all applications for woodland creation now fall under the CS scheme. Although this may offer some flexibility, especially for tree planting in upland areas of Cumbria. The new scheme does also have its limitations. Criticism has been made of the lack of financial incentives for the option of small woodland creation in upland regions (Nicholson T. 2016, personal communications, 1 May) and disproportionate economic support for 'scrub-planting'. Additionally, a new funding route supporting large scale woodland creation with a multi-purpose and productive aim has been instigated – the Woodland Carbon Fund (WCF). The emphasis of the WCF funding is to demonstrate a natural capital approach. Applications have to be >30ha and, similar to the CS scheme, a maximum of £6,800/ha is available (£8,500/ha with provision of permissive access).

These two new approaches to tree planting essentially means that the funding will be given to either small areas of scrub woodlands or large >30ha woodlands. This presents a problem to creating new woodlands in areas like Cumbria, where many small >30ha woodlands have been established in recent years on topographically challenging farmland deemed not profitable by landowners. This type of woodland now falls into the gap between the two categories. In August 2017, the FC announced that the minimum threshold for area size under the WCF of funding, has been reduced to 10ha. (Commission 2018b). This may have been driven by a lack of applications, due to the challenges described above.

2.2.1 The future of Woodland creation

On 23 June 2016, the United Kingdom voted in a referendum to leave the European Union (EU). The separation from the EU is likely to impact woodland creation in England in several ways. The EU does not have legislative influence on forestry and woodlands in England, but through its Forest Strategy it offers a range of policies which the UK currently are part of. Most importantly, England's forestry sector receives grant funding via the EU's Common Agriculture Policy (CAP) (Union 2019). This funding is a key tool in delivering woodland planting and management targets and funding is primarily paid directly to farmers via the European Agricultural Guarantee fund, commonly known as Pillar 1 of CAP. The payments and availability of this scheme heavily influence farmers' decisions on land management (Tatchell-Evans 2016). The incentive to plant new woodlands on agricultural land is dependent on the levels of payments offered.

The EU has a range of directives, conventions and regulations that impact the English woodland planting sector, which is outlined previously in this chapter. Brexit allows the UK government to develop and alter this legislation, but to what extent depends on the nature of the exit deal. If for example, the UK remains a member of the European Economic Area, much of the EU legislation would be maintained (Tatchell-Evans 2016). The outcome of trade deals could, according to a CONFOR analysis, also have an impact, especially on domestic production of forestry and timber, as the UK is a major importer within this sector (CONFOR 2016). This could lead to an increase in demand for domestically produced products.

When the UK decided to leave the EU it started a process for developing UK environmental and agricultural legislation to replace the CAP. Each of the four UK nations will develop separate policies, but one unifying piece of legislation is currently being developed: the Agriculture Bill (Parliament 2018). This legislation is very important to the woodland planting sector, as it will outline a strategy for how planting schemes will be funded beyond Brexit. Currently, the Bill offers no details om implementation, but merely sets out how the focus for future payments for farmers and managers will be towards public goods, such as for example higher animal welfare standards, measures to reduce flooding, climate mitigation and access to recreational activities.

This redirection of focus from direct payments which were previously targeting the size of areas farmed, towards a broader more societal holistic approach, is a theme that also occurs in the January 2018 environmental policy 'A Green Future: Our 25 Year Plan to Improve the Environment' (Defra 2018). Here, the government sets out long-term plans for the environment embedded in the context of Brexit and states that the current CAP system of direct farm payments has generated little actual public benefit. Furthermore, the government's opinion is, that here is an opportunity to move towards a payment system which supports the delivery of a range of public benefits. There is, additionally, a direct reference of interest to woodland planting and the uplands of Cumbria: *"In agriculturally marginal areas, including most of the uplands, payments could be used to overcome market barriers for an increase in the contribution of land to biodiversity, access, water and carbon benefits. This might include an expansion in native tree and woodland cover and creation and restoration of open habitats. It could also include adoption of rewilding or greater use of natural processes in marginally productive areas as a cost effective form of land management" (Defra 2018).*

And further:

"As announced in the 25 Year Environment Plan, we will kick start the planting of a new Northern Forest, which will cross the country using the M62 corridor as its spine. With £5.7 millions of government funding, we will support the existing partnership of the Community Forests and the Woodland Trust to accelerate and further develop the Northern Forest. This will deliver accessible community woodland to a large swathe of England and at the same time contribute to meeting carbon budget commitments. We will also implement other policies to accelerate planting rates, including the introduction of a Domestic Carbon Offset Unit to strengthen carbon markets and Forestry Investment Zones to support woodland planting" (Defra 2018).

This last paragraph and the reference to an introduction of carbon offsetting schemes is of particular interest, as it alluded to the possible direction of how woodland planting will be funded post-Brexit. Thus far, the Environment Plan does not offer any direct insight into implementation and funding streams, but merely lists pre-existing strategies as a way forward. For woodland planting and the reduction of carbon emissions, the UK government offers to address climate change more directly post-Brexit via, for example, the 2018 Clean Growths Strategy, whereby there is a commitment to plant 11 million trees in new networks of forests (Government 2017). Generally, the new Environment Plan has a much stronger focus on natural capital - that is the world's natural assets - as a concept and payments for ecosystem services (PES).

It is therefore likely that future woodland planting will, to a much higher degree, be funded via PES schemes such as, for example, carbon offsetting. There are similar references within the Agricultural Bill towards the upland environment (Parliament 2018). Here, there are promises towards preserving the rural resilience and the value that upland farmers provide with the management of the landscape in terms of production of food, environmental benefits, climate mitigation and aesthetics of the landscape. The Bill proposes that upland farmers will, in particular, be paid for their 'vital role as stewards of the countryside'. It is therefore likely that PES will also be available for services such as upland flood management, peat restoration and catchment based approaches for clean water. Within the PES Action Plan, which is part of the strategies underpinning the 25 year Environment Plan, there is further acknowledgement of the potential of developing place-based partnership initiatives, which provide multi-service PES (DEFRA 2013).

Woodland planting is viewed as being a good potential source for funding, as woodland can deliver multiple services and public benefits within one area. There are comments, however, within the Action Plan, that a key challenge is to capture the multiple values that woodlands offer (DEFRA 2013). The development of an impact rating instead of monitoring and evaluation can provide a way for potential investors to measure the social and environmental outcomes of investments. For example, tourism and recreation is often a service related to woodlands, but the economic value is often not understood by forest owners. This is all the more difficult on a site-specific scale, due to a lack of local data (Peh *et al.* 2013).

Brexit may also offer particular opportunities for the commercial aspect of the forestry sector (CONFOR 2016). If land and agriculture values decline, due to changes in agricultural direct payments, there may be an increasing interest in converting this land to forest. Demand is greater than the domestic supply (Cowie *et al.* 2018) and the UK is currently the second largest wood importer in the world. In 2016, 82% of the UK's wood consumption was imported. Depending on the outcome of the Brexit withdrawal agreement with the EU, this could increase both the cost and availability of imported wood. Furthermore, changes in exchange rates could become an important factor. This may therefore be an opportunity for the UK to increase domestic wood production (CONFOR 2016), as well as an important step towards fulfilling the targets for reducing carbon emissions via large-scale woodland creation set out in the 2018 Government's Clean Growth Strategy (Government 2017).

Importantly, the UK is also actively involved with other international woodland initiatives, which will not be impacted by Brexit. As a member of the United Nations, the UK is part of the UN Forum on Forests (UNFF), which promotes international sustainable development of forests (Nations 2019). The UK is also a member of Forests Europe, which seeks to develop a European forest resource which supports, "a green economy, livelihoods, climate change mitigation and biodiversity conservation" (Europe 2019). Finally, if woodland planting is publicly funded in the UK, it must meet the requirements of the UK Forestry Standard, which sets a standard for sustainable forestry, promotes the protection of biodiversity, public access and maintaining a healthy supply of forestry products (Commission 1998). These commitments to international agreements and initiatives will continue after the UK leaves the EU.

2.2.2 Woodland creation in the uplands of Cumbria

In Cumbria there is a large presence of forestry and woodland interests. Both Penrith and Kendal has local Forestry Commission offices, with the hub and North-west area director being based in Penrith. Both towns are also the home of the Natural England departments and several environmentally focussed NGOs. The area is home to many local woodland management consultancies, sawmills and timber processors. Finally, The National School of Forestry at the University of Cumbria is located in the heart of Cumbria. These bodies are influential in bringing woodlands and forestry forward in land management and land use debates within Cumbria. There is no set target for levels of woodland creation in Cumbria and the current 'Cumbria and the Lake District Trees, Woodlands and Forestry' strategy, does not focus much on expansion, but rather more on bringing Cumbria's undermanaged woodlands into management. There is, however, an increasing focus locally on the creation of new woodlands in Cumbria, both to compliment national targets, but also in line with the increasing acknowledgement of the value of landscapes for not just production, but also other services and goods. This will be further expanded on in the next section of this review, 2.3 – Woodlands and ecosystem services.

Currently, the Environmental Stewardship tree planting scheme has a large uptake for planting new woodlands in upland Cumbria, as it was perceived as suitable and flexible in the challenging upland terrain (Leeson, P. 2015, Personal Communication, 5 March 2015). As an example, a partnership between the Woodland Trust (WT) and Natural England between 2010 and 2014 carried out 1,500 ha of woodland creation in upland Cumbria. In the same amount of time - 4 years - the FC carried out the 'Woodland Carbon Task force'[5] initiative (under EGWS), which resulted in 36,5 ha of new planting. Both initiatives were set up to boost woodland creation regionally, but with very different aims and objectives (Fox 2012).

In addition, traditional and cultural management of the landscape in Cumbria presents challenges for woodland creation. The uplands of Cumbria specifically support a large amount of livestock production, especially sheep farming. This will be discussed in further details in later sections of this review, but is important to mention here as growing trees on the fells of Cumbria can be challenging to combine with this practice (Arkle, P. 2016, personal communication, 11 February). Much of this challenge is related to the fences, which are needed to protect new tree planting areas as livestock trample and eat new seedlings and large areas of new planting can be damaged very quickly. Therefore, finding the right balance between livestock stocking density[6] and the setting aside of fenced areas necessary for protecting new tree planting presents a challenge. Livestock numbers in any given farmed area are dependent on the carrying capacity of what the area can accommodate in terms of resources. What an

[5] The Woodland Carbon Task Force (WCTF) is a Forestry Commission initiative and was created with the aim of boosting the woodland creation uptake in England. Cumbria was used as a target region and pilot study.
[6] Stocking density is the relationship between livestock and the forage resource.

area is defined to be able to accommodate is based on the aims and objectives of the specific situation, which may be ecological restoration or perhaps production. A common and widely used indicator for this is Livestock Units (LU)[7] – see table 4.

Table 4 – Livestock units (LU) values of medium sized breeds. Large breeds will have approximately 20% higher LU values and smaller breeds approximately 20% lower (NE 2015).

Livestock type	LU values
Dairy cow	1.0
Beef cow	1.0
Cattle over 2 years	0.7
Cattle 6 months to 2 years	0.6
Lowland ewe and lamb	0.12
Hill ewe and lamb	0.6
Horse	1.0
Pony	0.8

LU is used to calculate stocking densities of grazing livestock on farms for subsidy schemes and the Basic Payment Scheme (NE 2015). For farmers to be eligible for payments, they must keep a certain stocking density (LU/ha) specific to their land, to ensure that the particular land/habitat is not over or under grazed, in keeping with their agreement. The Rural Payment Agency, who issues the BPS payments, states that Severely Disadvantaged Areas (SDA) and moorland can accommodate 0.25 LU/ha for common and shared land. This estimate is used in calculating whether there is a 'surplus' of rights. If so, the owner can claim an economic payment for any surplus. This estimate is average and does not take into account the detailed and differing specific conditions an area of land can contain.

[7] LU is a reference unit that reflects the energy requirements of different types of livestock (SAC 2016). As an example, the Farm Management Handbook (Consulting 2016), defines 1 LU as the equivalent of a 625kg Friesian dairy cow producing a calf and 4,500 litres of milk and by doing so, has the energy requirements of 48,000 MJ/year. Different types of livestock have a LU comparable to this.

During the period between 1970-1990, livestock farming received payments based on the number of stock held on the land. This led to a vast number of livestock on the hills with detrimental effects to both the ecology of upland habitats and to the condition and welfare of the animals (Reed *et al.* 2009). For sustainable livestock production within Cumbria, the stocking density and land area available to graze is therefore important. Deducting areas of land from grazing to be fenced in and planted with trees, will therefore have an impact on the level of stock of the fells. On some fell areas, this may not be a problem as stocking density is so low that the setting aside of land for tree planting would not make grazing by the existing stock levels unsustainable (Nicholson T. 2016, personal communications, 1 May). Fencing in areas of fell side does, however, impact not just on stocking levels, but also husbandry and management of the livestock. Hill sheep in Cumbria are often 'hefted'[8] and have a sense of belonging to certain areas of the fell (Capstick, J. 2016, personal communication, 5 May). Fences to protect areas of land for tree planting can result in such hefted systems to break down, causing difficulties to farmers in managing the herds as the sheep may stray further afield (Capstick, J. 2016, personal communication, 5 May). During an interview on 13 June 2016, hill farmer John Metcalf explained that fences, furthermore, can cause problems with young lambs getting their horns stuck in them, which is a particular problem in areas where traditional breeds, such as Rough Fell, are kept. Due to the isolated settings of the fells and fences for tree planting, this can cause lambs to be trapped for long periods of time undetected and, as a result, the lambs can perish. Others claim that on some fell areas fences can actually be an advantage for hill farmers. If placed and designed with care, fence lines can aid the gathering of flocks down from the fells and prevent livestock from entering potentially dangerous steep areas (Capstick, J. 2016, personal communication, 5 May). Moreover, fences can maintain the flocks in desired areas of grazing. Some have even reported that fences help to keep flocks hefted in areas with

[8] Hefted sheep are sheep that have a belonging to a certain area of a fell. They do not need fences to be kept there, but will instinctively seek to stay within this area. Such hefted flocks are often several generations old and this behaviour is passed down through generations of sheep.

very low stocking density as, if there are very few sheep on the fell, they are more likely to stray further (Metcalf, J. 2016, Personal communication, 13 June). This would suggest that sheep levels are not currently high enough to maintain natural hefted behaviour.

The combination of sheep farming and woodland creation, therefore, presents a challenge, which is strongly embedded in the public subsidy schemes and EU policies. The abovementioned section on the future direction of woodland creation under the context of Brexit will undoubtedly have an impact. In addition, in 2017 the Lake District was awarded UNESCO World Heritage Site status (WHS). This nomination was granted based on the areas' unique landscape, character, buildings and most important, local identity and farming community. This adds another challenge to planting new woodlands within this context. So far, the ambition and strategies underpinning management of the newly WHS designated area does not offer anything different from the what was already in place before the designation. Woodland management and creation aims within the WHS proposal and designation are embedded within the abovementioned 'Cumbria and the Lake District Trees, Woodlands and Forestry' vision and strategy, which has been in place since 2013.

2.3 Woodlands and Ecosystem Services

In recent years there has been a substantial amount of research undertaken that has aided in the understanding of how nature contributes to the existence of humans (Costanza *et al.* 1998; de Groot *et al.* 2012). The phrase 'Ecosystem Services' (ES) is now widely used in this context to describe the benefits people derive from ecosystems and how these sustain human wellbeing (de Groot *et al.* 2012; Costanza *et al.* 2017). The benefits of woodland to people, society and biodiversity are substantial and vital (Costanza *et al.* 1997; Broadmeadom & Nisbet 2010; Independent Panel on Forestry 2011; Kettlewell 2011). Culturally and landscape-wise, woodlands are generally accepted as aesthetically pleasing (Ward Thompson *et al.* 2005; Urquhart *et al.* 2012) and provide a place to be in closer contact with nature and escape the stress of daily life. Being in woodlands helps keep us healthy, both physically and mentally (Ward Thompson *et al.* 2005; Commission 2008; O'Brien & Morris 2014). On a societal level, woodlands provide essential ecosystem services such as food, fuel, shelter (Schütz *et al.* 2010), flood mitigation (Broadmeadow & Nisbet 2010b) and carbon storing (Cantarello *et al.* 2011; Nijnik *et al.* 2013) – figure 3. Woodlands aid farmers in animal husbandry and welfare (Mashaly *et al.* 2004; Bianchi *et al.* 2006) and sustain tourism, businesses and livelihoods, all of which benefit the national and local economy (de Groot *et al.* 2012). For biodiversity, woodlands provide a dynamic and ever-changing ecosystem that sustains a large variety of plants and animals (Croci *et al.* 2008; Lindenmayer *et al.* 2010; Timonen *et al.* 2010) . Although woodlands clearly can provide many positive benefits, it is worth considering that this is often at the expense of other likewise valuable land uses (Gimona & van der Horst 2007; Thomas *et al.* 2015) and woodland expansion can in some instances become a disservice. Thomas *et al.* (2015) argues that such benefits, *"are not quaranteed and depend on woodland type, spatial characteristics and cultural context"* and that for example poorly designed and located coniferous forests could have a negative impact on water quality and biodiversity. Increased woodland has also been seen to increase agricultural pests, such as increased levels of Bark beetle, suggested by Toivanen *et al.* (2009). In Bell (1999) survey of 40 Lancashire hill farmers, reports were made of increased levels of sheep's head-fly in connection with increased levels of woodland. It is, however, important to note, that in both examples put forward, the woodlands were of a coniferous type and the problem of Bark beetles does not occur in broadleaved woodlands. Therefore, as Thomas *et al.* (2015) suggests, services/disservices are context related. This will be explored in context relevant detail later in this review, as well as the concept put forward by Nijnik and Mather (2008) that stakeholders perceive and prioritise such benefits differently.

The importance of the delivery of ES by woodlands to the UK has been assessed nationally by the UK National Ecosystem Assessment (Watson *et al.* 2011b) – figure 3. The assessment states that woodlands provide more goods and services to the UK than any other habitat. The key findings of the report are that carbon sequestration, social and cultural services and timber production are some of the most important ES provided by woodlands in the UK. Many factors have had, and will continue to have, an effect on woodland ecosystems and their ES, such as climate change, pollution, government policy on land use, society, global and national trade and the ageing and dynamics of woodlands.

Figure 3 illustrates the many services and goods that woodlands as a habitat are deemed to deliver to the UK. Chapter 3 will identify key ecosystem services and goods, which are considered to be important to stakeholders in the uplands of Cumbria, as climate change mitigation, water-related services, nature-based recreation and cultivated goods (livestock production). This section (2.3) of this review will therefore review the literature behind these key services and goods.

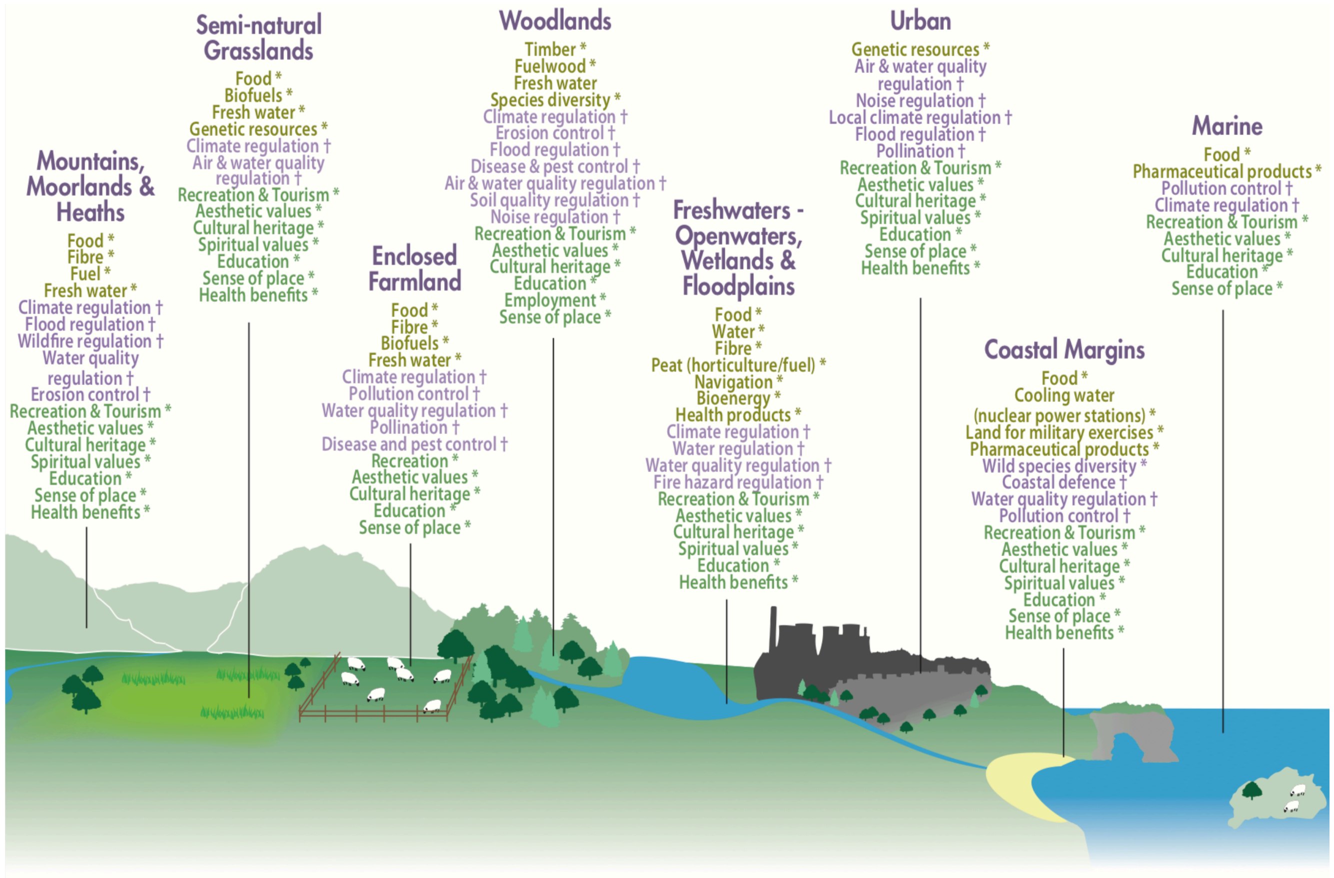

Figure 3 – The eight Broad Habitats assessed in the UK NEA and examples of the goods and services derived from each. Items marked with an * denote goods, those with + denote services. Items in yellow are considered to be from provisioning services, purple from regulating and green from cultural. The supporting services, including primary production and nutrient cycling, are not listed against individual habitats as they are considered necessary for the production of all other ecosystem services. Source: adapted from the Millennium Ecosystem Assessment (Watson *et al.* 2011b).

2.3.1 Woodlands and climate regulation services

There is strong evidence that climate change is driven by human activity, due to emissions of greenhouse gases (GHG) (Allard *et al.* 2007; Pachauri *et al.* 2014; Sookun *et al.* 2014; Bachelet *et al.* 2017). The largest contributor is carbon dioxide (CO_2), which is emitted either by natural processes, such as decomposition and respiration or human activity, such as deforestation or fossil fuel burning as a means of producing energy (Fowler & Ekström 2009; Pachauri *et al.* 2014). Other GHG emissions also contribute at a smaller, albeit significant scale, such as Methane (CH_4) and Nitrous oxide (N_2O) (Anderson ‐ Teixeira & DeLucia 2011). Additionally, landscapes can either contribute or help store carbon and offset CO_2, depending on land-use and management techniques (Alonso 2012). Two important sources of CH_4 in upland environments are the anoxic conditions of waterlogged soils and grazing animals, which releases CH_4 when soils are disturbed. CH_4 is also released as a by-product of the digestive process of animals and released by belching (Le Mer & Roger 2001; Richmond *et al.* 2015). Nitrous oxide (N_2O) emissions occur in managed agricultural land where nitrogen fertilization is applied (Allard *et al.* 2007; Jones *et al.* 2011). CO_2 is stored in high volumes in woodland and the organic peaty soils that often occur in the uplands (Alonso 2012). This is released when the soils are drained or woodlands felled, decay or are burnt (Pachauri *et al.* 2014).

Forests and woodlands are a significant contributor in removing CO_2 from the atmosphere through photosynthesis (Cannell & Milne 1995; IPF 2012). It is estimated that globally, they could reduce approximately 25% of current CO_2 emissions from fossil fuels by 2030 (Read *et al.* 2009). Plants are important stores of carbon in their above and below-ground biomass as well as litter, dead wood and in the soil (Alonso 2012; Vanguelova *et al.* 2013). Furthermore, plants sequester carbon from the atmosphere over time. Both of these factors have a positive impact on climate regulation, by removing and storing carbon from the atmosphere, which is also known as the 'negative flux'. Natural processes, land management techniques and human activity can release this stored carbon, for example by dead wood decaying, burning of fossil fuel, respiration, drainage or disturbance of soil. This is known as emissions or the 'positive flux' (Peh *et al.* 2013).

Research by Worrall *et al.* (2009); Cantarello *et al.* (2011) suggests that expansion of woodlands have a beneficial effect on carbon storage. In the UK, the average woodland stores 57 tonnes of carbon per ha (t/C/ha) above-ground (Broadmeadow 2003). This figure does, however, vary depending on species, age of trees and growth rate (Cannell & Milne 1995) and is shown by Morrison (2012) to be within a range as wide as 0 – 382 t/C/ha. A significant amount of carbon is additionally stored in the litter and soil of woodlands and other vegetation – table 5 (Patenaude *et al.* 2003; Vanguelova *et al.* 2013). This is illustrated in figure 4, which displays the average above and below-ground carbon storage of different vegetation types in the Lake District National Park (Hagon *et al.* 2013).

Carbon sequestration carried out in terrestrial plant habitats also varies markedly. Maintained, grazed grassland in the UK sequesters 2.20 t/CO_2/ha-1/y-1 on average (De Deyn *et al.* 2011), but this will vary depending on management, as illustrated in table 6 (Alonso *et al.* 2012). An average woodland sequestration rate is difficult to display, due to rates of sequestration in trees varying enormously depending on age and management (West 2012). Trees begin to sequester in small amounts after planting, which then increases substantially as growth rates increase. Whilst the tree is in this phase, sequestrating is at its highest rate. As the tree matures and becomes old growth, sequestration rates decrease again (Broadmeadow 2003). As different species grow at different rates, this process is species specific. During the 2012 carbon account for woodlands in the Lake District National Park, it was estimated by Greig (2012) that annually, Lake District National Park woodlands sequester 8.2 t/CO_2/ha-1 for conifers and 4.3 t/CO_2/ha-1 for broadleaves.

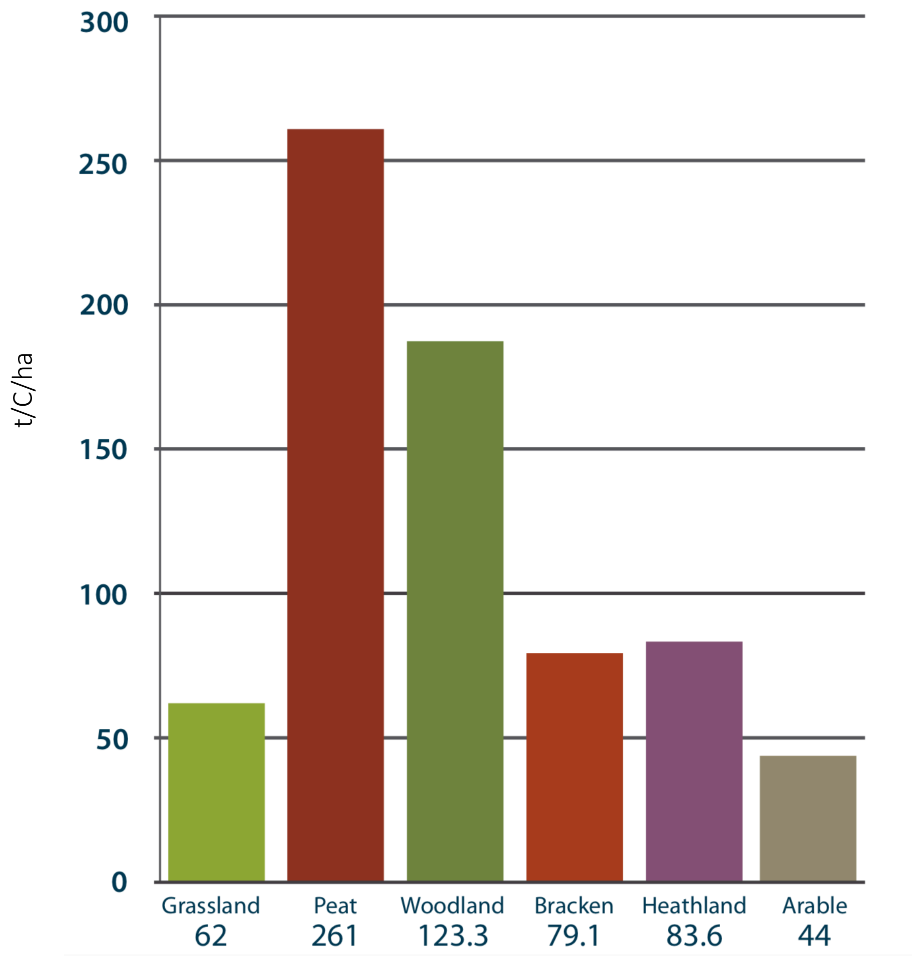

Figure 4 - Average UK broad category habitats above and below ground t/C/ha results from Hagon *et al.* (2013).

Table 5 - Average carbon stock estimates in soils and vegetation for broad habitat categories in the UK (Alonso *et al*. 2012). For most habitats the majority of carbon is stored below-ground in the soils, whereas in woodland habitat there is an equal amount of carbon stored below and above-ground.

Habitats	Carbon stock in soils ($t/C/ha^{-1}$)	Carbon stock in vegetation ($t/C/ha^{-1}$)
Dwarf shrub Heath	88	2
Acid grassland	87	1
Fen, marsh and swamp	76	?
Bog	74	2
Coniferous woodland	70	70
Broad leaf, mixed & yew woodland	63	70
Neutral grassland	60	1
Improved grasslands	59	1
Arable and horticulture	53	1
Coastal margins (UK)	48	?

Table 6 – Grassland management and carbon estimates (Alonso *et al.* 2012)

Grassland condition	Management option	Annual Carbon exchange (+emissions; -sequestration) (Mt/CO_2-e yr^{-1})	Area Carbon exchange (+emissions; -sequestration) (t/CO_2-e/ ha^{-1}/yr^{-1})
Degraded	Peat extracted	+0.422	
Restored (from other land use or improved grassland)	Restoration	-8.72	-11.62
Maintained	Biomass burning	+0.13	
Maintained	Grazed		-2.20
Land use change	Grassland to arable	+14.29	+3.48 to +6.23
Land use change	Grassland to afforestation		-0.37
Land use change	Grassland to wetland		-0.39 to -14.30
Restored	Restore unimproved grasslands (soil + veg, yr 1)		-6.96
Restored	Restore unimproved grasslands (soil + veg, yr 2-39)		-4.03

The planting and Management of woodlands could aid regulation of the effects of climate change, particularly via producing carbon-intensive wood products (Bates *et al.* 2017), woodland expansion (Ghazoul & Chazdon 2017), reducing deforestation (Houghton & Nassikas 2018) and the replacement of fossil fuels (Gustavsson *et al.* 2017). Furthermore, woodland creation could make a substantial contribution to the UK emission targets (Read *et al.* 2009; Hannam *et al.* 2017). This would entail a 23,200ha per year planting rate over the next 40 years. Such a change would lead to a 10% reduction of total GHG emissions by 2050 (Read *et al.* 2009). The current UK woodland creation target of 13,000ha (Scotland 8000ha, England 5000ha) is markedly below the recommended target. Read *et al.* (2009) recommended an afforestation programme that would bring the UK woodland cover to 16%, with a 4% change in land cover.

2.3.1.1 Payments for climate regulation services

For land managers and owners of both existing and new woodlands, ES can offer economic incentives by offering Payments for Ecosystem Services (PES). As examples, within the UK woodland this includes PES to carbon sequestration (Jenkins *et al.* 2011; Hannam *et al.* 2017; van der Gaast *et al.* 2018) and water management (Reed *et al*. 2017). In the UK carbon sequestration is, as a standard, calculated by use of the Forestry Commission Woodland Carbon Code (Jenkins *et al.* 2011). This is a voluntary standard for UK woodland creation projects and offers validation and verification about the carbon sequestered or stored in woodland (Jenkins *et al*. 2011). This has been a popular approach to businesses and private individuals to offset their carbon footprint (Hannam *et al.* 2017; Van der Gaast *et al*. 2017) and, as the project is certified, the carbon sequestered contributes directly to the UK's national targets for reducing GHG emissions (Jenkins *et al.* 2011; Hannam *et al.* 2017). Globally, there are similar payments for ecosystem service systems in place such as the IUCN REDD and REDD+ initiatives, which aim to reduce carbon emissions, by rewarding the enhancement of carbon storage via afforestation/reforestation, restoration and rehabilitation (Upadhyay *et al.* 2017). Carbon offsetting has however, been critiqued for being glorified and causing conflict and damage to local people (Cavanagh & Benjaminsen 2014) , only benefitting investment agencies, NGO's and policy targets (Corbera & Brown 2010), as well as fostering a trend of over-consumption (Lovell *et al.* 2009) and contributing little to mitigating climate change, due to ex ante assumptions, discounts in world carbon markets (van Kooten *et al.* 2015) and over- or under-crediting of emissions (Bento *et al.* 2016). Van Kooten *et al.* and Bento *et al.* suggest an increasing need for better and more precise emission accounting tools, which will help build trust in the concept. This will be addressed further in the discussion of the climate mitigation results from this study.

Climate change is a serious challenge confronting the world. Although there are discussions within the literature and challenges regarding methodologies behind carbon and GHG estimates, there is consensus that increasing woodland cover is beneficial for climate change mitigation as a whole. During the preliminary scoping study in chapter 3, stakeholders expressed particular interest in the carbon offsetting payment schemes as a means for new planting schemes. Chapter 4 addresses this and offers further information on the impacts to be expected within the study site.

2.3.2 Woodlands and water-related services

The impact of forests on water-related ES is a topical area of current research, especially due to the increased focus on natural flood management and its potential influence on mitigating flood risk (EA 2010, 2016; Ford & Smith 2016; Chandler *et al.* 2018). It is, however, an area that is relatively new and the science behind it is still very inconsistent (Ford & Smith 2016; Stratford *et al.* 2017). Water availability is an essential ES to society (de Groot *et al.* 2012) and is a resource that is created by a build-up of a water budget in a water catchment by inputs from climatic features, such as precipitation (rainfall, snow and ice melt, fog inputs) (Mulligan 2013). On catchment-scale, local upstream landscape and climatic features have a direct impact on water quality and quantity in the form of topography, geology, vegetation cover and land-use, wind, temperature and human interventions (Mulligan 2010). These all affect the run-off from the land surface via tributaries and into the main river channel. The water budget is then affected by the amount of water that is lost in a catchment, due to evapotranspiration (ET) from vegetation, water bodies and the ground (Mulligan 2010).

Different types of forest, such as coniferous or broadleaved, affect hydrology differently (Ford *et al.* 2016; Chandler *et al.* 2017) and the use of trees to mitigate floods has been recognised for over a hundred years (McCulloch & Robinson 1993). It has been suggested that the water balance in a forest landscape would be lower than that in a grassland landscape (Calder 2002; Andréassian 2004) because of a higher ET and reduced runoff rates. Hydrological models also seem to support this (Ford *et al.* 2016), but research which has made comparisons between estimates based on modelling and in-field actual data, has been less conclusive (Stratford *et al.* 2017). Additionally, Mulligan (2010) found that fog inputs can significantly change the water balance in forested landscapes in areas with particularly high fog settlement, which can be an overlooked variable to include in such estimates.

Global studies have contributed to the understanding of this relationship between woodlands and water quantity (Marion *et al.* 2014; Wehr *et al.* 2016; Nóbrega *et al.* 2018; Solek & Resh 2018), but implementing this knowledge and contextualizing to a specific case or area of interest is difficult, as demonstrated by Chandler *et al. (*2017). In Chandler's study, a comparison of the impacts of land use and tree species on surface runoff were made. Conclusions were that different tree species can create large differences in soil hydraulic properties, but that, *"the influence of land use can mask the influence of trees. The choice of tree species may therefore be less important than forest land use for mitigating the effects of surface runoff"*.

Although there is some evidence suggesting that woodlands have the ability to reduce water balance and flood flows (Robinson *et al.* 2003; Stratford *et al.* 2017), this issue is complex and continues to be debated (Stratford *et al.* 2017). There are several reasons behind this, such as the difficulties of measuring the effects of a change in land use in a large-scale catchment, the large number of variables involved, such as soil, type of woodland, topography and climate. Furthermore, testing the outcomes on an extreme 1% APE (Annual Probability Event) flood event is complex (Ford *et al*. 2016). Adding to this is the need for long-term monitoring, both on baseline and post-planting conditions and a large-scale catchment study area. It is not surprising, taking this into consideration, that current evidence is either derived from small-scale catchment experiments or modelling (Stratford *et al.* 2017). Increasing our knowledge of methods and tools to address such problems would be of substantial value to stakeholders, beneficiaries and policy decision making.

The evidence that woodlands have the ability to reduce the water balance (Stratford *et al.* 2017) and, compared with grassland, increase infiltration rates and ET and thereby, in theory, bring down the overall water balance (Nisbet & Thomas 2006) is influenced by land use and vegetation type. Several mechanisms, including water use (Iroumé & Huber 2002; Calder *et al.* 2003), infiltration (Christen 2007), hydrological roughness (Thomas & Nisbet 2007), soil protection and surface run-off (Nisbet 2016) have a particular impact and will therefore be discussed in detail below.

2.3.2.1 Water use

Water use of woodlands reflects the interception and evaporation of the woodland canopy of precipitation. This is carried out through evapotranspiration (ET) via a root-stem-leaf pathway (Neal *et al.* 1991; Iroumé & Huber 2002; Calder *et al.* 2003) and can reduce the volume of rainfall which reaches the ground (Ray & Nicoll 1998; Nisbet 2005; Dixon *et al.* 2014). This reduction in water balance has been estimated to be between 10% - 45% and a daily interception loss of 1 mm - 7 mm, depending on forest type (Nisbet 2016). Calder (2003) found a difference between conifers and broadleaves in their ability to intercept loss by 6-7 mm/day for conifers and 1-2 mm/day for broadleaves on a mean yearly average. Because of this, evergreen conifers are believed to have a higher impact (Nisbet 2005) and could lead to reductions of flood runoffs by >10% in complete conifer forested areas (Nisbet & Thomas 2006). Furthermore, there is also a seasonal variance in how much a forest can impact this, due to the changes in leaf cover during the year (Wehr *et al.* 2016). However, other research has suggested that evapotranspiration influence on reducing water levels in woodlands versus grassland, does not always yield significant changes. Harding *et al.* (1992) found that the planting of broadleaved forest as opposed to grassland, would only raise the mean rate of evapotranspiration from 400mm in grassland to 470mm in the woodland.

2.3.2.2 Infiltration

Infiltration is a another major component in a forest's relationship with the water balance (Mulligan 2013). Infiltration is the channelling of water into the ground via the roots (Christen 2007). Such pathways open the structure of soil and increase the organic content (woodland soil = higher organic content) of the soil, increase water infiltration and storage and, by doing so, decrease the risk of quick surface runoff (Thomas & Nisbet 2016). Tree cover protects the soil underneath from disturbance and the continuous addition of leaf fall builds up soil organic matter and good soil structure (Bischoff *et al.* 2015). This further increases the development of macroporosity, which encourages rainwater to penetrate the soil and follow pathways to streams (Nisbet 2016; Bird *et al.* 2003).

Infiltration rates in forests can be up to 67 times higher than that found in grassland (Carroll *et al.* 2004; Marshall *et al.* 2009; Marshall *et al.* 2014) – figure 5. A mean infiltration rate of 20 times greater than that of grassland has been found on measured plots consisting of 2-year-old trees, which may suggest that a change in land-use from grassland to forest could have a significant impact on infiltration rates in a short space of time (Carroll *et al.* 2004). The highest rate of mean infiltration found in the Carroll *et al.* (2004) study was 60 times higher. Research carried out in the Welsh Pontbren catchment by Marshall *et al.* (2009; 2014) supports these findings, by suggesting an increased mean infiltration of up to 67 times higher in fenced-off land under trees than adjacent grass grassland. The Pontbren results have, however, often been used as evidence for the benefits of trees over grassland, but it should be noted that this research was carried out on shelterbelts and hedgerows. Nor is much consideration given to differentiation of tree species, soil properties and landscape topography and their capacity on decreasing water balance when these results have been applied elsewhere (Ford *et al.* 2016). Additionally, other studies has found much smaller changes in infiltration rates between forested and grazed grassland. Archer *et al.* (2013) carried out research on upland landscape in Scotland and found a mean infiltration rate of 5-8 times higher under broadleaved forest versus grazed grassland. A further study carried out in 2015 in a different region of Scotland focussing on Scots pine plantations, indicated a greater infiltration in a mature plantation and that infiltration is likely to increase with age of forest (48-300 years), over a young plantation (6 years) or grazed grassland (Archer *et al.* 2016). This contradicts previous findings in 2013 by Archer *et al*., where no significant difference in infiltration rates between a Scots pine plantation and grazed grassland were found (Ford *et al.* 2016). This should be considered against the findings by (Evans & Boardman 2003; Fiener & Auerswald 2003); Carroll *et al.* (2004) whereby grassland was shown to have the potential to control soil erosion and surface runoffs in a beneficial way, if the grassland is lightly grazed or ungrazed and mixed within other arable crops. Intensively grazed grassland is, however, well known for the potential of soil becoming compacted and thereby reducing the infiltration of rainfall (Alderfer & Robinson 1947; Carroll *et al.* 2004).

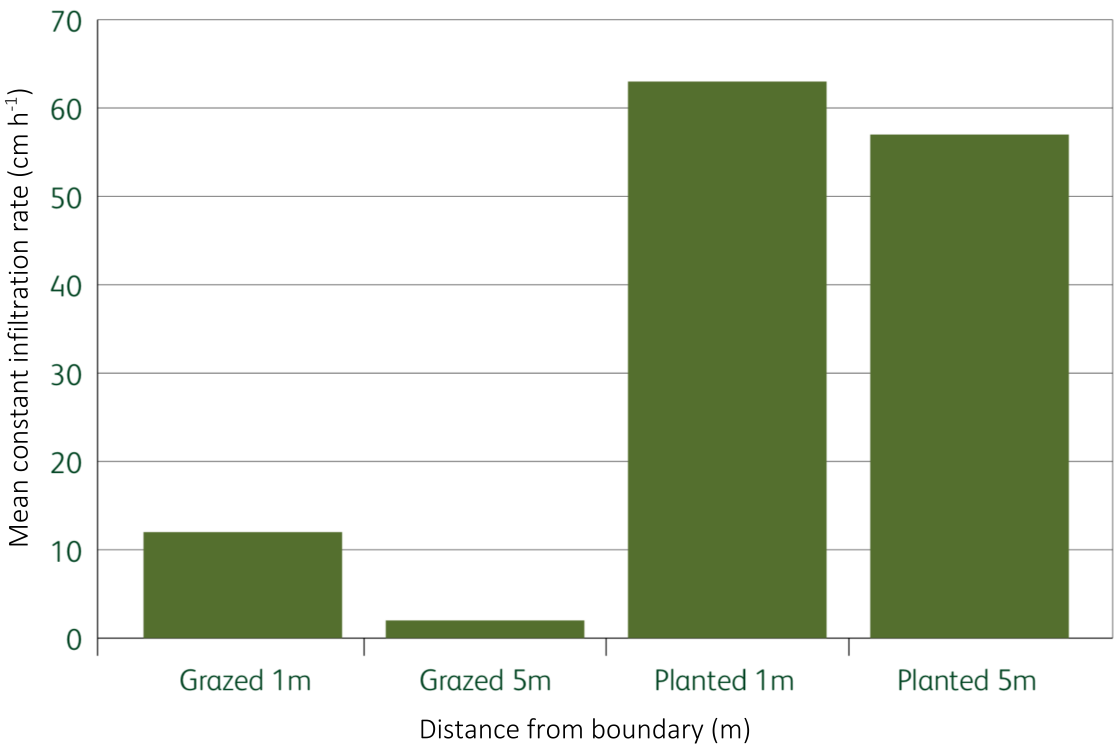

Figure 5 – Mean soil infiltration rates in woodland shelterbelts over sheep grazed pastures. Adapted from Carroll *et al.* (2004).

2.3.2.3 Surface runoff

Much of the evidence currently available on surface runoff is from smaller study areas and has been carried out on steep conifer plantations in upland catchments, rather than new planting, with the exception of the abovementioned Calder *et al.* (2017) study. Research has been carried out on hydrological processes on whole catchments which concludes that runoff in upland areas can be decreased by up to 300 mm/year in a forested catchment versus a grassland dominated one (Blackie 1993). Others have quantified a decrease in runoff by 1.5-2% per every 10% increase of afforestation in a catchment (Marshall *et al.* 2009). Subsequently, a further study (Marshall *et al.* 2014) found a reduction of 78% in runoffs and that near surface soil bulk density was significantly reduced in afforested plots compared to sheep-grazed pastures after only 2 years. This study also showed that a 48% reduction was obtained by simply excluding livestock by fencing. Other studies have found much less of an impact on forested catchments on water loss (Robinson *et al.* 2003; Nisbet 2016). Levels of runoffs and peak flows are also influenced by forestry management practices, such as ploughing and drainage ground preparation (Blackie 1993), and felling (Nisbet 2016) which, as a consequence, offset the delaying effect the trees would have on runoffs (Robinson *et al.* 2003; Chandler *et al.* 2017).

Hydrological roughness has also shown to have an impact on surface runoffs. This is due to roots, trunks, branches and debris creating a filter and a drag on flood water on the ground and thereby enhancing flood storage and "slowing the flow" (Thomas & Nisbet 2007). Further benefits from hydrological roughness are the reduction of sediment delivery and siltation and increasing transportation by providing physical shelter, reducing water runoff, soil strength/stability and protecting river banks. Large installations of large woody debris (LWD) dams have recently proven significantly effective in reducing runoff rates at the Slowing the Flow Pickering Project (Odoni 2010). LWD can have a significant impact on slowing the flow in the lower ends of the catchment if the intervention is situated correctly and in the upper half of the catchment.

The abovementioned research on the relationship between woodlands and water use, infiltration and surface runoffs suggests that woodlands do increase infiltration rates and water use and as a result, can decrease runoff levels, but that there are discrepancies as to the extent of how much and the validity of using modelled data. The section on 'Assessing ecosystem services' (2.4) will address this further.

2.3.3 Woodlands and nature–based recreational services

Nature-based recreation can be defined as the activities people may leisurely engage with in natural areas, such as hill walking, fishing, cycling, running, wildlife viewing and horse riding (Kuenzi & McNeely 2008). This form of recreation is an ecosystem service and is universally classified under the category 'cultural services'. Cultural services are defined by the Millennium Ecosystem Assessment as non-material benefits that society and people gain through spiritual enrichment, recreation, aesthetic experiences and reflection (Assessment 2005). Others have defined cultural services slightly differently, such as (Chan *et al.* 2012), who defined these services as being the, "*ecosystems contribution to the non-material benefits derived from human-ecological relations"* (Pröbstl & Haider 2013). Trips to the countryside, particularly quiet places and those offering a challenge, are very good for our physical and mental well-being (Tyrväinen *et al.* 2017) and may be perceived as a "*refuge from urban life as a place to heal*" (Cloke 2006; Nutsford *et al.* 2013). Others may seek a perceived rural idyll as expressed in the romantic period (Daugstad 2000). A tourism industry can be established based on nature-based recreational activities but is not regarded by some as an ecosystem service in itself, but as an outcome (de Groot *et al.* 2012). Others disagree (Daniel *et al.* 2012) and regard tourism in its fullness as a cultural ecosystem service (Pröbstl & Haider 2013).

Cultural services are suggested by some to be underrepresented in their significance compared with other broad ecosystem service categories (Daniel *et al.* 2012; Chan *et al.* 2012). In addition, Pröbst-Haider (2015), Daniel *et al.* (2012) and Chan *et al.* (2012) conclude that this is due to the lesser economical focus of these services in comparison to the more economically driven supportive, provisioning and regulating services. However, some cultural services such as nature-based recreation can, arguably, provide an important economic service to society (Paracchini *et al.* 2014; Sen *et al.* 2014). (Raudsepp-Hearne *et al.* 2010) suggests that there is a good level of research focussing on the economic value of cultural services and tourism specifically, but more is needed whereby the broader contexts of impacts to human health and well-being are considered. (Pröbstl & Haider 2013) agrees with this and adds that the research on the connection between human health and well-being and nature-based recreation is often divided across a wide range of research disciplines, which as a result, appears indistinguishable.

There is good evidence that time spent on nature-based recreation in woodlands, will have a positive impact on peoples' well-being, both mentally and physically. O'Brien and Morris (2014) found in the evaluation of 31 UK research studies that connectedness, mental well-being and sense of place were the three most notable benefits. Furthermore, physical, social and mental well-being (relaxing, sitting, thinking) activities were the three most popular activities undertaken. This is supported by Ward Thompson *et al.* (2005), who found in their study that the most cited feeling amongst woodland visitors, was *"feeling at peace".*

Milligan and Bingley (2007) do, however, suggest we take caution against uncritically accepting the idea of woodlands being therapeutic for all. Although Milligan and Bingley do not challenge the suggestion that woodlands can have beneficial impacts on mental and physical health, they do suggest that other factors than just merely having access to woodland and to nature-based recreational activities is not what, on their own, makes a positive influence. Early childhood experiences of being exposed to natural areas are a strong factor in how beneficial it will be later in life. Spending time in woodlands have by Li (2010); Li *et al.* (2011) been quantifiably shown to have positive effects on, for example, peoples' immune function and blood pressure. In Japan, the tradition of short leisurely visits to woodlands, so called forest bathing trips, increased participants' levels of immune functioning qualities. In a follow-up study in 2011, Li *et al.*, furthermore, found acute positive effects on cardiovascular and metabolic parameters by participants taking part in walking in woodland environments, as opposed to walking in an urban environment. These participants were from a mixed socio-demographic, but there is no mention or consideration towards childhood experiences.

2.3.3.1 Nature-based recreation in the uplands

Nature-based recreation is strongly connected to the uplands of the UK (Haines-Young & Potschin 2009). For the past 300 years the uplands have provided a platform for livestock grazing and supporting an important UK meat and wool production industry (Communities 2010). This production has shaped the landscape and underpins a cultural way of life for many residents in these regions (Mansfield 2011). Additionally, this has laid the foundation for a successful nature-based recreation tourism industry (Ilbery *et al.* 1998; Reed *et al.* 2017a).

Seventy-five percent of the UK's uplands have been designated as national parks or areas of outstanding natural beauty (Bonn *et al.* 2009). Walking in the hills for pleasure, fitness, education or a challenge, is a very popular recreational activity in the uplands (Young *et al.* 2003; Curry 2008) and, as a result, this tourism is increasingly becoming an additional source of income in many upland areas (Rotherham 2008; Communities 2010) which underpins local economies (Ilbery *et al.* 1998). Having a large amount of tourism in an upland landscape can, however, have detrimental environmental and social impacts (Young *et al.* 2003; Xu & Fox 2014). Some expected impacts are observed in terms of footpath erosion, wildfires and pressure on local infrastructure. As an example, 93% of all visitors to the Lake District travel by car (Park 2016) and approximately 70 million day visits are made to upland national parks each year from across the UK, with the Peak District and the Lake District receiving the most visitors (Park 2016). This consequently puts pressure on local infrastructure and, further to this, the dependent relationships between tourism and the environment in protected areas can, according to Connell *et al.* (2009), become either symbiotic or parasitic, where the benefits from tourism to the environment can be positive or damaging.

2.3.3.2 The value of nature-based recreation in Cumbria

The importance of tourism generated income to the uplands was demonstrated during the Foot and Mouth outbreak in 2001 in Cumbria (Donaldson & Alexandersen 2002; Phillipson *et al.* 2004) whereby the tourism sector lost £3.2 billion and the rural economy £8 billion as a result of visitor restrictions (Reed *et al.* 2009). In recent years Cumbria Tourism has been carrying out annual surveys on visitors to Cumbria. According to their 2016 statistics, The Lake District received 16.4 million visitors a year, which generated £1.15 billion. These statistics show that in Cumbria the majority of visitors come from within the UK (86%) and only a small proportion are of a minority ethnic community (1%). The life-stage of people visiting shows that most visitors are from a post-family[9] life-stage (65%), followed by younger families (15%) and pre-family (9%). The average length of stay is 5.71 nights, 73% of visitors stayed in paid accommodation and 28% in free accommodation. The average estimated cost for paid accommodation per person per night is £38.38 and per person per trip £177.24. The average spend per person per day[10] is £26.34 (excluding accommodation) and £43.95 (including accommodation). The total spend per person per trip is £166.99 (including both paid and free accommodation and other leisure spending).

Across many rural areas and communities in Europe, a similar pattern occurs, where tourism has either taken over from agriculture as the principle income generator or as a substantial contributor (Garrod *et al.* 2006; Silva & Leal 2015). This is driven by a need for additional income and the development of changes in production markets (Gahr *et al.* 2003). Such rural tourism development has been shown to result in improved socio-economic well-being, led to higher employment growth rates and a higher percentage of working-age residents being employed, as well as earning higher incomes (Reeder & Brown 2005). Rural tourism development also

[9] Post-family life-stage is people over 45 years of age with no children in their group.
[10] The spend includes food and drink, travel, shopping for gifts and daily needs, admission charges and other leisure expenditure.

resulted in the lowering of local poverty rates (Silva & Leal 2015) and an improvement of educational achievement (Jentsch 2017) and public health (Reeder & Brown 2005).

2.3.3.3 Impacts of nature–based recreational services on upland landscapes

Cultural and sociological impacts to local communities are expected by such changes in services provided by the landscape (Reeder & Brown 2005). These concerns were particularly associated with areas losing their uniqueness and authenticity in a changing agricultural system. Tourism is generally seen as a positive approach to generating income in these areas (Soliva & Hunziker 2009), but there is a widespread concern of 'Disneyfication' and loss of authenticity, a term put forward by Daugstad *et al.* (2006), to exemplify the commercial transformation of a given place. Authenticity is increasingly accepted as being of high importance in maintaining a cultural landscape (Urry 1994; Gustavsson & Peterson 2003; Daugstad *et al.* 2006).

An increase in housing prices, living costs and a pressure on infrastructure are also experienced along with an increase in tourists (Reeder & Brown 2005). This insight on the impacts from tourism is supported by an assessment carried out by the Lake District National Park (2016) (LDNP). LDNP estimates that the positive impacts encompass the creation of new jobs, support to local shops and products, services (public transport/roads) established for tourists can benefit locals, monetary value derived can be used for conservation and improvement of the areas and, as an outcome, increase how local people value and care for the environment. The negative impacts are, however, that the jobs created are often seasonal with low wages. The local shops and products may be supported, but are expensive and cater for the requirements of tourists, not locals. The large number of tourists can also have a detrimental impact on the environment in terms of more pollution and litter, pressure on footpaths, an increase in house prices and traffic congestion and parking issues.

Based on the review above, nature-based recreational tourism is undoubtedly important and connected to the Cumbrian upland landscape. During the preliminary scoping study, which will be presented in chapter 3, stakeholders expressed concerns regarding the potential impact creating more woodlands in this landscape may cause on tourism in particular. Chapter 3 and 4 will address this further.

2.3.4 Cultivated goods as a provisioning service

Provisioning ecosystem services are the goods people and society obtain from ecosystems, such as food, fibre, fuel and water (Constanza *et al.* 2017). These are often cultivated goods, which are provided by highly managed ecosystems and this is particularly the case with agriculture and food provision (Cong *et al.* 2014; Palm *et al.* 2014). Currently, the UK is 60% self-sufficient in foods (Firbank *et al.* 2014), but the global demand on this provisioning service is likely to increase as the human population increases (Ma 2005; Costanza *et al.* 2014) and it is estimated that, by 2050, global agricultural production will have to increase by at least 50% (Firbank *et al.* 2013).

Hill farming or pastoral farming is the primary agricultural use of the uplands in the North of England, particularly for sheep rearing (Mansfield 2012; Harvey & Scott 2016), with cattle rearing to a lesser extent and this acts a provisioning service of cultivated goods to society. This industry relies heavily on public subsidies from the EU Common Agricultural Policy (Reed *et al.* 2014). As an example, on average within a LFA (Less Favourable Area) region the average farm business income for an average level farm is £13,522 annually. Before subsidies, the average income would be £-4,778 annually (Consulting 2016). As such, optimal use of the land available to these farms is important and seeking income via alternative routes and diversification is important to ensure a sustainable business. Beckert *et al.* (2016) propose that integrating agriculture with forestry offers great potential in terms of both productivity and environmental benefits, such as mitigating climate change. Others, however, have shown that combining agriculture with tourism has proven to be beneficial for upland farmers. Talbot (2015) undertook research of the past 20 years of policy and rural development towards support for increasing tourism in rural upland Wales and concluded that farm tourism is a viable long term strategy.

Cultivated goods, in the form of food produced by the agricultural industry have been greatly improved in recent years by policy, technology and industry (Shortall *et al.* 2015). These provisionary services contribute substantially to both national and local economies and play a crucial role on other ecosystem services, such as cultural identity and nature-based recreation (Bateman *et al.* 2014). The main beneficiaries of cultivated goods are society at large (Constanza *et al.* 2014). The production of these goods is highly dependent on landscape and land-use management and a good balance between production and environmental protection is important, if both are to be managed sustainably (Reed *et al.* 2009; Firbank *et al.* 2013)

2.3.4.1 Agricultural livestock production in England

In England, 70% of the land area is currently under agricultural use, 55% being enclosed farmland and the remaining 15% used for extensive livestock grazing on semi-natural grassland and heaths (Bateman *et al.* 2014). Agricultural production has for the past 60 years also seen an increase in production from owned and managed resources and a decrease from wild resources (Bateman *et al.* 2014). EU agricultural policy has been a strong driver behind this increase, with its goal to maximize production (Burton 2004). Despite the highly technical and intensive nature of UK agriculture, (Firbank *et al.* 2013) states that the UK struggles to produce enough food to sustain its population. Only 59% of the food consumed is produced within the UK. Furthermore, agricultural exports in 2010 were worth £14 billion, but imports totalled £32.5 billion (Firbank *et al.* 2013).

There are large regional differences in England in terms of the type of agriculture, which is mainly driven by local terrain and geography (Harvey & Scott 2016). The southern and eastern areas generally have flat, large, relatively more fertile land for cereal crops, whereas the northern and western areas tend to focus on pastoral farming due to the upland terrain being generally less fertile (Mansfield 2012). Most farmland in the north-west is also within the designation of 'Less Favoured Area (LFA)', meaning land producing food at a lower yield. LFA is furthermore divided into two categories: 'Disadvantaged area' and 'Severely Disadvantaged Area (SDA)' (Mansfield 2012) – see figure 6. Most of the hill farms in Cumbria are within the SDA category. These designations are important as they have an impact on the level of subsidy the farm will receive (Steele 2016).

Pastoral farming is defined as the use of livestock to produce meat, wool, eggs and milk. In England, these constitute the majority of the agricultural outputs and the most common animals kept are cattle, sheep, pigs and poultry (Harvey & Scott 2016). Livestock productivity has increased over time, whilst actual numbers of animals have fluctuated (Burton 2004; Bateman *et al.* 2014). In England, sheep farming is an important agricultural industry and between the 1940s and 1970s there were approximately 26 million sheep in the UK (Firbank *et al.* 2014). The following twenty years saw a rapid increase and by 1990 the number had reached 46 million (Bateman *et al.* 2014). The number stayed constant up until the Foot and Mouth outbreak in 2001, but numbers have steadily declined since (Harvey & Scott 2016).

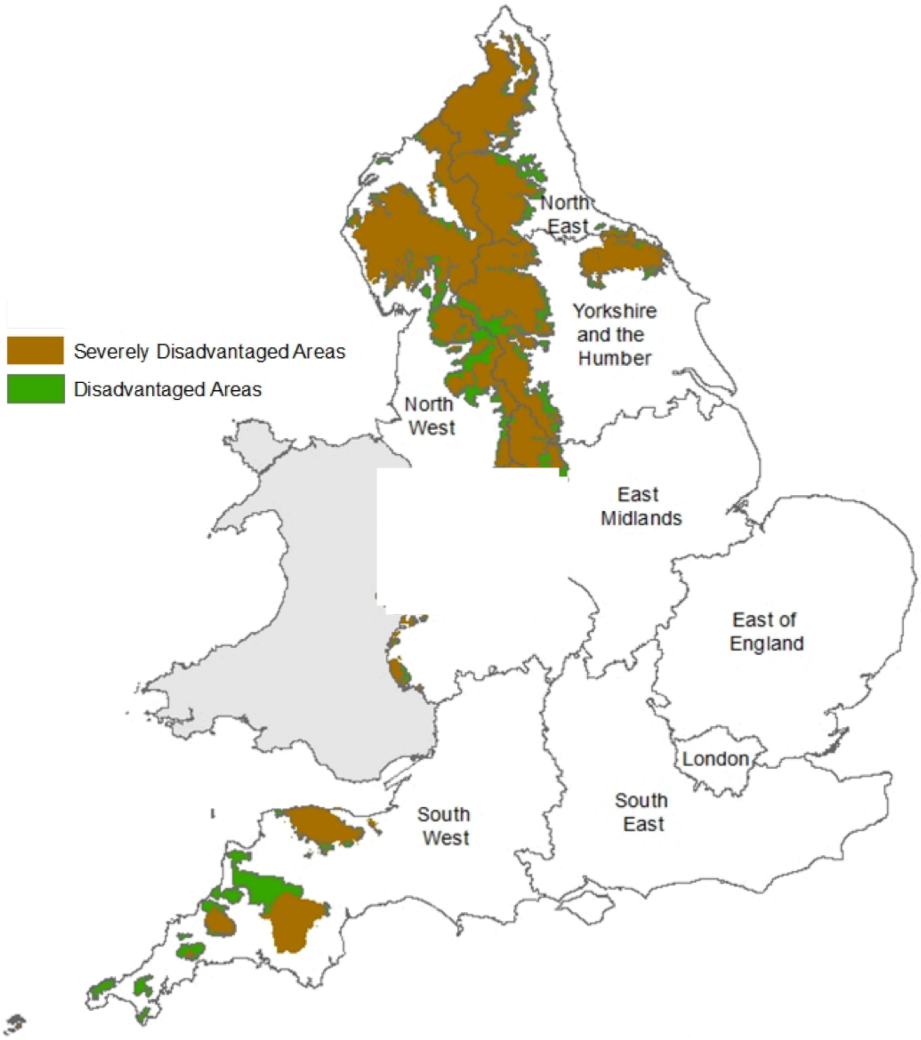

Figure 6 – UK designated ‘Disadvantaged Areas’ (DA) in green and the ‘Severely Disadvantaged Areas’ (SDA) in brown (Natural England 2016)

2.3.4.2 Hill farming in Cumbria

The typical upland farm in Cumbria has an average size of 15.6 ha and a large proportion of these are tenant farms. Nationally, half of upland farms are owner occupied and the remaining tenancies are of short-term licenses (Lobley *et al.* 2012). A farm will typically have a structure of farmstead in the valley with a patchwork of small ‘in-bye’ fields, enclosed by stonewalls and hedgerows. From there, moving up the hillside the lower parts of the fell (a ‘fell’ is the local term for mountain or upland area in the north of England) are typically semi-improved rough grass known as ‘intakes’ or ‘allotments’. At the top of the fell and onto the open fell the unimproved moorland exists (Waller 2006). In large parts of Cumbria these areas are commons with shared grazing rights (Robinson 2008) and common land is substantial in Cumbria, as it composes the majority of upland areas (Mansfield 2011). Common land is found mainly in the uplands and 30% of all common land in the UK is found in Cumbria (Federation of Cumbria Commoners 2015) – figure 7. These farms, aside from beef production, mainly produce breeding ewes to be sent to the lowlands where they are highly valued for their tough resilience, efficiency in terms of feed and good maternal instincts. Here they will be bred to lowland breeds for higher meat yield in production (NFU 2013). 44% of UK breeding ewes and 30% of beef cattle come from the uplands. The male lambs from the uplands will either stay on the farm to be fattened for slaughter or sold to lowland farms for slaughter.

Hill farming has played an important role in creating the upland environment and landscape as we know it today (Robinson 2008). According to the Federation of Cumbria Commoners (2015), "It has taken 450 years of hard work to make this land look untouched". Some would, however, argue that the Cumbrian upland landscape looks significantly 'touched' and are grazed to destruction (Monbiot 2013) . In the first 20 years of EU membership from the 1970s to the 1990s, EU agricultural subsidies were related to the number of sheep a farmer kept. This naturally led to a significant increase in sheep numbers, particularly in upland areas like Cumbria and Wales. Such a high number of sheep in the uplands created ecological changes in the composition in vegetation, habitats and soils (Oom *et al.* 2008; Mansfield 2012).

Hill farmers in Cumbria are facing severe challenges in sustaining their businesses and many are advocating a need for hill farms to diversify (Schwarz *et al.* 2006). This is mainly due to the low profitability of hill farming, changes in agricultural policy and subsidies. Some farms are still struggling with the effects of Foot and Mouth in 2001 and, additionally, there is a vast range of social factors such as an ageing farming population, a lack of affordable housing, a transfer of skills and interest, and the increasing difficulty for younger farmers to start up their own business (Schwarz *et al.* 2006; Mansfield 2011).

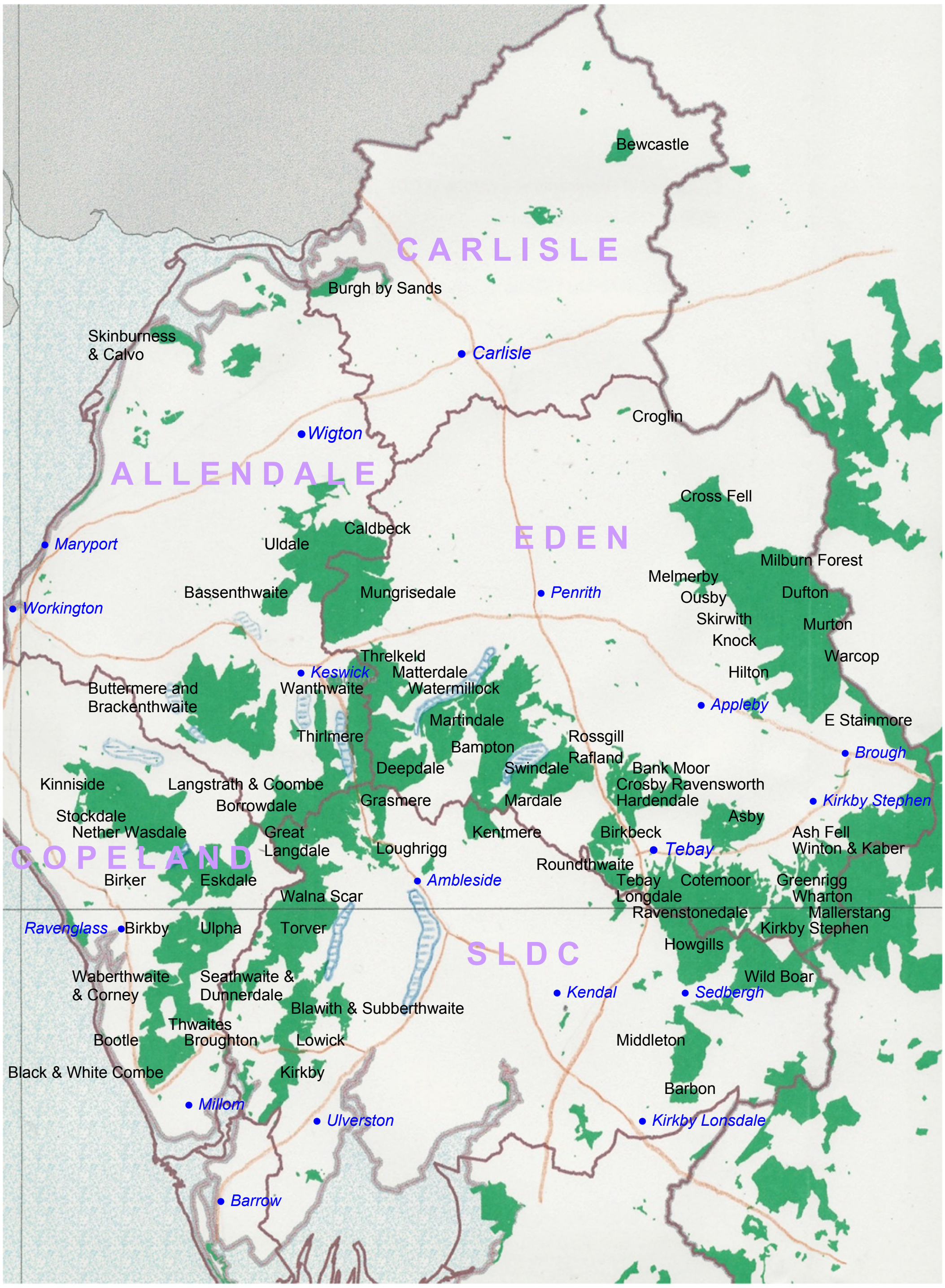

Figure 7 - Cumbria Common land areas (Federation of Cumbria Commoners 2015).

2.3.4.3 Drivers of change in hill farming

In the past 60 years the main drivers behind the changes in agriculture have been policy and technology (Burton 2004). Since the UK joined the EU and agricultural policy came under the umbrella of the EU there has been a substantial drive for increasing production up until the 1990s and, additionally, the introduction of the first agri-environment scheme Reed *et al.* 2009). Since then, the amount of agricultural land under these schemes has steadily increased in the UK (Bateman *et al*. 2014). The outbreak of livestock diseases, such foot and mouth, have also had a significant influence on hill farms in Cumbria. This has had a long-term impact, not just economically but also socially with regard to farmers' feelings of distress, bereavement, fear and loss in their trust of authority and the value of local knowledge. Mort *et al.* (2005) examined health and social consequences of the outbreak with participants making comments such as:

"I'll never be able to look at a cow or a sheep again without seeing blood pouring out of the hole in its head,… maybe I will in time. I walked, walking along the pier one night… I did actually think about jumping in… I felt so bad about myself"

"The silence, no it gets sad sometimes when you're in here… To be in here for a whole year, every day to see nobody… You begin to hate the place, you begin to hate the thing you love"

"What is being tested for in the surrounding streams? What exactly is classed as a danger? And if problems did arise, how would they be monitored and resolved? All these issues do tend to make you anxious"

Hill farmers in upland regions of England have, on average, a very low or even negligible annual net income (SAC Consulting 2016). This is due to the very close relationship between production costs and outputs and the small gross and net margins within this type of agricultural production (Mansfield 2011). Figure 8 shows the 2015/16 average LFA grazing livestock farm accounts from LFA regions on a national level, taken from the Farm Management Handbook (SAC 2016). These accounts show an average annual farm business income of £13,522 (£98/ha), including subsidies and diversification surplus. This is set within the context of the lower end being £10,143 (-£137/ha) and higher end being £41,853 (£200/ha). There is a clear trend of a higher income expected in connection with a higher average farm size and therefore a higher number of sheep (SAC Consulting 2016). In comparison, the Newcastle University led Farm Business Survey carries out annual regional statistic reports. Their data from LFA grazing livestock farms in the North-west region of England in particular reveals an even lower average Farm Business Income of £11,735. This amounts to an average of £78/ha with a strikingly large variation of a minimum of -£534/ha and a maximum of £590/ha (Steele 2016). Due to this, many farms seek to diversify and are heavily reliant on subsidies and participation in agri-environment schemes to make their businesses viable (Reed *et al.* 2009).

The production of cultivated goods in Cumbria is closely linked to industry, culture, sense of place and identity. It is therefore not surprising that within the topic of woodland creation in the uplands of Cumbria, this element of ES plays an important part. Chapter 4 will assess the impacts on cultivated goods within the study site, but chapter 5 will expand on this by exploring some of the perspectives closely linked to this particular area of the topic.

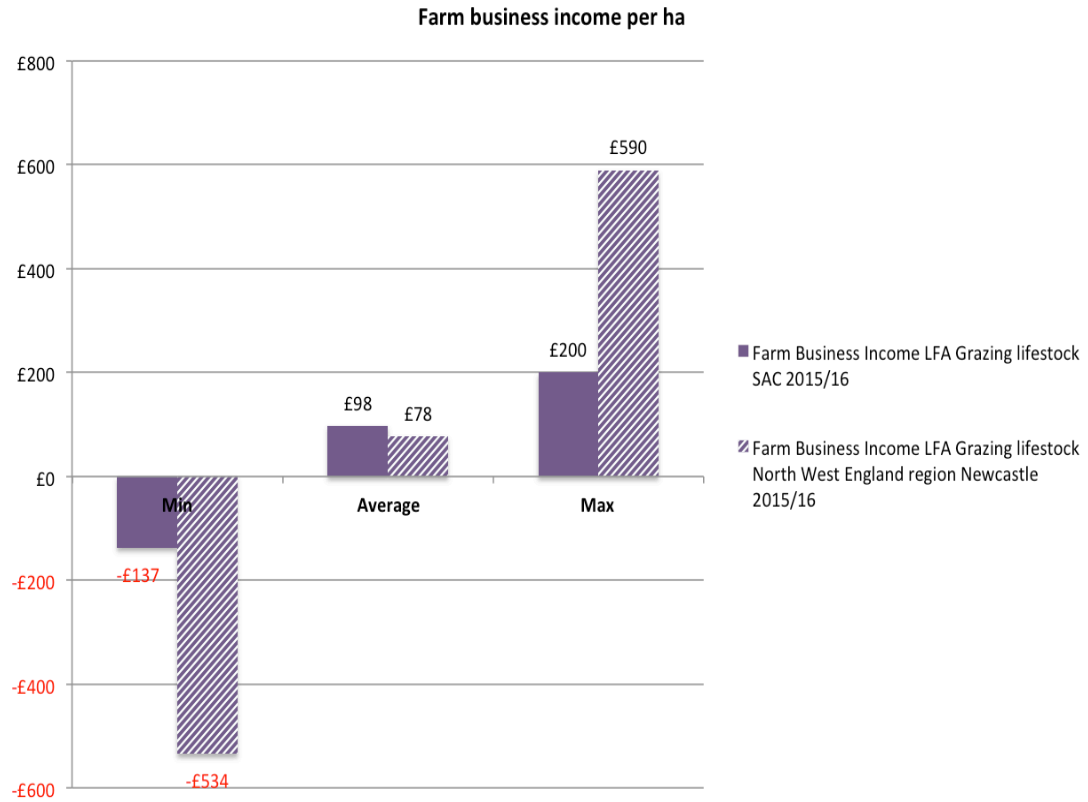

Figure 8 – Farm business income examples from two different sources: the Farm Management Handbook (2016) (dark purple) and the regional North West survey data from Newcastle University (Steele 2016) (purple hashed). The purple columns show an average annual income from LFA farms with a lower end income, an average income and a higher end income. The hashed columns show income from LFA farms regionally specific to North West England. These figures are depicted as a minimum, average and maximum annual income.

2.4 Assessing ecosystem services

The benefits from ecosystem goods and services (ES) are well documented as presented by the literature in the previous section. It can, however, be difficult to quantify site-specific ES due to the need for substantial resources and specialist knowledge (Birch *et al.* 2014). Therefore, such assessments are mostly carried out via modelling approaches which are limiting, relying on input data and with corresponding 'modelling caveats' (Peh *et al.* 2014; Zank *et al.* 2016). Many toolkits and approaches are available to measure ecosystem services and it is a field which is developing rapidly (Thapa *et al.* 2014; Guerry *et al.* 2015; Zank *et al.* 2016; Sharps *et al.* 2017; Constanza *et al.* 2017).

Quantifying ES by the use of economic valuation of ecosystems is commonplace (Constanza *et al.* 2017) and accounting or monetary value of ES is increasingly presented as part of the concepts of Natural Capital and Ecosystem Service Valuation (Sullivan 2017). These aim to provide a framework whereby benefits from ecosystems are better understood for policy and decision-making (Claret *et al.* 2018). Economic valuation as a conservation strategy began as a product of the 1992 Rio Conference on Biodiversity. In 2005, the United Nations published the Millennium Ecosystem Assessment, a significant research project running over 4 years and involving 1300 scientists. The report was closely followed by the influential United Nations report, The Economics of Ecosystems and Biodiversity (TEEB) (Sukhdev *et al.* 2010). The TEEB agreement was reached to, "Initiate the process of analysing the global economic benefit of biological biodiversity, the cost of the loss of biodiversity and the failure of protective measures versus the costs of effective conservation" (Sukdev *et al.* 2010). MEA and TEEB have had a significant impact on forming the framework around economic valuation of ES globally (Braat & De Groot 2012). This valuation of ES can lead to economic incentive schemes, whereby land owners and managers are offered Payments for Ecosystem Services. Within the UK some of the best examples of woodland related Payments for Ecosystem Services relate to carbon sequestration (Jenkins *et al.* 2011), water and peatland management (Reed *et al.* 2017)

Such assessments are, however, often carried out on a large scale (region, country, catchment) as smaller site-specific ecosystem service assessments are difficult, due to site-specific circumstances and the need for finer detail. Hypothetical scenarios are therefore often applied for smaller site assessments (Baral *et al.* 2016). This may be an advantage for land managers and decision makers, as the results obtained from such assessments have been used to provide evidence to interested stakeholders on what impacts can be expected (Thapa *et al.* 2014; Sharps *et al.* 2017). The promise of such positive information contribution by an ecosystem service assessment has, however, been questioned (Saarikoski *et al.* 2018) in regards to what exactly these benefits are. Saarikoski *et al.* (2018) showed that outcomes from assessments were rarely used as an instrument for decision making surrounding policy options, but that the value was found in the conceptual learning by the interaction between stakeholders, researcher and practitioners, as part of participatory assessment processes.

2.4.1 Strengths and weaknesses of ecosystem services assessment tools

Questions are raised regarding the quality and strengths and weaknesses of ES assessment tools. Sharps *et al.* (2017) carried out a review of three of the main modelling tools: ARIES, InVest and LUCI, looking at the quality of outputs as well as their sensitivity to different levels of land-use change. They concluded that these modelling tools can provide useful decision support outputs and validation against in-field measurements were very good. The different modelling tools do, however, provide different types of outputs and have differing strengths and weaknesses. Sharps *et al.* (2017) therefore recommended care should be taken in selecting the appropriate tool for specific site circumstances, aims and objectives.

Hydrological modelling is often applied when assessing alternative land management or land use options for water management and can be a valuable tool for decision making (Sharps *et al.* 2017). Results from studies based on modelling have suggested that afforestation can reduce downstream flood levels and delay peak flows. For example, (Ballard *et al.* 2013) showed that on a catchment level, afforestation can reduce flood peaks, but quantities deviate greatly. One study site, (Pickering, with an area size 68 km^2), showed a 4-8% decrease. Other sites experienced varying reductions; Hodder (25 km^2) showed a 0-13% decrease, River Tone 3-27%, Pontbren (6 km^2) 2-54% and finally the New forest 6-19%. Flood risk alleviation decreases with catchment size (greatest decreases are for areas <100 km^2) (Nisbet 2016) and the ability for woodland to reduce flood flows declines with flood size, although modelling suggests that afforestation can influence 1 in 100 year or larger events (Nisbet 2016). Thomas & Nisbet (2012) and Odoni & Lane (2010) modelled the hydraulic impact of installing Large Woody Debris dams into watercourses on a catchment-scale and found that these dams could delay the flow of a flood peak by an average of 2-3 minutes. Modelling has also aided the understanding of the importance of location and scale for the afforestation carried out in a catchment. Interestingly, this modelling has shown that small-scale planting can have a significant impact which is not necessarily increased with the scale of planting (Nisbet 2016).

Modelling suggests that afforestation has the potential to reduce flood flows in the range of 5-20%. Research outputs from the Pickering, North Yorkshire "Slowing the Flow"[11] project (https://www.forestresearch.gov.uk/research/slowing-the-flow-at-pickering), predicted that increasing woodland cover in the catchment will deliver the primary objective of protecting Pickering from at least a 1 in 25 year flood, reducing the chance of flooding in the town from 25% to 4% or less in any given year. However, research on the ground suggests that evidence of afforestation reducing flood flows in larger catchments remains 'light' and difficult to prove

[11] www.forestresearch.gov.uk/research/slowing-the-flow-at-pickering/

(Nisbet 2016). This suggestion is further confirmed by Stratford *et al.* (2017) who observed that amongst studies of impacts of level of woodland cover on flood peaks, there was a difference in results between studies relying on observational data and modelling data – figure 9. Studies which supported the conclusion that increasing woodland cover would decrease peak flows, relied mainly on modelled outputs. Studies that were using observational data had more mixed conclusions. Here, there remains a consensus towards the conclusion that increasing woodland cover would decrease peak flows, but Stratford *et al.* (2017) observed notable numbers supporting results of no difference or influence, or even the opposite effect.

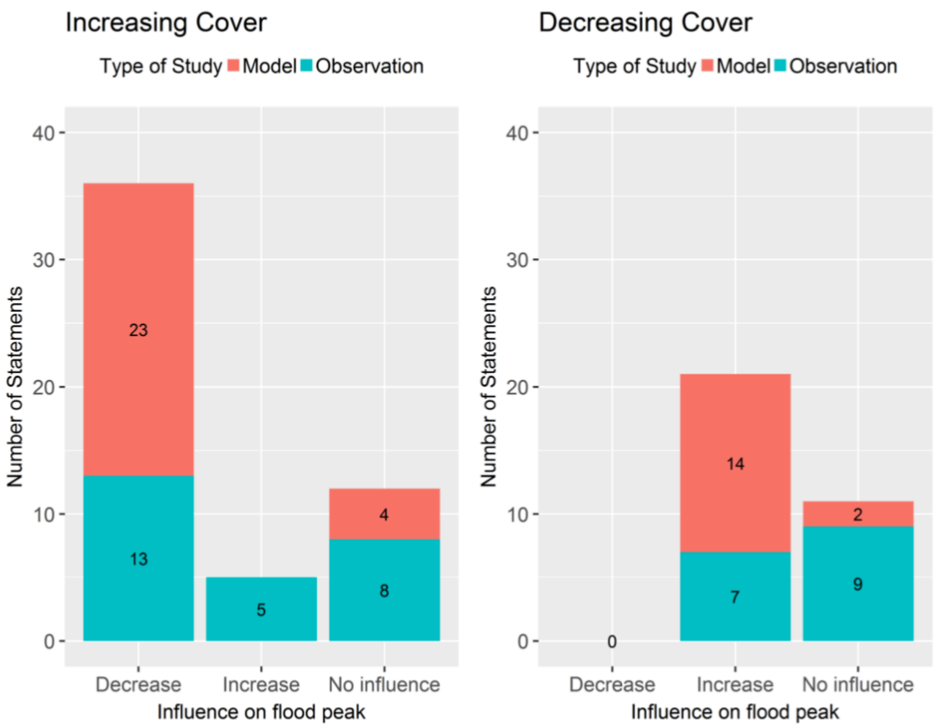

Figure 9 – Difference between modelled and observational data as concluded from the Stratford *et al.* (2017) review of impacts of the level of woodland on flood peaks, using both observational and modelled data. The figure shows a combined analysis of all statements, distinguishing between the tree cover basis (increasing/decreasing) and type of study.

2.4.2 Contextualising ecosystem service assessment approaches

For this study it was important that results were meaningful on a local level and the use of modelling tools that utilise generalised data and algorithms would be received with scepticism. Different ecosystem services and goods need specific approaches relevant to each and having just one tool that assesses multiple ecosystem services and incorporates such varied approaches is problematic. As described previously within this chapter, many tools have a focus on, for example, hydrological process models or carbon stock assessing. It was also of importance that the tool to be used for this study was at a site-specific-scale, publicly available and could be used without contracting academic or consultation agencies for application. Added to this, this study also aimed to assess stakeholder perspectives on the topic, so a strong stakeholder engagement component was deemed important, as well as the ability to address both aims and objectives within the study given the time and resources available.

The most widely used ecosystem assessment tools, such as ARIES, InVest, Co$ting Nature and LUCI that are within the public domain are at a landscape-scale, not site-specific, use generalised data and struggle to provide meaningful outputs for cultural services and recreation in particular. A generalised data large-scale approach may have been suitable for a study with the focus of comparing landscapes in different regions, but this would be unsuitable for the aims of this study. Within the category of assessment tools which can be used at a local site-specific scale, the tools Envision, EPM (Ecosystem Portfolio Model) and InForest are to be found. These do not apply generalised data, but can provide detailed information. They have however proven to be expensive and time-consuming, but have been valuable in areas where they have already been developed. Bagstad *et al.* (2013) has carried out a substantial review of available ecosystem services tools , which was largely used to inform the choice of tool to be used in this study.

The problem with the abovementioned approaches, is also that the local stakeholder context and detail is missing, which was deemed important to this study

Reed *et al.* (2013b) evaluated the importance of the use of stakeholder participation in the process of scenario development in ecosystem services of the uplands of the UK. Here, they concluded that by taking a participatory approach, scenarios become more relevant to stakeholders, scenarios became more detailed and precise and, through the integration of local knowledge further adaptation of recommendations were more likely. They argued, furthermore, that, "*Participatory scenario development can empower stakeholders and lead to more consistent and robust scenarios that can help people prepare more effectively for future change".*

The challenge is therefore to incorporate more participatory involvement and social perspectives into a quantifiable assessment tool. The next section of this review introduces a newly developed assessment toolkit, with aims for a higher level of participatory stakeholder involvement.

2.4.3 Toolkit for Ecosystem Service Site-based Assessment (TESSA)

TESSA (Toolkit for Ecosystem Service Site-based Assessment) is a newly developed toolkit, which is not reviewed by Bagstad *et al.* (2013b) against the other currently available toolkits. At the beginning of this project, TESSA only offered a first edition under development, but aimed to overcome the challenges mentioned above by offering guidance on how to assess the chosen services in a scientifically sound and practical approach (Peh *et al.* 2013). This made it of specific interest to this study, with the acknowledgement, that there were elements of TESSA which still needed fine-tuning. The outputs from TESSA allow the users to get an estimate for the positive and negative impacts to be expected, by changing one land use or management to another.

Finer-scale measurement of ecosystem services, which include a strong participatory element and site-specific data, are increasingly needed to inform decision making on a local scale (Peh *et al.* 2013; Saarikoski *et al.* 2018).The guidance within the toolkit aims to be applicable world-wide and under very different scenarios (Peh *et al.* 2013; Van Soesbergen 2013). Currently, TESSA has only been tested on relatively few case-studies world-wide, such as assessing ES benefits and drawbacks from community forestry in Nepal (Birch *et al.* 2014), trade-offs between ES and different people in biodiversity conservation in Nepal (Thapa *et al.* 2014) and impacts on ES of invasive species in Montserrat (Peh *et al.* 2014b). Most of these case studies have been in data-poor regions, with the exception of two case studies in the UK. Blaen *et al.* (2015) assessed differences in the provision of ES under two common mineral site after-uses: agriculture and nature conservation and Peh *et al.* (2014a) explored the benefits and drawbacks of ecological restoration in a UK wetland. A common thread in all of these studies is that stakeholder collaboration throughout the process has been included and strongly valued.

TESSA recommends a strong collaborative approach by engaging with stakeholders throughout the whole process of ecosystem service assessment, which is partly what makes this tool different from other tools available. This is advantageous as it addresses the need for a site-specific ES assessment (Peh *et al.* 2013) and provides results relevant to local stakeholders. The concept of collaboration between scientists and stakeholders is well documented as being beneficial and may influence long-term thinking on the topic of changes in land-use by changing perspectives on the subject, as well as the willingness to engage with the research as time and the research progresses (Pocock *et al.* 2017). Additionally, a genuine interest can build towards the outcomes and interest in the results from the study as well as being a beneficial educational experience to take part in (de Vente *et al.* 2016; Reed *et al.* 2017b).

Ecosystem service assessment, with guidance from the TESSA toolkit, is adapted as necessary to local specified needs. This means that in some parts of the assessment, primary data collected within the study area is applied and, in other parts, secondary data from previous studies applied. The TESSA methodology allows and encourages this (Peh *et al* .2013). TESSA is a toolkit designed to be applicable for site-specific ES assessment worldwide and, therefore, any user will have to apply a separate methodology for each indicator suitable for the specific region, site and data available. Guidance is provided from TESSA to do this, but is often limited. It is important to note, that TESSA is a method that aims to assess ES 'rapidly', i.e. allowing users to carry out an assessment with limited resources and this is another difference from other ecosystem service assessment methods currently available, but finding a balance between obtaining and analysing dependable and good quality data and keeping the assessment 'rapid', is very challenging. To this date, TESSA has not been applied in an upland UK landscape.

Assessing ecosystem goods and services which are site-specific are, as detailed above challenging, due to finding the balance between making the assessment relevant for the specific case or project despite the assessment carried out with often limited resources. What is lacking in all previous research carried out in this area, is the additional insight of stakeholder perspectives. Stakeholder engagement may be part of the process of assessing ecosystem services, but no other study has, to date, complemented this with a subjective analysis of stakeholders perspectives. Within this study, this subjective analysis has proven to add valuable knowledge in understanding how changes in an area may impact ecosystem services. This will be explored further in chapter 5.

Chapter 4 aims to assess the four ecosystem goods and services identified in chapter 3 and how they may change under four scenarios of woodland creation. The next section of this review focusses on the perspectives related to woodland creation, which are identified in chapter 3 as being a central part of the topic of creating new woodlands in the uplands of Cumbria.

2.5 Perspectives Of Woodland Creation

The interest in private landowners, their land and environmental resource management is an increasing trend observed in the UK (Kirby 2003; Church & Ravenscroft 2008; Urquhart *et al.* 2012). Previous research has focussed on landowners and manager attitudes to policy tools, incentives and regulation (Madsen 2003; Langpap 2006; Church & Ravenscroft 2008) and the outcomes of such regulatory tools (Sorice *et al.* 2014; Nielsen-Pincus *et al.* 2015; Ruseva *et al.* 2015). Additionally, creating typologies of stakeholders as a means of gaining understanding of attitudes and opinions is increasingly gaining interest (Eves *et al.* 2013; Lawrence & Dandy 2014; Valatin *et al.* 2016).

Farmers are often the focus of attention in these studies (Kim & Langpap 2016; Holstead *et al.* 2017; Walder & Kantelhardt 2018) and they are often perceived as having negative attitudes towards woodland creation due to the conflict between land use, culture, history and personal values and experiences (Bell 1999; Stubbs 2011; Fox 2012; Eves *et al.* 2013; Holstead *et al.* 2017). This perception is proposed as being too simplistic by Lawrence *et al.* (2010) and Mann (2018) who challenge the idea that farmers are against woodland creation *per se*, proposing that the subject it is much more complex and context specific. For example, (Stubbs 2011) identified that farmers responding to his survey on woodland expansion in the UK would have up to 10% of their land set aside for woodland creation. The wording of 'Woodland' and 'Forest' was also identified by Lawrence and Edwards (2013) as significant, as 'Forest' comes with the connotations of forestry historically being, "The big bad guy marching over the hills, stealing all the land".

2.5.1 Cumbrian perspectives

In Cumbria, farmer attitudes have been explored by the Woodland Carbon Task Force report, which carried out a pilot study in Cumbria by engaging with the agricultural sector (Fox (2012). The aim of that project was to stimulate an increase in woodland creation to aid the UK's climate change mitigation targets. Out of 117 responses, sixty replied that they would plant trees on their land. Forty of those considering planting would only go ahead if the level of subsidy was higher than the current level. This indicates a strong economic driver behind motivations for woodland creation. Fox (2012) did, however, identify that for some landowners it does not matter what economic incentives there might be, they simply do not wish to plant trees. This resistance is supported by older studies by (Bateman 1996; Harrison *et al.* 1998; Bell 1999). This mindset among the farming communities may have strong cultural and community roots and may be a question of personal values, preferences and sense of place. This was also identified by (Fox 2012) whereby participants stated, "*We farm sheep, not trees*" and, "*Farming is a way of life, we want to farm these hills as our fathers have done before us and not plant trees on them"* and, "*No amount of money would change their minds".*

2.5.2 Identification of motivators and woodland creation typologies

Lawrence *et al.* (2010) suggests that, despite the findings of Church & Ravenscroft (2008) where they report that 60% of landowners rate the importance of grants as 'very important or vital', there are a lot of assumptions being made about the influence of economic incentives, whereas little actual research has been carried out to support them (Lawrence *et al.* 2010). Stubbs (2011) noted during his research into barriers to woodland creation in Scotland, that the participants did not believe that an increase in grant support would lead to more woodlands being planted. In fact, participants commented that the process for putting an application forward was so complicated that it could lead to withdrawal or even self-funding of the project. This observation has since been supported by (Bell 2014). More recent research (Kim & Langpap

2016) has addressed this and found increasing support for economic incentives as a motivator for woodland creation. Eves *et al.* (2013) found that among a large study of a thousand woodland creation stakeholder participants in the UK, higher grant payments and reducing the complexity of grant applications were the most important incentives in encouraging planting.

A trend of recent research is to focus more on investigating typologies of landowners and managers, with an acknowledgement that economic incentives are a motivator for everyone (Mann 2018). There is also a need to better understand the underlying feelings and values behind decision making (Morgan-Davies *et al.* 2012). These typologies are used as a means to understand which interest groups to target and how to do so (Eves *et al.* 2013; Lawrence & Dandy 2014; Valatin *et al.* 2016). An early approach to identifying different stakeholder typologies was carried out by (Madsen 2003) in a study in Denmark on farmers' reasoning behind woodland creation. They found a more complex variation of attitudes and perspectives depending on the individual's values and interests pre-engaging with planting schemes. This study, furthermore, identified a polarised typology of different interest groups of landowners of a production-nature orientation. All participants had applied for woodland creation subsidies, but for very different reasons. When participants were asked to comment on their reasoning, the production-oriented participant would state, '*Area not useful for production', 'Woodlands give shelter', 'Edges not useful', 'Difficult to cultivate', Hilly* or *filled with stones'.* The nature-oriented participant would state; '*Wish to do something for nature', 'Protect water resources', 'Create recreation areas for towns'* or, *'I like woodlands'.* (Madsen 2003) concluded, furthermore, that the landowners who were of the nature-oriented group would be more likely to go ahead with the planting, regardless of the presence of a granted subsidy or not. A similar study was followed up by (Eves *et al.* 2013) using a segmentation model to categorise sub-groups of woodland creation stakeholders. They identified a wider range of typologies - table 7

– and potential typology-specific approaches and incentives for further woodland creation engagement.

2.5.3 The need for interdisciplinary research

Taking the conflicting information in the current literature and the highly diverse perspective on this topic by stakeholders into consideration, identification of stakeholder typologies could be valuable for future policy making on woodland creation. The research reviewed above focussed on using surveys as a mean of gaining understanding. However, more insight into human behaviour and subjectivity would be beneficial to understand, support and implement these results (Eves *et al.* 2013; Lawrence & Dandy 2014; Berry *et al.* 2016; Valatin *et al.* 2016; Nijnik *et al.* 2017). Valatin *et al.* (2016) supports this notion and encourages interdisciplinary research interests to aid this understanding, suggesting that within the field of behavioural economics there may be knowledge that can beneficially be applied to understanding how woodland creation can be increased in the UK. They state that their evidence demonstrates how cognitive factors have a large influence on people's values, preferences and choices in life and that, furthermore, these can be influenced by so-called policy 'nudges' (encouraging, or guiding behaviour (Halpern 2016)). Valatin *et al.* (2016) argues that the evidence suggests that by gaining understanding for cognitive factors within people, we can apply specific 'nudges' to certain typologies of people at the correct stages of their engagement with woodland creation and, by doing so, overcome policy barriers. This approach is still relatively novel, but has been applied in the United States of America (USA) and UK to a varied area of policies, such as environmental behaviour, health, crime and consumer empowerment (Team 2011; Valatin *et al.* 2016; Selinger & Whyte 2017). Policy 'nudging' has, however, received some criticism (Selinger & Whyte 2017), due to its potential lack of ethical considerations. Valatin *et al.* (2016) argue that, *'All government policies include, to a greater or lesser extent, some element of intended behaviour change'*.

Table 7 – Woodland planters typologies and the recommended engagement approaches for woodland creation identified from Eves *et al.* (2013).

Pragmatic Planters	tended to have large individual land holdings, environmental sympathies and were the most likely to plant woodland in the future. They were interested in timber, wood fuel, carbon sequestration and income generation from woodlands more generally and were the most responsive segment to interventions. Targeting Pragmatic Planters with incentives designed to increase the income generated from woodlands would seem a logical step, for example grants to develop a wood fuel resource or assistance to enter a local wood fuel supply chain. Pragmatic Planters were often members of the NFU, which might provide a route to help engage with them in future.
Willing Woodland Owner	had smaller individual landholdings but were willing to sacrifice profit for the environment and were the second most likely segment to plant. They diverge quite sharply from the Pragmatic Planters in terms of their relative lack of profit motive. Given their positive attitudes to the environment and a lower interest in income generation from their woodland or farm, targeting this segment with incentives designed to increase the environmental benefits provided by woodland might be a useful approach, for example by providing advice on how woodland planting can deliver biodiversity benefits and other public goods.
Business-orientated Farmers	were the third most likely to plant woodland in the future. However, they were far less likely to plant than both the Pragmatic Planters and the Willing Woodland Owners (who are around ten times more likely to plant than the remaining three segments). Business-orientated Farmers had a strong profit motive and were open to public funding. As such, they may be responsive to a similar package of incentives as the Pragmatic Planters. However, given a lesser belief in the need for environmental action and a greater desire to make a profit, the price point at which these farmers will plant is likely to be higher and they will want to see higher income from their woodland once planted.
Casual Farmers	were the second least likely segment to plant woodland. They were motivated by profit to a limited degree and had a low interest in the benefits of woodland, although they had some interest in creating wildlife habitat and were somewhat conscientiousness towards the environment. Casual Farmers had high levels of responsiveness to the majority of interventions and given some similarities with the more responsive Willing Woodland Owners there is the potential to simultaneously target them with incentives focussed on the environmental benefits of woodland creation in a cost effective manner.
Farmer First	had the lowest stated likelihood of planting woodland in the future. They considered their existing woodland as a source of income or useful for shelter only and they believed that woodlands result in few public benefits compared to agriculture. This segment was the least likely to state that they would consider planting trees even if there was decent money to be made out of woodland. This segment also scored consistently lowest in terms of the degree to which each of the suggested incentives would encourage them to plant, and so despite their large land holdings, it is suggested that they should not be a target of action in future

Other motivators identified by Lawrence & Dandy (2014), besides economics, are conservation, biodiversity and wildlife as the main priorities associated with woodland creation, followed by landscape feature, shelter for stock, sporting activities, personal and amenity activities. Interestingly, timber production and provision of public access was a low priority. However, it should be noted that the priority for timber production increased in accordance with area size and was a high priority for estate landowners and large landowners in Scotland in particular. (Crabtree *et al.* 1998) suggested in their study that farm size is a significant indicator for woodland scheme uptake, especially on farm land of poor agricultural value and with existing woodlands on site. This is further supported by (Eves *et al.* 2013; Wynne-Jones 2013). It is also evident that landowners of larger land areas are more likely to engage with woodland creation (Eves *et al.* 2013), which is one of the factors (Lawrence & Dandy 2014) identified for why landowners are more likely to carry out woodland creation in Scotland in comparison with England.

2.5.4 The importance of feelings and emotions

What is lacking in the literature regarding stakeholder perspectives of woodland creation is, as identified by Buijs and Lawrence (2013), the important element of feelings and emotions. Again, this can only be explored by the use of methods that can investigate subjectivity instead of objective views. Methods which rely on quantifiable approaches, such as questionnaires, do not allow for such deeper elements to emerge. Thomas *et al.* (2015) argues that this is because these factors are not easily observable. Social science as a research paradigm still carries a stigma to some extent of not being as valid as quantitative science within some scientific fields (Davis & Michelle 2011; Eyvindson *et al.* 2014). A clear example of this was the comment made by participant (51) - a senior forestry professional - regarding this study, *"I just hope that the results are not a report of emotional statements... We can't use that for anything".* Social science and the relationship between society and the environment are, however, increasingly valued in environmental research (Berry *et al.* 2016; Colvin *et al.* 2016; Jacobsen & Linnell 2016; Hermelingmeier & Nicholas 2017) and thus, interdisciplinary knowledge and approaches are shared. Methodologies rooted in the field of psychology aim to understand and identify underlying values, feelings and emotions which underpin stakeholder behaviour (Hall 2008; Walder & Kantelhardt 2018) or perspectives on complex and conflict-intense case studies (Chamberlain *et al.* 2012; Rust 2016) are increasingly being used. One such method - Q-methodology, which is a subjectivity factor analysis - has been successfully used to explore human subjectivity and to develop new management strategies (Chamberlain *et al.* 2012; Rust 2016). Chamberlain *et al.* (2012) found Q-methodology to be a particularly powerful approach for finding mutual ground in situations of strong conflict and diverse opinion. (Berry *et al.* 2016), in a multi-national study on conservation practitioners' view on arguments for biodiversity conservation, found Q-methodology to be useful for identifying underlying values and morals which underpin participants' perspectives. It is therefore not surprising that Q-methodology has also been applied to gain understanding of human subjectivity in environmental conflict situations (Bredin *et al.* 2015) and the methodology is increasingly gaining popularity across disciplines (Haslam & McGarty 2014).

2.5.5 Introducing Q-methodology

Q-methodology is a combined quantitative and qualitative tool that examines human subjectivity of values, opinions and beliefs within a specific subject (Davis & Michelle 2011). The methodology combines both quantitative and qualitative data collection and analysis through statistical discourse analysis, using an application of multiple regression and factor analysis tools (Stephenson 1935; Brown 1980; Watts & Stenner 2012). The tool gives insight into the range of opinions that exist on a topic and allows for individuals within the study group to be grouped and categorised, based on shared viewpoints. As a result, a typology of people and their views and beliefs is created and the criteria and factors which influence these are examined (Nijnik & Mather 2008). Davis & Michelle (2008) state that in comparison with purely qualitative methods, such as interviews, focus groups and observation, the method provides more structure, scientific rigour and a richer insight into subjectivity than provided by conventional surveys. Moreover, Q-methodology is particularly beneficial in research that explores a diversity of opinions within smaller study groups (n = <60) (Watts & Stenner 2012), but it is not suitable for explaining representativeness of opinions within a larger population due its subjectivism rather than objectivism (Bredin *et al.* 2015).

The methodology creates a selection of statements that are representative of the subject. Participants are then asked to evaluate and rank each statement on a ranked grid, depending on the level of agreement and disagreement. The result is the so-called Q-sort – figure 10 & 11. An explanation of the terminology used is found in appendix III for guidance.

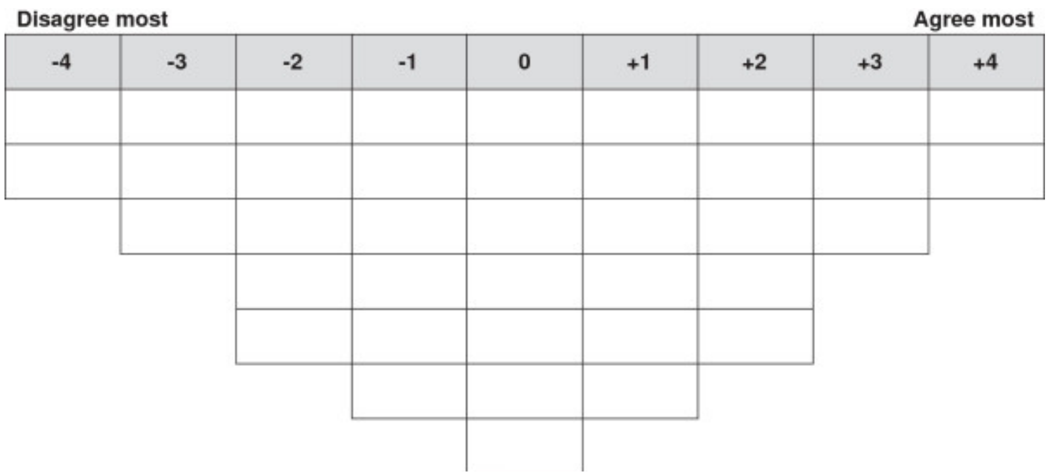

Figure 10 – An example of a traditional grid for Q-methodology sorting. Participants rank the statements on the grid according to level of agreement/disagreement.

Figure 11 – Manual execution of a Q sort. Statements on cards are placed on the grid according to level of agreement (Watts & Stenner 2012).

2.5.5.1 Contextualising Q-methodology

Q-methodology originated within the field of psychology during the 1930s by William Stephenson, a psychologist and physicist at Oxford University. Stephenson was a student under Charles Spearman[12] and thus part of the early movement of the statistical method factor analysis. Stephenson first introduced Q-methodology as an inverted R methodological[13] factor analysis with a first publication in Science (Stephenson 1935) and it has since been widely used in education and health science (Farrimond *et al.* 2010; Ahmed *et al.* 2012; Watts & Stenner 2012). Stephenson's inversion of the R method meant that it was no longer the traits that were the focus of interest, but people became the variable which loaded onto the factors of such tests. Applying such approaches and new ways of theoretical thinking to the British community of psychology was not without difficulties at the time and was received with opposition, but Q-methodology has slowly developed and gained popularity since (Watts & Stenner 2005).

[12] Charles Edward Spearman (1863 – 1945) was an English psychologist well known for his pioneering research on factor analysis and especially the Spearman's rank correlation coefficient

[13] R-methodology is a statistical test also known as a regular factor analysis, whereby correlation between variables (traits or tests) are measured,

2.5.5.2 Q-methodology as a qualitative/quantitative hybrid approach

Q-methodology often has indefinable status as a hybridity amongst methodologies and is often quoted as, "*A quantitative methodology to qualitative researchers, but like a qualitative methodology to quantitative researchers*" (Davis & Michelle 2011; Watts & Stenner 2012). Due to this position of Q-methodology between the two qualitative/quantitative research paradigms, there is also often confusion amongst researchers regarding the analytic and data collection procedures. In particular, the factor analysis carried out by a Q-methodology is often observed to be confused with R-methodology (Watts & Stenner 2005; Haslam & McGarty 2014). The tendency of valuing the quantitative aspect of Q-methodology above the qualitative aspect is common (Eyvindson *et al.* 2014).

For some, the hybrid position of Q-methodology is viewed to be second-rate compared to other qualitative methods (Robbins & Krueger 2000), such as surveys and Likert scale. Eyvindson *et al.* (2014) carried out a comparison between Likert scale (R-method) and Q-methodology to investigate forestry policy and concluded that responses between methods were consistent but that outcomes were method dependent. R-methodology was found to be more comprehensive in analysing the data and more able to analyse large sample sizes and is therefore stronger at estimating generalised opinions. Alternatively, Q-methodology was stronger in revealing perspectives and allowing for viewpoints, which did not load on any factor with R-methodology, developing deeper profile relationship amongst factors/viewpoints (Eyvindson *et al.* 2014). The Eyvindson *et al.* (2014) study did, however, mainly focus on the statistical analysis of both methods and little consideration was given to the qualitative interpretation and value of Q-methodology. This has since been addressed by (Ho 2017), whereby a comparison between R-methodology and Q-methodology concluded that the former is efficient and easy to analyse, but difficult to interpret into meaningful practice. Q-methodology results proved to be limited for a generalised interpretation and more complex to conduct, but did yield a more in-depth understanding of subjective perceptions.

2.5.5.3 The use of Q-methodology in practice

The subjective nature of Q-methodology is also observed when participants are selected. Most often, when choosing participants, a neutral unbiased selection process is required to obtain representativeness. With Q-methodology, this is not the case as the aim is subjectivity, not objectivity (Stephenson 1953; Brown 1980) and, in some instances, the method has been used on single case studies whereby a single person's viewpoint is explored (Brown 1993a; Smith 2001). An example of this is Carl Rogers, a prominent psychologist during the mid-twentieth century, who employed Q-methodology as part of his clinical work. He used a set of statements about personal characteristics which patients were asked to Q-sort according to their viewpoint of self and ideal self. Rogers then applied a standard measure of the distance between them continuously, as the patients went through treatment, as a measure of personal progress (Rogers & Dymond 1954; Watts & Stenner 2005).

Q-methodology has undergone an increasing popularity with environmental resource research in particular, partly due to its systematic and rigorous approach to bridging qualitative and quantitative data analysis (Farrimond *et al.* 2010; Chamberlain *et al.* 2012; Davies & Hodge 2012; Urquhart *et al.* 2012; Curry *et al.* 2013; Bredin *et al.* 2015). When applied to conflicted stakeholder dynamics, Q-methodology has proven to be particularly useful in identifying common ground among stakeholders in situations where conservation or resource management is contested (Chamberlain *et al.* 2012; Bredin *et al.* 2015). Others have, however, found working with Q-methodology non-conclusive, biased and difficult to replicate (Robbins & Krueger 2000; Davis & Michelle 2011). This could perhaps be explained by the researchers' own role and expectations with Q-methodology and participants. Davis & Michelle (2011) argue that it should be emphasised that the purpose of Q-methodology is not to arrive at one single truth of the topic from the perspective of the researcher. Further to this, the method does not aim to be objective (Kline 2014).

2.5.5.4 Contextualising Q-methodology to project

For our study, Q-methodology is used to explore stakeholder perspectives of woodland creation in the uplands of Cumbria in chapter 5. The method is particularly useful for our case study due to the benefits of the method as described above, such as the subjective nature of using smaller participant groups and its ability to find areas of consensus in strongly conflicted circumstances. Added to this, from within one of the funding collaborators of this study, there was expressed a need for quantifiable results, as expressed by the senior forestry professional, who said, *"I just hope that the results are not a report of emotional statements... We can't use that for anything"* Therefore, there was a need to try and obtain subjective qualitative results, which could also address this need. The hybrid approach between two research paradigms that Q-methodology applies, fulfils this need. The comment above is also particularly interesting, as it later emerged from the results of this study, that viewpoints such as these, are in fact what adds to creating barriers to woodland creation. This will be explained in much further detail in the discussion of results in chapter 5 and 6.

The next chapter will present the preliminary scoping study that was carried out in the early stages of the project. This study helped develop the research questions, shape the direction of the project and identify the study site and participants.

3. SCOPING STUDY

In chapter 3, a preliminary scoping study was carried out to develop the research questions and meet objectives 1.1, 1.2 and 2.1. Objective 2.1 is partly addressed in this chapter and partly in chapter 5. The extent to which these have been met is discussed and concluded in chapter 6.

1.1. To identify a suitable and typical Cumbrian upland landscape study site for assessment as a case study

1.2. To identify, via stakeholder consultation, four ecosystem services which are important to the Cumbrian uplands and which will be used as indicators for the assessment

2.1 To identify key stakeholders relevant to the case study of creating new woodlands in an upland Cumbrian landscape

3.1 Developing research question and scoping study

At the beginning of this study, thirteen preliminary semi-structured interviews were held with influential stakeholders within the woodland creation sector in Cumbria – see appendix I for details. During early conversations with these stakeholders it became apparent that there was consensus regarding the topic of woodland creation in Cumbria and their focus was often surrounding questions regarding:

- What changes from mainly grazed grassland to woodland would entail. Especially on ecosystem goods and services such as:
  - Climate regulation
  - Water related services
  - Nature-based recreation
  - Cultivated goods (farming)

- How much woodland there should be.
- Stakeholder's perspectives and opinions were fundamental to the debate, which was perceived as being highly conflicted.

Examples of this are participant statements that were often voiced, such as, *"We lack understanding for how new woodlands would impact the area… especially in regards to water. Water is so important in Cumbria!"* (P9), *"We have an obligation to society to do what we can towards mitigating climate change"* (P2), "*If we plant more woodlands, the tourists will stop coming"* (P6). But statements like these were often followed by, *"But we do not know for sure how it will impact the area"* (P6) or, *"It depends how much woodland we are talking about"* P7). Comments on farmers willingness to plant trees was often commented on with, "*It's all about money"* and, *"Farmers want to produce livestock, not grow trees"* P4). Finally, all participants stated that woodland creation in the area is difficult due to differences in opinions amongst stakeholders: "*They will never agree" (*P14)*.*

The interviews were conducted in an inductive, explorative manner, as the aim of gaining the information was discovery in order to get an initial understanding of the subject and not to test an already established hypotheses. There was also a need to further to develop the research questions in conjunction with the literature review and policy context. Participants were chosen based on them being deemed as key stakeholders locally and being influential within the subject of woodland creation. All were invited in writing, with an attached brief introducing the project and purpose of the interview. A snowballing sampling approach[14] was used to verify the choice of participants. The interviews were all, except one, conducted face to face at locations convenient to the participant and generally lasted for approximately 1-1.5 hours. The one exception was conducted over the phone due to the participant being overseas. All interviews were recorded and a very simple thematic and constant comparison analysis (Glaser 1965; Boeije 2002) was carried out, by review of the material and simple memo writing in order to identify theoretical categories and identify the broad themes as described above.

In chapter 5, these interviews were also used to identify relevant stakeholders by the use of a further snowballing sampling approach and to inform the concourse for analysing stakeholder subjectivity and perspectives. Additionally, the interviews highlighted the need to address these questions with both quantitative and qualitative methods to gain a more balanced understanding for the topic.

[14] Snowball sampling is a technique whereby recruitment of further participants occur by recommendation by existing study participants. This process continues until it becomes obvious that a saturation level has been reached, as no new identities are offered (Newing 2011).

3.2 What kind of woodland creation?

From the preliminary interviews it also became evident that within the topic of woodland creation in upland areas of Cumbria there was often confusion and disputes regarding what constitutes a forest or woodland (Jones, K. 2015, Personal Communication, 2 March 2015) as woodland or forest can mean many different things. The Forestry Commission Forestry Standard (UKFS) (2013) define woodlands and forests as:

"The term forest is used to describe land predominately covered in trees (defined as land under stands of trees with a canopy cover of at least 20%), whether in large tracts (generally called forests) or smaller areas known by a variety of terms (including woods, copses, spinneys or shelterbelts). The alternative term woodland has local nuances of meaning so it is used in the text where it is more appropriate, but for the purposes of the UKFS and Guidelines the meaning is synonymous with forest".

Planting of trees in England is as previously detailed in chapter 2, subsidised and managed primarily by the two Governmental agencies of the Forestry Commission (FC) and Natural England (NE). FC is the leading agency for the management of woodland and the creation of forest corresponding to the description above. NE has for the past ten years planted a considerable amount of woodland and scrub under the Higher Level Stewardship Scheme, as part of the Environmental Stewardship Scheme. These woodlands have been of a different type, patchy in design, linking up existing landscape features, aiming to 'blend in' with the landscape and focussing on native species and including both large trees and scrub species (Nicholson T. 2016, personal communications, 1 May). Within Cumbria, from 2004 to 2014, the vast majority of trees planted were by NE compared to the FC approach. In 2015 an agri-environmental scheme transition from the Environmental Stewardship Scheme to Countryside Stewardship Scheme (2015-2025) took place and with this a change in funding approaches. This may have an impact on the level and type of woodland planted in this this time period (Jones, K. 2015, Personal Communication, 2 March 2015).

The definition of woodlands by the FC allows for a certain level of personal interpretation. The woodland creation stakeholders that took part in the preliminary interviews expressed a range of opposing opinions such as:

"The planting carried out via Natural England in the uplands is just scrub... it's not a proper woodland" – Forestry Commission Woodland Officer – (P4)

"All that scrub tree planting... it is no good for anything... can you tell me what it is good for!?" – Carbon off-setting agent (P13)

"Forestry Commission woodland planting is all about productivity. It does not fit the Cumbrian uplands" Natural England Officer (P10)

The perception of what constitutes "scrub woodland" or "productive Forestry Commission woodland" raises a sense of conflict and competition between agencies and stakeholders planting via one route or the other. The reality is, however, that many of the planted woodlands fall between both opposite extremes. Undoubtedly, a lot of the "woodlands" planted via Natural England in Cumbria are scrub habitats. However, some of the planting leans more towards being a woodland, such in the case of the Tebay planting carried out within the Howgill Fells NCA. Additionally, much of the woodland created by the Forestry Commission is not of a productive conifer-dominant type. This discussion is interesting as it was observed to create a barrier between stakeholders in the creation of new woodlands, which will be explored in chapter 5 and 6 in this thesis.

It is therefore important to clarify that, for this project, and in terms of the assessments carried out, woodland is defined as a woodland consisting mainly of native species of trees and planted under the 'Woodland creation' and 'Successional scrub' categories and carried out by Natural England in line with the Tebay planting proposal. Furthermore, climax vegetation is based on the plausible assumption that if the woodland were to reach their climax state, they would be similar to that of the Murfield forest on the east side of the Howgill Fells NCA. This woodland is a protected Ancient and Semi-Natural Woodland[15]. The woodland consists of native species of trees adapted to the upland environment (dwarfed and warped) and the woodland shows indications of having been coppiced in the past, as many trees have been cut back periodically to stimulate growth.

[15] Ancient Semi-Natural Woodlands are woodlands that have been located on maps dating back to 1600. (Cumbria Woodlands 2016)

3.3 Introducing the study site – a typical Cumbrian upland landscape

This study concerns upland afforestation in Cumbria and it was therefore important that the study site was of such a typical landscape characteristic. Within Cumbria there are three upland massifs: the Pennines, the Orton-Howgills and the Lake District, all of which are above 300 m (Burton *et al.* 2005) – figure 12. Landscape characteristics have been defined via Natural Character Areas (NCA) on a national scale in England, as part of Natural England's approach to defining all of England's major landscapes (NE 2010).

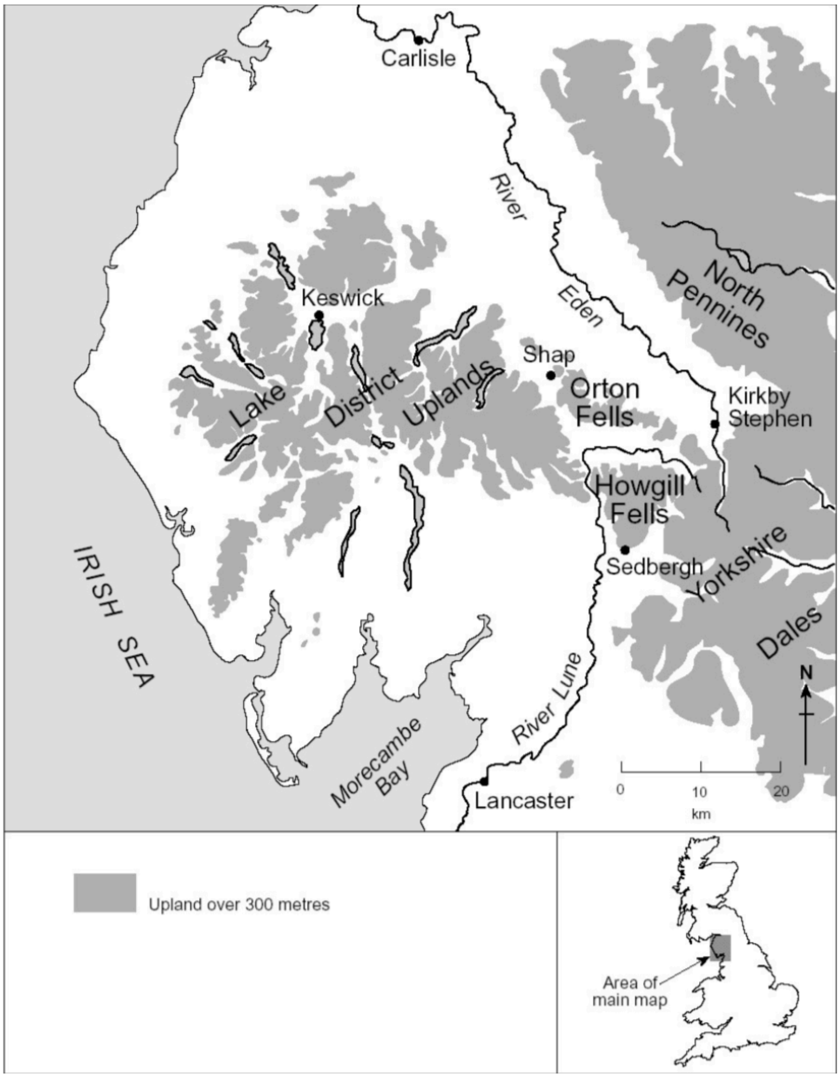

Figure 12 Cumbria and the North-west of England. Upland areas above 300m are displayed in grey (Burton *et al.* 2005)..

Using an NCA boundary line and area as a case for the study was seen as being desirable by some key stakeholders as it ties in with existing landscape-scale policy guidelines. Any outcomes from the study would therefore be more meaningful and useful for informing decision making. The NCA profiles are working documents and can be adapted according to new information available (Natural England 2010). Furthermore, the NCA profiles consider the area and landscape in a rounded view, focussing not only on one or two factors, such as climate change and economics, but everything it perceives as being important in understanding the natural characteristics of an area. This is important when considering changes in land-use and its impacts. Afforestation in upland Cumbria is linked in with the NCAs. Before any woodland planting is considered on a landscape scale, the Forestry Commission or Natural England would seek guidance from the area-relevant NCA profile and assess whether new planting would be suitable for this particular area. Moreover, the Forestry Commission is using the NCAs as a foundation for their Woodland Potential Calculation Tool (Commission 2016). The WPC is a map based tool that presents information on woodland, the environment and landscape and afforestation within each NCA.

Within the boundary of Cumbria, there are ten Natural Character Area profiles, but only four of these are of an upland character and capable of satisfying the research aim and objectives based on the following criteria:

1. Upland area in Cumbria
2. Be an area size of under 100,000 km^2 to keep the assessment achievable (TESSA guideline)
3. Include a variation of stakeholders from a broad range of sectors
4. Have an identified objective of increasing woodland

5. Have an identified group of stakeholders which are interested in participating in tree planting
6. Not suffering from “stakeholder fatigue” (identified as being a barrier to participation in previous research (Hall 2014)

Following these criteria, the Howgill Fells NCA was chosen as the most appropriate NCA to use as a study site. This NCA in its current state of 1.5% woodland cover was defined as the ‘current state’. The NCA covers an area of 10,360 ha – figure 13 - situated in Cumbria, in the north-west of England. Although within the county of Cumbria, the Howgill Fells NCA lies within the boundaries of the Yorkshire Dales National Park. It is an area of Cumbria with a strong upland cultural hill farming heritage. There is one large town to the south – Sedbergh - but the rest of the NCA consists of a few scattered settlements and very isolated farms. The area is very representative of the rest of the upland regions of Cumbria by being rural, remote, strongly influenced by hill farming and having a strong cultural identity and similar socio-demographics (Natural England 2010). The NCA is a fell massif of characteristically rounded, smooth hills, which reach a height of 676m, and is separated from the surrounding fell regions to the west and east by steep-sided valleys (Natural England 2014) – figure 14. The fells are open and exposed, with very little variation in vegetation cover. The most abundant habitat is upland heath, mainly acid grassland and bracken. The area is grazed by domestic stock, mainly sheep and to a smaller extent cattle and fell ponies. 77% of the area is common land, which is collectively owned by a number of people who all hold traditional and statuary rights to graze their livestock on it. Four individual Common Associations are found in this area: Tebay, Lonsdale, Ravenstonedale and Brant Fell (Federation of Cumbrian Commoners 2014). All four commons have both active and inactive graziers on them. Most of the agricultural land falls within the land use payment category regions of: 2) Severely Disadvantaged area (SDA) and 3) Moorland.

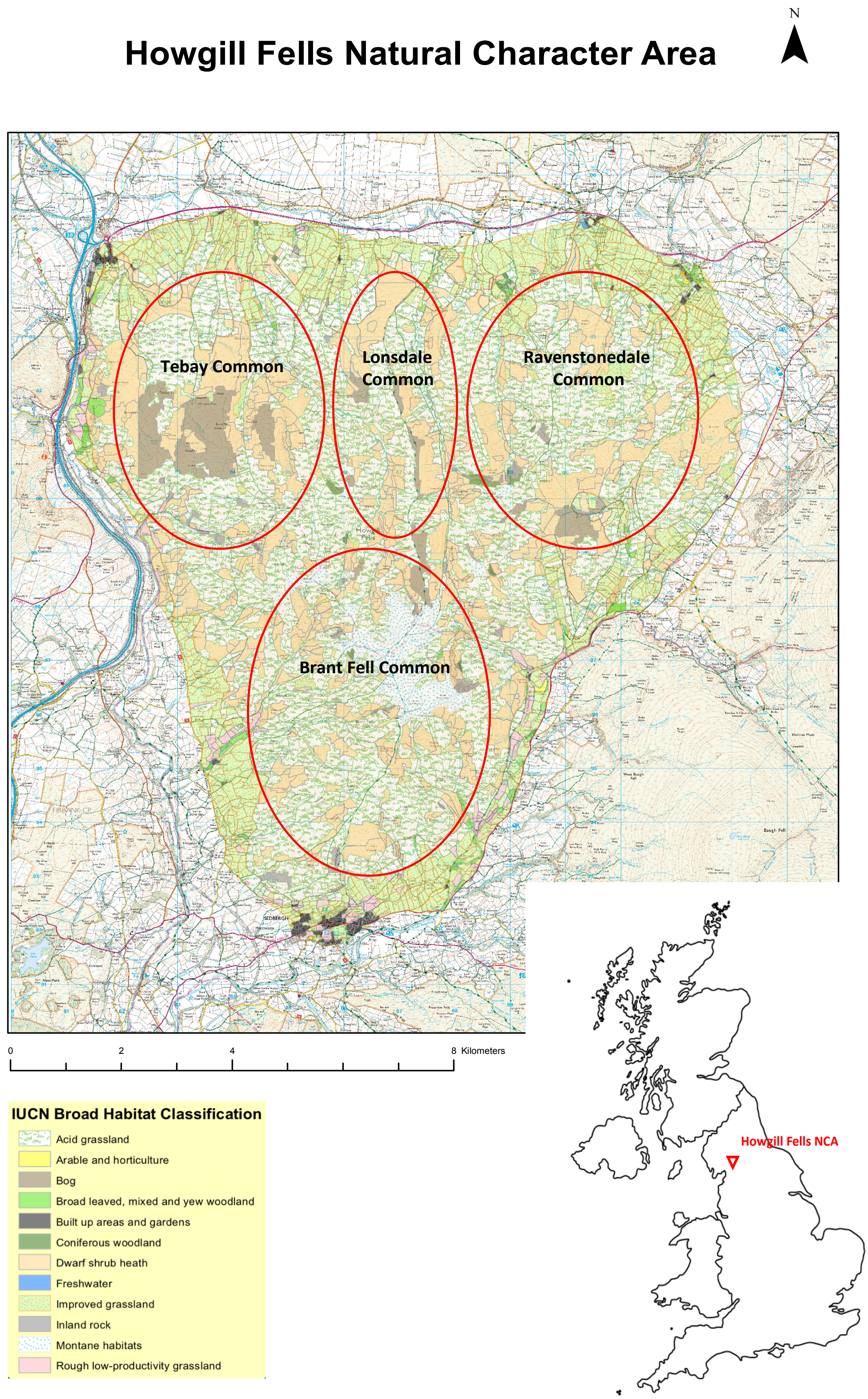

Figure 13 – Howgill Fells NCA study site with an illustration of the approximate location of each of the Common Associations within the Howgill Fells NCA. Small map inserted in right bottom corner, with location of the Howgill Fells NCA within the UK.

Woodland cover within the NCA is, at 1.5%, one of the lowest levels found in NCAs in England and the lowest in Cumbria (Natural England 2010). Moreover and importantly, within the Natural England NCA profile report, the opportunity for woodland expansion is proposed in the form of the Statement of Environmental Opportunity (SEO) – figure 15 – as an appropriate and desirable land-use for some areas within the NCA. Within the NCA there has, in recent years ,been 700 ha of tree planting carried out under Countryside Stewardship Higher Level Stewardship. Of the four commons within the study site, Tebay and Ravenstonedale commons are participating in the planting scheme, and Lonsdale and Brant Fell commons are also considering participation in similar planting schemes.

Figure 14 – Photograph of the southern end of the Howgill Fells and lower lying pastoral fields. This image is typical of the landscape of the NCA. (Natural England 2010).

3.3.1 Howgill Fells NCA & ecosystem services

3.3.1.1 Climate change mitigation

Within the Natural England Natural Character Area Profile report, opportunities for improving climate change mitigation is proposed in the form of the SEO. Woodland expansion is mentioned within this statement as a suitable approach to improving climate change mitigation within this landscape (Natural England 2010) – figure 15. In the NCA's current state, carbon is stored in the vegetation and soil. The peaty soils of the area are estimated to be roughly 40% of the NCA area. However, only 10% of these soils are deemed to be storing a large amount of carbon in blanket bog, due to the challenging steep terrain and therefore shallow soils (NE 2014). Furthermore, the vegetation - mainly acid grassland, heath and bracken cover also contribute to carbon storage (Natural England 2010). Emissions of GHG are likely to occur over the organic soils due to drainage (Alonso *et al.* 2012; Nicholson T. 2016, personal communications, 1 May). The pastoral grazing of primarily sheep, cattle and horses, contribute to GHG emissions in form of Methane (CH^4) (Le Mer & Roger 2001; Richmond *et al.* 2015). Although most of the grazed fields are not improved, the lower slopes are being fertilised and, as a result, Nitrous oxide (N_2O) emissions will occur (Richmond *et al.* 2015; Nicholson T. 2016, personal communications, 1 May).

SEO 1: Conserve, enhance and restore the tranquil, open, unenclosed fells, with their dramatic seasonal colours and textures, mix of upland habitats and active fluvial features, for their national recreation value, their geomorphological interest and their biodiversity. Encourage quiet recreation focussed on enjoyment and appreciation of these features, while improving water quality, reducing soil erosion and mitigating climate change.

For example, by:

Restoring, expanding and encouraging management of gill, as well as ancient woodland and other broadleaved woodlands and wood pasture, especially on slopes which are covered with bracken and thus have suitable soil, but avoiding the high ridges and areas of geological, biodiversity or historical interest. This will increase woodland connectivity, enhance biodiversity and landscape interest, reduce soil erosion, improve water quality and produce local wood fuel and wood products.

SEO 2: Conserve and enhance the pastoral lower slopes and valleys with their complex of field patterns, hedges and drystone walls; their range of pasture types, including northern hay meadows, purple moor-grass, species-rich verges, woodlands, and waterside and boundary trees; and their dispersed farmsteads and villages, to conserve upland farming culture and to enhance landscape character and biodiversity.

For example, by:

Restoring and expanding broadleaved woodlands, riparian woodland and wood pasture, ideally through natural regeneration and use of local provenance and locally grown seed – especially on slopes that are covered with bracken and thus have suitable soil, and also in the lower river valley areas (but avoiding areas of geological, biodiversity or historical interest). Such restoration and expansion will increase woodland connectivity, improve biodiversity and landscape interest, increase carbon capture, and reduce run-off and soil erosion.

Encouraging management of existing woodlands, to provide a local wood fuel/biomass supply by developing open glades, encouraging natural regeneration and leaving patches of deadwood, to enhance biodiversity.
Encouraging use of a wide range of locally native species suitable for the ground conditions in new woodland and existing upland ash woods, to reduce reliance on ash. Examples of appropriate native species include rowan, hazel, holly, alder, hawthorn, blackthorn, bird cherry, crab apple and oak. This will increase resilience to climate change and ash die-back and will encourage re-establishment of black grouse.

Figure 15 - Statement of Environmental Opportunity (SEO), which is relevant to woodland creation, within the Howgill Fells NCA. SEOs are used as guidelines by Natural England and the Forestry Commission to ensure that any development or environmental land management takes into consideration the characteristics of the area when proposing changes within it

3.3.1.2 Water-related services

The Lune catchment covers 1,300 km^2, extending from the Howgills NCA in the northeast down through the Yorkshire Dales in the east, Morecambe Bay in the west to Cockerham Moss in the south (EA 2014) - figure 16. It is a catchment of both steep slopes in the north and west and flat terrain in the east and south. The most influential river in the catchment is the river Lune, which runs through the whole catchment from the north to the south (Natural England 2010). Several larger tributaries terminate at the river Lune, such as the Rawthey, Greta and Wenning. There are several minor settlements in the catchment, such as Carnforth and Calgate and one large urban area - Lancaster. All of these settlements are in the downstream reaches of the catchment (Agency 2014).

The Howgills Fells NCA has experienced flooding in past and current times. The most recent 2015 flood event caused flooding in Tebay, Sedbergh and isolated incidents at farms and rural properties. Tebay village experienced 13 properties flooded which was primarily caused by Tebay Gill Beck bursting its banks and further increased by the River Lune overflowing from the north and surface water from blocked highway drainage (Council 2016a). Anecdotal evidence from local consultation carried out by Environment Agency discovered that Tebay had been flooded twice before, once with the same level of flooding 40 years ago and once at a smaller scale during the summer of 1950 (Council 2016a). Sedbergh also has a history of being affected by flooding. In recent times, the town has been flooded in 2000, 2005, 2009 and 2015. The 2015 floods were mainly caused by several water courses feeding into the main water course that runs through the town which resulted in several areas within the town flooding. Sedbergh is surrounded by steep local topography and as such is prone to flash floods by surface water run offs (Council 2016b).

Figure 16 – Lune catchment with the Howgill Fells NCA position within the catchment enclosed in red. Adapted from Agency (2014)

3.3.1.3 Nature-based recreation

The NCA experiences approximately 300,000 visitors a year (Tourism 2015) and tourism is an important source of income to the area, evidenced by the many local farms in the area that have in recent years diversified their income stream by offering accommodation via camp-sites, B&Bs and self-catering options. According to (Tourism 2015) the motivations for visiting are varied, but the top four reasons are: 'Because of the physical scenery and landscape' (61%), 'Because of the atmospheric characteristics of the area – peaceful, relaxing, beautiful etc.' (40%) and 'Been before' (37%), followed by 'Undertaking a specific activity' (19%). Under this category, most participants stated that 'walking' was the specified activity. 96% stated that, 'It is a good place for outdoor activities'. Additionally, the majority of visitors stated that they, 'Very much so' or 'quite a lot' felt physically (85%) and mentally (90%) better after their visit. The natural environment and landscape are therefore very important in terms of sustaining this industry.

3.3.1.4 Cultivated goods

The majority of the land area within the NCA is used for pastoral agriculture grazed by livestock and managed by hill farms. There are currently 36 farms within the NCA and these have declined in numbers over the years, partly due to farms being bought up and combined, a lack of a next generation to carry on from a retired generation and changes in farming traditions. This decline in farm numbers is an issue that exists at a national level in the UK uplands (Reed *et al.* 2009). Sheep, cattle and fell ponies are the main grazers in the area. The NCA has a strong farming cultural identity and many farming families have been in the area for many generations. Sheep reared in the area mainly produce breeding ewes to be sent to the lowlands where they are highly valued for their tough resilience, efficiency in terms of feed and good maternal instincts. Here they will be bred with lowland breeds for higher meat yield in production (Mansfield 2012).

3.3.2 Future drivers of change in the Howgill Fells NCA

The Howgill Fells NCA is likely to experience changes to weather and local conditions in the future due to climate change (Orr *et al.* 2008; Garner *et al.* 2017). Evidence from the UK Climate Impact Programme (UCP 2016) shows that more frequent and extreme weather events are expected to increase rates of erosion to the wider catchment and, subsequently, impact the fells and in-bye land, increase flood risk and siltation in the rivers in the NCA (NE 2014). Temperature and precipitation are also expected to increase on average, with warmer and wetter winters, and warmer and drier summers. The UK Climate Impact Programme (Projections 2016) has offered projection scenarios and under a medium scenario the mean temperature will rise by 2.6°C with a 16% increase in precipitation for winters and a rise of 3.7°C and 22% increase in precipitation in summers by 2080. Furthermore, an increase in frequency of extreme flood/droughts is expected (Garner *et al*. 2017; Projections 2016).

Such changes may cause modifications to the vegetation dynamics (Ackerly *et al.* 2015; Britton *et al.* 2017). Land use and management may also change with longer growing seasons (Britton *et al.* 2017), changes to animal husbandry approaches and areas of bog and peat (Reed *et al.* 2013a), especially as a result of longer, warmer and drier summers, which could lead to a loss of stored carbon, biodiversity and habitat and an increased risk of erosion and wildfires (Reed *et al.* 2013a). Impacts on water quality are expected, with an increase in water temperature leading to an increase of nutrients, sediment and colouration in water abstracted for public supply (Ritson *et al.* 2014). Additionally, Natural England (2014) has commented on the need for natural and semi-natural habitats to be expanded, connected and buffered to increase connectivity and resilience to climate change impacts.

In addition to climatic changes, sociological changes are also expected. Hill farmers in Cumbria are facing severe challenges in sustaining their businesses and many are advocating a need for hill farms to diversify (Schwarz *et al.* 2006). This is mainly due to the low profitability of hill farming, changes in agricultural policy and subsidies (Reed 2009). Some farms are still struggling with the effects of Foot and Mouth in 2001 (Convery *et al.* 2005) and, additionally, there is a vast range of social factors such as an ageing farming population, a lack of affordable housing, a transfer of skills and interest and the increasing difficulty for younger farmers to start up their own business (Schwarz *et al.* 2006; Mansfield 2011). Adding to this are the constraints of environmental schemes, which require substantial changes to the farming practice, particularly in terms of reducing stocking rates on the fells (Communities 2010).

The UK's referendum decision to leave the EU has created uncertainty regarding the future of Common Agricultural Payments (CAP). In August 2016, the Government announced that CAP Pillar I payments, structural and investment funds and Pillar II agri-environment schemes will be funded via the Treasury until 2020 (DEFRA 2015). However, the exact future of the rural aid scheme beyond the exit from the EU is currently unknown. Hill farmers in upland regions of England have, on average, a very low or even negligible annual net income (Harvey & Scott 2016). This is due to the very close relationship between production costs and outputs and the small gross and net margins within this type of agricultural production (Mansfield 2011). These farms are therefore relying heavily on subsidies for a sustainable business.

This chapter has introduced the preliminary scoping study used for identification of research questions and helped shape the direction of the project. It has, furthermore, introduced the study area. The next chapter will begin the assessment of potential changes and impacts to be expected in this study area if woodlands are created, with focus on the four ecosystem goods and services identified in this chapter by stakeholders to be of high importance to the area.

4. IMPACTS OF WOODLAND CREATION

4.1. INTRODUCTION

In recent years, the understanding of how ecosystems contribute to human needs has increased greatly (Costanza *et al.* 2017; Braat & de Groot 2012). The phrase Ecosystem Services (ES) is now widely used in this context to describe the benefits people derive from ecosystems and how these sustain human wellbeing (de Groot *et al.* 2010; Pearce & Moran 1994; Costanza *et al.* 1997, 2014) – figure 17.

Ecosystem services can be difficult to assess, due to the requirement of substantial resources and specialist knowledge (Birch *et al.* 2014) relying mostly on modelling approaches which are limiting, relying on input data and modelling caveats (Peh *et al.* 2015; Zank *et al.* 2016). Many toolkits and approaches are available to measure ecosystem services and it is a field which is developing rapidly (Thapa *et al.* 2014) (Thapa *et al.* 2014; Guerry *et al.* 2015; Zank *et al.* 2016). Peh *et al.* (2013) argues that current available approaches still have issues in addressing site-scale assessments. Therefore, smaller site-specific ecosystem service assessments are often not carried out or extrapolated from larger studies (Baral *et al.* 2014). This is a disadvantage for land managers and decision makers, as the results obtained from such assessments can greatly inform and provided evidence for involved stakeholders on what impacts can be expected. Finer-scale measurement of ecosystem services are increasingly needed to inform decision making on a local scale (Peh *et al.* 2013).

Provisioning services
Food, crops, water, and medicinal resources.

Regulating services
Pollution filtration by wetlands, water cycling, pollination, climate & air regulation and protection against natural disasters, carbon sequestration, biological control.

Cultural services
Recreation, education, spiritual and aesthetic value, mental and physical wellbeing, sense of place, inspiration for culture, art, design.

Supporting services
Habitat for species, genetic diversity, nutrient cycling, photosynthesis, soil formation.

Figure 17 Millinennium Ecosystem Assessment (2005) categories

A rapid ecosystem service assessment aims to assess the chosen services, with limited resources and/or time. It is a particularly valued approach in circumstances where the knowledge gained could aid decision making or be part of establishing an understanding of the topic and impacts complementary to other assessments carried out (Peh *et al.* 2013). The 'rapid' nature of the assessment does, however, come with limitations. For this project, such an approach is sensible, as site-specific information was needed of both ecosystems and socially. The services identified as indicators were informed as being important by key stakeholders and previous research (Reed 2009; Curtis *et al.* 2014; Broadmeadow & Nisbet 2012; Bunce *et al.* 2014) for the Cumbrian uplands and also within the limitations of this study (Peh *et al.* 2013). The focus of assessing the four ES indicators climate change mitigation, water-related services, nature-based recreation and cultivated goods were first and foremost guided and informed in collaboration with key stakeholders in the early scoping stage of the study (Chapter 3) and further supported by review of the literature.

TESSA is a relatively new ecosystem service rapid assessment tool, which aims to bridge this gap between the need for knowledge and the high resource and specialist cost of obtaining it (Peh *et al.* 2013). TESSA aims to offer the user guidance on how to assess the chosen services in a scientifically sound and practical approach, with strong stakeholder engagement. The guidance within the toolkit aims to be applicable world-wide and under very different situations (Peh *et al.* 2013; Van Soesbergen 2013). This guidance is therefore relatively general and a site-specific methodology has to be employed and developed according to circumstances of the site and resources available by the user. By doing so, TESSA allows the users to develop an understanding of the ecosystem service benefits an area/site provides and how to assess their value on a site-specific level (Birch *et al.* 2014). It does so by comparing empirical data derived from the current site and compares them to estimates for an alternative site. The guidance recommends using secondary data when possible, but if the resources allow it the use of site-specific primary data is encouraged (Peh *et al.* 2013; Birch *et al.* 2014). Moreover, strongly embedded within the toolkit is engagement with key stakeholders to inform and be part of the process. Stakeholder engagement in the process of conservation related environmental decision making, has proven to be very beneficial for the implementation of such agreements (Chamberlain *et al.* 2012; Bredin *et al.* 2015)

In chapter 4, a rapid ecosystem service (ES) assessment of four key services within the Howgill Fells NCA has been carried out. This assessment is using a case study approach and was assessed in line with TESSA (Toolkit for Ecosystem Service Site-based Assessment) by making an assessment and comparison between current state of the study site and alternative scenarios of woodland expansion of 10%, 25%, 50% and 75% in land area. Each service will therefore be assessed for both its current state and the four alternative scenarios – figure 18.

The overall objective for this assessment is to address objectives 1.3, 1.4 and 1.5. The extent to which this has been met are discussed and concluded in chapter 6.

Objectives:

1.3. Develop scenarios of alternative states (levels of increased woodland creation) within the study area

1.4. Carry out data collecting for each of the four chosen indicators by the use of the TESSA toolkit:

i) **Climate regulation**
   - *(1) Carbon storage in tonnes*
   - *(2) Annual flux of GHG in tonnes of 'carbon dioxide equivalents'*

ii) **Water-related services**
   - *(1) Above-surface water balance in* m^2

iii) **Nature-based recreation**
   - *(1) Estimate the number of visits for nature-based recreation*
   - *(2) Estimate the economic value of nature-based recreation*

iv) **Cultivated goods**
   - *(1) Estimate the economic value of cultivated goods*

1.5. Compare changes between the chosen ecosystem service indicators between current and alternative states

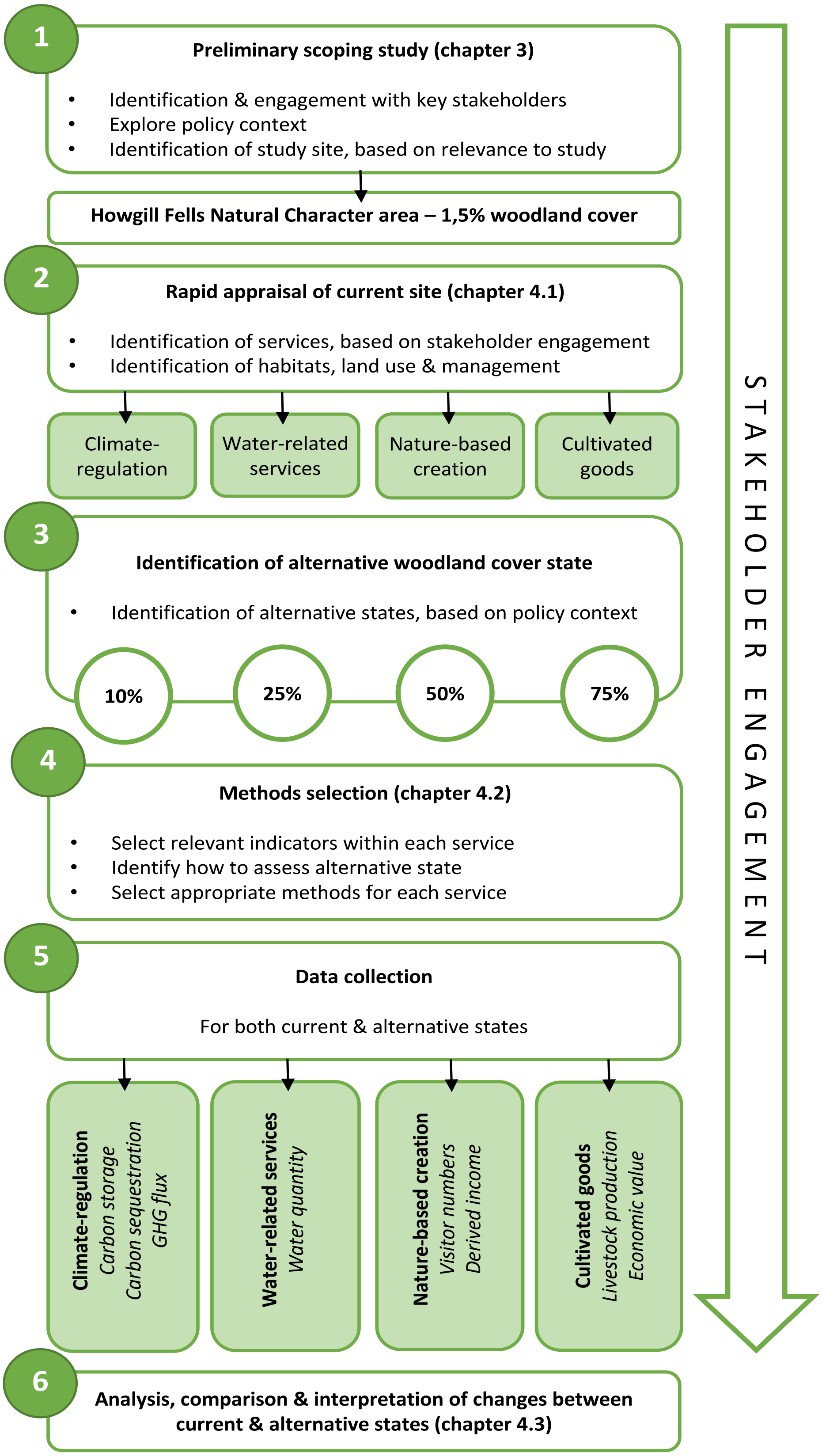

Figure 14 – TESSA ecosystem service assessment outline and systematic approach to the assessment of four ecosystem services delivered by the study site. Each service will be assessed for both the current and alternative states and a comparison of the potential impacts of the change in land use will be explored. Developed from Peh *et al.* (2013)

4.2 METHODOLOGY

4.2.1 Defining current and alternative scenarios

The foundation of the TESSA ecosystem services approach is the assessment of a current site and an alternative one; the current site being the study site under its current land-use and the alternative state being the proposed change in land-use (Birch *et al.* 2014).

Following the definition of the Howgill Fells NCA as the ‘current state’, an ‘alternative state’ had to be defined in order to carry out the assessment. The scenarios of alternative states were developed based on there being a proposed modelled target to expand the woodland cover in the NCA to 8.9% (Commission 2016). Since 2012 there has been intensive planting of native woodlands in the NCA, mainly instigated by the Woodland Trust and Natural England (Leeson, P. 2015, Personal Communication, 5 March 2015). To date, approximately 700 ha of new woodland has been planted, which is close to the proposed target of 8.9%. This planting has been carried out on the common land, which makes it unusual. To be able to plant woodland on common land an agreement has to be made between all graziers with rights to that land, which is generally believed to be difficult (Leeson, P. 2015, Personal Communication, 5 March 2015). More planting has subsequently been carried out on Ravenstonedale Common and there is also ongoing discussion in place for Brant fell and Lonsdale Common regarding considerations to participate in tree planting on their commons. Due to the unknown extent of the planting, four scenarios were applied consisting of an expansion of woodland cover to 10%, 25%, 50% and 75% of land cover in the NCA.

These alternative state scenarios were also influenced by the preliminary interviews in chapter 3. The interviews would often start with the participant asking “But how much woodland are we talking about?", "The tree planting in upland Cumbria discussion is not so much about people liking/disliking trees and woodland in those areas, but more about how much is being planted up" or, "We would like to see more trees... just not too much". There also seemed to be an often-repeated opinion of, "Too many trees will ruin the landscape and therefore tourists will stop coming". It also became very apparent, however, that the level of tree planting thought to be appropriate was highly variable, depending on the specific views, values and interests of the participants.

4.2.2 Rapid ecosystem services assessment

Having defined the study site and alternative scenarios, a rapid site-based ecosystem services assessment was carried out using the TESSA toolkit. Each assessment was carried out for the current state and the four alternative scenarios, using a combination of primary and secondary data, with the following approach:

Climate regulation

Climate regulation aim:

1. Carbon storage in tonnes
2. Annual flux of greenhouse gases, in tonnes of 'carbon dioxide equivalents'

Climate regulation objective:

1. Calculate carbon storage
2. Calculate carbon sequestration
3. Calculate carbon dioxide (CO_2) emissions
4. Calculate methane (CH^4) emissions
5. Calculate nitrous oxide (N_20) emissions
6. Synthesize the results of 2-5 above into a single figure for flux of greenhouse gases

Water-related services

Water related services aim:

1. Above-surface water balance in m^2

Water related objective:

1. Estimate modelled water quantity and above-surface water balance

Nature-based recreation

Nature-based recreation aim:

1. Assess the extent of nature based recreation in the Howgill Fells NCA
2. Estimate the economic value of nature-based recreation

Nature-based recreation objective:

1. Estimate the number of visits for nature-based recreation
2. Estimate the average spend per visit
3. Estimate the percentage of current visits that would occur under alternative states
4. Synthesize the results from 1-3 into a single figure for the value of the current and alternative scenarios generated by nature-based recreation

Cultivated goods

Cultivated goods aim:

1. Estimate the economic value of cultivated goods

Cultivated goods objective:

1. Estimate the number of livestock units
2. Estimate how many livestock units the area can sustain for the production of cultivated goods.
3. Conversion of livestock units into livestock numbers
4. Estimate the economic value of livestock

Finally, combine the above into an overall estimate of benefits and drawbacks under each of the four alternative woodland expansion scenarios.

The following sections details the specific methodology used for each of the assessment of the four ecosystem services.

4.2.3 Climate regulated services

The ES climate change regulation within the Howgill Fells NCA are assessed focussing on the three factors that influence climate regulation:

- Carbon stored above and below-ground in plant biomass, dead organic matter and soil.
- Carbon sequestered (taken in from the atmosphere) over time by plants and soil.
- Greenhouse gases emitted by plants, soil and animals over time

This is carried out in line with the TESSA Toolkit approach and will be based on: a) changes in carbon storage and, b) changes in annual greenhouse gas fluxes between the four predesigned scenarios and under the aims and objectives outlined.

Outputs are presented in the following format and comparison is made between the current state and the four scenarios:

1. Carbon storage in tonnes
2. Annual flux of greenhouses in tonnes of 'carbon dioxide equivalents'

4.2.3.1 Carbon storage

Carbon storage was assessed within each of the broad habitat classifications occurring within the study site and thereafter combined to create a total amount of tonnes of carbon stored within the site. TESSA offers two ways of estimating carbon stock: i) by the use of IPCC Tier 1 estimates or, ii) collecting site-specific data within the study site. Although the IPCC estimates are widely used (Pearson *et al.* 2013) and reliable, they lack the regional and site specific accuracy that local field data can provide. It was decided, therefore, to collect and process site-specific primary data manually.

The process of carbon stock estimation started by identifying and stratifying all broad habitat categories and area sizes of each calculated in ha. using Geographic Information System (GIS) software ArcGIS and Habitat Classification Landcover Map 2007 by The Centre for Ecology and Hydrology. The Landcover maps include data of each habitat type identified using the Broad Habitat Classification system. Within the study site and using these data sources, the following habitats were identified:

- Bog
- Broadleaved, mixed and Yew woodland
- Built up areas and gardens
- Coniferous woodland
- Rough low-productivity woodland
- Acid grassland
- Arable and horticulture
- Dwarf shrub heath
- Improved grassland
- Inland rock
- Montane habitats
- Freshwater

Landcover Map 2007 (Hydrology 2016) is data-derived using satellite imagery and digital cartography and it is therefore expected to contain a certain amount of error in classification of habitat, due to the limitations of method and change in land use since 2007. Ground truthing is therefore essential to obtain accuracy within the identification of the habitats. Ground truthing identified many areas which needed editing and particularly areas of different classification of grassland and shrub was often in need of editing. The decision was made to compound all grassland types into one category due to similar qualities in carbon storage, sequestration and GHG flux (Hagon *et al.* 2013). The study site, after ground truthing, editing and grassland compounded into one category, was divided into four categories: broadleaved woodland, coniferous woodland, grassland and bog – table 8 and figure 19. Thereafter, above-ground biomass and carbon stocks were calculated in grassland and woodland habitats, followed by below-ground carbon stock calculation for both grassland and woodland and finally carbon stocks in soil following TESSA recommended protocol.

Table 8 – Habitat area size in hectare by IUCN broad habitat classification in each of the proposed scenarios. 'Other' signifies: Inland rock, fresh water and built up areas. Due to the tree planting only occurring on grassland and being a 'native type consisting mainly of broadleaved tree species, only the habitat categories of broadleaved woodland and grassland will change under each scenario. Coniferous woodland and bog is expected not to change in area size.

IUCN Habitat (ha)	Broadleaved Woodland	Coniferous woodland	Grassland	Bog	Other	Total
Current state	68	12	10,436	332	153	11,000
10%	1,088	12	9,416	332	153	11,000
25%	2,738	12	7,766	332	153	11,000
50%	5,488	12	5,016	332	153	11,000
75%	8,238	12	2,266	322	153	11,000

4.2.3.1.1 Above-ground carbon storage - Grass-dominated habitats

Above-ground live biomass and carbon stocks in grassland were assessed by combining the following broad habitat classification grassland related habitats into one stratum:

- Acid grassland
- Arable and horticulture
- Dwarf shrub heath
- Improved grassland
- Montane habitats
- Rough low-productivity grassland

All types of grassland, bracken and shrub were compounded into one category, as required for the carbon stock assessment (Peh *et al.* 2013) The broad approach to categorise the above habitats into one category was carried out due to the large scale of the project. Furthermore, the habitat classification that underpins the stratification is the IUCN Habitat Classification, which classifies 'Grassland' as, 'lands with herbaceous types of cover (IUCN 2016). Additionally, tree and shrub cover is less than 10%'. It was judged, therefore, that by doing so, it would not risk or skew the overall results obtained. This is mainly due to the following reasons:

- Acid grassland, Rough Low-productivity grassland, Improved grassland and Montane habitats all fall into the category of IUCN Classification of "Grassland" (IUCN 2016).
- Arable and horticulture habitat is <5%
- Dwarf Shrub heath - which in this region contains a large amount of Bracken (*Pteridium*) - on site is very limited (7% - Natural England 2011) and of a highly degraded nature. Heathland furthermore, stores similar amounts of carbon in its above-ground biomass (2 t C/ha^{-1}) (Jones & Donnelly 2004; Hagon *et al.* 2013). However, it should be acknowledged that carbon in the soil of heath and bracken is slightly higher than

grassland (On average, Heathland 81.6 C/ha^{-1}, Bracken 77.1 C/ha^{-1}, whereas grassland is on average 60 C/ha^{-1}) (Hagon *et al.* 2012).

Sampling protocol in the field consisted of a set of ten plots. Two from each of the above grassland habitats measuring 1m x 1m was sampled following the protocols of Den Holland (2008) and Peh *et al.* (2014). Dwarf shrub heath, due to the high amounts of woody segments found was not included, as they contribute a relatively small proportion of total above-ground biomass (Peh *et al.* 2014). Furthermore, very little dwarf shrub heath was detected within the study site. The plots were selected using the ArcGIS 'Random Selection Tool', which randomly picks ten locations within the grassland category on the map – figure 19.

All vegetation within each sampling plot was clipped as close to the ground as possible, but without cutting stem base, corms or roots (Den Holland (2008). All samples were then weighed for 'fresh weight' within two days. Each sample was then separated into two fractions: dead material (DM) and live material (LM) and these two fractions were then measured separately. Five sub-samples (of no less than 100g) were taken from each of the two fractions (DM & LM) and weighed in fresh weight. The fractions were then placed in separate paper envelopes and oven-dried at 105° C for a minimum of two days to obtain a constant dry weight (oven-dry mass)

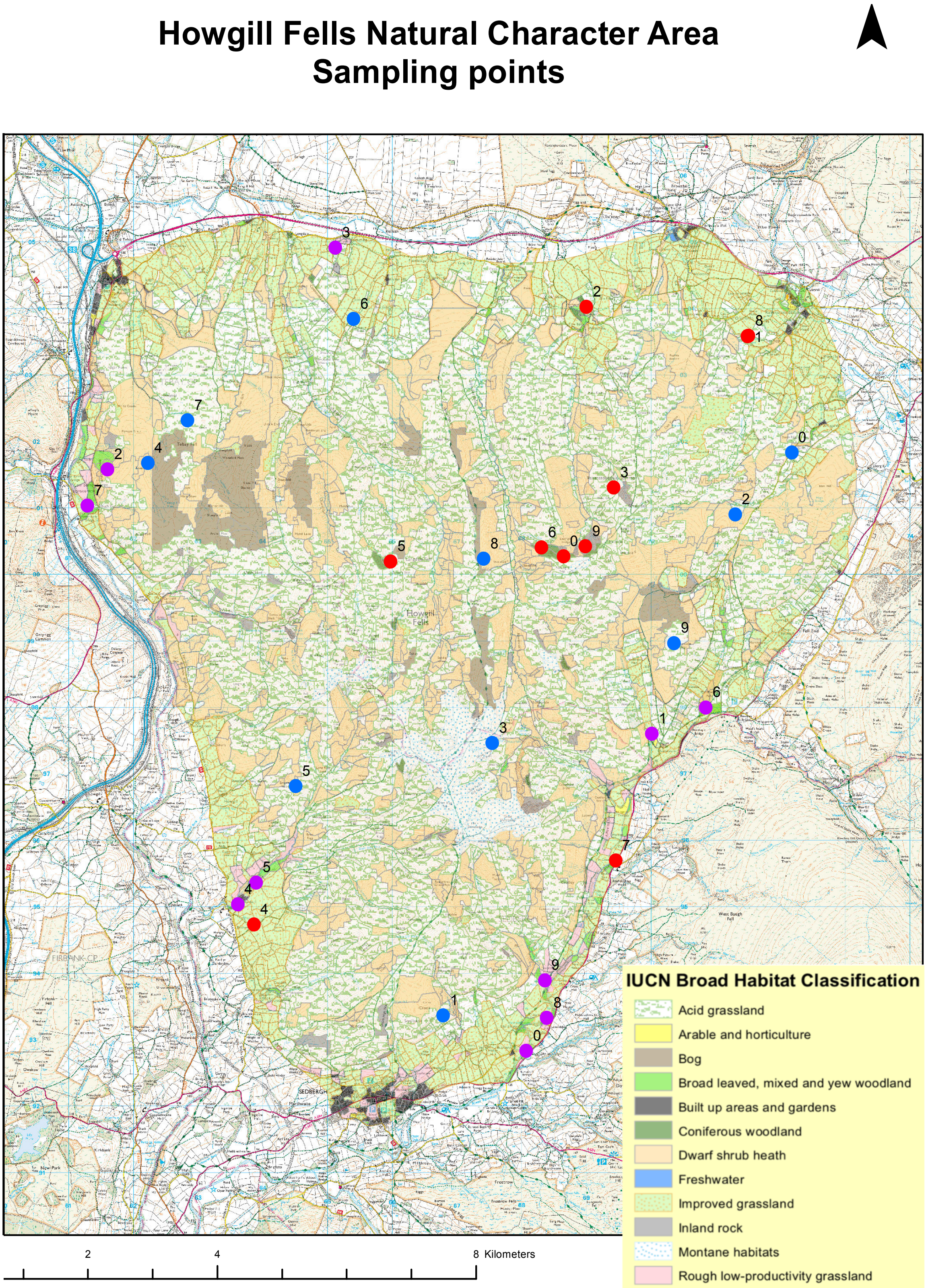

Figure 15 – NCA study site with IUCN Broad classifications identified. Above-ground carbon stock assessment survey plots are identified with purple being broadleaved woodland habitat, red being coniferous woodland habitat and blue being grassland habitat. Each habitat had ten sampling points.

After drying the sub-samples each was weighed and, using conversion factors established by (den Hollander 2008), the total dry weight for each plot measured in table 9. The mean dry biomass weight was then calculated for all the ten sampling plots and this value was then divided by 100 to express dry biomass per hectare (t) Ha^{-1}. Above-ground carbon was then assumed to be 47% of the total dry biomass (Eggleston *et al.* 2006). Total above-ground biomass carbon stocks (t/C) were then calculated for the whole land area by multiplying (t/C/ha^{-1}) with area size in hectares.

Table 9 – Grassland survey plots measured samples obtained from each sampling plot in grams (g).

Plot	0	1	2	3	4	5	6	7	8	9
Fresh weight total	382g	802g	485g	732g	705g	693g	436g	298g	759g	323g
Fresh weight dead material (DM)	96g	192g	224g	231g	528	256g	379g	178g	352g	199g
Fresh weight live material (LM)	286g	609g	264g	501g	176g	436g	57g	126g	407g	124g
Sub-samples										
Fresh weight (DM)	100g	100g	100g	100g	100g	100g	100g	100g	100g	100g
Dry mass (DM)	39g		55g	61g	72g	74g	46g	76g	63g	64g
Fresh weight (LM)	100g	100g	100g	100g	100g	100g	N/A	100g	100g	100g
Dry mass (LM)	30g		57g	64g	74g	74g		74g	60g	57g
Conversion factors										
Dead material (Dry mass divided by fresh weight)	54g	108g	126	130	298	144	214	100	199	112
Live material	171	364	157	299	105	260	34	75	243	74
Total	225	472	283	429	403	404	248	175	442	186
Total dry mass from all plots					3,267g					
Mean dry mass					594g					
Mean dry mass per ha 594/100					5.94g					
Adding the conversion factor of 0.47 (IPCC) (tonnes per ha)					2.79g					

4.2.3.1.2 Above-ground carbon stock - Woodland habitats

Above-ground biomass and carbon stocks in woodland habitats were measured in the following IUCN Broad Habitat Classification 2 strata:

- Broadleaved, mixed and Yew woodland
- Coniferous woodland

How many plots?

The correct level of sampling plots for sampling is based on the variability of biomass in the trees measured (Peh *et al.* 2014). Therefore, an initial set of nine plots was sampled in each of the strata following TESSA protocol (Peh *et al.* 2013). Equation 1 – appendix II - was then applied to determine the required total number of plots to achieve the correct level of precision (Verplanke & Zahabu 2009; Peh *et al.* 2013).

This was calculated for Broadleaved woodlands and Conifer woodland separately and the results are as follows:

Broadleaved woodland sampled plots = 15.93

Coniferous sampled plots = 9.28

The results from the preliminary nine plots indicated that the coniferous woodland strata required nine plots and the broadleaved woodland strata required fifteen plots in total to obtain a 95% confidence level. Within the broadleaved woodland strata, a high level of standard deviation was found, which explains the need for more data and an additional six plots were added to acquire a satisfactory precision level. The conifers were, however, satisfactory at the current nine plot levels.

4.2.3.1.3 Sampling method for woodland biomass within plots in the field

Sampling biomass within each woodland plot was carried out by first determining the location of each sampling plot. Each location was a minimum of 200m from another. Each plot consisted of 100m long transects by 5m wide (2.5m on each side) and all trees where at least two-thirds of the tree within this parameter were measured.

Variables to measure in the field were:

- Diameter at breast height (DBH) - at a height of 1.3m using DBH tape
- Identification of each tree to species level

Measurements of DBH and species collected from the field were then used to determine above-ground biomass (kg), which was then converted into carbon (kg) and carbon (tonnes) for the whole site. Three regression equations for calculating biomass were used, which were selected for being as species and geographical region specific as possible – equation 2, 3 and 4 – appendix II. Within the study site, there were many veteran broadleaved trees present, with a very high DBH measurement (>70cm). The Schroeder *et al.*(1997) method yielded the most consistent and reliable results and was therefore applied for species not mentioned under the first equation.

Above-ground biomass was calculated for each transect (plot) and a carbon value of tonnes of carbon (t/C) (carbon = 50% of biomass (Peh *et al.* 2013) and tonnes of carbon per hectare (t/C/ha^{-1}) was then calculated per plot (t/C / 0.05 (ha)). A further calculation was then made of the mean carbon value from all plots within each strata (broadleaved and conifers) – see results. The mean value was then applied to the total area size within each strata to calculate the total amount of carbon stored within above-ground of both broadleaved and coniferous woodlands.

Finally, litter carbon stocks were calculated using IPCC Tier 1 estimates of 13 t/C/ha^{-1} for broadleaved woodland and 22 t/C/ha^{-1} for coniferous woodland (Peh *et al.* 2013), which were applied to the area size of each of the two woodland habitat classifications.

4.2.3.1.4 Below-ground carbon storage in grassland and woodland

The calculation of below-ground biomass and carbon stocks was based on using a value transfer approach to keep in line with the overall aims and objectives of this project. In grassland, the majority of carbon is stored below ground in the roots and soil (Jones & Donnelly 2004). In order to calculate the below-ground carbon values, firstly below-ground biomass in grassland was calculated following TESSA protocols (Peh *et al.* 2013) and based on estimates by Anderson-Teixerira & DeLucia (2010) of a generic value of 14t dry matter/ha^{-1}. This was then multiplied by the carbon value of 0.47 (Peh *et al.* 2013). This was calculated using equation 5 – appendix II.

Below-ground carbon in woodland habitats were similarly calculated by recommendation of TESSA protocol (Peh *et al*. 2013) and by the use of IPCC conversion factors 0.23 for the category "other broadleaf above-ground biomass" 75-150 t/ha-^{1} and conversion factor 0.29 for "conifers above-ground biomass" 50-150 t/ha-^{1}. These factors were derived from allometric equation produced for woodland habitats by (Mokany *et al.* 2006) – equation 6 – appendix II.

4.2.3.1.5 Soil carbon storage

Determining carbon amounts in soil is complicated due to the high variation in sampling methodology and at what depth the carbon is measured (Alonso *et al.* 2012; Vanquelova *et al.* 2013). To carry out site-specific data collection of the carbon stored in the soil would have been resource and time intensive, due to the scale of the study site. There is, furthermore, a large amount of established literature and research on the relationship between soil and carbon and it was therefore decided to use a value transfer approach for this part of the assessment (Vanguelova *et al.* 2013). Hagon *et al* .(2012) carried out a review of current literature on carbon stored in the soil of various habitat and concluded a mean value for each habitat. These values were used to inform this part of the assessment, with the acknowledgement that they are generated as a broad approach.

Soil carbon stocks are particularly relevant and of high value in organic soils, such as deep peat, which both emit and capture CO_2 (Cannell *et al.* 1990). The peaty soils within the Howgill Fells NCA are mainly found in the bog habitat (Natural England 2010). The bog is a wetland that accumulates peat as a result of dead plant material such as mosses decomposing and accumulating over time. The bog habitats found in the NCA are degraded due to land-use management, such as grazing and draining (NE 2014). The values derived from Hagon *et al.* (2012) used for estimating carbon in the soil should therefore be approached with caution, as this disturbance due to land use is not considered. Estimating carbon values in peaty soils is difficult, due to the great variation in soil depth. The time required to carry out site-specific measurements to determine carbon stocks was deemed too resource intensive taking into consideration the rapid assessment approach of the TESSA Toolkit. Additionally, the tree planting in the NCA is not being carried out on the bog habitats and thus the carbon stock and sequestration values remain a constant value and will not be affected by the planting. The bog habitats do, however, add to the total carbon stock and sequestration value of the study area and therefore remain relevant.

4.2.3.2 Carbon sequestration

Carbon sequestration is the carbon extracted from the atmosphere over time by plants and soil and is also known as the negative flux. A negative flux direction indicates an extraction of carbon from the atmosphere and positive as a release/emission (Peh *et al.* 2013). Carbon sequestration is an important aspect of climate regulation as an ecosystem service and the amount sequestered varies greatly, depending on habitat and land-use (IPCC 2006). To assess the carbon being sequestered within the Howgills Fells NCA, the focus was on three habitats: bog, grassland and woodland.

4.2.3.2.1 Carbon sequestration in bogs

Carbon sequestration in bog habitat was estimated using the following equation, following TESSA protocol (Peh *et al.* 2013) and (Nieveen *et al.* 2005) – equation 7 in appendix II.

Result: -124.7. A negative value indicates carbon uptake, positive indicates an emission of carbon. Therefore, the bogs on site are taking up (sequestering) a total amount of 124.7 tonnes of carbon per year.

4.2.3.2.2 Carbon sequestration in woodland and grassland habitats

Carbon sequestration rates in the UK are calculated using the Forestry Commission Woodland Carbon Code (WCC) as standard. The WCC was established in 2011 and aims to provide an independent protocol and 'best practice' for calculating levels of carbon sequestration from woodlands (West & Mathews 2012).

The WCC allows users to estimate carbon sequestration from a given woodland at a 5-year interval, using input variables such a species, age, yield class, spacing and management. Due to this, it is very efficient in estimating carbon sequestration in woodlands with little dynamic complexity, such as even-age and little species variation woodlands. However, applying the WCC protocol to woodlands with large age and species differentiation is difficult and any results obtained from this should be approached with caution. It is, nonetheless, the best approach for carbon sequestration calculation in the UK at this moment, unless extensive resources and time are available for in-depth data collection and analysis.

The input variables for the carbon sequestration calculations were derived from a combination of collected field data and modelled data from previous research. Species and spacing variables were collected in the field, as part of the carbon stock estimate – see results. Age and management technique estimates were obtained by questioning landowners where possible. Conversations with the local Forestry Commission Woodland Officer helped further estimates for these two variables where uncertainty existed. Yield data were obtained using the Forest Research Ecological Site Classification (ESC), as recommended by WCC (West & Matthews 2012). ESC is a practical classification web-based tool, which aids foresters and practitioners in silvicultural site-specific decision making based on climatic and soil data (Pyatt & Suárez 2001). Although ESC is fundamentally based on local data from the UK Meteorological Office and National Soil Surveys, some assumptions must have been made, as is typical with modelled data, which should be considered when estimating a specific yield class for a species in site. The yield data obtained via ESC was subsequently discussed with the local Forestry Commission Woodland Officer, who deemed the estimates plausible (O'Neill, J. 2016, Personal communication, 10 March 2016). However, the decision of using ESC was made partly due to the recommendation by WCC, but also due to trying to reach the desired balance of time/resource efficiency in the TESSA Toolkit. Furthermore, the use of the yield category of SAB [16] and yield class four, was recommended for most native species or scrub species where no specific species yield class was available (West & Mathews 2012).

Carbon sequestration in grassland habitats were estimated using a UK specific average grassland estimate derived by De Deyn *et al.* (2010) of -2.20 t/C/ha^{-1}. Precise estimation of sequestration rates in grassland habitats requires monitoring over long periods of time of both

[16] Yield category SAB (Sycamore, Ash, Birch) is recommended for planting of a mixed native woodland with a number of different native species. The Carbon Code guidance by West & Mathews (2012) states that, "This encompasses three species which grow and sequester carbon at different rates. This is the best model to singly represent any mix of native species. A conservative approach would also be to assume Yield Class 4, as this errs on the side of caution of known growth rates of native woodland in the UK".

vegetation and soil (Jones & Donnelly 2004), which is not possible within the rapid assessment framework of TESSA. Therefore, the De Deyn *et al.* (2010) UK average was applied. By multiplying this value to the total area size of grassland, a total carbon sequestration value was obtained.

Carbon sequestration per ha in each habitat was then calculated by dividing total sequestration in each habitat by area size.

For both woodland and grassland habitats, the total amount of annual sequestration was calculated for each alternative scenario by using the mean t/CO_2/ha^{-1}/y^{-1} derived from each habitat category and applied to the change in area size for each category. For the woodland habitats, mean sequestration rate for broadleaves only were used, as only broadleaved woodlands are planted as part of the alternative scenarios.

4.2.3.3 Greenhouse gas emissions

4.2.3.3.1 Carbon dioxide (CO_2) emissions

Carbon dioxide (CO_2) is only calculated for drained organic soils, as CO_2 emissions from mineral soil and soil without disturbance is deemed insignificant (Peh *et al.* 2013). Drained organic soil within the study site was identified using Soilscape (Institute 2016) and an interview with Natural England area representative who advised on drained practices carried out in the NCA.

Soilscape identified 5,490ha of organic soil within three soil-types: 16, 2 and 25. Tonnes of Carbon per ha per year (t C/ha^{-1}/y^{-1}) was calculated using IPCC tier 1 annual emission factors (0.25) for drained organic soil (IPCC 2006) in grassland dominated habitats in cold temperate regions – equation 8 – appendix II.

Subsequently, the result must be converted from carbon to carbon dioxide, which is carried out by multiplying the result by 44/12 (3.67). The atomic mass of carbon is 12 atomic mass units and the mass of carbon dioxide is 44.

The organic soil is mostly found in the upper levels in the NCA (Institute 2016). With the knowledge that tree planting will not be carried out on the bog habitat, the area size for this category was deduced as follows: 5,490 ha organic soil minus 332 ha bog = 5,158 ha.

To be able to calculate the changes in CO_2 emission on organic soil from the alternative scenarios of woodland creation of 10%, 25%, 50% and 75%, a calculation of how much of the tree planting would affect the organic soils is needed. With the organic soil roughly covering 50% (5,158 ha organic soil and 10,436 ha grassland) of the grassland in which the tree planting would occur on, the scenarios were corrected with 50% less area size – table 10. The woodlands planted under the alternative scenarios would not be managed or harvested and CO_2 emissions from organic soil under these woodlands are deemed not significant (Peh *et al.* 2014). Subsequently, the CO_2 emissions from each scenario were calculated following the same IPCC tier 1 emission factors as above and applied to the changed area size in table 8.

Table 10 – Organic soil adjustment of area size with 50% organic soils under each of the scenarios, as well as the annual tonnes of CO_2 emitted under each scenario.

Scenario	Current grassland area size (ha)	Area size (ha) adjusted with 50%	$t/CO_2/y^{-1}$
Current			5.037.7
10%	9,416	4,708	4,319.6
25%	7,766	3,883	3,562.6
50%	5,016	2,508	2,301.1
75%	2,266	1,133	1,039.5

4.2.3.3.2 Methane (CH_4) emissions

Methane (CH_4) is a significant GHG and emissions can result from the effects of land management (Allard *et al.* 2007). Two important sources of CH_4 in upland environments are grazing animals and the anoxic conditions of waterlogged soils (Le Mer & Roger 2001). As the habitats and soils in the NCA are mainly drained, this assessment only takes CH_4 emissions from grazing animals into account. CH_4 emissions from grazing animals, such as ruminants (cattle, sheep, deer) and other herbivorous species (horses, pigs) are caused by the digestive process of these animals. It is a by-product of digestion and released by belching (Le Mer & Roger 2001; Allard *et al.* 2007; Peh *et al.* 2013).

IPCC tier 1 emission factors (IPCC 2006) and the 2013 DEFRA Agricultural Statistics for Howgills NCA are used to calculate the CH_4 emissions. Due to the difficulties of estimating relatively accurate levels of wild grazers, such as deer, in the NCA these have been omitted and only domestic livestock of cattle and sheep are included in this assessment. Key stakeholders furthermore informed that deer is not in abundance in the area. Ponies are also present at the NCA but at very low levels and, again, obtaining reliable estimates was difficult, thus they are also omitted. These omissions are, however, deemed to have little significance in the overall results, but the estimated CH_4 levels should be prudently treated as an underestimate. In fact, in comparison with National Atmospheric Emissions Inventory (NAEI) data the results obtained using IPCC and DEFRA Agricultural Statistics are much lower than theirs. The reason for using the described method is due to the subsequent possibility of adjusting the data for comparison with the alternative state. NAEI data does not allow this to the same extent.

Livestock levels taken from the 2013 DEFRA agricultural statistics of the current state of the Howgills NCA indicates grazing stock levels of: Cattle - 693, Sheep - 26,354. Set out below is an example used for the calculation of the annual flux and Global Warming Potential (GWP)[17] for the current state. For each of the predesigned scenarios, this calculation was carried out according to the stock level expected under each scenario.

CH_4 emissions have been calculated using equation 9 – appendix II.

Cattle: 57 x 693/1000 = 39.501 t/CH^4/yr

Sheep: 8 x 26,354/1000 = 210.832 t/CH^4/yr

Amount of carbon (as methane) emitted per year by grazing animals on site:

250.3 x 0.75 = 187.7 t/$C_{ch4/}y^{-1}$

To calculate the Global Warming Potential (GWP) in CO_{2eq} multiply 187.7 t/ C_{ch4}/y^{-1} with 25 (Methane GWP_{100}) = 4692.5 t/ CO_{2eq}/y^{-1}

[17] CO_2eq is a necessary conversion and a measure used to compare fluxes of various GHG, based on their Global Warming Potential (GWP)(Peh *et al.*2014). CH_4 and N_2O are labile compounds and therefore degrade with time. This needs to be considered and for the use within this assessment, a GWP over a 100 year horizon is used.

4.2.3.3.3 Nitrous oxide (N_2O) emissions

Nitrous oxide (N_2O) emissions are an important non-carbon greenhouse gas (GHG), which occur particularly on managed agricultural land where nitrogen fertilization is applied (Allard *et al.* 2007). Estimates of N_2O are not easily obtained from field measurements without technical expertise and extensive resources. Estimates, therefore, are often based on existing data or the use of IPCC tier one estimates.

For the purposes of this study, N_2O emissions were estimated using National Atmospheric Emissions Inventory (NAEI) data. The NAEI data is substantial and provided via a user-friendly online mapping tool, which allows the user to explore and download UK emission data from a large variety of sectors. The emission data from the agricultural sector is derived and modelled from the 2014 Agricultural Census for the UK and combined with emission factors for livestock, fertilizer use and CEH Land Cover Map 2007 (Dore *et al.* 2016). By selecting the area of interest (Howgills NCA), total emissions per year is obtained in tonnes of N_2O.

N_2O t/y^{-1} is then converted to Global Warming Potential (GWP) in CO_2eq. by multiplying 12.41 t N_2Oy^{-1} with 298 (N_2O GWP_{100}) = 3698.2 t/CO_2eq/y^{-1}.

As tree planting is not being carried out on the lower altitude levels where the improved grasslands occur and, due to farmers wishing to keep the planting on the less productive common land, stakeholders are informed that the N_2O emissions are not likely to change under any of the alternative scenarios.

4.2.3.3.4 Annual flux of GHG

Annual flux of GHG is calculated by combining the GHG emissions obtained to the carbon sequestration levels. Caution should be taken with regard to interpreting the values, as positive values represent emissions and negative values represent uptake (sequestration). All values are displayed in CO_2.

4.2.4 Water-related services

This research has applied a spatially explicit hydrological modelling tool to assess water-related ecosystem services (ES) within the study area. Firstly, a baseline scenario was developed and then four predesigned plausible scenarios of different levels of afforestation were modelled. The Policy Support System (PSS) WaterWorld (Mulligan 2013) was chosen to carry out the assessment in order to meet research aim 1 and objectives 1.4 and 1.5. WaterWorld is capable of carrying out a detailed analysis of hydrological services within a specified area of interest, as well as carrying out a comparison of scenarios of land-use change. To complement some of the analysis carried out by WaterWorld, Geographical Information Software (GIS) such as SAGAGIS and ArcGIS was used. The hydrological modelling focusses on above-ground hydrological changes, such as precipitation, evapotranspiration (ET), runoff, infiltration and water balance. The water balance is the main focus and is calculated using long term climatic data, land cover characteristics and topography. Wind driven rainfall is added to fog inputs before the actual ET is subtracted which is accumulated downstream as run-off.

WaterWorld is capable of analysing hydrological ES on a global scale from either a 1km or 1ha resolution scale. Due to the small size of the study area a 1ha resolution scale was attainable, providing more accurate modelling results (Mulligan 2013). The model can calculate either monthly or annual datasets with inputs of mean precipitation, wind direction, temperature, relative humidity, sea-level pressure and cloud frequency, to create total average outputs based on different land-cover type, soil, and topography. The outputs generated by the model calculates monthly and annual average rainfall (wind-corrected), fog inputs, ET rates, water balance, infiltration and erosion (Mulligan 2013).

To be able to carry out the required analysis for the intended hydrological modelling under different scenarios, hydro-climatic and biophysical datasets are needed. WaterWorld's primary database is SimTerra, which is the source of the major spatial datasets consisting of the best available global datasets generated, or sourced from, both remote-sensing and ground-based sources (Mulligan 2013). Some of the properties with SimTerra are datasets from sources such as WorldClim climatology (Hijmans *et al.* 2005), cloud climatology (Mulligan 2006), SRTM terrain/elevation (Farr & Kobrick 2000), wind speed/relative humidity and temperature (New *et al.* 2002) and Landsat Land cover (Sexton *et al.* 2013). This impressive database consists of more than 400 different maps for approximately 200 different variables and is the core supplier of the input data for the model.

4.2.4.1 Selection of hydrological model

Ecosystem service assessment and modelling has in recent years become widely used and a range of different approaches have been developed (Bagstad *et al.* 2013). In terms of modelling hydrological ES, several explicit tools are currently applied, with the most commonly used globally being Artificial Intelligence for Ecosystem Services model (ARIES) (Villa *et al.* 2009), the Integrated valuation of Ecosystem Services and Trade-offs Model (InVets) (Tallis *et al.* 2011) and the Soil and Water Assessment Tool (SWAT) model (Winchell *et al.* 2010; Neitsch *et al.* 2011). Regionally in the UK, more specific modelling on forest impacts on hydrology has been carried out by Nisbet and Broadmeadow (2000). Pandeya *et al.* (2016) and Peh *et al.* (2014) carried out an extensive comparison of modelling tools which allow for the modelling of hydrological ES and found that, although the aforementioned tools are highly sophisticated and implicit, they also require extensive resources and specialist experience to implement them. Sharp *et al. (*2017) found, however, that results can vary significantly between different modelling software and therefore recommended results obtained from such should be approached with caution if not verified by data collected in the field.

Selecting a modelling tool for assessment is dependent on the aim/objectives of the research. Several studies have used modelling to assess potential impacts of change in hydrological fluxes on a catchment scale (Sahin & Hall 1996; Costa *et al.* 2003; Brown *et al.* 2005). This research requires a site-specific approach, with the option of entering and comparing outcomes of specific land-use/management and policy scenarios. Additionally, due the rapid ES assessment approach adopted by TESSA, assessing hydrological ES within this research should be possible to carry out with limited time/resources and technical expertise. WaterWorld is unique in its development by having the best available and high resolution data incorporated, which can thus be applied rapidly with high quality outputs that are then easily interpreted by a wide range of stakeholders. Furthermore, the following criteria and considerations were taken into account when choosing a model for this research:

- The model should be in line with the TESSA Toolkit objectives such as: user-friendly, able to be carried out by non-specialists within a limited time frame and be cost effective
- It should be possible for the model to assess both a baseline scenario as well as multiple plausible scenarios
- Outputs should be spatial and be able to be interpreted by a range of stakeholders
- The model should allow for easy implementation of land-use changes
- The model should allow large scale catchment-scale modelling

This study focusses on the potential impacts of a change in land-cover from grassland to forest and, for this chapter in particular, hydrological processes. This is a widely-used practice for gaining a preliminary understanding of the potential outcomes of such changes (Kepner *et al.* 2004; Breuer *et al.* 2009). As described earlier, many of the other available modelling toolkits do require specialist knowledge to operate and require significant time resources, which was not possible within this study. The TESSA Toolkit recommends and collaborates with the WaterWorld Policy Support, as it aligns with the criteria and objectives of TESSA, and this was an important consideration in choosing which approach to take. WaterWorld allows for the scenario modelling needed for this study and was therefore deemed suitable.

4.2.4.2 WaterWorld specifications

The WaterWorld Policy Support System is a process-based and self-parameterised hydrological model. It is therefore based on the theory and mathematical algorithm behind relevant ecological processes to understand and incorporate specific responses to changes in environmental settings. It is data intensive and spatially explicit (Mulligan 2013). The model is used to estimate baseline hydrological fluxes globally and can construct scenarios of changes in land-use or management, climate or policy context for the understanding and evaluation of potential impacts of such changes and therefore aids the decision-making process. The model has the ability: i) to estimate baseline hydrological fluxes on an annual and seasonal basis; ii) to assess the impacts of scenarios for land use and cover change; iii) to analyse the impacts of scenarios for climate change and vi) to assess the impacts of multiple land and water management interventions (Mulligan 2013).

WaterWorld's primary database is SimTerra, which is the source of the major global spatial datasets Mulligan 2013). This therefore enables global analysis and is of particular use in regions of poor data sets, such as ungauged rivers and mountains (Van Soesbergen 2013). The model includes data for distribution of precipitation through rainfall (wind-corrected) and cloud water inputs and its interaction with wind, solar radiation receipt and evapotranspiration dependent on climatic conditions, vegetation, water balance and its cumulative downstream flow (Mulligan 2013). The model also permits the user to upload one's own data, should this be of better resolution or more recent than that currently held by SimTerra.

WaterWorld incorporates the 'FIESTA[18] model', which is a hydrological model specifically designed for understanding hydrological properties of spatial and seasonal variation of cloud forests (Pandeya *et al.* 2016) . The integration of FIESTA in WaterWorld is unique and no other model has the capacity to perform such modelling. This can be applied to mountain regions to assess land cover and climate change impacts on water related ecosystem services, water production, soil erosion and sedimentation. FIESTA was originally developed for tropical cloud forests, but is equally suitable for analysis of all mountain regions globally. It has been applied on different geographical scales, such as country level (Mulligan & Burke 2005), geographical region or globally (Mulligan 2010; Bruijnzeel *et al.* 2011; Pandeya *et al.* 2016) . As with WaterWorld, this model is process-based and models water balance on either a monthly and/or diurnal time-step. This enables the depiction of average daily dynamics within a month, which is important for fog and evapotranspiration, which is highly diurnal. The model repeats the time-steps 4 times (00:00-06:00 hrs, 06:00-12:00 hrs, 12:00-18:00 hrs and 18:00-24:00 hrs). These calculations are carried out for one year (and therefore a total of 48 time steps for a complete simulation) of data using long term (i.e. 50 years) climatology (Bhopal 2014). The

[18] Fog Interception for the Enhancement of Streamflow in Tropical Areas (FIESTA) is a simulation model originally developed for the hydrological processes to understand the impacts of forest conversion in tropical montane cloud forests (TMCFs) in Costa Rica (Mulligan and Burke, 2005). The model was originally developed for the improved scientific understanding of TMCF cover in Payment for Environmental Services (PES) schemes (Pandeya *et al.* 2016).

analysis of the Howgills consists of some water inputs from cloud water interception[19] and FIESTA has therefore been part of this modelling.

The primary output from WaterWorld is the estimation of mean water balance (1950-2000). The model is grid-based around sets of tiles and it is possible to run simulations of tiles of either 1ha resolution (dimension of 1 degree latitude/longitude) or 1km^2 resolution (10 degree latitude/longitude) (Mulligan 2013). Simulation outputs are presented visually via value defining maps or the user has the option of downloading GIS files for further analysis in other software packages, such as ArcMap. The model runs on above-surface components of the hydrological cycle only and does not have subsurface properties included, as soil and base/through flow cannot be defined at the aforementioned spatial scales (Mulligan 2013). Therefore, soil moisture, groundwater and canopy water balance are not considered. Version 3 (under development) does have the option of simulating infiltration and this has been applied to this study.

One of the most notable outputs of interest from WaterWorld in terms of afforestation scenarios, is actual evapotranspiration (AET). AET is the amount of water that evapotranspiration and transpiration processes remove from the surface and vegetation canopies. Evapotranspiration analysis in WaterWorld is driven by a simple energy driven model only considering the vegetation parameters of Leaf Area Index[20] (LAI), height and cover of three functional vegetation types; ‘tree’, ‘herb’ and ‘bare’ (Pandeya *et al.* 2016). The model can differentiate from potential evapotranspiration (PET) and AET. PET is calculated on the basis of energy and atmospheric requirements, which is then combined with the LAI for the interception

[19] Cloud water interception refers to the water derived from clouds, which does not reach the soil, but is intercepted by the leaves and branches of plants.

[20] Leaf Area Index (LAI) is a dimensionless quantity (a quantity without any physical units), which is used to define plant canopies. It is defined as the one-sided green leaf area per unit surface area (Leaf area m^2/ground area m^2) in tree canopies.

of solar radiation and evaporation of water to produce the approximate AET (Mulligan 2013). Total runoff quantities can also be estimated via WaterWorld, which is the cumulative downstream outflow. This is calculated based on AET deducted from the total precipitation amount. This cumulative downstream outflow is not entirely equivalent to surface runoff, as such may have baseflow components that are not represented in the WaterWorld model (Mulligan 2013).

4.2.4.3 Building up a scenario

The modelling for ES impacts caused by changes in land-use carried out in this project was carried out under a comparison of a baseline (current state) to the four previously described scenarios of woodland creation of 10%, 25%, 50% and 75%. WaterWorld carries out analysis with a system of set tiles on a global scale. The user can further narrow down the area of interest by using a smaller scale tile but is always limited to carrying out analysis within these boundaries. Analysis can be based on specific smaller scale areas of interest, such as catchments, but the preparation of specified Zones Of Interest (or areas/points), must be carried out beforehand. To do this, a Zone Of Interest (ZOI) which depicts the Howgill Fells NCA was first created by the use of SAGA GIS (System for Automated Geoscientific Analyses). SAGA GIS is a free open-source geographic information system used to edit spatial data (Böhner *et al.* 2006). The ZOI was created using an Ordinance Survey MasterMap of a 1:50000 scale, and prepared in SAGA GIS as an ASCII file and transferred to WaterWorld. Creating a ZOI allows the user to model hydrological fluxes within a confined area. The ZOI was then uploaded in WaterWorld and scenario rules applied. Under each scenario, the relevant percentage was set and applied per pixel within the ZOI – figure 20. Thereafter, an additional rule was applied by applying the afforestation only to areas within the ZOI no higher than 450m altitude to remain within the policy context of the planting, which only allows planting under this altitude.

The outputs and results from the WaterWorld modelled analysis are presented both spatially and statistically – figure 21 - for each of the scenarios applied. The output maps allow the user to obtain a clear spatial understanding for the hydrological processes within the ZOI and the statistical output aids further understanding in a quantifiable manner. Outputs can furthermore be downloaded and uploaded within other GIS software, such as ArcGIS, for further analysis should it be needed

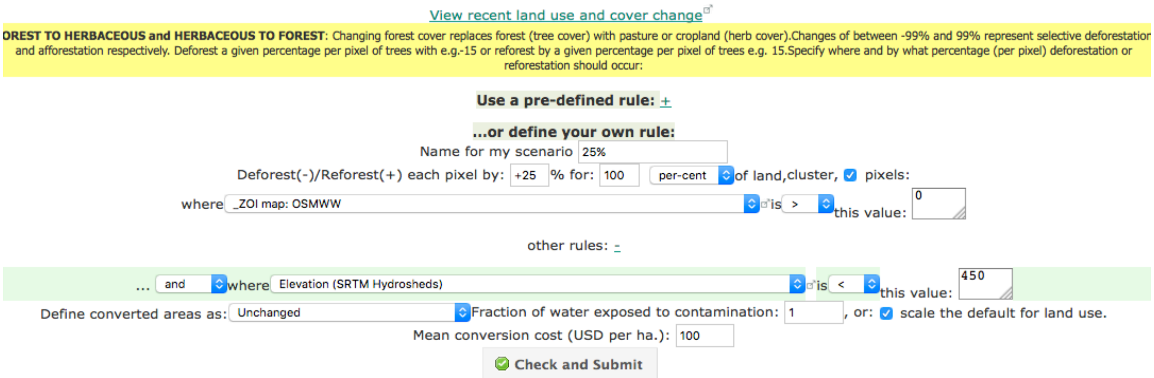

Figure 6 – WaterWorld modelling example of the rules applied under a 25% afforestation scenario in WaterWorld

Areas	Min	Max	Sum	Count	Mean	SD	CoV	Area Fraction	km^2
All	-230.561035156	2632.25732422	1731047040.0	1399234.0	1237.13906323	244.299321497	19.7471188776	1.0	3329.68115234
Zero	-	-	-	-	-	-	-	-	-
Non-zero	-230.561035156	2632.25732422	1731047040.0	1399234.0	1237.13906323	244.299321497	19.7471188776	1.0	3329.68115234
Positives	0.206547155976	2632.25732422	1731515776.0	1394041.0	1242.08382393	231.213630369	18.6149779841	0.996288683665	3317.15209961
Negatives	-230.561035156	-0.45542049408	-390816.34375	5193.0	-75.2582984306	36.56919585	-48.5915794173	0.00371131633451	12.3129673004
All (ZOI: OSMWW)	1139.47058105	2562.64868164	44921480.0	27987.0	1605.0837889	281.216295623	17.5203498763	0.02000165805	68.6227798462
Zero (ZOI)	-	-	-	-	-	-	-	-	-
Non-zero (ZOI)	1139.47058105	2562.64868164	44921480.0	27987.0	1605.0837889	281.216295623	17.5203498763	0.02000165805	68.6227798462
Positives (ZOI)	1139.47058105	2562.64868164	44921480.0	27987.0	1605.0837889	281.216295623	17.5203498763	0.02000165805	68.6227798462
Negatives (ZOI)	-	-	-	-	-	-	-	-	-

Figure 7 – WaterWorld modelled data output example of statistical outputs from a WaterWorld 50% scenario analysis. The results are displayed for the whole tile (purple tile) in the 'All' row and results from within the ZOI within the 'All (ZOI) OSMWW' row. All values are displayed per pixel.

4.2.5 Nature-based recreation

Nature-based recreation as a cultural ecosystem service of, was assessed in line with the TESSA Toolkit guidelines (Peh *et al*. 2013), which recommends carrying out in-site data collection via surveys of visitors, to estimate of the impact of woodland creation on the economic value of nature-based tourism in the Howgill Fells NCA study site. This research has applied primary data via an in-situ intercept convenience survey and photo visualisation to assess nature-based recreation as a cultural ecosystem service within the study site. No site specific visitor number data was available for the area and primary data collection was therefore necessary. An economic value of nature-based recreation within the study site was applied using economic survey data from the regional tourism board and local tourist information centre. Impacts from a change in landscape were estimated, based on a participant group consisting of 491 people, whom were questioned on whether a change in woodland levels in the Howgill Fells NCA would affect the likeliness of them visiting again. The four predesigned scenarios of different levels of woodland were presented via the survey to participants. The scenarios were of 10%, 25%, 50% ,75% and 100% woodland levels, which was informed by policy context and preliminary local stakeholder interviews. An economic value was added to each of the scenarios, informed by the results from the survey. Finally, results were presented to the regional tourist board for validation.

4.2.5.1 Convenience sampling

The principle behind the survey is non-probability convenience intercept sampling (Newing 2010). This is mainly due to the exploratory nature of this study, whereby the survey aims to assess the views of a specific target participant, who are people that visit the Howgills NCA for nature-based recreational purposes. These participants can be reached most efficiently by being within the study region of the NCA and interviewing them directly. Convenience sampling has the benefit of exploring selected people's views and documenting specialist knowledge in cases where there is no need for making comparisons and determining the views of the whole population (Chhetri *et al.* 2004; den Breejen 2007; Newing 2010). In the case of this study, non-probability sampling is appropriate, since to be able to assess the aim of this particular part of the project only the views of these particular participants are necessary (den Breejen 2007; Kim & Weiler 2013).

4.2.5.2 Photograph visualisation

Scenario visualisation can be carried out in various ways, such as using basic maps, drawings or charts (Jansens 1990; Primdahl 1990; Palang *et al.* 2000; Tress & Tress 2003) or more sophisticated GIS-based modelled landscapes (Möltgen *et al.* 1999; Appleton *et al.* 2002). Using a photograph for visualisation allows for a more realistic visualisation. A large-scale photograph enables a sense of how the proposed woodland scenarios would aesthetically impact the area from afar or by being in the valley bottom of the outskirts of the NCA. It does not, however, allow the participants to get a sense for the more detailed experience of being within or immersed in the landscape under the different scenarios. This sampling was carried out in-situ and is a common approach in studies, where perceptions of a changing landscape are explored (Chhetri *et al.* 2004; den Breejen 2007; Soliva *et al.* 2008; Kim & Weiler 2013).

The design of the manipulated photographs used for the visualisation was created by using a landscape photograph of the Howgill Fells NCA obtained from the landscape online photograph library Gallery3 (now closed) and a copyright was secured. Care was taken to utilize a photograph which was as realistic as possible in depicting the characteristics of the NCA. The photograph editing software PaintShop Pro X9 Ultimate was used to manually edit the photographs and add an increasing level of woodland to each of the pre-designed scenarios – figure 22. The woodland already present within the original photograph was used as an added woodland resemble the proposed woodland in type and design as much as possible - i.e. a native woodland with a mixed type of tree species, spatially located on the lower levels of the fells, gradually increasing upwards, not increasing and covering the highest peaks. The area size to be increased under each scenario on the photograph was determined by calculating the total geometrical area size of the parts of the photograph to be edited and then applying the woodland scenario percentage accordingly.

Original – 1.5% woodland cover

10% scenario

25% scenario

50% scenario

75% scenario

100% scenario

Figure 22 - manipulated photos of the Howgill Fells NCA under each of the woodland creation scenarios. These were used as support to the questionnaire and survey of the ecosystem service nature-based recreation.

4.2.5.3. Questionnaire design

The questionnaire designed for the survey followed recommendations by Dillman *et al.* (2014) and was a formal standardised questionnaire and not explorative, due to the quantifiable need to estimate visitor numbers and the likelihood of return visits under each proposed scenario. A pilot survey in-site and with participants within the targeted socio-demographics were carried out, which highlighted a need for adjustments to the questionnaire in regards to the design of scenario choice, as participants found this section to be confusing and vague. A final edited version of the questionnaire was successfully trialled afterwards. Four sections were included: 1) socio-demographics, 2) reasons for visiting, 3) scenario and woodland preference and 4) expenditure during the visit – appendix IV. The first section established the socio-demographics of participants, such as age, gender, postcode of residence, mode of transport and visiting pattern. The second section assessed the participants' primary reason for visiting. This section has five options: i) appreciating/viewing nature/landscape, ii) exercise, sports or hobbies, iii) visiting towns/shopping, iv) time with friends or family and finally v) 'other', where any reason not falling into any of the above categories could be entered. This section was designed to establish the primary reason for the participants' visiting the area. The third section asked the participants to consider each of the woodland scenarios of 10%, 25%, 50% and 75% woodland cover (accompanied by the digitally altered photographs of the Howgill Fells NCA) and whether they would be 'more likely to visit again', whether the woodland would 'make no difference to visiting again' or be 'less likely to visit again' under each scenario. In addition to being asked the above questions regarding a change in visiting pattern, they were also asked if they had a preference for any of the scenarios.

Sample size was initially determined using the knowledge that annually 317,160 people visit the Howgill Fells NCA for nature-based recreational purposes. This figure was ascertained using data obtained from Cumbria Tourism and visitor numbers collected by the Sedbergh Tourist

Information Centre (TIC) – figure 23. Sedbergh TIC has a door visitor number 'ticker', which counts every person who walks through the door, giving a very accurate estimation of visitor numbers to the TIC. On the assumption that each visitor to the TIC creates two ticks as they enter and leave, the ticks/counts were halved to obtain realistic visitor numbers. Furthermore, it was estimated by TIC staff that each staff member accounts for six ticks a day and, on average, four ticks a day account for locals or deliveries to the shop. With these subtractions, the aforementioned visitor number was established. By setting the confidence level at 95% and confidence interval at 5, a questionnaire sample size was determined to be of a minimum of 384 participants (Newing 2011).

4.2.5.4 Data collection

Primary data was collected from the 1st of June 2016 to the 1st of September 2016 during the hours of 08:00 to 17:00 including weekdays, weekends and days within and outside school term time. The timings during the day were designed to be able to intercept visitors as they began or finished their walks on the hills, but were also varied to try and intercept a variation of visiting participants. On average, 15 questionnaires were completed a day over 32 days in the field. The researchers positioned themselves at strategic points on streets, paths on the fells, cafés, caravan/campsites and at the tourist information centre - all within the study area. Contact with participants was made to people passing with one of the opening questions along the line of, "Are you visiting or a local resident?", to establish whether they were indeed a tourist or visitor and eligible to participate in the survey. All visitors were asked to participate, with no stratification of age or gender. Furthermore, participants were asked about their primary reason for visiting to ensure they fit the participant profile (visitors for nature-based recreational purposes).

4.2.5.5 Estimation of economic value of nature-based recreation in the Howgill Fells NCA

Estimation of the current economic value of nature-based recreation in the Howgill Fells NCA and after the proposed woodland scenarios was carried out using a monetary figure of visitors per person per trip expenditure, derived from the regional tourist board data and following TESSA guidelines (Peh *et al.* 2013). This figure amounts to £167 per person per trip, which was then multiplied by the visitor number of 317,160, derived from the tourist board and local tourist information centre, and totals £52,965,803. This figure was applied as the current value of nature-based recreational tourism in the Howgill Fells NCA. Determining the value of the alternative scenarios was then calculated with the same approach, but using the adjusted visitor numbers according to their probability of return visits obtained from the survey. An assumption was made that a 'more likely to visit again' choice under certain scenarios would entail one extra visit per year, with the added value of an extra £167. Therefore, each participant choosing the 'more likely to visit again' category, would be given the value of £334. For participants choosing the category of 'make no difference to visiting again', an assumption was made that this would entail a current status of one visit per year and therefor the value of £167 was applied. For participants choosing the category of 'less likely to visit again', the value of £0 was applied. These figures were then applied under each of the woodland scenarios and the percentage of visitor's choice of the three categories of probability of return visits.

- Visitor data from Sedbergh Tourist Information Center shows that 37,313 people use the TIC per year.
- Visitor data from Cumbria Tourism (2015) indicates that 8% of visitors use a Tourist Information Centre.
- Therefore, 12.5 x 37,313 = 466,412.5 = 100% numbers of tourist to the Howgill Fells NCA per year.
- Visitor data from Cumbria Tourism shows that 68% of visitors come to Cumbria (average from all counties) for nature-based recreational purposes.
- Therefore, 0.68 x 466,412.5 = 317,160.5.

Annually, 317,160.5 people visit the Howgill Fells NCA for nature-based recreational purposes.

Figure 23, illustrating how current visit numbers were established, using data from Cumbria Tourism and Sedbergh Tourist Information Centre.

4.2.6 Cultivated goods

The provisioning ecosystem services delivered to society by the Howgill Fells NCA in the form of cultivated goods are sheep and cattle production. The assessment of this ES is therefore an assessment of how woodland creation under the predesigned scenarios impacts i) the number of livestock the area can accommodate and, ii) the economic value of the cultivated goods.

Production of sheep and cattle by hill farming in the UK is, and historically has been, financed via public agricultural and environmental subsidies (Reed *et al.* 2009) and is a loss-making activity in the absence of such subsidies. The assessment draws on site-specific conditions from the NCA and the particular agreements between the participants in the tree planting scheme. Every common has its own unique agreement between graziers and a generalization is therefore difficult to make (Harper, P. 2015, personal communication, 1 March; Mansfield

2012). The example used for this assessment, however, draws on what is typical of such agreements on common land in Cumbria (Leeson, P. 2015, Personal Communication, 16 June 2016) and results derived from this example can thus be generally interpreted as occurring elsewhere under similar circumstances. Furthermore, this part of the TESSA assessment relies heavily on stakeholder involvement and much of the information used is provided by key stakeholders directly involved with land management, agri-environment schemes and tree planting in the NCA. These stakeholders included a Local Common Association chairperson, representative for the Cumbria Federation of Commoners, an independent farm & agri-environment consultant, the Natural England Advisor and Forestry Commission Woodland Advisor for the area, farmers and an agricultural, economic and rural development academic from Newcastle University (Harvey & Scott 2016). This approach was taken as a necessity, due to the lack of area specific information in the literature, the well-known difficulty of understanding and gaining site specific information for common areas (Lewis 2016), as well as some decisions regarding land management approaches on the commons within the NCA being verbal and therefore with no written references. This research does, however, acknowledge that no two farms are alike. Resources, in terms of land, labour and finances will be different. With this in mind, some generalisation is necessary but it should be interpreted with objectivity.

4.2.6.1 Livestock Units

Firstly, the assessment applied a baseline account of the livestock numbers within the NCA. This was informed by the 2013 DEFRA June Agriculture Statistics (DEFRA 2013) and key stakeholders. The DEFRA agricultural dataset is categorised into NCAs and states a livestock number of 26,254 sheep and 693 cattle – table 11.

Livestock numbers in any given farmed area are dependent on the carrying capacity of livestock such an area can accommodate in terms of resources. What an area is defined as being able to accommodate is based on the aims and objectives of the specific situation, which may be ecological restoration or, in this case, production. A common and widely used indicator for this is Livestock Units (LU). LU is a reference unit that reflects the energy requirements of different types of livestock (SAC 2016).

The agricultural carrying capacity is defined for the purpose of this study as the level of LU/ha the land area can accommodate for optimal livestock production. The meaning of optimal livestock production is that the animals thrive within the resources available. A maximum stocking density of 0.25 LU/ha is applied as the agricultural carrying capacity to this assessment, informed as a guideline recommendation from the Natural England advisor, farmers, an independent advisor, the Rural Payment Agency's Basic Payment Scheme payment stocking density estimates for SDA and moorland shared grazing and finally supported by Harvey & Scott (2014) in their annual Farm Business Survey from 2015 as being the level of stock reported by the farmers themselves. This LU level was applied to each of the predesigned woodland creation scenarios.

Key advisors from the NCA informed that it was most likely that, with an increase in woodland creation, the cattle numbers would remain constant and sheep numbers would decrease. Therefore, cattle is applied as a constant for the assessment. The sheep breeds kept within the NCA are predominantly Swaledale and, to a lesser extent, Rough Fell. An assumption was therefore made of 75% Swaledale and 25% Rough Fell, which was deemed appropriate by advisors. Swaledale is a medium sized hill sheep and was therefore categorised according to Natural England's LU definitions as 0.08 LU/ha. Rough Fell is a larger breed and, following Natural England guidelines, an additional 20% was therefore applied resulting in a definition of 0.10 LU/ha. A further adjustment was made to reach an average between the two LU/ha definitions and a final average of 0.09 was applied to the calculations – table 11. The habitat is defined as rough grazing, from information provided by key stakeholders.

Finally, an economic value was applied to the cultivated goods produced by the Howgill Fells NCA. The net value of sheep grazing was estimated using the 2015/16 report on Hill Farming (Harvey & Scott 2016) by applying the average net margin per ewe figure to the number of sheep under each of the predesigned scenarios – see results in chapter 6. These figures exclude agricultural and environmental subsidies. Including the unpaid labour of farmer and spouse, the average loss per ewe for hill sheep in 2015/16 was £66.

Table 11 – Grassland area in hectare available for livestock production, Livestock Units and sheep numbers under the current state of the NCA and each of the woodland creation scenarios

	Current stock levels	Current state potential	10% woodland creation	25% woodland creation	50% woodland creation	75% woodland creation
Grassland available for grazing (ha)	10,436	10.436	9,416	7,766	5,016	2,266
Livestock units (LU)	2,196	2,416	2,180	1,798	1,161	525
Sheep numbers	26,354	28,989	26,156	21,572	13,933	6,294

4.3 RESULTS

4.3.1 Climate-regulation

4.3.1.1 Carbon stocks

In this part of the climatic regulating ecosystem service assessment, the research focusses on calculating the carbon stored in the Howgill Fells NCA with the four broad IUCN categories: broadleaved woodland, conifer woodland, grassland and bog. Carbon was calculated for above and below-ground, in litter and soil following the aforementioned methodology described.

Carbon storage value (t/C) of the woodland categories were obtained by data collected manually in the field comprising of 15 sample plots from the broadleaved woodlands and 9 from the coniferous woodland. The results indicate a higher mean tonnes of carbon per hectare (t/C/ha) within the broadleaved woodlands, compared to the coniferous woodland – table 12.

A total carbon storage value (t/C) (above and below-ground) was obtained by combining all the four aforementioned categories, which was then converted into tonnes of carbon per hectare (t/C/ha^{-1}) – table 13 and figure 24. The results showed that a similar amount of carbon is stored in broadleaved and conifer woodland: 169.4 t/C/ha^{-1} (broadleaved) and 159.2 t/C/ha^{-1} (conifer). Grassland stores 70.2 t/C/ha^{-1} and bog stores a comparatively large amount at 259 t/Cha^{-1}. This data was then used as the foundation for calculating the total carbon storage value within the study area.

Grassland currently stores the largest amount of carbon in the study area due to its relatively large area: 734,484.6 t/C, compared to 11,520.2 t/C in broadleaved woodland, 1,910.4 t/C in conifer woodland and 85,988 t/C in bogs. The large amount of carbon stored in bogs is impressive considering the small area of bog cover in the NCA. By applying the t/C/ha^{-1} values to changes in area between grassland and broadleaved woodland according to the four woodland expansion scenarios, changes in carbon storage values were derived – table 14 and figure 25. The result shows that with each woodland expansion scenario there is an increase in total carbon stock, which would be expected considering the higher amount of carbon stored in woodland compared to grassland (Hagon *et al.* 2013). The coniferous woodland and bogs remained unchanged in each woodland expansion scenario, due to there being no planting on these categories.

Table 12 – Mean tonnes of carbon per hectare in each woodland plot surveyed, as well as a mean score from each category within both woodland categories of both broadleaved and coniferous woodland.

Broadleaved plot ID	t/C/ha	Coniferous plot ID	t/C/ha
0	37.5	0	17.5
1	114	1	29.26
2	70.3	2	118.86
3	41.6	3	92.12
4	131.8	4	14.84
5	53.3	5	72.1
6	67.1	6	30.8
7	228.6	7	173.18
8	210.1	8	104.16
9	73.5		
10	88.5		
11	21.4		
12	126.1		
13	8.9		
14	47.9		
	Mean 88.07		Mean 72.54

Table 13 – Above and below-ground carbon storage in the Howgill Fells NCA in litter and soil of each broad IUCN habitat category.

IUCN Habitat	Area size (ha)	Above-ground carbon (t/C)	Below-ground carbon (t/C)	Litter carbon (t/C)	Soil carbon	Total Carbon stocks in (t/C)	Carbon stocks in (t/C/ha^{-1})
Broadleaved woodland	68	5,988	139.03	884	4,508	11,520	169.4
Coniferous woodland	12	870.4	28.3	242	770	1,910	159.2
Grassland	10,436	29,220	68,668		636,596	734,484	70.4
Bog	332				85,988	85,988	259
Total						834,112	

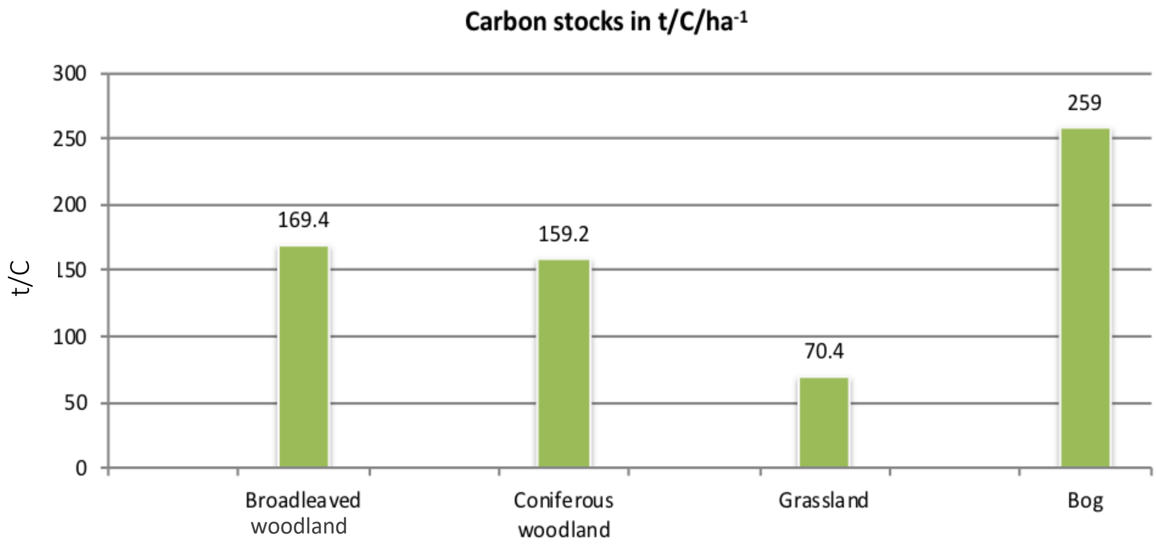

Figure 24 – Above and below-ground carbon stocks in tonnes of carbon per hectare in each of the broad IUCN habitat categories.

Table 14 – Total t/C in each IUCN category in the current state and alternative scenarios of the Howgills Fells NCA. Coniferous woodland and bog habitats are unchanged, as there will be no planting of trees carried out on the bogs or an increase in coniferous planting.

IUCN Habitat	Broadleaved woodland	Coniferous woodland	Grassland	Bog	Total Carbon stocks
Current state	11,519	1,910	734,684	85,988	834,112
10%	184,307	1,910	662,886	85,988	935,092
25%	463,817	1,910	546,726	85,988	1,098,442
50%	929,667	1,910	353,126	85,988	1,379,692
75%	1,395,517	1,910	159,526	85,988	1,642,942

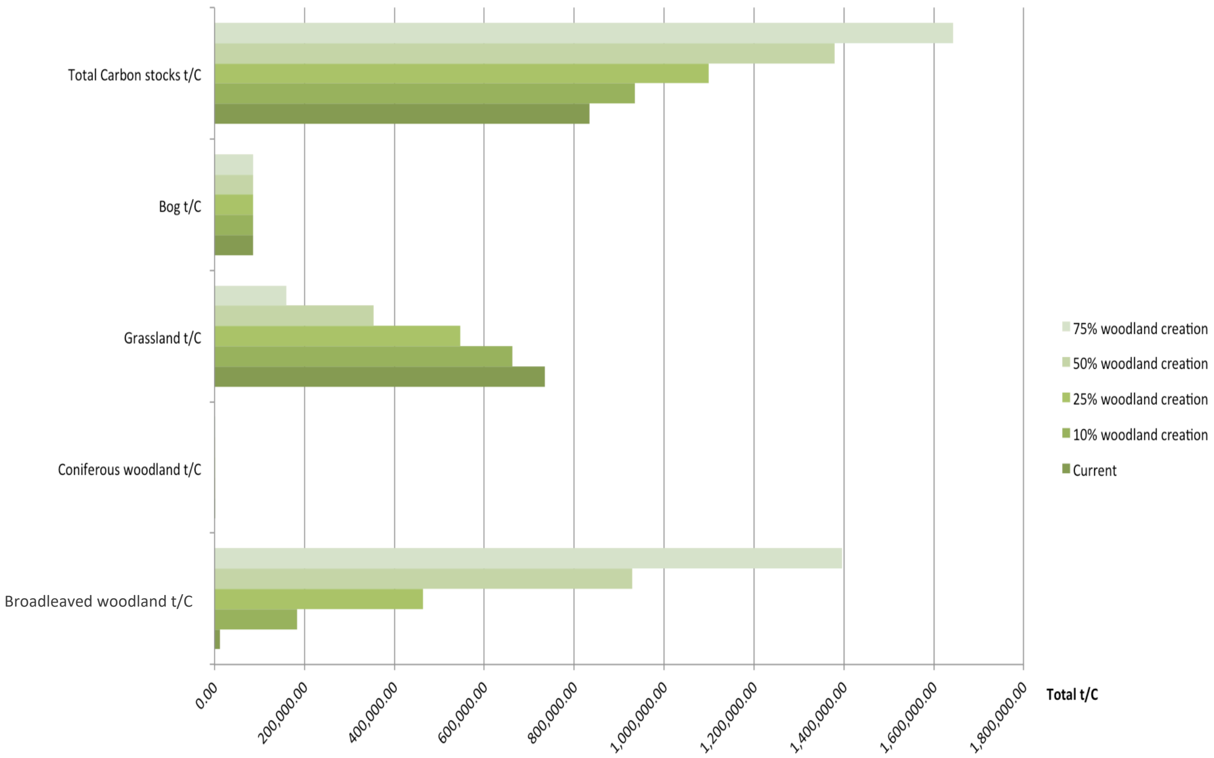

Figure 25 – Total amount of carbon stored under the current state and each of the four woodland creation scenarios. The results indicate that, with each increase of woodland, the carbon stores increase in the broadleaved woodland habitat and decrease in the grassland habitat.

4.3.1.2 Carbon sequestration

Carbon sequestration assessments were carried out on all four vegetation habitats following the methodology described above to give values of tonnes of carbon dioxide (CO_2) annually ($t/CO_2/y^{-1}$) and a further value of tonnes of CO_2 per hectare annually ($t/CO_2/ha^{-1}/y^{-1}$). Firstly, this was carried out for each of the surveyed woodland sites to obtain a mean value to be used as the foundation for further total calculations – table 15 & 16. Positive values represent emissions (release) and negative values represent sequestration (uptake). The results indicate that the coniferous woodland habitat has the highest rate of sequestration at -9.29 $t/CO_2/ha^{-1}/y^{-1}$, followed by broadleaved woodland at -4.54 $t/CO_2/ha^{-1}/y^{-1}$. Grassland sequesters CO_2 at a much lower rate of -2.2 $t/CO_2/ha^{-1}/y^{-1}$ and bogs at a rate of -1.42 $t/CO_2/ha^{-1}/y^{-1}$ – table 17. The carbon storage values were assessed by applying these values to the changes in area size according to the pre-designed scenarios, with the coniferous woodland and bog habitat remaining unchanged – figure 26. The result shows that with each scenario, the sequestration values increase substantially, which is unsurprising due to broadleaved wood sequestering twice as much CO_2 compared to grassland. By the 75% woodland expansion scenario, carbon sequestration values are almost doubled from -23,836.36 $t/CO_2/y^{-1}$ to -42,954.84 $t/CO_2/y^{-1}$ – figure 26. Finally, a monetary value was determined by applying 2014 carbon trading values in Pounds Sterling (£). These results show that there would be a major increase in monetary value from the current state of £1,848.24 to the maximum achieved in the 75% scenario of £224,405.12 – table 18.

Table 15 – CO_2 sequestration in Broadleaved woodland plots. ID number and name, approximate age, species category, yield class, spacing between trees and total amount of tonnes of CO_2 per hectare per year in each of the 15 sampled plots in the broadleaved woodland category

ID	Site	Age	Species	Yield class	Spacing (m)	Total ($t/co_2/ ha^{-1}/y^{-1}$)
0	Ellerthwaite	150	SAB	4	2	-0.17
			Oak	8	2.5	-1.19
1	Lane Farm old	200	SAB	4	1.5	-0.13
			Beech	5	1.5	-1.3
2	Brockhole	50	SAB	4	1.5	-7.77
			Beech	2	1.5	-8.54
3	Midfield	30	SAB	4	1.5	-11.35
			Ped. Oak	5	2	-30.2
4	Heartshape	200	Beech	7	2.5	-1.77
			SAB	4	2	-0.13
			Ses. Oak	5	2	-1.05
5	Lane Farm young	150	SAB	4	1.5	-0.17
6	Murthwaite 1	100	SAB	4	1.5	-0.15
7	Lyne Bridge	150	SAB	4	2	-0.17
			Oak	5	2	-1.19
			Beech	7	1.2	-3.12
8	Thursgill	150	SAB	4	2	-0.17
			Oak	8	2	-3.17
9	Fawcett Bank	150	Beech	10	2.5	-2.04
			SAB	4	1.5	-0.17
			Sessile Oak	8	2.5	-1.19
10	Lane Hall	100	SAB	4	2	-0.17
			Beech	5	2	-4.64
11	Gaisgill	20	SAB	4	1.5	-17.68
12	Beckstone	40	SAB	4	1.5	-7.77
			Beech	3	1.5	-6.63
13	Weasdale NN	15	SAB	4	1.5	-19.02
			Beech	3	1.5	-2.14
			Oak	5	1.5	-2.68
14	Murthwaite 2	100	SAB	4	2	-0.15
Mean						-4.53

Table 16 – CO_2 sequestration in conifer woodland plots. ID number and name, approximate age, species category, yield class, spacing between trees, management technique and total amount of tonnes of CO_2 per hectare per year in each of the 9 sampled plots in the coniferous woodland category.

ID	Site	Age	Species	Spacing (m)	Yield Class	Managed	Total ($t/CO_2/ha^{-1}/y^{-1}$)
0	Studfold	40	Norway spruce	1.5	18	No thin	-16.33
			Larch	1.5	8		-3.37
1	Midfield	30	Norway spruce	2	16	No thin	-17.36
			Scotch pine	2	9		-16.4
			Sitka spruce	2	23		-30.52
2	Weasdale	60	Norway spruce	1.5	18	Thinned	-7.53
			Scotch pine	1.4	8		-4.31
			Sitka spruce	1.7	24		-7.08
3	Weasdale small	100	Scotch pine	2	8	Thinned	-1.64
4	Piper hole B	60	Norway spruce	1.5	18	Thinned	-7.53
			Scotch pine	2	12		-6.64
			Sitka spruce	1.7	24		-8.38
5	Weasdale large	30	Norway spruce	1.5	18	Thinned	-12.76
6	Piper hole A	60	Scotch pine	2	12	Thinned	-2
7	Little Ashbeck	60	Norway spruce	1.7	18	Thinned	-7.53
8	Ashbeck Gill	60	Norway spruce	2	18	Thinned	-7.53
			Larch	1.7	8		-1.03
Mean							-9.29

Table 17 – CO_2 sequestration in the current state of the Howgill Fells NCA. carbon sequestration is calculated based on the current age of woodlands. The $t/CO_2/y^{-1}$ are calculated based on the $t/CO_2/ha^{-1}/y^{-1}$ multiplied by area size.

IUCN category	Broadleaved Woodland	Coniferous woodland	Grassland	Bog	Total Carbon sequestration
Carbon sequestration $t/CO_2/y$-1	-308	-111	-22,959	-457	-23,836
Carbon sequestration $t/CO_2/ha$-1/y-1	-4.54	-9.29	-2.2	-1.42	

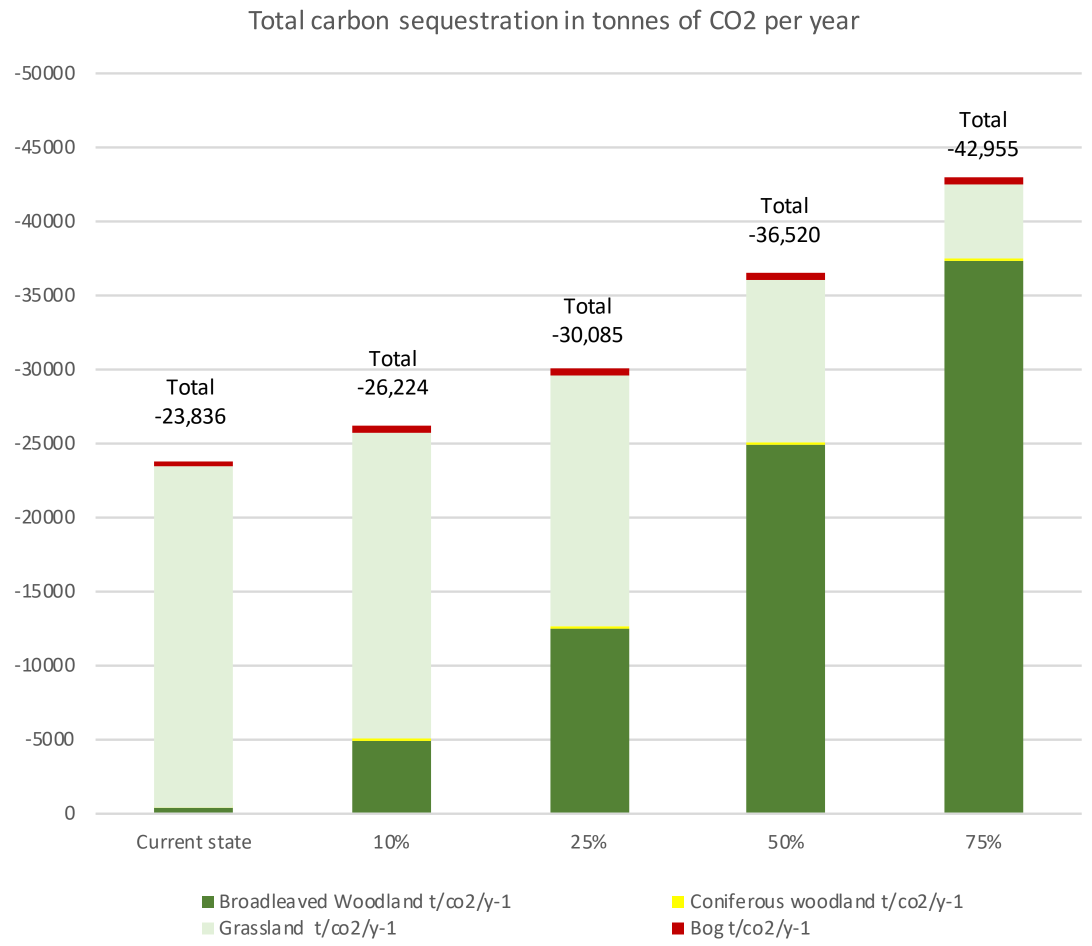

Figure 26 - total carbon sequestration in tonnes of CO_2 per year under current state and each of the scenarios, in each of the IUCN Broad habitat groups.

Table 18 - Monetary value based on a 2014 carbon trading value of the planting over 100 years under current state and each of the scenarios, in each of the IUCN Broad habitat groups.

	Current state	10%	25%	50%	75%
Total CO_2 trading value in £	£1,848	£29,637	£74,583	£149,493	£224,405

4.3.1.3 Greenhouse Gas (GHG) flux

The total GHG flux within the Howgill Fells NCA was obtained combining the total amount of CO_2 emitted and sequestrated into a total flux of tonnes of CO_2 a year ($t/CO_2/yr^{-1}$), which indicates a steady increase of CO_2 sequestration with each increase of woodland creation scenario – figure 27. Finally, the CO_2 values were combined with the values obtained from the other significant GHG, Methane (CH^4) and Nitrous oxide (N_2O) to generate a total GHG flux value for the study site – figure 28. This indicates that the Howgill Fells NCA would sequestrate an increasing amount of total GHG with each woodland creation scenario and, as a result, have a positive impact on climate regulation and mitigation by reducing GHG emissions.

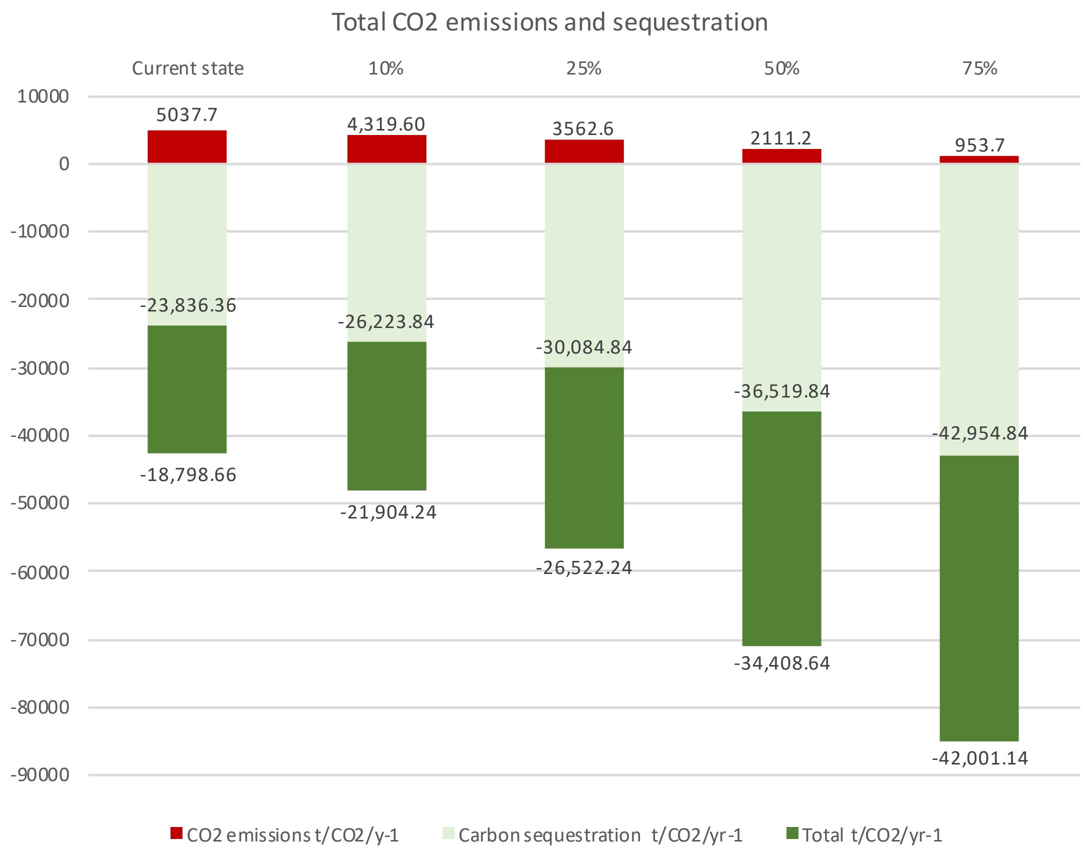

Figure 27 - Total CO_2 emissions and sequestration for current and alternative states. The negative values indicate sequestration and the positive values show emission values. The dark green values illustrate the total amount of CO_2 sequestrated under both current and alternative states.

Figure 28 - Current state and alternative state total GHG flux final summary, incorporating CO_2, CH^4 and N^2O into the total flux assessment. The positive values indicate emissions and the negative values sequestration. Total sequestration in $t/CO_2/y^{-1}$ increases under each alternative scenario.

4.3.2 Water-related services

The assessment carried out for water-related services focussed on five factors for above-surface water quantity: i) water balance, ii) infiltration, iii) erosion, iv) run off and v) evapotranspiration. This analysis is carried out on a baseline current state of 1.5% forest cover and then applied to further scenarios of 10%, 25%, 50% and 75% woodland creation levels. The most important indicator is water balance, as an increase/decrease in this balance will have an impact on the other four factors. The more water held above surface, the higher the erosion, evapo-transpiration and runoff levels expected. See figure 29 for an example of an analysis of the current state of the NCA's run off pattern. Generally, it would be expected to see infiltration increase along with a higher water balance, but other factors, such as soil and vegetation type could have a major impact.

The results show a baseline assessment of water quantity in total m^3 of the five factors at the NCA at its current state of 1.5% woodland cover and compared to the four woodland creation scenarios. In each of the scenarios there is an overall increase in water quantity in all five factors – figure 30. The water balance as the main driver of each factor is expected to increase from a current state baseline to 4% (1,708 m^3) under the 10% scenario, 9% (3,663 m^3) under the 25% scenario, 16% (6,062 m^3) under the 50% scenario and 16% (6,080 m^3) under the 75% scenario – figure 31. Analysis of the sensitivities affecting the results was carried out, which indicated that fog inputs[21] were a strong contributor - table 19. The sensitivity table shows an example of a query carried out on a 50% woodland expansion scenario. This clearly shows that whereas the precipitation inputs of rainfall are a constant under both baseline and 50% woodland

[21] Total fog inputs is the impacted (wind driven) and the sedimented (deposited under low wind speed) fog inputs. Total fog inputs as % of water balance is the proportion of precipitation (rainfall+fog-actual evapo-transpiration). Total fog deposition is the sedimented (deposited under low wind speed) fog inputs.
Total fog impaction is the amount (in mm) of fog that is blown against surfaces such as vegetation by wind. This affects exposed surfaces more than sheltered surfaces and combined with fog deposition creates the total fog inputs in an area.

expansion of 1,500mm/yr (1,200mm/yr wind corrected[4]), fog input increases considerably from 100mm/yr to 740mm/yr, which is the equivalent of a 32% increase from a baseline of 6.2% input as a percentage of water balance. The total fog impaction also shows a high difference, with an increase from 0mm/yr to 610mm/yr. Fog impaction is higher at exposed locations and thus, the increase is not surprising. This is combined with the fog deposition, which also increases and together forms the total fog inputs. These results suggest that the higher water balance is driven by the fog regularly occurring at higher altitudes. A 50% scenario and sensitivity query was therefore carried out at a lower altitude of 250m to test these assumptions. The lower altitude scenario did show a lower fog input, compared to the 450m scenario. This again suggests that the increase in water balance is driven by high fog inputs occurring in the higher altitudes of the uplands.

The results also show an increase in ET from 5% at a 10% woodland creation scenario up to 31% at a 75% woodland creation scenario. This is not surprising considering the strong evidence behind the process of ET from forests. ET is calculated into the water balance and is therefore accounted for as part of the total output of the water balance. Total net erosion and total annual surface runoff also increase with each woodland creation scenario (from 12% at 10% scenario to 48% at 75% scenario). Although both increases are in spite of a higher percentage of forest cover, the figures do not mean much in terms of actual m^3/yr. Net erosion increases from 0.12mm/yr at baseline to 0.14mm/yr at the 75% scenario and surface runoff increases from 271m^3/yr to 332m^3/yr. The total water balance would have an impact on net erosion and surface runoff since, simply put, the more water the surface stores, the more water there would be to runoff.

Infiltration is shown to increase with each woodland expansion scenario, levelling out with no notable difference between the 50% and 75% scenarios. Infiltration increases by 3% (929m^3/yr) in the 10% scenario, 6% (1804m^3/yr) in the 25% scenario, 8% (2580m^3/yr) in the 50% scenario and a slight decrease to 8% (2494m^3/yr) at the 75% scenario. The infiltration indicator is not incorporated into the WaterWorld calculations of overall water balance. This should therefore be taken into consideration as it is well documented that infiltration increases with woodland expansion compared to grassland (Marshall *et al.* 2015; Archer *et al.* 2016) and the trees are therefore expected to have a significant impact on channelling above surface water into the ground. This is an important consideration in our interpretation and understanding of the results.

The results obtained from modelling using the WaterWorld Policy Support System show that, whilst woodland expansion at all the different scenarios increase ET and infiltration as expected from the results from other studies (Calder *et al.* 2003; Marshall *et al.* 2014; Archer *et al.* 2016), then climatic and site-specific conditions, such as high fog inputs, occurring at the study area in the uplands of Cumbria ultimately means that the overall water balance increases with woodland expansion.

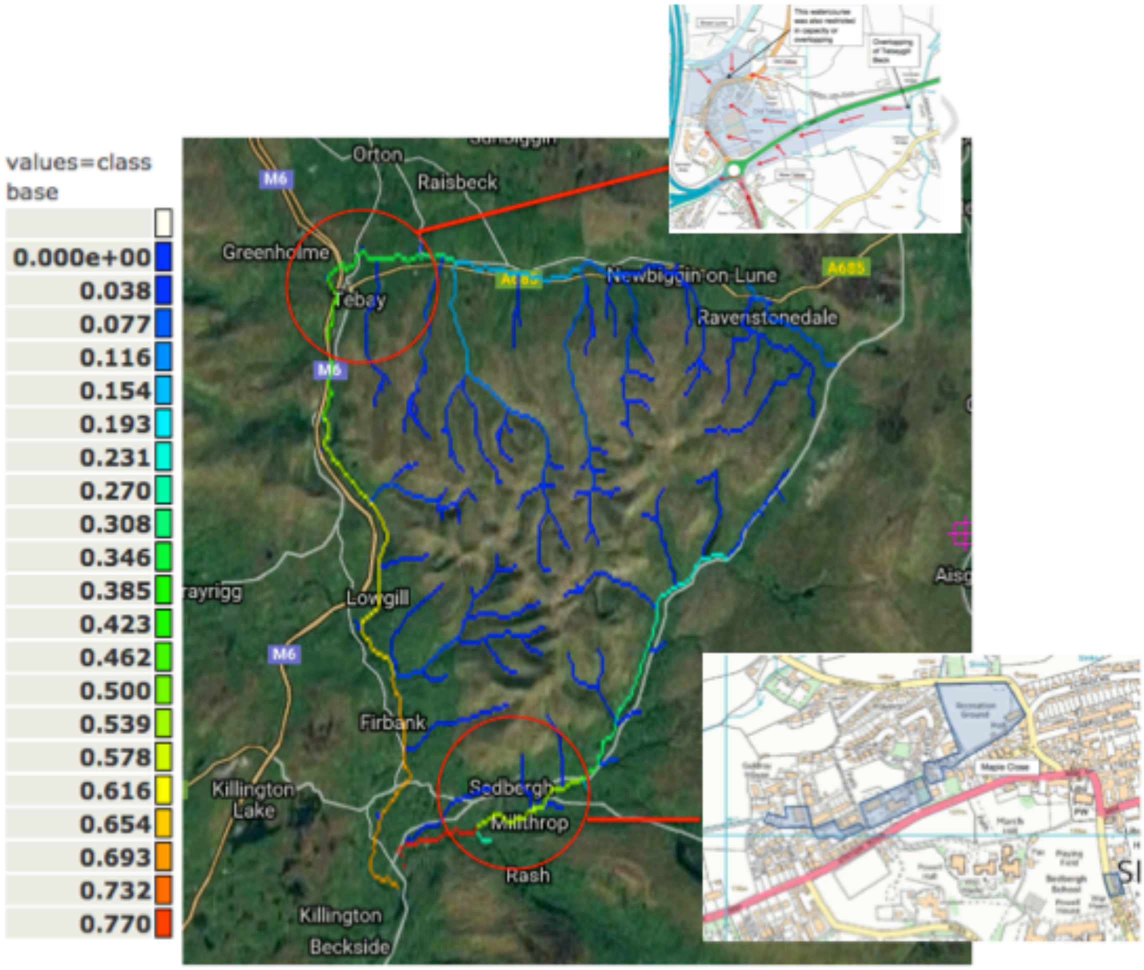

Figure 29 – Water World modelled outputs of water courses within study site. This is the topography and pathways of water courses within the Howgill Fells NCA in its current state. The Lune River runs along the north and west of the NCA, with the River Rawthey on the east. The coloured values represent flow in m^3/sec. The figure shows an increase in flow in certain areas, such as around Tebay, and a steady increase down the River Lune as it builds up running south. The same pattern is observed on the eastern side on the NCA. The inserted figures depict the two towns of Tebay and Sedbergh, which were flooded during the December 2015 floods and where the flood water flooded the towns (Council 2016a, b).

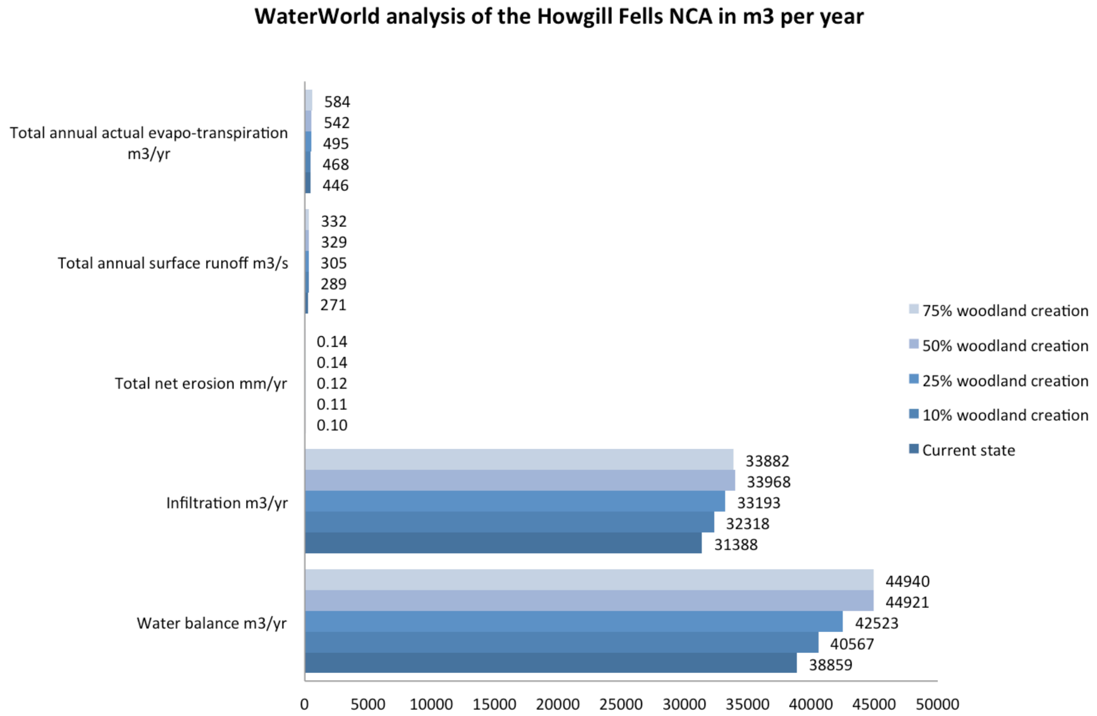

Figure 30 – WaterWorld total current state and alternative state output of both the baseline and four woodland creation scenario results. All results are shown in m3/yr, except the total net erosion which is shown on mm/yr. The results show an increase on all five indicators from baseline.

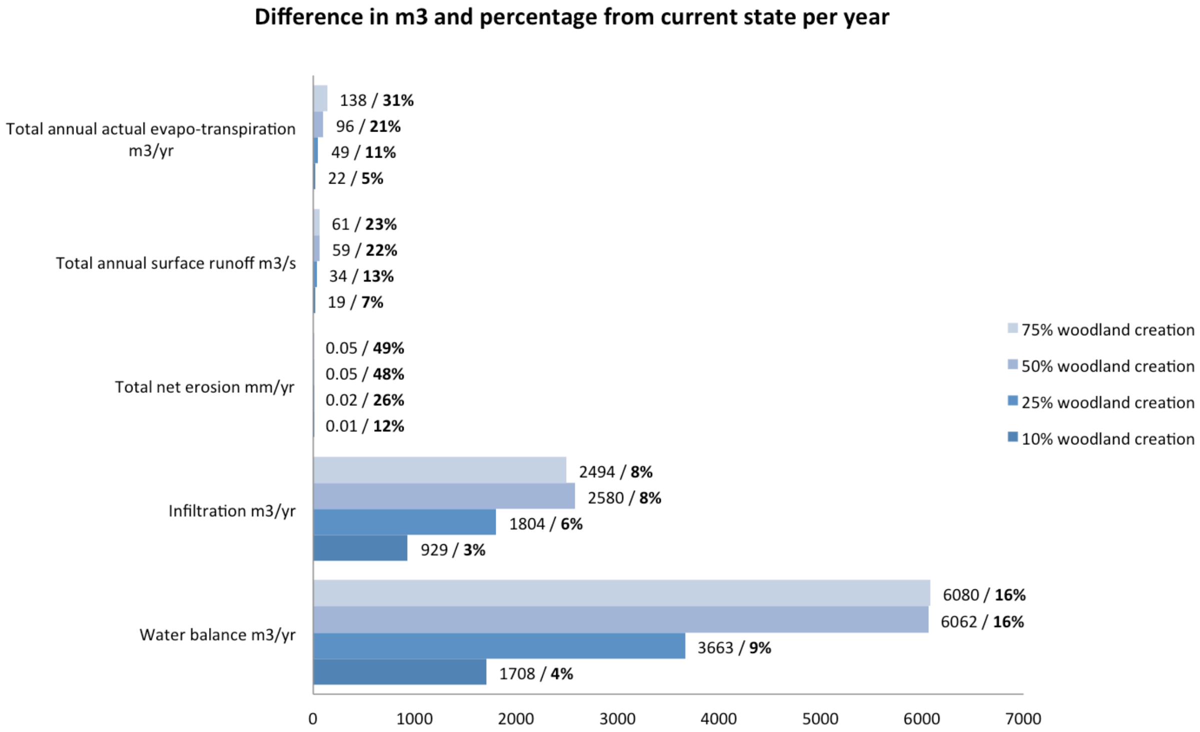

Figure 31 – WaterWorld total current state and alternative state outputs in percentage. This shows the difference from each scenario compared to the baseline in m3/yr (mm/yr for Total net erosion) and percentage. The results show an increase in all five indicators from baseline.

Table 19 – WaterWorld example of outputs created by 'querying a pixel' which scored high values in change of water balance caused by a 50% woodland creation scenario. The baseline indicates the study region in its current state and the alternative a 50% woodland scenario. The table illustrates that the majority of precipitation inputs are generated by rainfall. However, there is a strong contribution in the alternative state caused by fog contributions and indicators such as 'total fog inputs', 'fog inputs as a percentage of water balance', 'total fog deposition' and 'total fog impaction'

Variable	Baseline	50% woodland expansion	Units
Total wind-corrected rainfall	1,500	1,500	mm/yr
Total annual rainfall (not wind-corrected)	1,200	1,200	mm/yr
Total fog inputs	100	740	mm/yr
Fog inputs as a percentage of water balance	6.2	32	%
Total fog deposition	100	120	mm/yr
Total fog impaction	0	610	mm/yr
Total annual actual evapo-transpiration	53	69	mm/yr
Annual % of runoff generated by snow-melt	0	0	%
Annual % of runoff generated by fog	4.9	23	%

4.3.3 Nature-based recreational tourism

A total of 493 questionnaires were collected from visitors to the Howgill Fells NCA. From these, 426 questionnaires were from visitors that stated that they were primarily visiting for nature-based recreational reasons, by choosing either or both categories of: a) 'Appreciating/viewing/landscape' or b) 'Exercise/sports/hobbies'. The remaining 67 questionnaires were from people who stated that they were visiting primarily for other reasons, such as : c) 'Visiting town', d) 'Visiting family or friends' or e) 'Other'. Additionally, these visitors did not choose any of the reasons in category a or b, and were therefore disregarded in the analysis.

4.3.3.1 Visitor preference for woodland expansion scenarios

For each of the four woodland creation scenarios a majority of the 426 participants indicated that an increase in woodland levels would not influence their decision to visit the area again – figure 32. However, this majority decreases as woodland levels increase, with 74% of participants being indifferent to a 10% woodland creation scenario, which decreases to 56% of participants being indifferent to a 100% woodland creation scenario.

A similar trend, albeit less severe, is found amongst the participants more likely to visit again under a change of woodland levels. In this category, 23% of participants were more likely to visit again under both a 10% and 25% woodland scenario, which then slightly increased to 24% under a 50% scenario and then decreased to 16% under the 100% woodland scenario. An opposite trend, which complements the aforementioned choices, is observed among the participants less likely to visit again under a change in woodland levels. In this category, the number of visitors being less likely to visit again rises under an increase in woodland levels. Under the 10% woodland scenario, only 3% of participants are less likely to return and this then steadily increases to 28% under the 100% woodland scenario. Interestingly, the 75% woodland scenario indicates the level of woodland whereby the level of visitors returning are evened out and visitors' probability of returning becomes less likely.

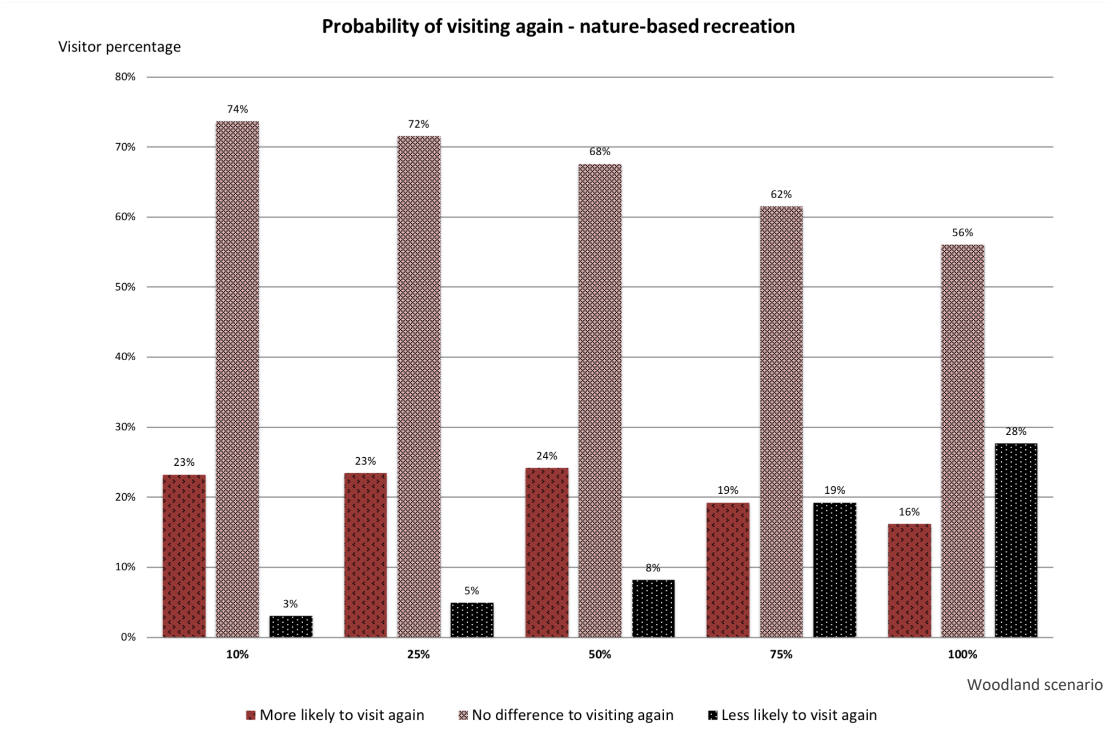

Figure 32 – Probability percentage of visitors under each of the woodland scenarios and probability choice for return visits.

4.3.3.2 Monetary value of nature-based recreational tourism

A monetary value of nature-based recreation per visitor was obtained from Cumbria Tourism (2015) and applied to the data and visitor number under each woodland scenario as described above. According to Cumbria Tourism's data, £52,966,000 per year is generated within the Howgill Fells NCA from nature-based tourism. The results obtained from this study indicate that an increase in woodland levels could economically benefit revenue derived from nature-based recreational tourism in the Howgill Fells NCA – figure 33 & table 20. The results show that monetary value of nature-based recreational tourism increases under each of the lesser woodland scenarios (10%, 25% and 50%). The highest monetary increase (20%) to be expected is under the 10% scenario, which amounts to an increase of £10,593,000 a year. An similar increase (18%) is also expected under the 25% woodland scenario and finally a 16% increase under the 50% woodland scenario. However, the increase in revenue is halted as we reach the 75% woodland scenario, whereby only a minimal increase is expected by £250 a year (0%). By the 100% woodland scenario, woodland expansion starts to have a negative impact on the monetary value of nature-based recreational tourism to the NCA and a substantial decrease in value (£6,356,000) is expected to be lost with a decrease of 12% visitors - figure 33 and table 20.

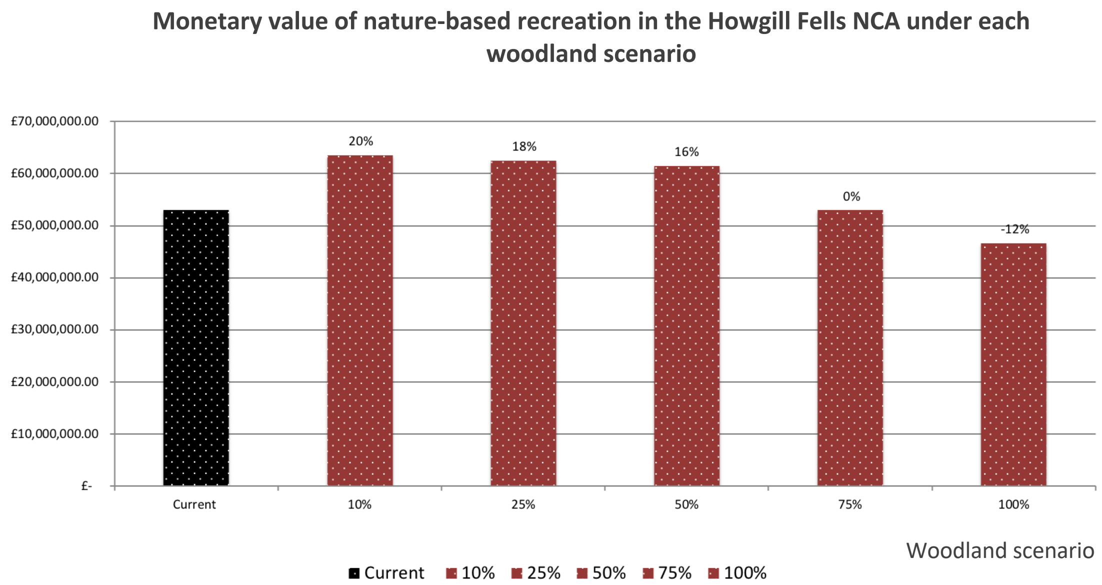

Figure 33 – monetary value of nature-based recreation in the Howgill Fells NCA under each of the woodland scenarios (red columns). The black column displays the value in the NCA's current state.

Table 20 - Monetary value of nature-based recreational tourism under each scenario derived from Cumbria Tourism data using the £167 figure (rounded up from the original figure of £166.99) and a per person per visit value.

Woodland scenario	Value £ derived from per person per night spent	Change from current state	Percentage change from current state
Current	£52,966,000		
10%	£63,559,000	+ 10,593,000	+ 20%
25%	£62,499,000	+ 9,534,000	+ 18%
50%	£61,440,000	+ 8,474,000	+ 16%
75%	£52,966,000	- 250	- 0%
100%	£46,610,000	- 6,356,000	- 12%

4.3.4 Cultivated goods

The ecosystem service of cultivated goods (livestock production) was assessed by a combination of obtaining data from key stakeholders on grazing levels and livestock units (LU) and area-specific agricultural economic values (DEFRA 2015; Harvey & Scott 2015). The results indicate that the Howgill Fells NCA is currently stocking livestock at approx. 0.25LU/ha. This amounts to a total of 2,416LU in the whole of the grazing area of the NCA or 26,000 sheep. Given this stocking rate, the NCA could potentially sustain a further 220LU (2,600 sheep). The current stocking rate was applied to the decrease in grazing available under each of the woodland creation scenarios. Consequently, the results indicates that under the 10% woodland creation scenario, the NCA would be able to sustain an approximately very similar level of stock amounting to a decrease of 198 sheep. Under each of the higher woodland creation scenarios, a much higher decrease in livestock production would occur – figure 34.

Further to this, an economic net value (without agricultural and environmental subsidies) was applied to the livestock following the aforementioned methodology. Livestock production from hill farms in England are a loss-making activity without subsidies and, currently, each ewe on a hill farm has a net profit margin of -£66. The results show that, by applying the per ewe value to the stock levels (LU units) that the NCA would be able to sustain under each woodland creation scenario, an economic value decrease would be expected from this cultivated good in the Howgill Fells NCA.

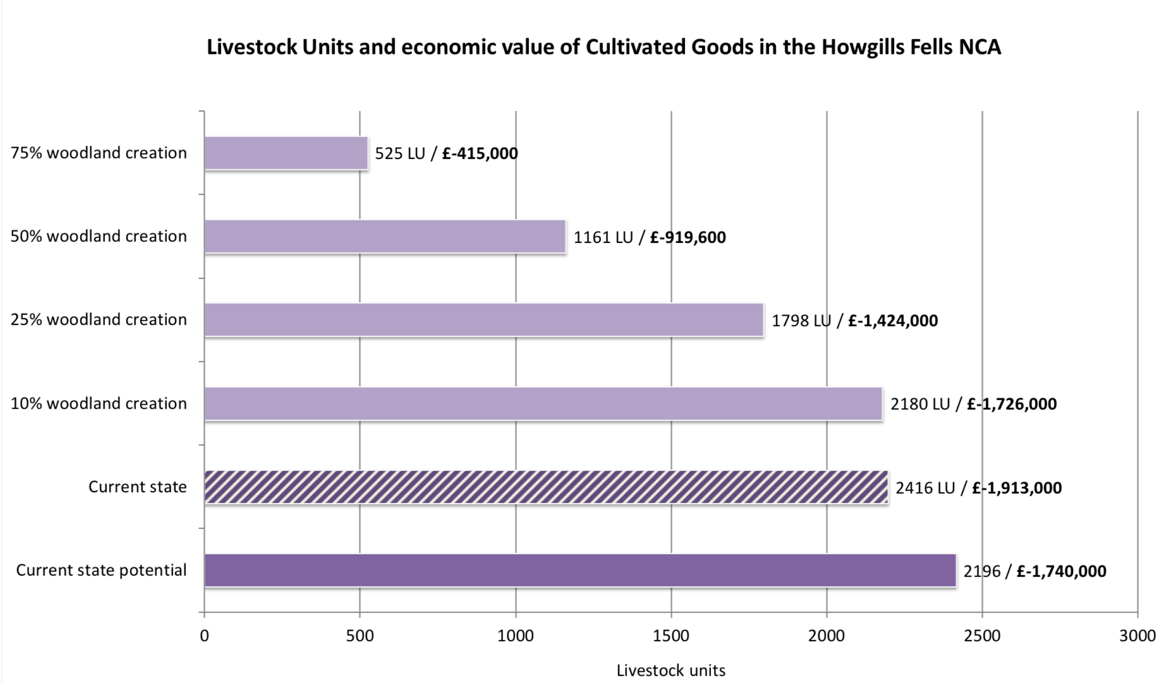

Figure 34 - Livestock units and economic value of cultivated goods in study site as livestock units (LU) under the current state and alternative woodland creation scenarios. The dark purple bar illustrates the potential level of stocking rates the NCA could sustain as a maximum. The economic net profit margin value of the cultivated goods are displayed in bold.

4.3.5 Overall impacts of woodland creation on ecosystem services in the Howgill Fells NCA

A rapid assessment of ecosystem services for the Howgill Fells NCA were carried out under the guidelines of the TESSA ecosystem service assessment toolkit. This assessment focussed on the pertinent ecosystem services provided by the NCA to society, as informed by key stakeholders and impacts on these ecosystem services under four predesigned woodland creation scenarios of 10%, 25%, 50% and 75% woodland cover.

A summary of the results obtained from the assessment of the four services were combined using the following indicators:

- Climate regulation – total carbon storage (t/C) and GHG flux (t/CO_{2eq}/y^{-1})
- Water-regulated services – Water balance (m^3)
- Nature-based recreation – Net revenue (£'s)
- Cultivated goods – Stock levels (LU)

Figure 35 illustrates the proportional differences that can be expected to occur under each of the woodland creation scenarios. By using the four above indicators, the greatest changes in ecosystem services provided by the NCA are found with the higher woodland creation scenario, due to water-related services and cultivated goods showing a strong decrease by being potentially 76% less able to produce cultivated goods (livestock production) and a 16% increase in water balance (water-related services). Furthermore, at the 75% scenario level there are no benefits to nature-based recreational tourism, as this experiences no increase. Large benefits in terms of an increase (carbon storage = 97%, GHG sequestration = 252%) would be expected from climate regulating services, as a result of the substantial increase in woodland cover and therefore a larger capacity for carbon storage and the reduction of GHG emissions.

The scenario of 10% woodland creation is perhaps the less divisive of all the proposed scenarios. This scenario is results in beneficial outcomes on climate regulating services (12% & 30%) and especially nature-based recreational tourism (20%), without markedly diminishing the beneficial services provided by cultivated goods (-1%) and water-related services (-4%).

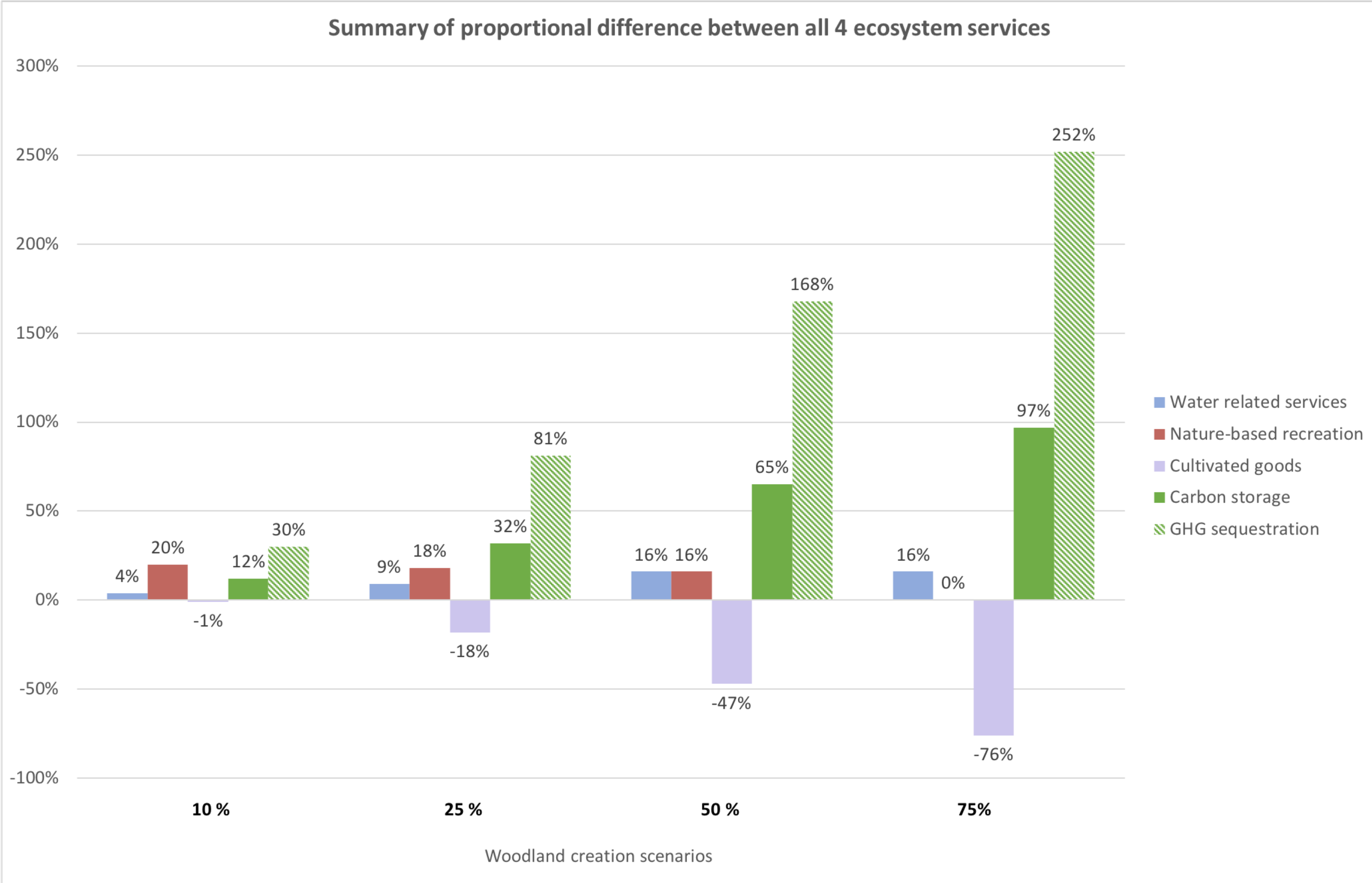

Figure 35 – Summary of the proportional differences of the four ecosystem service indicators between the current state and the four woodland creation scenarios.

4.4 DISCUSSION & CONCLUSION

The uplands of England provide ecosystem goods and services to society as demonstrated by Cong *et al.* (2014) and Palm *et al.* (2014). In Cumbria, stakeholders identified four key services as being important to the upland areas of the county: climate regulating services, water-related services, cultural goods (in this case nature-based recreational tourism) and cultivated goods (livestock production). National forestry policy aims to increase woodland areas in England by 15% by 2050 and upland areas have been suggested as suitable areas for tree planting, due to changes in European agricultural and environmental policies, changes to socio-demographics within upland farming communities and changes in expectations and demands for services provided by upland landscapes. Woodlands have been identified by the UK National Ecosystem Assessment to provide more goods and services to the UK than any other habitat (Watson *et al.* 2011a; Church *et al.* 2014). The key findings of the reports are that carbon sequestration, social and cultural services and timber production are some of the most important ES provided by woodlands in the UK.

The upland landscape in Cumbria is used mainly for livestock production and nature-based recreational tourism. Changing the land use from grazed grassland to woodland could impact the ecosystem services provided, which causes concerns within stakeholder groups in Cumbria and generates a need for understanding what impacts to expect in order to inform decision making.

Assessing ecosystem services is complicated, especially when assessment is required on a site-specific level, which is increasingly becoming a necessity and requires substantial resources. Consequently, assessments are either not carried out or conclusions are based on very broad unspecified information which cannot be applied to local circumstances (Bagstad *et al.* 2013;

Peh *et al.* 2013; Baral *et al.* 2016). There is, therefore, a need for site-specific assessments of how woodland creation in upland areas would impact ecosystem services.

In chapter 4, a site-specific assessment was carried out in the Howgill Fells NCA, by the use of a rapid ecosystem services assessment toolkit: TESSA. The focus of assessing the four ES indicators of climate change mitigation, water-related services, nature-based recreation and cultivated goods were first and foremost guided and informed in collaboration with key stakeholders in the early scoping stage of the study (Chapter 3) and further supported by review of the literature. It should therefore be acknowledged that this ES assessment only brings insight into the four indicators described above and there will be other ecosystem services of importance, which are not included in this assessment.

Assessing each of the four indicators has been carried out with guidance from the TESSA toolkit and adapted as needed to local specified needs. This means that in some parts of the assessment, primary data collected within the study area has been applied and, in others, secondary data from previous studies applied. The TESSA methodology allows and encourages this application of data (Peh *et al.* 2013). It is important to note that TESSA is a method that aims to assess ES 'rapidly', i.e. allowing users to carry out an assessment with limited resources. This is what makes TESSA different from other ecosystem service assessment methods currently available. Finding a balance between obtaining and analysing dependable and good quality data and keeping the assessment 'rapid' is, however, very challenging. For this study, this meant that more time was used on developing methods, gathering data and analysing than the TESSA guidelines suggest.

TESSA recommends a collaborative approach of engaging with stakeholders for site-specific advice and information throughout the whole process of ecosystem service assessment. During this study the collaborative approach recommended by TESSA has been very beneficial. From start to finish, stakeholders, such as local residents, farmers, land managers and local representatives from governmental departments (Forestry Commission, Environment Agency and Natural England) have taken part in providing information and advice on local conditions and approaches. This addresses the need for site-specific ES assessment (Peh *et al.* 2013) and the results relevant to local stakeholders. It has also been observed that attitudes and opinions on the subject of woodland creation, as well as the willingness to engage with the research, changed within the group of stakeholders as time and the research progressed. Participating stakeholders have commented that they felt, "Listened to by an objective observer" and, "Respected for their local knowledge". This was particularly heard from stakeholders with a farming background. As a result, a genuine interest seemed to build towards the outcomes, with an interest in the results from the study and many felt that taking part has been a beneficial educational experience. Collaboration between scientists and stakeholders are documented as being beneficial (de Vente *et al.* 2016; Pocock *et al.* 2017) and may influence long-term thinking on the topic of changes in land use. Considering the significance of farmers within the subject of woodland creation, this could be very valuable as a driver and opportunity for future natural resource management projects.

Due to the extent and variation of methodology applied and the results of each of the four ES indicators within the study, the results, implications and methodology will be discussed separately below and finally summarised at the end of this chapter. What is essential to consider about the climate regulation assessments carried out in the TESSA study, is that the emphasis in this assessment is estimates of how carbon storage, carbon sequestration and GHG flux levels changes with an expansion of woodland cover on grassland. As long as estimates for both the current and alternative states are the same, then the comparison is valid Peh *et al.* (2013).

4.4.1 Climate regulating services

The rapid ecosystem service assessment carried out in this thesis focussed on climate regulation in terms of carbon storage, carbon sequestration and GHG flux, as these factors are proven to be drivers of climate change (Eggleston *et al.* 2006; Sookun *et al.* 2014; Bachelet *et al.* 2017).

The climate regulation results suggest that climate regulation under each of the measured factors would gradually increase in correspondence to the escalation of woodland creation scenarios, with the highest levels of climate regulation occurring at the higher scenarios (chapter 4.3 - figure 35). This is caused by both carbon storage and carbon sequestration increasing. These results are supported by Alonso (2012), Morrison (2012) and Hagon *et al.* (2013) as carbon storage and sequestration are well documented to be higher in woodland habitats compared to grassland. The calculations used in the climate regulation analysis do, however, have limitations.

4.4.1.1 Carbon storage

The methodology behind the carbon storage analysis revealed that tree biomass estimations are an area of research with room for improvement, despite this being a well-researched topic (Brown & Schroeder 1999; Brown 2002; Jenkins *et al.* 2003; Zianis *et al.* 2005; Muukkonen 2007; Vashum & Jayakumar 2012). The regression equations currently available and readily used for such calculations can be contradictory and inconclusive (Zianis *et al.* 2005; Muukkonen 2007; Vashum & Jayakumar 2012). The equations are often derived from very little data sets or from trees with small DBH[22] measurements. Applying such equations to large trees of a high age with a significantly larger DBH (>50cm) results in biomass estimates which are

[22] 'Diameter of breast height'. This refers to the tree diameter measured and used as a variable as part of the carbon storage calculation methodology in chapter 5.

proportionally wrong (Brown & Schroeder 1999; Brown 2001). Furthermore, the use of equations derived from different climatic regions where trees grow at different rates is problematic (Zianis *et al.* 2005; Muukonen 2007) and caution should be taken when choosing equations to use. The equations used in this study, although deemed the most appropriate, should be regarded with the knowledge that certain assumptions have been made as described in chapter 4.2.

The complications surrounding the carbon storage estimates required the results to be validated. Within estimation of woodland habitats both Hagon *et al.* (2013) and Broadmeadow & Mathews (2003) suggest an average 57 $t/C/ha^{-1}$ stored in the vegetation and Hagon *et al.* (2013) furthermore a total of 123.3 $t/C/ha^{-1}$ including soil. Morison *et al.* (2012), however, suggests that this can vary by as much as 0 – 382 $t/C/ha^{-1}$, depending on age, species and growth rate. The results from this study found a value of 169.4 $t/C/ha^{-1}$ in the broadleaved woodland category and 159.2 $t/C/ha^{-1}$ in the coniferous woodlands. Our results fall within the range of estimation from Morison *et al.* (2012) but are higher than the UK average estimated by Broadmeadow & Mathews (2003) and Hagon *et al.* (2013). The higher values from our study, may be explained by the large amount of old mature trees within the NCA, which store a substantial amount of carbon. Comparing total carbon store values is also complicated by the high variation in research methodologies and, in particular, what part of the tree has been included in the biomass calculation and whether both above- and below-ground biomass, litter and leaf cover have been included.

The results obtained from our study provide a mean value of carbon stored in the vegetation of 2.79 $t/C/ha^{-1}$ and a total of 70.4 $t/C/ha^{-1}$ including soil. Hagon *et al.* (2013) also reviewed current evidence of carbon stored per tonne per hectare ($t/C/ha^{-1}$) in grassland habitats and found similar values to those used in the TESSA carbon storage assessment. For example, Hagon *et al.* (2012) estimate the vegetation stored in grassland to be an average of 1 t/C/ha^{-1} and a total of 62 t/C/ha^{-1} including soil. The slightly higher values derived from our study can possibly be explained by the large volume in grass found in the predominantly rough, low-productivity and acid grassland in the Howgill Fells NCA.

4.4.1.2 Carbon sequestration

Carbon sequestration estimates in the UK are mainly carried out by the Woodland Carbon Code (WCC) protocol and this approach was therefore taken for the TESSA assessment. The WCC protocol is limited, however, and does not provide enough flexibility for native woodlands with large variations in species, age and type, as it was originally developed for commercial forestry use. When estimates for mixed native species woodland are required, the WCC categorises such woodlands into 'SAB' (Sycamore, Ash, Birch) (West & Mathews 2012). Although the SAB category is derived from a mean across a large dataset, the results obtained in this study using the WCC approach should be considered with caution and the new MOSES application currently under development from Forest Research may be a good additional approach for empirical validation of the values (Forest Research 2016).

However, the results from other carbon sequestration estimations derived locally - from the Lake District National park (LDNP) - are comparable. Greig (2012) estimates that the woodlands in the LDNP, both coniferous and broadleaved, currently annually sequester 5.6 t/CO_2/ha-1/y^{-1}. This compares well with results obtained from this study, which shows an annual sequestration in the broadleaved woodlands in the Howgill Fells NCA to be 4.54 t/CO_2/ha^{-1}/y^{-1} and the coniferous woodlands to be 9.29 t/CO_2/ha^{-1}/y^{-1}.

Further to the discussion surrounding the values, the carbon sequestration results obtained in our study are an indication of the amount of carbon sequestered at the time of the research.

Trees sequester differently at different growth stages of their lifespan and results obtained at this point would be different in, for example, ten years' time even if the current level of woodland cover would not change. The results also indicated a larger amount of CO_2 being sequestered in the coniferous woodland compared to broadleaved. This can be explained by the age of the tree. Most of the coniferous woodlands within the NCA are of a similar age (40-80 years), which is the stage in a tree's lifespan where they sequester at the highest rate. As they grow older, sequestration rates slow, hence the broadleaved woodland's lower sequestration rate as they older.

4.4.1.3 GHG Flux

Finally, an estimation of the Greenhouse gas (GHG) flux in the current state of the NCA and the four woodland creation scenarios was applied. This indicates that the Howgill Fells NCA would sequestrate an increasing amount of total GHG with each woodland creation scenario and, as a result, have a positive impact on climate regulation and mitigation by reducing GHG emissions.

The Nitrious Oxide (N_2O) levels within the NCA were expected to remain constant between scenarios, but the sequestration of CO_2 would increase substantially, which is unsurprising with the large change in vegetation from grass to trees (Morrison *et al.* 2012; Ionnas *et al.* 2016). Additionally, Methane (CH^4) emission levels would be expected to decrease in correlation to woodland cover increasing, due to the decrease in livestock numbers, which is beneficial in terms of lowering GHG emission from the NCA.

The climate regulation assessment in this study quantifies how a change in land-use in the Howgill Fells NCA from grazed grassland to woodland would aid climate regulation by increasing carbon storage and GHG sequestration rates. On a local scale, then these results address the need for climate mitigation evidence, which was raised by stakeholders in the early scoping study – chapter 3. Moreover, the results are useful for informing local stakeholders participating in woodland creation carbon off-setting schemes and local commitments for reducing carbon emissions in line with UK climate change act targets.

The values derived for our study are from a combination of primary and secondary data and the carbon storage and GHG sequestration values therefore offer a useful model for further research and estimates in woodland and grassland habitats in upland areas of England. These values are, however, area and woodland/grass-type specific, which is the strength and benefit from a site-specific assessment and relevant to this study, but a limitation if applied to other studies. These values will only be accurate for similar sites in this area, as soil, climate, species and growing conditions will differ elsewhere (Pearson *et al.* 2005; Morrison *et al.* 2012; Hagon *et al.* 2013; Vanquelova *et al.* 2013).

4.4.2 Water-related services

In the early stages of this thesis (December 2015), Cumbria experienced a severe flood event (CCC 2016). This followed similar flood events in 2009 and 2005 and generated much interest for both engineered and natural flood management approaches within the topic of natural flood management and the UK uplands. Tree planting is often discussed as a means to slow water runoff from the hills and thereby mitigate flooding in low lying areas (Chandler *et al.* 2017; Stratford *et al.* 2017).

Unsurprisingly, water-related services were therefore deemed very important by the stakeholders participating in the scoping study, which helped inform the TESSA assessment and there was much interest in the assessment of how a change to woodland would impact runoff and flood mitigation. Finding a method by which such an assessment could be carried out within the remits of the study was very difficult due to the severe complexity surrounding the relationship between water, landscape and land use. Tools currently available for such an assessment are, as detailed in chapter 2, often modelled, time-consuming, expensive, require specialist knowledge and the validity of results are still debated (Stratford 2017; Sharps *et al.* 2017). Collecting meaningful field data is also not an option, due to the time constraint of the study.

4.4.2.1 WaterWorld

Following guidance from the TESSA protocol, the WaterWorld Policy Support System (Muliigan 2013) was deemed to be a suitable approach. The WaterWorld Policy Support System focussed on water balance as the main factor for above-surface water quantity analysis. Details of impacts on infiltration, erosion, runoff and evapotranspiration (ET) is part of the analysis and adds to the overall understanding of the results.

The results suggest an increase in the water balance from baseline under the 10% afforestation scenario with 4% (1708m^3/yr), the 25% afforestation scenario with 9% (3663m^3/yr), the 50% afforestation scenario with 16% (6062m^3/yr) and the 75% afforestation scenario with 16% (6080m^3/yr). This increase is particularly interesting as afforestation carried out on grazed grassland would be expected to lower water balance, not increase it (Robinson *et al.* 2003; Ford *et al.* 2016; Stratford *et al.* 2017). The reason behind this result was found by the sensitivity query to be driven by high fog inputs, which are a localised climatic occurrence typical of upland areas worldwide. Although infiltration and ET do increase with the afforestation scenarios, this high fog input tips the overall balance. It may be that fog inputs are generally not included in hydrological analysis of water balance and land-uses. Mulligan (2013) and Pandeya-Bhopal (2014) found similar results in their research and this is an area that needs to be investigated further, taking particular consideration into the discrepancy between modelled and field data in flood risk analysis results found by Stratford *et al.* (2017). The climatic conditions of the uplands will differ from areas of lower altitudes (Metlink 2016) and the results obtained from the WaterWorld analysis suggests that this needs to be considered when carrying out large-scale afforestation, especially as such schemes are often aimed at lowering water balance in upland catchments to help mitigate flood risk (Nisbet 2016).

The infiltration results from this modelled analysis show that infiltration would be expected to increase by between 3% at the 10% afforestation scenario to 8% at the 75% afforestation scenario. This does not support the very high mean infiltration rates of up to 60-76 higher in forested land over grazed grassland found by Carroll *et al.* (2004) and Marshall *et al.* (2009; 2014). However, it does support the more moderate finding by Archer *et al.* (2013), whose research found a mean infiltration rate of 5-8 times higher under broadleaved forest compared to grazed land. The similarity in findings between this study and Archer *et al.*'s (2013) research could be explained by both studies having been carried out on broadleaved forests compared to grazed grassland, whereby the Carroll *et al.* (2004) and Marshall *et al.* (2009; 2014) studies focussed on shelterbelts and hedgerows, as opposed to woodlands. This highlights the difficulties in using value transfer from the very limited research carried out on this subject and the need for site-specific data.

The results also show an increase in ET from 5% at a 10% afforestation scenario up to 31% at a 75% afforestation scenario. There is much evidence that ET increases with afforestation versus grazed grassland, so this is not surprising. The results obtained from this modelling broadly supports the general evidence of ET increasing by between 10% - 45% in forested landscapes versus grassland (Neal *et al.* 1991; Nicoll & Coutts 1998; Iroume & Huber 2002; Calder *et al.* 2003).

The results surrounding net erosion and surface runoff show an increase in both these factors, although both results do not increase much and are not likely to have much impact. Net erosion increases from 0.12 mm/yr at baseline to 0.14 mm/yr at the 75% afforestation scenario and surface run off increases from 271 m^3/yr to 332 m^3/yr. The total water balance would have an impact on net erosion and surface runoff since, simply put, the more water the surface stores, the more water there would be available to run off. These figures would be driven by the overall water balance that is shown to increase as well. Validating these results against other published research is difficult due to issues of data paucity and comparability. Nevertheless, these results are important to consider since, despite being such moderate increases, they still question the generally accepted viewpoint that afforestation will aid in mitigating flood risk and decrease runoff and erosion.

4.4.2.2 Caveats of modelling

With these results in mind it is important to consider the caveats of using a model as demonstrated by Stratford *et al.* (2017). WaterWorld is an application designed to be applied anywhere in the world and, as such, it comes with limitations as to what it can deliver. The model is fundamentally an above-surface water balance model and does not therefore account for the complexities of subsurface hydrology, although version 3 of WaterWorld does allow for infiltration to be taken into account. As a water balance model, it essentially helps to understand: i) changes in water balance on a catchment-scale, as a result of changes in land use and cover and climate change and, ii) how such changes are delivered in proportion to the scale of change. Both of these factors are important for influencing decision making processes and the results obtained here raise important questions which need to be further investigated.

WaterWorld is certainly a powerful and suitable model for rapid water-related ecosystem services, but it relies on global datasets, such as wind speed and the MODIS cloud frequency, both of which are of low spatial resolution and may be limited in representing variability in a small catchment, though inputs of locally derived data could potentially improve results. The broad vegetation definitions of forest, herb and bare land cover, do not capture the possible variation in forest types, such as conifers and broadleaves and their relationship with hydrology. This could have an impact on ET outputs. Furthermore, the model does not account for seasonal differences in leaf cover of broadleaved forests typical of the temperate regions, which could particularly impact the cloud and fog outputs.

In terms of assessing flood mitigation, WaterWorld is unable to assess the characteristics of peak/low flows and the resulting data should be viewed with caution. Further to this, this assessment was carried out on an area of increasing forest cover over previously grazed grassland and its impact on water quantity. There are other important factors to consider for such an assessment that are not covered in the WaterWorld Policy Support System, such as hydrological roughness. Hydrological roughness techniques are increasingly being installed and trialled in upland catchments and the evidence from these does suggest that forests would help increase water storage and slow peak flows at the lower ends of catchments. Therefore, it would be reasonable to assume that such measurements would highlight areas of afforestation that will aid in mitigating floods. Leaky woody debris is, however, not currently being installed at the Howgill Fells NCA study site and therefore not of relevance to this assessment.

The scenarios of increasing afforestation levels in percentage was applied per pixel and therefore identical to what is being carried out in terms of tree planting on the ground. Care was taken to try and imitate the design of the current and future planting strategies by keeping the modelled afforestation scenarios below an altitude of 450m. However, the percentage cover of trees were then allocated over the rest of the ground at the different percentage scenarios, instead of the current planting compartments. It is likely that focussing on how the current planting would impact water balance on a much more localised scale within each planting compartment and the nearby stream would yield different results. However, this is currently not possible to do without long-term monitoring and data collection from the field.

The WaterWorld model does not also account for differences in forest design, type, species, tree density and management, which are evidently important factors according to the current literature (Archer *et al.* 2016). Forestry practices have shown to have the potential to both increase and decrease water balance, depending on which stage the forest management is at (Iroume & Huber 2002; Nisbet 2005; Archer *et al.* 2016). The tree planting at the Howgill Fells NCA is not a commercial forest and therefore this is not an issue for this assessment. It should, however, be considered in interpreting these results and validating against other current evidence as these factors would be expected to yield different results.

Water-related ES services are well known to be difficult to assess, particularly with regard to obtaining reliable site-specific data and combining this with a rapid assessment approach. TESSA guidelines of time required for the overall assessment states a mean 44 person days (PD) per site (ranging from 13 to 153 PD). This estimate does not include data analysis or write-up time and a total estimate of a minimum of 3 months person time is offered. This time was as part of this study spent at least on the WaterWorld analysis alone. It would be recommended that a more practical and user-friendly approach to water-related service assessment be included. Taking the limitations into consideration, the WaterWorld analysis has highlighted the need for further investigation and supplementation of data to support our results before a conclusion is made. Water–related ES are coming under increasing focus and the need for evidence-based information to inform decision making is important and urgent (EA 2016; Stratford *et al.* 2017).

4.4.3 Nature-based recreation

The NEA (2014) assessment identified cultural services and particularly nature-based recreational services to be of high importance to the uplands of England. The key stakeholders who were consulted as part of the preliminary stage (chapter 3) expressed particular concerns about whether increasing woodland cover in the uplands of Cumbria would impact the nature-based recreational tourism sector.

The analysis carried out for this part of the TESSA assessment offered insight into the economic value of visitors to the Howgill Fells NCA and the potential change in monetary value caused by the increase in woodland cover under each scenario. The outcomes of this therefore addresses the concerns and aids the understanding of potential impacts. The evidence illustrated here suggest that nature-based recreation in the Howgill Fells NCA contributes substantial monetary value to the area in its current state. The alternative woodland scenarios could provide an increase of this value, but only up until a certain point - the 75% afforestation scenario, where the monetary value would be of no higher level than the current state. By the 100% scenario a decrease in value would be expected.

Additionally, the results also provide insight into how there is a difference between peoples´ preference for woodland levels in the uplands of Cumbria and the probability of return visits. This could potentially be an important observation, as preference studies are commonly used as an indication for how changes in landscape can impact economic revenue. It is recommended that further studies into this area may well try and increase our knowledge into this area of human behaviour and attitude.

4.4.3.1 Photograph visualisation

The use of photograph visualisation as part of this assessment was very useful in helping participants envisage the proposed alternative scenarios and has been a valuable tool in the research by many others (Karjalainen & Tyrväinen 2002*;* Tress & Tress 2003). Preparation of photographs used for visualisation were, however, time-consuming and should be carried out with caution, as it is a potentially powerful and persuasive tool that can influence participants' opinions (Tress & Tress 2003; Sheppard 2005). During this study, the manipulated scenario photographs were used as an aid when participants were struggling to visualise how a scenario might appear. Additionally, concerns have been raised about the method for its lack of allowing participants the sense of the proposed scenarios and that such assessment cannot be fully separated from its non-visual aspects (Orland *et al.* 2001; Lange 1994; Soliva *et al.* 2008). As Karjalainen and Tyrväinen (2002) concluded, a mixed technique approach is the most appropriate if it incorporates an on-site visit. This may be due to the argument, raised by many, that landscapes are perceived and appreciated not just for their aesthetic appearance, but how they make us feel – or rather – the 'sense of the place' (Leader-Elliott 2012; Convery & O'Brien 2012; Mansfield 2012). Consequently, this study addressed that concern by carrying out the survey *in-situ* within the actual landscape proposed to change. This decision was partly informed by Soliva *et al.* (2008), who observed in their research using photograph visualisation on a changing landscape that such a lack of separation did indeed occur, especially with participants that are local residents, but that if the participant did not have a personal connection to the place it was easier for them to focus on the visual dimensions and not be influenced by cultural or place specific factors (Soliva *et al.* 2008). Our study did observe a similar trend to the study of Soliva *et al.* (2008) and anecdotal evidence from many of the locals we spoke to found it challenging to separate their local cultural connection to the place and merely consider the proposed scenarios visually. Locals would often voice their opinions with reference to the past, such as:

"*These hills have looked like this for thousands of years... why is it suddenly so important to plant trees?"*

"The farmers are relying on the hills for farming – it's always been like that".

"I just don't like it (tree planting). They (the hills) have always looked like that"

Visitors to the area were not so much concerned about the past, but did express interest in how such a change in landscape would impact local residents. Insight into differences of opinion between locals and visitors is not the focus of this assessment, but it strengthens the validity of using photograph visualisation as a method. Had the emphasis of the study been on the difference in opinion between stakeholders, perhaps this method would not have been appropriate. A further consideration is the potential persuasive nature of the approach in that it deliberately engages emotions with the photographs, as argued by Sheppard (2005). In this study, participants only used the photograph visualisation as an aid. Many found it more useful to simply look at the surrounding hills and by the aid of the scenario photographs, imagine the tree line and type of woodland. The edited photographs were of a simplistic nature and if a more sophisticated photograph manipulation software, such as augmented reality (Portman *et al.* 2015), had been employed perhaps the photograph visualisation would have had more strength as a standalone method. Acknowledgement should, however, be made and considered towards such limitations of the method and the interpretation of the results.

4.4.3.2 Monetary value

The Howgill Fells NCA receives high numbers of visitors for nature-based recreational purposes, and the monetary value of nature-based recreation offers a substantial source of income to the local economy. A 'current' state value in British Pounds (£) was derived using the economic value data from Cumbria Tourism and the visitor numbers data from Sedbergh Tourist

Information Centre. This value (£) was then compared to the value of the proposed scenarios. Interestingly, the results indicate that despite the higher support for the middle level woodland scenarios, the biggest monetary value is to be found with the 10% scenario. By this estimate, the monetary value would increase by 20% (£10,593,060) and both the scenarios of 25% and 50% indicate an increase of 18% and 16% respectively. This trend ends at the 75% scenario, where a 0% monetary value is to be gained and by the 100% scenario, a decrease of 12% (£6,355,769) would be expected. This is driven by the pattern of visitors more and less likely to return, as by the 75% woodland level visitors are equally more or less likely to return. This value may seem high, but perhaps not so much when taken into consideration and compared to the annual monetary value of £1,146 million generated by tourism to the Lake District National Park.

4.4.3.3 Limitations of approach

The methodology follows the protocol of the TESSA Toolkit, and does have its limitations. Firstly, the calculations carried out used a value of £167 per person per trip, which were informed by Cumbria Tourism data. This is under the assumption of only 1 visit per year by that person. The information derived from the data collection indicates that most visitors visit the Howgill Fells NCA 1-2 times a year (4 5%), but that 18% visit 3-5 times to year and 15% +5 times a year. Additionally, 23% indicated that they had visited in the past, but not on a regular yearly visiting pattern. Therefore, the derived value can be observed as being conservative. The intent behind using the value as it stands, is that it is unclear from the information collected on return visits as to whether the visits are day visits or with accommodation. Therefore, the data from Cumbria Tourism (2015) was deemed more accurate, but nonetheless a conservative estimate. Data was collected on a per person per day spent by the participants, but this data focussed on expenditure excluding accommodation. The results obtained from this showed an average spend of £28 per person per day. In comparison, £26.34 was estimated by Cumbria Tourism (2015) as a daily per person spend excluding accommodation.

Secondly, the emphasis of the information collected is on return visits. Therefore, data was not collected on the probability of return visits under the current state. Upon reflection, such observation would have been beneficial and added a higher degree of understanding between the current state and proposed scenarios. Nevertheless, considering the data as it is, a comparison between the monetary value of the current state as described must be used, with acknowledgement of its limitations.

Finally, using the convenience intercept sampling approach, participants who were visiting the Howgill Fells NCA were targeted. Consequently, the average age of these participants was 45 years old. Very few families or young people took part. Some older teenagers accompanying their parents were observed, which has contributed to lowering the average age. This was purely due to the fact that these particular age groups were not present. The Cumbria Tourism data supports this with 65% of visitors being in the post-children life-stage.

The results address the strong concerns raised by stakeholder in the preliminary scoping study regarding potential loss in tourism levels if the landscape were to be covered by more trees and woodlands. The results here are, therefore, very useful for local stakeholders in addressing these concerns and may inform further land management and policy decision-making. To the author's knowledge, no other study has provided evidence which is this site-specific and supported with such a large dataset. Due to the representative nature of the study area, the results here may be applied to the Cumbrian uplands as a whole, but not other areas of a distinctively different landscape character.

4.4.4 Cultivated goods

The provisionary ecosystem service of cultivated goods were assessed for this chapter with the focus of using livestock production and sheep stock levels in particular as the indicator. The results indicate that under the 10% woodland creation scenario, the NCA would be able to sustain approximately a very similar level of stock as it is currently sustaining. Under each of the higher woodland creation scenarios, a much higher decrease in livestock production would occur. In upland areas of the UK livestock grazing is a loss-making business in the absence of agricultural subsidies (which represent a cost to the general public). Therefore, although the results indicate a negative loss under the alternative woodland creation scenarios, grazing actually represents a net positive. It could, however, be argued that less food is being produced under these scenarios, because monetary value is the only realistic way to incorporate the external outputs that enable grazing to occur on the sites, at current food prices grazing does not represent a net benefit. Despite this, there are social arguments for keeping grazing in the uplands, to support livelihoods that are viewed as culturally important, and to maintain landscapes that are considered attractive (Angus *et al.* 2009; Reed *et al.* 2009b; Hall 2014).

The assessment for the Howgill Fells NCA included grazed land on mainly common land areas. This is very typical of grazing in upland Cumbria, but one should acknowledge that each common is unique in terms of graziers rights, vegetation and stocking levels. Therefore, although stocking levels used for the analysis of the study site are generally similar to other upland areas of common grazing (Haley & Scott 2015), localised differences will occur. Further to this, many grazed upland areas and farms are participating in agri-environmental schemes and will as such have grazing level agreements in place according to aims and objectives. Hill farmers in Cumbria are facing severe challenges in sustaining their businesses and many are advocating a need for hill farms to diversify (Schwarz *et al.* 2006); DEFRA 2010). This is mainly due to the low profitability of hill farming, changes in agricultural policy and subsidies. Some farms are still struggling with the effects of Foot and Mouth in 2001 and, additionally, there is a vast range of social factors such as an ageing farming population, a lack of affordable housing, a transfer of skills and interest and the increasing difficulty for younger farmers to start up their own business (Schwarz *et al.* 2006; Mansfield 2011). Added to this are the constraints of environmental schemes such as Countryside Stewardship. Most of these require major changes to the farming practice and particularly in terms of reducing stocking rates on the fells (DEFRA 2014).

This assessment provides insight into the cost to society of livestock production in upland areas of Cumbria with the public support from agricultural and environmental subsidies and grants. This is very relevant in the current political climate and debate, as these subsidies are mostly controlled through the EU Common Agricultural Policy (CAP) from member states' contributions. The UK's referendum decision to leave the EU has created uncertainty regarding the future of CAP payments. In August 2016, the Government announced that CAP Pillar I payments, structural and investment funds and Pillar II agri-environment schemes will be funded via the Treasury until 2020 (DEFRA 2015b). However, the future of the rural aid scheme beyond the exit and how it will impact livestock production in upland areas of the UK is currently unknown.

For the Howgill Fells NCA, the results from the TESSA assessment demonstrate how livestock numbers within the area would decrease under each scenario. This is useful information for the farmers within the area, as discussions are currently taking place between stakeholders regarding the extent of common land areas to be planted with trees, as described in chapter 1. This planting will directly impact their businesses as discussed above, but also the cultural element of hill farming which underpins the existence of the local community (Mansfield 2011). Further perspectives on this are explored in chapter 5. The TESSA model created by this study for assessing cultivated goods in upland areas of England is useful for further research, but needs further empirical validation regarding the full economic extent of creating new woodlands in upland areas of Cumbria.

4.4.5 Summary

The TESSA rapid ecosystem service assessment has proven, with consideration to the caveats described above, to be a useful tool in the site-specific assessment of ecosystem services in the uplands of Cumbria and in addressing the concerns identified in the scoping study – chapter 3. These concerns can act as a barrier for woodland creation in Cumbria and the results obtained from our study therefore help overcome this barrier, by providing evidence for potential impacts caused by a change in land-use. The collaborative approach of engaging stakeholders throughout process of the TESSA assessment has added to the value, validity and need for site-specific ES assessment. This may influence long-term thinking on the topic of changes in land-use locally and could be very valuable as a driver and opportunity for future natural resource management projects.

The combination of using field-specific primary data, value-transfer secondary data from previous studies and expert opinion allowed the assessment to become site-specific and the results are therefore pertinent to the Howgills Fells NCA. Due to the representative nature of the study site, the results can be used to a large extent to aid understanding of the similar circumstances across upland Cumbria. They also provide a model which, with small adjustments of site-specific data, can be applied on a larger scale to upland areas and be used to aid assessments of the impacts of woodland creation schemes nationally.

The results from each indicator were combined and displayed visually to provide an understanding for how the combined proportional differences would be - figure 35. This demonstrated that the largest proportional differences are to be found within the higher levels of woodland creation. A substantially large amount of carbon could potentially be stored and GHG sequestrated, with benefits mitigating climate change. This should, however, be considered against the fact that under the highest level of woodland creation – 75% - this would be the only indicator which according to these results would be an additional benefit. Nature-based tourism would at this level deliver the same level of service as it currently does under the current state of the NCA and no 'extra' benefits would therefore come from this ES by creating more woodland according to the results. Additionally, at the 75% level, there could potentially be detrimental impacts experienced from water-related services, although, exactly how such impacts would occur on the ground is difficult to predict based on the WaterWorld analysis, which at this stage needs supporting from further data and analysis to reach a conclusion. Finally, at the 75% scenario level cultivated goods as an ES would decrease. This may be interpreted as equally a benefit and adverse output, as there would potentially be less livestock production, which leads to less reliance on public payments towards agricultural subsidies. However, less livestock has an impact socially and economically on locals who farm this area. Considering the current political development of the UK's exit from the EU, the results from the TESSA assessment could aid understanding for the most cost effective use of public and private funds (Bateman *et al.* 2013).

At the 10% woodland creation scenario there is little detrimental impact to changes from the current state. The results suggest that a good compromise may be reached at 10%, as nature-based tourism would be at its highest positive outcome. This may, in addition to providing a service to society, be of interest to hill farmers seeking to diversify and offer an opportunity for extra income. Very low levels of adverse impacts would be expected between the 10 - 25% level, compared to the current state of the NCA. Additionally, the positive outcomes from climate-regulation and nature-based tourism would be beneficial to society and stakeholders within the NCA. These considerations and results suggest that creating woodlands at higher levels than between 10 – 25% would not provide substantial benefits on all four ES indicators. Although climate regulating services would benefit, it would have too large an impact on the other ES assessed, especially cultivated goods, which are deemed important to the study area and upland Cumbria as a whole. It should also be considered that large changes to the production of cultivated goods may also cause higher levels of conflict between stakeholders, due to the strong cultural association between farming and the landscape in the study area. This is further explored in the next chapter (chapter 5).

5. PERSPECTIVES OF WOODLAND CREATION

5.1. INTRODUCTION

The creation of new woodlands in the uplands of England requires collaboration from a wide range of stakeholders, including landowners, managers, tenants and NGOs. Furthermore, co-operation is necessary between these stakeholders and the Governmental bodies which implement and guide the process. Understanding such stakeholder perspectives on woodland creation is therefore an important element of being successful in achieving national policy targets (Eves *et al.* 2013; Thomas *et al.* 2015). State ownership of land is low in the UK compared to other countries, such as the US, and achieving the aims of changes in land-use nationally, therefore, requires the cooperation of key stakeholders (Lawrence & Dandy 2014). Lawrence *et al.* (2014) suggests that some stakeholder groups, such as agents, managers, community woodland groups and local authorities are often neglected in research on this topic. Moreover, there is a consistent theme of private landowners not meeting the ambitions of national woodland creation policies (Ma *et al.* 2012). In England a planting target of 5000 ha yearly is underperforming compared to an actual 3000 ha yearly average (Forestry Commission 2014). A similar pattern is also observed internationally, for example in the US (Straka 2011; Creamer *et al.* 2012; Camblanne 2013), Australia (Tyrväinen *et al.* 2003), Belgium and Holland (Van Gossum *et al.* 2008; Van Gossum *et al.* 2010).

Much research has been carried out to understand the relationship between woodland creation and stakeholders both nationally, (Madsen 2003; Langpap 2006; Church & Ravenscroft 2008; Lawrence & Dandy 2014; Sorice *et al.* 2014; Nielsen-Pincus *et al.* 2015; Ruseva *et al.* 2015;

Thomas *et al.* 2015) and internationally (Gregory *et al.* 2003; Madsen 2003). Lawrence and Dandy (2014) carried out a substantial review of current evidence of private landowners' approaches to woodland creation in the UK, which encompassed forty studies. They identified two main focusses for previous research carried out on this topic, which are: (a) attitudes of landowners and managers towards policy tools, such as incentives and regulation (Madsen 2003; Langpap 2006; Church & Ravenscroft 2008) and (b) the outcome of such regulatory tools on behavioural decisions (Sorice *et al.* 2014; Nielsen-Pincus *et al.* 2015; Ruseva *et al.* 2015). Most of the research Lawrence & Dandy (2014) reviewed, as Thomas *et al.* (2015) commented, focussed on 'external' behavioural controls, such as economic considerations, policy frameworks and advice. Thomas *et al.* (2015) argue that this is because these external factors are easily observable as opposed to less definable factors, such as values and emotions. (Buijs & Lawrence 2013) suggest that this focus may also arise from a perspective that feelings and emotions in forestry are perceived as irrelevant.

Buijs & Lawrence (2013) suggestion is particularly interesting, as it is rare that research focusses on the emotions behind social conflict in forestry. Foresters and researchers tend to explain differences in opinion and conflict surrounding forestry, by divergence in interests, values and knowledge. Buijs & Lawrence (2013) argue that emotions and feelings are equally relevant components of an environmental resource conflict. Environmental social conflict is part of the concourse that surrounds the topic of woodland creation and has been identified as a barrier to woodland creation (Buijs & Lawrence 2013; Lawrence & Dandy 2014). Discussion of this conflict is therefore a key underrepresented area of research in the field of woodland creation and forestry. For this reason, the focus of chapter 5 is an exploratory approach to meet this gap in knowledge and, as a result, increase understanding of stakeholder perspectives of woodland creation in the uplands of Cumbria, UK. This addresses the second aim of this thesis. Q-methodology has been chosen as the method for this exploration as it is particularly useful for our case study due to the benefits of the method described in chapter 2, such as the subjective nature of using smaller participant groups and its ability to find areas of consensus in strongly conflicted circumstances.

In this chapter a Q-methodology factor analysis will be carried out, to explore stakeholders' perspectives and subjectivity on the topic of woodland creation in upland Cumbria. The overall objective for this assessment is to address objectives 2.1, 2.3 and 2.4. Objective 2.1 is partly addressed in chapter 3. The extent to which these objectives have been met is discussed and concluded in chapter 6.

Objectives:

2.1 To identify key stakeholders relevant to the case study of creating new woodlands in an upland Cumbrian landscape

2.2 Explore perspectives, feelings and emotions that relate to woodland creation in a Cumbrian upland landscape by a Q-methodology study of the key stakeholders

2.3 Explore opportunities and barriers to woodland creation in a Cumbrian upland landscape based on the findings of the study

5.2. METHODOLOGY

Q-methodology is first and foremost an explorative method which was not designed to prove hypotheses (Watts & Stenner 2005). The method is illustrated in figure 36 and follows a seven-step procedure: 1. Identification of the discourse, i.e. the subject of interest; 2. Development of the Q-sample (concourse); 3. Piloting the Q-sample; 4. Selection of participants; 5. Execution of Q-sorts; 6. Statistical analysis of the Q-sorts and 7. Interpretation of the results (Brown 1980; Watts & Stenner 2005).

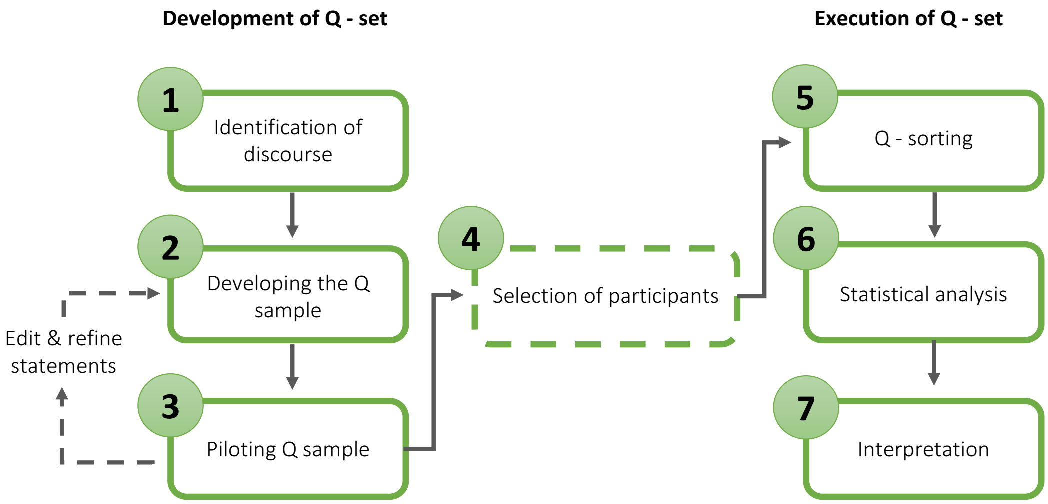

Figure 36 – Q-methodology research structure of the seven-step structure of a Q-methodology study, developed from Brown (1980) and Watts & Stenner (2005).

5.2.1 Development of a Q-set

The Q-set is the foundation of the Q-sort. It is a collection of items that participants will sort on a grid according to the level of agreement. These items can be as varied as traditional statements, pictures, smells and objects (Stephenson 1936). The research question guides the development of the Q-set. The Q-set has to be clearly defined as it acts as a condition of instruction for the participants (Watts & Stenner 2005). If statements are used, then all statements must be able to relate to and answer the research question.

(1) Identification of the discourse

The subject of interest was identified as per the second aim of the study: To assess stakeholder perspectives of woodland creation in a Cumbrian upland landscape. This was carried out via the second objective of "Exploring perspectives, feelings and emotions that relate to woodland creation in a Cumbrian upland landscape". Therefore, the question which was provided to guide participants through the Q-sorting process was, *"What do you think about planting new woodland in the uplands of the Howgill Fells NCA? Please sort the provided statements in order to best describe your opinion on the matter".*

(2) Developing the concourse & Q-sample

The statements used in the Q-sort are derived from a large compilation of statements called the concourse - typically > 100. The concourse aims to capture the breadth and depth of opinion of the discourse and statements are typically selected from previous research or discussion, such as interviews, surveys, general media or literature, but also day-to-day ordinary conversations (Paige & Morin 2016). The researcher continues to gather statements until the subject is saturated and nothing new is added (Watts & Stenner 2005).

A concourse of 102 statements were gathered using the aforementioned sources and additional verbal information from the preliminary interviews held at the early stages of the study with key stakeholders. Seven key themes were developed, partly informed by the preliminary interviews in chapter 3 and literature review, to ensure that the breath of the topic was represented: 1. Ecosystem services, 2. Policy, 3. Productive woodlands, 4. Nature conservation, 5. Farming, 6. Recreation/inspiration and 7. Landscape.

From this large selection of statements a smaller representative selection is chosen, with care taken to include both positive and negative representation. It is normally recommended that the size of concourse selection be approximately one third of the size of the discourse (Brown 1980). A concourse of between forty-sixty statements is recommended, depending on subject, time and participant ability (Watts & Stenner 2012). The final concourse then becomes the Q-set. The ultimate aim is that any participant should feel that he/she can get their opinion on the topic expressed, without feeling frustrated by a lack of statement options or the size of the Q-set.

(3) Piloting

The concourse was therefore reduced to forty-four statements, which were piloted on a selected group of fifteen experts, academics, and people with practical experience within the field of woodland creation. Based on the results and feedback given during the pilot, a further three statements were added to the Q-sample and adjustments were made to seven statements. As a result, a final Q-set of forty-seven statements was used for the Q-sorts - Appendix VI.

(4) Selection of participants

Selection of participants in Q-methodological studies differ from traditional quantitative approaches, whereby selection of a representative sample of the population is essential (Stephenson 1953). Participants of a Q study are selected as a sample that covers a range and diversity of viewpoints present amongst the participants. The sampling should be strategic instead of random (Brown 1993a). Watts and Stenner (2012) state that participants should be individuals that are "data-rich" and "express a particularly interesting or pivotal view".

The participants were all relevant to the case study of woodland creation in the Howgill Fells NCA – appendix V. These included woodland creation advisors, NGOs, interest groups, farm advisors, general public, land owners and farmers who were either considering planting, had already planted or did not wish to take part in any planting scheme. These participants were identified as relevant stakeholders following the criteria by Reed (2008). (Colvin *et al.* 2016) states that there are 3 categories of stakeholders within environmental and natural resource management:

- Those who are affected by or can affect a decision (Reed 2008)
- Those who may be interested in a decision, (Soma & Vatn 2014)
- Those who may be impacted by a decision (Fischer *et al.* 2013)

Applying these criteria can be difficult due to the interconnectedness of landscapes, society and nature (Colvin *et al.* 2016). Therefore, a further distinction was made following Reed (2008), between 'stakeholder engagement' and 'public participation'[23].

[23] Reed (2008) describes public participation as "a broad movement toward involvement of civil society in decision making". This is an approach which attempts to engage all of society in democratic decision-making as representatives for the 'public good' (Colvin *et al.* 2016). (Colvin *et al.* 2016).

Recruitment of organisational participants was carried out by consultation with key people who had been involved in existing tree planting consultation processes and by the use of the recommended 'snowballing' approach (Reed 2008). Additionally, each participant was asked if they would recommend anyone relevant to the study. Two large landowners are in ownership of most of the land within the study area and these were contacted directly. The vast majority of the land is farmed and there are thirty-three working farms within the study site. All farms were contacted by a personal visit to the farm with a verbal and written invitation to take part in the study delivered personally. Before this was carried out, leading and respected farming families were identified and visited first. This included the four chairpersons of each of the four common land associations within the study area. Many farmers were thereafter recruited by word of mouth and after a recommendation to take part. Initially, local farmers were hesitant to partake, but after familiarising themselves with the researcher and an element of trust being established, the majority of the farming community were very open, helpful and interested in participating. As a result, a total of sixty participants took part in the study – appendix V.

5.2.2 Execution of Q-set

(5) Q-sort execution

Execution of the Q-sort was carried out on a one-to-one basis in a mutually agreed location. Each participant was asked to rank the forty-seven Q statements according to opinion. Post Q-sorting, a follow-up recorded interview was carried out, where participants were asked to elaborate on their choices for ranking of the Q-set. This is important, both for the interpretation of the data, but also because participants will often have a need to explain their thoughts and feelings for particular statements. This leads to a much deeper understanding of their perspective on the topic and the reasons behind ranking (Stephenson 1953).

(6) Statistical analysis

"Any new analysis should start with a fresh and puzzled attitude,

believing nothing, and expecting little"[24]

Fundamentally, a Q analysis is a factor analysis, which aims to simplify complex data sets and find correlations between variables (Kline 2014). Nevertheless, contrary to the traditional R-methodological factor analysis where the items are the variables and participants the sample, Q-methodology reverses this to participants being the variables. Due to this, traditional analytic software packages, such as IBM SPSS can be applied for analysis if the variables are turned. Such traditionally quantitative software packages do, however, not have the facility to create the factor arrays that are used to assist the unique Q-methodology interpretation of the results, as will be explained later in this chapter. Therefore, a purely statistical understanding of the results

[24] Stephenson (1935).

may be gained without the qualitative qualities which fundamentally underpin Q-methodology. It is therefore the preferred choice of most Q-methodologists to use a Q-methodology specifically designed software package. Many of these exist, with PQMethod and PCQ being the most often used (Watts & Stenner 2012). In 2016 a new free open access online application for Q-methodology analysis was launched: Ken-Q. Ken-Q offers a contemporary user-friendly and visually pleasing analytic tool in contrast to the other free software - PQMethod.

Additionally, bespoke Q-methodology analytic software packages also offer the option of carrying out a traditional centroid factor analysis[25] (CFA) as opposed to the more recently used (Chamberlain *et al.* 2012; Bredin *et al.* 2015; Berry *et al.* 2016; Hermelingmeier & Nicholas 2017) principle component analysis (PCA). Whether to use a PCA or CFA approach is a subject often discussed and choice is basically embedded in the researcher's personal preference and analytic strategy (Stephenson 1953; Brown 1993a; Watts & Stenner 2012; Kline 2014). Neither approaches are considered wrong and both have different strengths (Stephenson 1953). PCA is statistically superior and will appeal to a strategy that relies predominantly on statistics (Watts & Stenner 2012). This approach will result in a single preferred outcome. CFA, on the other hand, allows for an infinite number of possible outcomes to be rotated. This appeals in particular to an inductive strategy to the data analysis and allows the researcher to choose a solution that is regarded to be the most appropriate within the theoretical framework of the study. In reality, in large data sets there is often not much difference between the mathematical outputs from CFA and PCA (Kline 2014), as illustrated in table 21.

[25] The traditional factor analyses aims to describe variability amongst observed variables and to search for, via the use of factors, for underlying joint variations. This is done in an explorative approach.

Table 21 – An exemplary comparison between different outputs from, a. centroid factor analysis and, b. principle component analysis from the extraction of 8 different factors. The results show little difference between the two approaches.

a.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Eigenvalues	19.9704	8.3111	3.82858	1.70187	1.88627	1.44788	1.40992	1.30059
% Explained variance	33	14	6	3	3	2	2	2
Cum % Expln var	33	47	53	56	59	61	63	65

b.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Eigenvalues	20.48140	8.87249	4.259220	2.351357	2.08592	1.82885	1.75527	1.610078
% Explained variance	34	15	7	4	3	3	3	3
Cum % Expln var	34	49	56	60	63	66	69	72

Q-methodology also differs from a R-methodology factor analysis by accepting multiple outcomes from the data analysis. There are in fact many acceptable and plausible outcomes depending on the approach and analytic strategy of the study. Pre-conceived reasons for a certain viewpoint of the data may be present that are relevant, or the study may be aiming to obtain as many viewpoints as possible on the subject. The former is of a deductive nature, often referred to as confirmation factor analysis (Kline 2014). Analysis of the data in an inductive manner, by being led by what the data shows, is often viewed as preferable (Brown 1980; Robbins & Krueger 2000; Haslam & McGarty 2014) and this is referred to as exploratory factor analysis (Kline 2014). Both approaches were promoted by Stephenson (1935) as acceptable and (Watts & Stenner 2012) has commented that, “Pure induction is a philosophical fallacy”. Such tolerance to the analysis of the data should, however, be approached with caution and not exploited (Watts & Stenner 2012).

“A factor is a particular arrangement of Q statements – a social perspective”

The Ken-Q Analysis v. 0.11.0 software was used to carry out a centroid factor analysis. Firstly, the full set (n=60) of Q-sorts was entered and a correlation matrix was extracted from the data – table 22. This table of matrix shows the extent and type of relationship that exist between the Q-sort in the study. The matrix consists of all viewpoints collected and therefore represents 100% of the overall variance in the data set – all the meaning and variability amongst participants. Essentially, a factor analysis seeks to account for as much of this variance as possible (Kline 2014) and by finding correlations within the variation and between variables (people), groups this variation into factors. This matrix allows for preliminary examination of the data before factor rotation and understanding of which Q-sorts that correlate significantly with each other (Watts & Stenner 2012). Correlation significance levels must be calculated for each independent study (number of statements will influence the outputs) using equation 10 – appendix VIII. The result from this calculation for this study was 0.39 being the significance level. As a result, all correlations in the matrix above ±0.39 are of significant correlation. Factors are then made up by patterns of similarities which make up the viewpoint participants have expressed. Such extracted factors are often called common factors, due to these portions being common variance identified and removed from the correlation matrix (Watts & Stenner 2005). The figure scale in the correlation matrix ranges from 1.00 to -1.00. A large positive correlation (similarity in viewpoint) would be indicated by, for example 0.70, whereby -0.70 would indicate little similarity and a conflicting viewpoint (Brown 1993a).

Table 22 – Correlation matrix. This was created as one of the first outputs from the analysis. It shows the extent and type of relationship that exists between the Q-sort in the study. The matrix consists of all viewpoints collected and therefore represents 100% of the overall variance in the data set – all the meaning and variability amongst participants. The column and row highlighted shows an example of how participants no. 9 and 13 have a high correlation of 0.62 (circled in red). These two participants therefore have a high level of agreement and are likely to be located within the same factor.

	Respon.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	100	56	47	-32	45	57	-57	-1	-4	36	29	-49	-24	69	-48	-30	64	36	62	30
2	2	56	100	47	-29	43	59	-40	27	8	35	45	-23	-8	39	-31	-22	20	37	59	26
3	3	47	47	100	-28	36	65	-43	4	4	50	22	-39	-13	53	-44	-29	39	40	58	27
4	4	-32	-29	-28	100	-44	-40	25	-26	-38	-50	-38	1	-27	-37	7	13	-38	-56	-45	-40
5	5	45	43	36	-44	100	60	-16	48	34	50	58	-14	16	58	-28	-34	42	44	51	60
6	6	57	59	65	-40	60	100	-48	35	28	70	54	-24	4	57	-31	-35	39	59	72	52
7	7	-57	-40	-43	25	-16	-48	100	-2	15	-27	-7	66	43	-44	55	48	-45	-34	-49	-7
8	8	-1	27	4	-26	48	35	-2	100	45	7	31	15	28	14	19	0	-2	14	25	49
9	9	-4	8	4	-38	34	28	15	45	100	19	41	51	62	-5	47	13	-11	22	10	42
10	10	36	35	50	-50	50	70	-27	7	19	100	50	-18	6	51	-24	-27	44	60	62	52
11	11	29	45	22	-38	58	54	-7	31	41	50	100	-6	12	26	5	-12	6	52	58	58
12	12	-49	-23	-39	1	-14	-24	66	15	51	-18	-6	100	58	-52	73	59	-47	-21	-42	-5
13	13	-24	-8	-13	-27	16	4	43	28	62	6	12	58	100	-18	57	28	-8	2	-23	26
14	14	69	39	53	-37	58	57	-44	14	-5	51	26	-52	-18	100	-61	-38	70	49	63	39
15	15	-48	-31	-44	7	-28	-31	55	19	47	-24	5	73	57	-61	100	62	-50	-18	-35	2
16	16	-30	-22	-29	13	-34	-35	48	0	13	-27	-12	59	28	-38	62	100	-38	-20	-34	-12
17	17	64	20	39	-38	42	39	-45	-2	-11	44	6	-47	-8	70	-50	-38	100	33	48	32
18	18	36	37	40	-56	44	59	-34	14	22	60	52	-21	2	49	-18	-20	33	100	66	49
19	19	62	59	58	-45	51	72	-49	25	10	62	58	-42	-23	63	-35	-34	48	66	100	51
20	20	30	26	27	-40	60	52	-7	49	42	52	58	-5	26	39	2	-12	32	49	51	100

Factor extraction

The number of factors that should be extracted was guided and supported by the CFA results. It is recommended as a starting point to extract seven factors (Watts & Stenner 2012). In fact, PQMethod will begin the factor extraction process at this level by default if enough Q-sorts are available. Otherwise, the additional advice is to start with extracting a factor for every six to eight Q-sorts in the study (Watts & Stenner 2005). Guided by the results from this preliminary analysis, the decision of how many factors to continue with is informed by the six mathematical criteria below. Each criteria and accompanying equation is described in detail in appendix VIII. The extent to how many of the factors fulfil the below criteria is shown in table 23.

1. **Factor Eigenvalues**
2. **>2 sig. loading[26] rule**
3. **Factor variance**
4. **Communality**
5. **Humprey's rule**
6. **Cattell's Scree test**

Table 23 shows the statistical support for factors to retain for analysis. At this point, there is support for between three and seven factors, with the suggestion of three factors being of preference. Taking this into consideration, all seven factors were initially retained for rotation and factors were not disregarded until the rotation of the data had been carried out. The combined insight from both the unrotated data and rotated data will aid in understanding how many factors to retain.

Table 23 – The results from each of the statistical tests carried out to support the retention of factors.

Name of criterion	Criterion	No. of factors
Factor Eigenvalues	> 1.00	7
> Sig. loading rule	> 2 sort must load at significant level 0.39	3
Factor variance & communality	Variance > 35%	6
Humphrey's rule	Cross-product > 2 x SE	3
Cattell's Scree test	Point of change in slope	3

[26] Loading is a common term in Q-methodology and refers to a Q-sort reaching a high enough significance level to be included.

Factor rotation

Following the decision of retention of factors, a factor rotation is carried out. Factor rotation is a means of optimising and making the data clearer for interpretation. Prior to data rotation, the variance is accounted for by the first factor and then subsequently the following factors in sequence. As a result, the first factors account for the largest amount of data and some sorts can load significantly onto several factors. Wolf (2006) states that, "The rotation helps to reduce 'noise' from sorts, which loads significantly on more than 1 factor". Fundamentally, the rotation seeks a simple structure and forces the factors to become orthogonal, as advocated first by Thurstone (1947) and supported by Cattell and Schuerger (1978). For this, a Varimax rotation technique is the most used approach in Q-methodology (Watts & Stenner 2012; Rust 2016; Hermelingmeier & Nicholas 2017; Ho 2017), as this automatically seeks to maximise the explained variance of the data[27] (Watts & Stenner 2005).

Following a Varimax rotation, a three-factor solution was identified as being the best fit for interpretable data that was familiar to comments made during the sorting procedure. The full CFA procedure was therefore repeated with extraction and rotation of only three factors. Finally, factor arrays were created by the use of factor weights[28] - appendix VIII (equation 12) and Z-scores[29] – equation 13. A factor array is single Q-sort configured to represent the viewpoint, or 'best fit', of a particular factor. This is the best possible estimate of the particular factor. It is a useful visual representation of the factor in question and aids interpretation (Watts & Stenner 2012).

[27] Some argue , however, that a 'theoretical' (also known as 'judgemental' or 'by-hand') rotation, as advocated by Stephenson (1953) and Brown (1980), is the superior choice for rotation, as this allows researchers to position themselves in the qualitative research paradigm of Q-methodology, in relation to the data (Newman & Ramlo 2010).

[28] Calculation of factors' weights are the **first step** in the process of creating a factor array. Factor weights give an insight into each factor's overall viewpoint (Watts & Stenner 2012). These are then converted into Z-scores.

[29] Calculation of Z-scores are the **second step** in the process of creating a factor array. Z-scores allow for comparison across factors (Watts & Stenner 2012). These are then used to create factor arrays.

5.3 RESULTS

The Ken-Q Analysis v. 0.11.0 was used for the statistical centroid factor analysis and applied to the data set of 60 Q-sorts. Based on the criteria for selection of factors – table 23, three distinct factors (viewpoints) were retained for a Varimax rotation. The output from the rotation lists the Q-sorts and their loadings against each of the three factors – appendix VII. Each Q-sort that exemplifies a particular factor is flagged automatically[30] by the Ken-Q software. The flagged Q-sorts will only load significantly on one factor and are used to create factor arrays by the weighted formula (Spearman 1927). If a Q-sort loads significantly on more than one factor, it is deemed to be compounded and disregarded from the analysis. One Q-sort was found to be bi-polar[31] on factor 1 and 3 and disregarded from the analysis. The loadings of each Q-sort against the three rotated factors are shown in Appendix VII with exemplified Q-sorts flagged and compounded Q-sorts identified. Following the rotation, three factor arrays were created. Table 24 shows the arrays with scores against each statement, as well as the associated Z-scores. Further to this, an idealised Q-sort was created for each factor as a visual indicator of each of the factor arrays – Figure 37, 38 & 39. This is illustrated as part of the factor interpretations.

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[30] The algorithm flags cases according to the following rules: flag loading a if (1) $a^2 > h^2/2$ (where h^2 is the sum of the squared loading coefficients, i.e. the proportion of a sort's variance explained by the factors) and (2) $a > 1.96/\sqrt{n}$ items (loading significant at $p < 0.05$). (Bryant 2013)

[31] A Bi-polar Q-factor consists of both positive and negative loading Q-sorts (Watts & Stenner 2012). Such factors would normally require an interpretation from the perspective of both opposite poles, but as only one Q-sort was found to show a bi-polar quality, this sort was disregarded.

Additionally, two statements did not distinguish significantly (P>0.05) between any pair of factors. These were, *"Planting trees in the uplands of the NCA is difficult… there are so many opinions and values*" and, "*There are concerns about uncertainties, such as payments, risk of planting failures and impacts"*. By not distinguishing significantly means that these are 'consensus' statements, whereby there is agreement across all three factors. Tables 25 & 26 list the top ten statements of consensus/disagreement amongst the participant group. These aid the understanding for where, within the topic of woodland creation, high and low levels of conflict exist.

Table 24 – Factor arrays and their associated Z-scores. The factor array is single Q-sort configured to represent the viewpoint, or 'best fit', of a particular factor. The factor arrays display each factor's level of agreement of each statement used for the Q-sorts, ranging from -5 (severe disagreement) to 5 (severe agreement). The darker the colour, the higher level of disagreement/agreement. Each factor array has an associated Z-score column.

		Factor arrays					
ID	Statement	F1	Z-score	F2	Z-score	F3	Z-score
1	New woodlands in the uplands should be planted with consideration to flood protection	3	1.23	-2	-0.84	0	0.26
2	Farmland in the uplands should be used for agricultural production, not woodland planting	-4	-1.49	3	1.13	-3	-1.26
3	New woodlands in the uplands should be planted with consideration to water resource management	3	1.1	-2	-0.62	1	0.65
4	New woodlands in the uplands should be created with equal benefit to the environment, economy and society	2	0.66	0	0.04	1	0.68
5	New woodlands in the uplands should be planted with consideration to climate change	3	1.08	-1	-0.58	0	0.14
6	The tree planting consultation process between landowners/farmers, advisors and governmental departments is not good enough	1	0.41	2	1.12	2	0.85
7	New woodlands in the uplands can positively contribute to alternative and renewable energy sources	0	-0.02	-3	-1.36	2	0.8
8	More woodlands in the NCA would negatively impact tourism and therefore the local economy	-3	-1.37	-1	-0.52	-5	-1.7
9	We need more resources on the ground for helping people get into woodland planting in the uplands	3	0.85	-3	-1.03	-1	-0.04
10	Planting trees in the uplands of the NCA is difficult.. There are so many opinions and values.	2	0.67	2	0.71	1	0.64
11	Economic incentives for tree planting are too low	-1	-0.17	0	-0.01	4	1.15
12	Tree planting incentive programmes (grants/schemes) are too complex	0	0.31	1	0.43	3	0.86
13	There are concerns about uncertainties, such as payments, risk of planting failures and impacts	1	0.36	1	0.71	1	0.54
14	A big barrier to tree planting around here is the disagreement amongst ourselves/stakeholders	1	0.65	1	0.29	2	0.79
15	There is not enough information given about tree planting opportunities	0	0.03	0	-0.14	0	0.45
16	Opinions towards woodland creation are heavily influenced by managers, agents and regulators	0	0.01	1	0.57	4	1.18
17	Opinions towards woodland creation are heavily influenced by family members, friends and neighbours	0	0.13	-1	-0.46	0	0.09
18	New woodlands in the uplands could help with creating a timber resource for the future	-1	-0.21	-3	-1.08	4	1.15
19	New woodlands in the uplands should be coniferous for production and the economy	-5	-1.94	-2	-0.88	-2	-0.7
20	New woodlands in the uplands should be mixed species and multifunctional	2	0.7	0	0.08	3	1.01
21	We should promote creation of productive woodlands in the uplands, as this provides employment opportunities in remote rural communities	-1	-0.19	-2	-0.93	0	0.4
22	New woodlands in the uplands should be native species for wildlife and people	5	1.69	-1	-0.29	-2	-0.75
23	New woodlands in the uplands would be beneficial for nature, wildlife & biodiversity	5	1.95	-2	-0.88	2	0.81
24	Enough is already done to protect and enhance the upland environment	-5	-1.74	0	0.05	-3	-1.45
25	There has been too much planting of woodland with native only species	-4	-1.61	-1	-0.25	-1	-0.06
26	More woodland in the uplands would be beneficial to the hill farmers in terms of caring and shepherding for livestock, shelter and shade	1	0.38	-5	-2.25	3	0.9
27	We have worked so hard to make the uplands suitable for farming... seems a real shame to now change that back	-3	-1.07	3	1.24	-2	-0.96
28	More woodlands would negatively affect the way of life for people deriving a living from the land	-2	-0.96	2	1	-4	-1.55
29	New woodland could help diversify the income to a business relying on upland areas for income	2	0.79	-3	-1.23	2	0.8
30	There is little consideration to landowners/managers/farmers trying to make a living from the land	-1	-0.64	3	1.26	3	0.92
31	More woodland in the uplands could encourage more outdoor leisure activity	0	0.35	-4	-1.47	-1	-0.21
32	The rights of people to enjoy the beauty of the landscape is more important than making profits from the land	-1	-0.43	-4	-1.43	-5	-1.99
33	It is important to have woodlands in the uplands – it is good for our mental and physical health	1	0.61	-5	-1.56	-1	-0.16
34	More woodland in the uplands would help in creating a sense of wilderness	0	0.12	-4	-1.43	-2	-0.71
35	Increasing woodlands on the fells of the NCA would negatively change the identity and local cultural heritage	-2	-0.93	4	1.26	-1	-0.65
36	I support creation of new woodlands, but it has to be done in tune with the landscape	4	1.66	0	-0.1	1	0.66
37	The characteristic landscape of the fells in the NCA would be ruined if there were more trees up there	-2	-0.78	3	1.26	-4	-1.6
38	The use of the land for pastoral farming is more aesthetically pleasing than woodland on the fells	-2	-0.97	5	1.5	-1	-0.54
39	Woodlands should be planted with future generations in mind	4	1.27	0	-0.06	5	1.47
40	A lot of the recent planting in the uplands has been of scrub species... It's no good for man nor nature	-4	-1.47	2	0.79	0	-0.02
41	I am concerned about a negative irreversible change in land use that tree planting would entail	-2	-0.76	4	1.44	-2	-1.23
42	We have enough woodland in the uplands of the Howgill Fells NCA	-3	-1.44	4	1.28	-4	-1.58
43	Tree planting schemes are too short in duration	1	0.38	-1	-0.27	1	0.66
44	When planting trees in the NCA, we need to respect the rights of the commoners/landowner	4	1.3	5	1.66	5	1.94
45	Some woodland planting in the NCA is ok, just not too much	2	0.73	1	0.28	0	0.05
46	It is a waste of time planting trees up on the Howgill fells - they will struggle to grow	-3	-1	2	0.84	-3	-1.41
47	It is difficult to combine the management of upland farming with woodland creation on the fells of the NCA	-1	-0.22	1	0.7	-3	-1.28

Table 25 – Top 10 consensus statements. This is the where factors agreed the most, with statement ID 10 being the one of most agreement.

Statement ID	Statement	Factor 1	Factor 2	Factor 3	Z-score variance
10	Planting trees in the uplands of the NCA is difficult. There are so many opinions and values.	2	2	1	0.001
13	There are concerns about uncertainties, such as payments, risk of planting failures and impacts	1	1	1	0.021
14	A big barrier to tree planting around here is the disagreement amongst ourselves/stakeholders	1	1	2	0.044
12	Tree planting incentive programmes (grants/schemes) are too complex	0	1	3	0.055
15	There is not enough information given about tree planting opportunities	0	0	0	0.061
44	When planting trees in the NCA, we need to respect the rights of the commoners/landowner	4	5	5	0.067
17	Opinions towards woodland creation are heavily influenced by family members, friends and neighbours	0	-1	0	0.073
45	Some woodland planting in the NCA is ok, just not too much	2	1	0	0.079
6	The tree planting consultation process between landowners/farmers, advisors and governmental departments is not good enough	1	2	2	0.087
4	New woodlands in the uplands should be created with equal benefit to the environment, economy and society	2	0	1	0.088

Table 26 – Top 10 disagreement statements. This is where factors disagreed the most, with statment ID 26 being the one of most disagreement. These statements can be identified as the matters of the greatest contention and debate.

Statement ID	Statement	Factor 1	Factor 2	Factor 3	Z-score variance
26	More woodland in the uplands would be beneficial to the hill farmers in terms of caring and shepherding for livestock, shelter and shade	1	-5	3	1.909
42	We have enough woodland in the uplands of the Howgill Fells NCA	-3	4	-4	1.729
37	The characteristic landscape of the fells in the NCA would be ruined if there were more trees up there	-2	3	-4	1.452
2	Farmland in the uplands should be used for agricultural production, not woodland planting	-4	3	-3	1.403
41	I am concerned about a negative irreversible change in land use that tree planting would entail	-2	4	-2	1.356
23	New woodlands in the uplands would be beneficial for nature, wildlife & biodiversity	5	-2	2	1.35
28	More woodlands would negatively affect the way of life for people deriving a living from the land	-2	2	-4	1.184
38	The use of the land for pastoral farming is more aesthetically pleasing than woodland on the fells	-2	5	-1	1.165
27	We have worked so hard to make the uplands suitable for farming... seems a real shame to now change that back	-3	3	-2	1.131
22	New woodlands in the uplands should be native species for wildlife and people	5	-1	-2	1.122

5.3.1 (7) Interpretation

The remainder of the results chapter will focus on an interpretation of each of the three factors: 1. '***Not enough is done to protect the environment***', 2. ***'Changing the landscape is changing us'*** and 3. '***Let's not let our emotions get in the way***'. This interpretation is based on the ranking of the level of agreement/disagreement of the +5, +4, -5 and -4 statements, which indicates areas of the concourse where there is strong opinion and the lesser ranked statements. Importantly, the statements ranked neutrally are also considered. Additionally, table 27 shows the factor arrays and statements divided into the themes which underpinned the development of the Q-set. This is a useful visual illustration which aids understanding for where, within the topic of woodland creation in the uplands of Cumbria, each factor shows different degrees of interest and level of agreement. Appendix VI lists the complete Q-set used in the study for guidance when reading the factor interpretations.

Further to this, insights and understanding gained from listening to participants during the Q-sorts and the post-sort interview are incorporated into this understanding. Therefore, this understanding for the factors are added where appropriate. As part of the interpretation of the results, a 'crib sheet' approach was applied to ensure a rigorous and standardised interpretation of all three factors (Watts & Stenner 2012) – appendix IX. Each factor interpretation is accompanied by their idealised sort. As an introduction into the interpretation of the factors, figure 34, 35 & 36 is presented in the beginning to give a sense of where the main feelings and opinions are embedded within the themes of the topic and the factor.

Table 27 – Factor arrays are divided in themes which underpin the woodland creation topic. The darker colour illustrates a stronger degree of agreement/disagreement. It is clear from this that certain areas of the discussion are of different interest to the three different factors. For example, within the theme of 'Recreation/Inspiration', factor 1 shows little interest by having sorted these statements either neutrally (0) or with a slight disagreement (-1). Factor 2, on the other hand, strongly disagrees with these statements, which is indicated by having sorted these statements by the use of the highest level of disagreement possible (-4 and -5).

			Factor arrays		
Theme	Statement ID	Statements	F1	F2	F3
Ecosystem services	1	New woodlands in the uplands should be planted with consideration to flood protection	3	-2	0
	2	Farmland in the uplands should be used for agricultural production, not woodland planting	-4	3	-3
	3	New woodlands in the uplands should be planted with consideration to water resource management	3	-2	1
	4	New woodlands in the uplands should be created with equal benefit to the environment, economy and society	2	0	1
	5	New woodlands in the uplands should be planted with consideration to climate change	3	-1	0
	7	New woodlands in the uplands can positively contribute to alternative and renewable energy sources	0	-3	2
	39	Woodlands should be planted with future generations in mind	4	0	5
Policy	6	The tree planting consultation process between landowners/farmers, advisors and governmental departments is not good enough	1	2	2
	8	More woodlands in the NCA would negatively impact tourism and therefore the local economy	-3	-1	-5
	9	We need more resources on the ground for helping people get into woodland planting in the uplands	3	-3	-1
	10	Planting trees in the uplands of the NCA is difficult.. There are so many opinions and values.	2	2	1
	11	Economic incentives for tree planting are too low	-1	0	4
	12	Tree planting incentive programmes (grants/schemes) are too complex	0	1	3
	13	There are concerns about uncertancies, such as payments, risk of planting failures and impacts	1	1	1
	14	A big barrier to tree planting around here is the disagreement amongst ourselves/stakeholders	1	1	2
	15	There is not enough information given about tree planting opportunities	0	0	0
	16	Opinions towards woodland creation are heavily influenced by managers, agents and regulators	0	1	4
	17	Opinions towards woodland creation are heavily influenced by family members, friends and neighbours	0	-1	0
	43	Tree planting schemes are too short in duration	1	-1	1
Productive woodlands	18	New woodlands in the uplands could help with creating a timber resource for the future	-1	-3	4
	19	New woodlands in the uplands should be coniferous for production and the economy	-5	-2	-2
	20	New woodlands in the uplands should be mixed species and multifunctional	2	0	3
	21	We should promote creation of productive woodlands in the uplands, as this provides employment opportunities in remote rural communi	-1	-2	0
Nature conservation	22	New woodlands in the uplands should be native species for wildlife and people	5	-1	-2
	23	New woodlands in the uplands would be beneficial for nature, wildlife & biodiversity	5	-2	2
	24	Enough is already done to protect and enhance the upland environment	-5	0	-3
	25	There has been too much planting of woodland with native only species	-4	-1	-1
	40	A lot of the recent planting in the uplands has been of scrub species... It's no good for man nor nature	-4	2	0
	46	It is a waste of time planting trees up on the Howgill fells - they will struggle to grow	-3	2	-3
	42	We have enough woodland in the uplands of the Howgill Fells NCA	-3	4	-4
	45	Some woodland planting in the NCA is ok, just not too much	2	1	0
Farming	26	More woodland in the uplands would be beneficial to the hill farmers in terms of caring and shepherding for livestock, shelter and shade	1	-5	3
	27	We have worked so hard to make the uplands suitable for farming... seems a real shame to now change that back	-3	3	-2
	28	More woodlands would negatively affect the way of life for people deriving a living from the land	-2	2	-4
	29	New woodland could help diversify the income to a business relying on upland areas for income	2	-3	2
	30	There is little consideration to landowners/managers/farmers trying to make a living from the land	-1	3	3
	47	It is difficult to combine the management of upland farming with woodland creation on the fells of the NCA	-1	1	-3
	44	When planting trees in the NCA, we need to respect the rights of the commoners/landowner	4	5	5
Recreation inspiration	31	More woodland in the uplands could encourage more outdoor leisure activity	0	-4	-1
	32	The rights of people to enjoy the beauty of the landscape is more important than making profits from the land	-1	-4	-5
	33	It is important to have woodlands in the uplands – it is good for our mental and physical health	1	-5	-1
	34	More woodland in the uplands would help in creating a sense of wilderness	0	-4	-2
Landscape	35	Increasing woodlands on the fells of the NCA would negatively change the identity and local cultural heritage	-2	4	-1
	36	I support creation of new woodlands, but it has to be done in tune with the landscape	4	0	1
	37	The characteristic landscape of the fells in the NCA would be ruined if there were more trees up there	-2	3	-4
	38	The use of the land for pastoral farming is more aesthetically pleasing than woodland on the fells	-2	5	-1
	41	I am concerned about a negative irreversible change in land use that tree planting would entail	-2	4	-2

Factor 1

'Not enough is done to protect the environment'

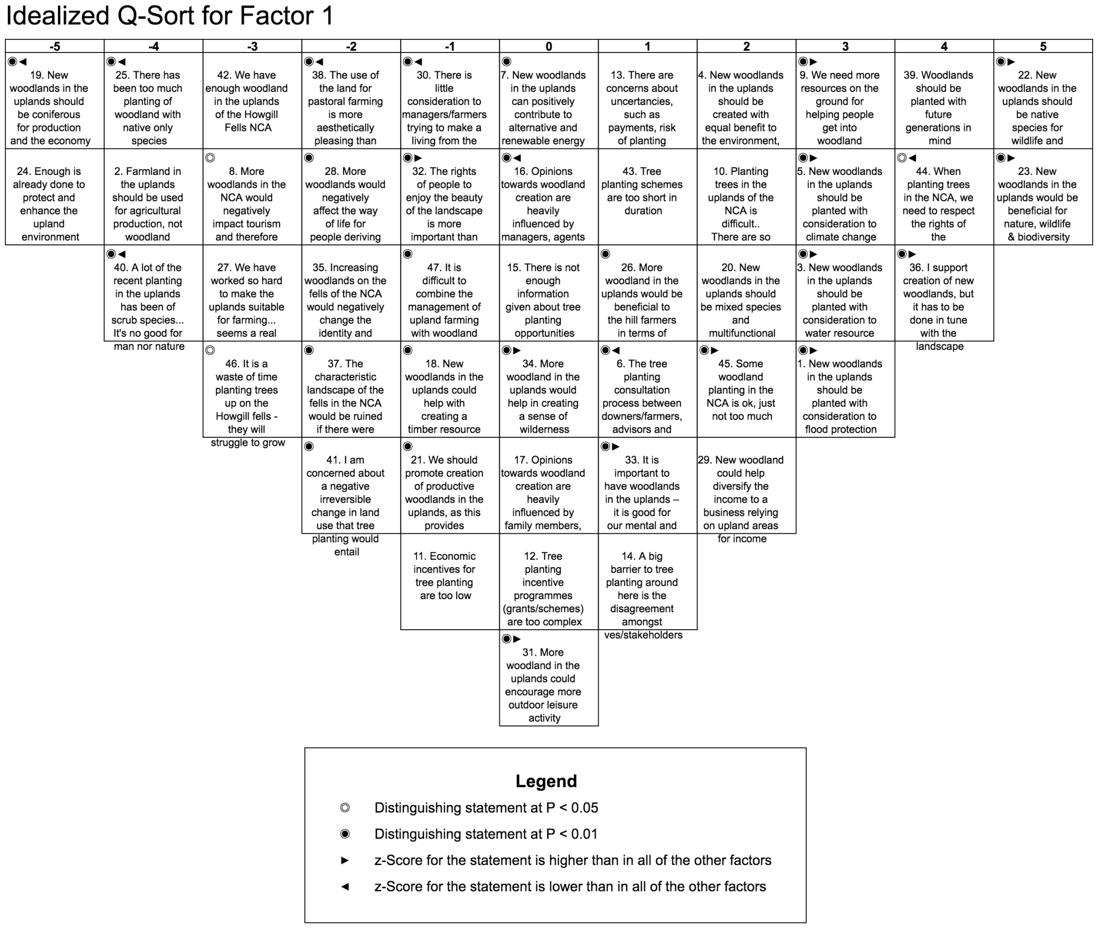

Figure 37 - A visual indicator of the factor array for factor 1. The legend describes the indicators for statements, which are significantly distinguished for that particular factor in comparison with the other factors. Statements which are Z-scored higher on this factor than others are also identified.

Factor 1 has an eigenvalue of 12.6 and explains 21% of the study variance. Twenty-one participants are significantly associated with this factor. They are from a wide range of backgrounds such as NGOs, interest groups, general public, pub owners and environmental advisors. The majority of them do not make a living from the land directly, but have an interest or connection in other ways, such as in advisory or specific interest roles, and they all have a strong interest in the area. A few farmers are included, all of which are farming as part of an environmental farming scheme.

Woodlands for environmental benefits, such as wildlife and biodiversity are very important to this group (S23:+5) and they believe that more should be done towards environmental protection in the uplands of Cumbria (S24:-5). They feel that a focus on planting native trees is the best way forward (S25:-4) and this would very much be beneficial to nature as a whole (S23:+5). For example, participant (14) said, "Essentially, this is why we do this!". Despite this strong focus on environmental benefits, there is also strong consideration for people and the perceived benefits from woodlands (S22:+5). Further to this, there is a belief that woodlands would be beneficial not only to the environment but also people making a living from the land (S28:-2). These benefits are not, however, to be achieved by the production of timber (S18:-1, S21: -1) or establishment of productive forests of a coniferous type in this area (S19:-5), but woodlands of a mixed type and multifunctional nature are perceived as acceptable (S20:+2)

The focus of these perceived benefits to people are related to ecosystem services provided at a societal level and likely to be influenced by recent local flooding events. New planting should be planted with consideration to flood protection (S1:+3) and the management of water is of great concern to this group (S3:+3). Therefore, the use of the upland landscape should be for multiple purposes and consideration to the long-term 'bigger picture' (S5:+3, S39: +4). There is a strong feeling of 'need' for this and for more resources towards achieving this which is perceived as fundamental to society (S9:+3). For example, participant (01) said, "We have an intrinsic obligation to do everything we can for the environment".

Some benefits of woodlands, such as physical and mental benefits to health, creating a sense of wilderness and the general encouragement of outdoor leisure activity is perceived as already in existence by this group, but given less focus and not prioritised (S31:0, S33:+1, S34:0). This part of the subject is perceived as a given added benefit from woodlands, but whether or not this is to be increased under more woodland creation in an upland area is questionable and other parts of this subject discussion take priority.

How more planting is achieved and the underlying policies behind planting in such upland areas is not of significant interest to this group. Fundamentally they feel that there should just be more trees planted for the greater good! There is an acceptance that planting trees in the uplands of Cumbria is difficult and that one reason is the many different opinions and interests behind the subject (S10:+2). There is also acknowledgement that one of the barriers to more planting is disagreement between stakeholders (S14:+1). Another barrier is concern surrounding uncertainties, such as planting failures and impacts and the current political situation of the UK's separation from the EU and the financial consequences, which may impact agri-environmental scheme payments (S13:+1). But ultimately, whether or not planting schemes are too complex, too short in duration, whether economic incentives are too low, whether enough information is given or who are the influential drivers behind planting is not too much of a concern (S12:0, S15:0, S16:0, S17:0).

There is, however, the belief that planting in upland areas would be beneficial to local business as a means of diversifying an income stream (S29:+2). They strongly disagree with upland areas being used predominantly for agricultural purposes (S2:-4) and it is perceived that benefits to local business should come from nature-based recreation tourism (S8:-3) or the concept of payments for ecosystem services. There is a strong belief that the rights of the commoners/landowners should be respected (S44:+4).

Although the commoners/landowners rights should be respected, there is less interest in any difficulties regarding combining hill farming with woodland creation(S47:-1) They are perceived as being able to co-exist and would not negatively affect a way of life for people deriving a living from the land (S26:+1). This may be connected to the feeling that although there is support for creation of new woodlands, then it has to be done in tune with the landscape (S36:+4) and the establishment of poorly placed or the wrong type of woodland would not be accepted. Nonetheless, changes are acceptable (S27:-3) and woodlands are not seen as having a negative impact on the identity and local cultural heritage (S35:-2), nor would the characteristics of the landscape be ruined with more trees. This may be linked with the fact that they do not perceive tree planting as an irreversible change that cannot be undone (S41:-2). Added to this, there is a strong belief that woodland creation in this area is practically possible (S46:-3).

Factor 2

'Changing the landscape is changing us'

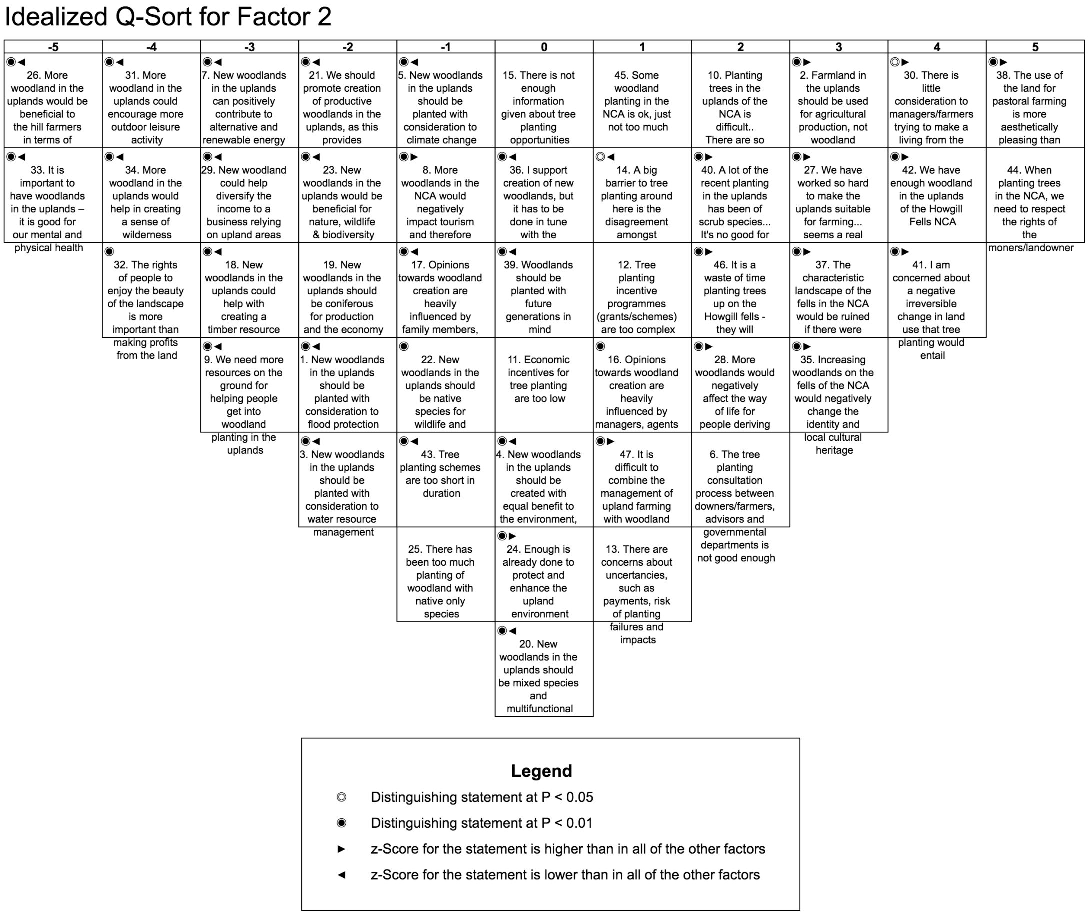

Figure 38 - A visual indicator of the factor array for factor 2. The legend describes the indicators for statements, which are significantly distinguished for that particular factor in comparison with the other factors. Statements which are Z-scored higher on this factor than others are also identified.

Factor 2 has an eigenvalue of 16.6 and explains 16% of the study variance. Seventeen people are significantly associated with this factor. With the exception of two people, all are actively hill farming and reside in the area or have retired from doing so. The two which are not from a farming background are, through their profession and personal interest, strongly interested in the preservation of the landscape.

The environmental benefits that woodland can provide, is not of as much interest to this group. They are not too concerned about protecting and enhancing the upland environment for environmental reasons (S24; 0). They feel that this landscape has enough woodland as it is (S42; +4) and do not believe that creating new woodlands would have an increased benefit to themselves or society as a whole, in comparison to what the current landscape provides. They do believe that beneficial environmental impacts are to be had, but there is a strong element of scepticism with regard to the extent of any benefits. Adding to this, the environmental elements of this topic are overpowered by stronger concerns of what the landscape ought to be used for (S38; +5), a worry of changes ahead (S41; +4) and strong feelings that, although they are the primary user group (perceived by themselves), they are not listened to or consulted on these changes (S44; +5, S6; +2): "I wish they would just listen more" (09). Participants often commented on the irreversible impact woodland creation can have on traditional livestock keeping: "Woodland creation does not help farmers. Once the sheep are off the fell, we cannot bring it back" (24), in reference to the hefting tradition.

This area and landscape is perceived by the participant loading onto this factor to be closely linked to a sense of place, culture and a way of living (S37; +3) and should primarily be used for what it traditionally has been used: hill farming (S2; +3). Participant (30) said, "The land has always been for making a living off". The idea that such a landscape should be wild is therefore strongly opposed (S34; -4). The trees themselves, and planting more of them, are not so much a concern as what they represent (changes) (S37; +3, S27; +3). Participant (27) said, “What is wrong with the fell the way it is?”. Creating more woodlands would change the landscape. Changing the landscape is changing them and their way of life (S28; +2). This raises strong emotions and concerns as this touches on their sense of identity, which is strongly linked to the landscape and way of life. Participants would often voice a local quote with a sense of pride: “My grandad lost money on sheep, my dad lost money on sheep and now I will” (31).

Creating new woodlands and the beneficial impacts this would bring to society as a whole is perceived with an element of distrust (S1; -2). Participants often voiced, in association with statement 1, that they did not believe trees would have an impact on flooding and that tree planting in this area would not have much impact on the claimed environmental societal benefits, such as climate change (S5; -1). More pragmatic and economically driven opportunities, such as the creation of timber resources on the fells are perceived with a critical eye (S18; -3) and the use of the land for planting of productive woodlands of a coniferous type in particular are not well received (S19; -2, S21; -2). That woodlands could be productive, functional and of multi-species is, however, less disputed (S24; 0). Participants often commented that they were disappointed with the type of planting that had been carried out and would have preferred bigger broadleaved species. For example, participant (56) said, “I just wish that we planted proper trees up there”.

What the area and landscape delivers in its current state is seen to be of bigger value, both for the local community but also society as a whole. The notion that aesthetics and nature-based recreational activities would benefit if more woodlands were created is regarded with strong contempt (S33; -5). Nature-based recreational activities are perceived as already being plentiful and the current landscape is well functioning for the delivery of this (S31; -4). That such values are of more, or equal, importance than what it should deliver in terms of agricultural produce is met with strong disapproval (S32; -4).

In many ways, the viewpoints within this factor contain a sense of conflict. Conflict between the practicalities of combining hill farming with tree planting (S26, -5) and between the varied opinions between people on this topic and also the feeling of not being listened to (S30; +3). Because there is a general objection to the creation of more woodlands by this group, the details of policy elements of the discussion are not given much priority (S11; 0, S12; +1, S15; 0, S43; -1), except where there is a need to state that communication between landowners/farmers and governmental departments are not good enough (S6; +2). Participants said that they felt, "Bullied into the scheme" (24, 51), "Sick of meetings" (30) and, "Only took part to keep the peace" (08, 51). Unsurprisingly, there is consequently a feeling of not wanting more resources on the ground to encourage more planting (S9; -3) and a feeling that it is a waste of time and resources to focus on tree planting (S46; +2, S40, +2).

Factor 3

'Let's not let our emotions get in the way – seeing the bigger picture'

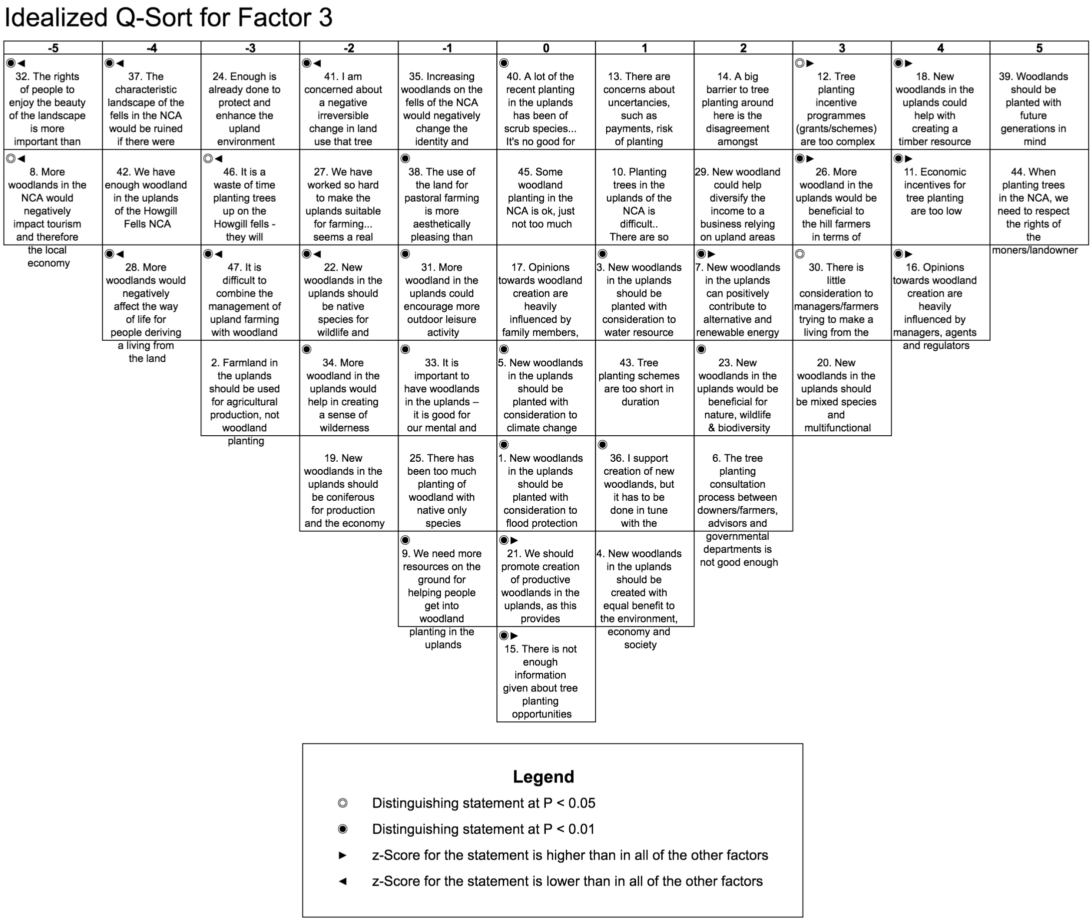

Figure 39 – A visual indicator of the factor array for factor 3. The legend describes the indicators for statements, which are significantly distinguished for that particular factor in comparison with the other factors. Statements which are Z-scored higher on this factor than others are also identified.

Factor 3 has an eigenvalue of 10.2 and explains 17% of the study variance. Seventeen people are significantly associated with this factor. This factor consists of a variety of forestry, landscape and farming related advisors and businesses, as well as farmers. All of them have currently or, in the past, had an economic experience with woodland creation, either in an advisory role, business or directly. Besides the people in advisory roles, all of them have a business or are diversifying their farm business with additional incomes related to the land and area.

The participants loading on to this factor share a viewpoint that is embedded in the thought that we do not have enough woodland within the study area (S42: -4). They believe that changes in land management and use is impending and that such changes can be for the positive (S41: -2). Further to this, they believe the creation of new woodlands would play a vital and beneficial part in this change. This change is seen as being able to compliment positively to the existing use of the landscape (S26: +3) and that if the creation of more woodlands were to happen, it would allow for an additional income stream to be generated, which would be beneficial for the local communities (S28: -4). Participant (35) said, "After foot and mouth things have changed... not enough sheep or people to manage them and keep them hefted. It is now a lot of work. By putting up all them fences, it makes it possible to run sheep up there again". There are, however, suggestions that there is an element of respect for the existing landscape and that creation of such desirable multifunctional woodlands have to be carried out in tune with this, albeit under the acceptance that changes are needed (S36: +1). What is more important to the participants loading onto this factor is the need for respecting the local people as opposed to the landscape as such (S44: +5). As participant (35) said, "We/they are the ones that have to live with it".

Consideration towards future generations and the 'bigger picture' are very important to the people loading onto this factor (S39: +5). These considerations are, however, not connected to what woodlands deliver in terms of ecosystem services to society (S4: 1). This is indicated in the considerations towards management of water resources (S3: +1), flood mitigation (S1: 0) and climate change as a whole (S5: 0), which are of less concern. This is not to say that there is a complete disregard for the relationship between woodlands, landscape and the importance of such ecosystem services, but merely that there is another important aspect, which is felt to be underrepresented and should be brought into the discussion of this topic. Further to this, during the interviews it was clear that there is also an element of ambiguity as to how much woodland creation would have an impact on such ecosystem services. Participant (51) said, "The evidence for this is just not conclusive" and (38) "I just don't trust what they say… there have been so many opinions voiced".

What these participants are saying, is that there are elements to this discussion of woodland creation in the uplands of Cumbria that are overshadowed by the polarised and often more emotionally driven views on this topic, which are embedded in either environmental or cultural heritage conservation. Fundamentally, this is driven by an extrinsic viewpoint that focusses on values such as economics and resource security. Participant (37) said, "Landscapes are developed by the needs of production and society". The participants loading onto this factor do not identify with the sentiments of intrinsic value, such as aesthetic appreciation of the landscape, recreational activities and the potential mental and physical well-being connected to the landscape and woodlands (S31: -1; S33: -1). They therefore believe that these aspects should not take precedence above making a profit from the land (S32: -5). This is well exemplified in (S37: -4) where they feel very strongly that woodland creation would not negatively affect the characteristics of the area, and further demonstrated by a lesser interest in (S35: -1; S38: -1), whereby cultural heritage or pastoral farmed landscape is seen to be less aesthetically pleasing than woodland in this area. Participant (24) commented that, "Newcomers, people who move up here to retire, they want to pickle the landscape in its current state". Adding to this exemplification, a strong opposition is made towards the idea that more woodlands would have a negative impact on tourism (S8: -5). In this context, participant (33) said, "These Londoners, coming up here to live. They have no understanding of how we have to make a living". Tourism is seen as an important income stream and challenging this by the use of emotionally driven and fact-absent arguments are perceived with a feeling of antagonism.

As such, the economic aspect of the topic features highly within this factor. These considerations are with future generations in mind and embedded in an interest for increasing sustainable resource security for the future (S18: +4) by the use and design of multifunctional woodlands (S20: +3). The multifunctional aspect is an important point, as purely creating woodlands for the sake of production of timber is not perceived as being the right approach either (S 19: -2; S21: 0). This may be connected to the belief that more should be done to protect the environment (S24: -3) and increasing woodland in this area would be beneficial both to the environment and biodiversity (S23: +2). However, these intrinsic environmental considerations are prioritised less (S25: -1) as it is believed that the creation of new woodlands should not just be about intrinsic environmental or cultural heritage values (S22: -2). Participant (42) said, "It is fundamentally about how public money is best spent".

The policy aspect of this topic is of interest and importance to this group, with identification of policy components of less concern (S15: 0). Again, a pragmatic view is taken with the identification of barriers to the establishment of woodland creation, such as the process is currently too complex (S12: +3), economic incentives are too low (S11: +4) and the consultation processes are not good enough (S6: +2). This is perceived with some frustration, as it is deemed to be heavily driven and influenced by the opinions of a vast variety of NGOs, forestry agents, land managers and regulators (S16: +4). All of these bodies have differing opinions which leads to a conflicted debate (S14: +2) and loses touch with what is perceived by this viewpoint to be of importance. Participant (53) said, "If we amongst us organisations could agree more, it would be easier to approach external stakeholders with a strategic plan. No good that we are all saying different things… NE and FC are the implementational arms of the same body. We should be working in a unified manner"

5.3.2 Summary

The results from the Q-methodological study indicated three main viewpoints (factors) of woodland creation within the Howgill Fells NCA. These were identified and titled as, factor 1. '***Not enough is done to protect the environment***', factor 2. ***'Changing the landscape is changing us'*** and factor 3. '***Let's not let our emotions get in the way***'. Each of these viewpoints are described and interpreted above in detail.

The key outputs are that there is strong conflict within this topic, leading to an impression of negativity and the sense that there is a reluctance to engage with tree planting. The findings suggest, however, that stakeholders are generally not against planting trees *per se,* but a strong divergence of feelings and values has created conflict and disagreements, which the findings suggest are further fuelled by past experiences and consultation processes. The next part of this chapter will expand on the conclusion with an accompanying discussion.

5.4 DISCUSSION & CONCLUSION

Chapter 5 concerns the Q-methodological analysis of stakeholder subjectivity on the subject of woodland creation in the uplands of Cumbria. This analysis has met three objectives within this thesis: 2.1, 2.2 and 2.3. Objective 2.1, which aimed to identify the key stakeholders that are instrumental and relevant to creating new woodlands in an upland landscape in Cumbria, was carried out in chapter 3, but is discussed here due to the connection between chapters 3 and 5. Objective 2.2 aimed to explore perspectives, feelings and emotions that relate to woodland creation in a Cumbrian upland landscape and, based on the findings, explore barriers against and opportunities for creating new woodlands (objective 2.3). This chapter will discuss the results and limitations of the study and what conclusions can be drawn. Furthermore, suggestions are made towards future research.

5.4.1 Participants

The first objective (2.1 – chapter 3) of the study was to identify the key stakeholders within the study. The term 'stakeholder' can have multiple meanings, but using the definition by (Reed 2008), it includes the people who are affected by or can affect a decision regarding woodland creation within the study area. A snowballing technique was used in addition to information from existing woodland creation consultation documents, to identify relevant stakeholders. Further to this, each participant was asked if they would recommend someone relevant to the study, who may be included. In doing so it became obvious that participant selection had reached a saturation level, as towards the end no new identities or organisations were offered. Lawrence *et al.* (2014) concluded in their review of attitudes to woodland creation, that some stakeholder groups are neglected in the evidence, such as agents, managers, community woodland groups and local authorities and this was taken into consideration.

Organisations, industry and NGO participants were easily recruited and, although very interested in sharing their opinion on the topic, some found it difficult in the early stages of the Q-sort to differentiate between their personal opinion and the opinion they felt they should take as representative of their organisation. This is a common dilemma (Primmer *et al.* 2017) and participants were advised to carry out the sorting according to what they were most comfortable with. At the end of the Q-sort, the participants were asked if they felt that the finished sort represented their personal or professional opinion. At this point, all stated that the Q-sort displayed, both professionally and personally, their opinion. This could, however, be seen as a limitation of the method and should be considered in the interpretation stage of the results when working with participants representing an organisation.

Recruitment of participants within the farming community was very successful, as every farmer approached regarding participation agreed to take part and the use of Q-methodology was received well. In particular, participants commented that they felt listened to and appreciated the combination of their views being gathered unbiased via the Q-sort, and then having the ability to further elaborate on their Q-sort with the follow-up interview. Developing trust between the researcher and farming community was critical. In the early stages of the engagement with stakeholders, the researcher was often questioned about personal opinions and on their relations with official bodies, such as Natural England. There is a strong feeling of 'Them' (Natural England, DEFRA etc.) and 'Us' (farming community) within the study area and people who are perceived as belonging to the 'Them' category are met with a level of suspicion in this context. This may be rooted in a long history of farm inspections and agri-environment schemes and would benefit from being investigated further in future research. Many participants from the farming community would comment that, *"They don't understand us".* It was therefore crucial that the researcher made it clear that her position was neutral and the overall objective was to gather opinions from all involved. Working in the area for a prolonged amount of time also made the engagement process easier, as the researcher became a known figure, which was further facilitated by the personal visits to every farm within the study area.

5.4.2 Perspectives and feelings

Stakeholder's perspectives and feelings towards woodland creation were explored by the use of Q-methodology in relation to objective (2.2). Q-methodology allows participants to express their viewpoint on a topic of interest by the use of a set of statements: the Q-set. It is therefore important that the Q-set incorporates the full concourse of the topic and allows the participants to express their opinion sufficiently. Developing the concourse is rigorous and piloted to ensure its quality. The 'perfect' Q-set is, however, an almost impossible achievement (Watts & Stenner 2012). At the end of a Q-sort, each participant was asked if they felt that their Q-sort represented clearly their opinion and whether they felt anything was missing. The vast majority of participants were satisfied by their sort and only few felt a need to expand on reasons behind the sort. A few commented that there was a need for statements that expressed viewpoints on access laws, as this is an important element of creating new woodlands in the uplands. The follow up interview did, however, allow for absent viewpoints to be considered and are a crucial part of Q-methodology, as a much greater understanding of participants' viewpoints were obtained from these. This is partly what makes Q-methodology stand out as a quantitative/qualitative methodology.

Much research has been carried out to understand the relationship between woodland creation and stakeholders (Madsen 2003; Langpap 2006; Church & Ravenscroft 2008; Lawrence & Dandy 2014; Sorice *et al.* 2014; Nielsen-Pincus *et al.* 2015; Ruseva *et al.* 2015; Thomas *et al.* 2015) and many have suggested a tendency of reluctance or negativity towards tree planting (Bell 1999; Stubbs 2011; Fox 2012; Eves *et al.* 2013; Holstead *et al.* 2017). There has, however, been less focus on the role of people's emotions, feelings and values as highlighted by (Buijs & Lawrence 2013; Thomas *et al.* 2015) and more focus on landowners' and managers' perspectives of policy tools (Madsen 2003; Langpap 2006; Church & Ravenscroft 2008) or on the pragmatic element of incentives and nudges (Eves *et al.* 2013).

The results from the Q-methodological study indicated three main viewpoints (factors) of woodland creation within the Howgill Fells NCA. These were identified as, 1. '***Not enough is done to protect the environment***', 2. ***'Changing the landscape is changing us'*** and 3. '***Let's not let our emotions get in the way***'. It is interesting that amongst these three viewpoints, factors 1 and 2 do not care much about the policy element of the topic, but feelings on a broader scale are what dominate the viewpoints. Factor 3 on the other hand does care significantly about the policy element. This is not surprising as the people loading onto this factor are foresters, policy influencers and farmers with highly diverse businesses. What exemplifies this group is, in fact, a strong opposition to letting feelings get in the way of this topic.

This supports (Buijs & Lawrence 2013) suggestion that feelings and emotions in forestry are perceived as irrelevant and aids an understanding of this underrepresented focus in the literature. As participant (37), which loaded onto factor 3 said, *"Landscapes are developed by the needs of production and society".* Among the sixty participants within the Q-methodology study, this factor contains seventeen people. Considering that creating new woodlands requires collaboration between the many diverse stakeholders identified here, then it highlights a problem of polarisation. Two-thirds of the stakeholders (factor 1 and 2) have viewpoints that are highly driven by intrinsic values and feelings. These people are farmers, NGOs, environmental advisers and interest groups. One-third of the stakeholders (factor 3) have the viewpoint that feelings are of less importance. This factor consists of the stakeholders that are instrumental in delivering woodland creation, which identifies an important element and underlying cause for conflict amongst stakeholders within the topic of woodland creation. Not surprisingly, the number one consensus statement (Z-score variance of 0.001) amongst all three factors is, *"Planting trees in the uplands of the NCA is difficult… There are so many opinions and values"* – table 25.

5.4.3 Personal against public perspectives

Despite factors 1 and 2 agreeing that feelings are important, they strongly disagree on what specific issues within this topic are perceived as important. Factors 1 and 3 do have many similarities, despite a fundamental difference in values. The results displayed in table 27 highlighted that factor 2 has little similarities with both factors 1 and 3. This is not surprising since, although factors 2 and 3 have polarised views on intrinsic/extrinsic values, they both consider what is important to be at a broader theoretical scale, whereby for factor 2, it is personal. For the people loading onto factor 2, woodland creation symbolises change. This change will not only change the landscape, but also them, their way of life and culture. These people have engaged long-term with the land and experienced themselves - or have been informed from older generations - what change driven by forestry (Lawrence & Edwards 2013), policies and environmental schemes (Morgan-Davies *et al.* 2012) or even sudden large-scale disease outbreaks (Mort *et al.* 2005) can entail. One participant (31), who was a local farmer's son contracted to carry out the planting, commented when asked how he felt about the planting he was doing, *"I don't like it… feels like a real shame. My family has spent years drying up this land to make it suitable for sheep grazing. We were paid to do it! And now we're told to go and make it wet again and fill it with all this rubbish (trees)"* (meaning that earlier agri-environmental schemes have paid them to clear scrub and dig dykes to drain the land). This mindset is further fuelled by a sense of ´not being listened to´ and that decisions are made without them being truly consulted. Interestingly, both factors 2 and 3 agree that the consultation process is not good enough (S:6, +2). However, they are perhaps not referring to the same consultation issues and the specifics of this would be beneficial to address further in future research.

Factor 2's strong emotional relationship with this topic supports the need for qualitative research, suggested by (Morgan-Davies *et al.* 2012) and increases the understanding for why some, especially farmers, do not wish to participate in woodland creation despite obvious economic incentives, which has been suggested to be the most important planting incentive by (Eves *et al.* 2013). There has been increasing interest in identifying typologies of stakeholders interested in woodland creation (Madsen 2003; Eves *et al.* 2013; Lawrence & Dandy 2014) and subsequently, how we can use these typologies to apply typologically specific policy 'nudges' as a means of encouraging people to engage with, for example, woodland creation (Valatin *et al.* 2016). The evidence from our study supports the typologies offered by (Eves *et al.* 2013), if the focus is only on farming stakeholders. Factor 2 fits well within (Eves *et al.* 2013) 'Farmers first' category and the farmers loading onto Factor 3, are similar to the 'Pragmatic planter' and 'Business-orientated Farmers' categories. It is, however, interesting to note that the (Eves *et al.* 2013) study, despite claiming to focus on stakeholders, does not take organisational, governmental and interest groups into consideration. This supports the Lawrence *et al.* (2014) conclusion of some stakeholder groups being neglected in the evidence, such as agents, managers, community woodland groups and local authorities. Woodland creation needs a collaborative approach to be successful. Focus should not just be on understanding farmers, but also on other relevant stakeholders, as demonstrated by the findings of our study, whereby it is clear that perspectives of other stakeholders, not just farmers, can be a possible barrier in the woodland creation process.

5.4.4 Is economics important?

Much of the literature (Church & Ravenscroft 2008; Fox 2012; Kim & Langpap 2016) on woodland creation suggests that economic incentives are an important driver for woodland creation and some (Eves *et al.* 2013) suggest that it is the most important incentive. This has, however, been challenged by many (Bateman 1996; Harrison *et al.* 1998; Stubbs 2011; Morgan-Davies *et al.* 2012; Bell 2014; Mann 2018). Our Q-methodology study addressed this via the statement, "Economic incentives are too low" and the results show a strong difference in opinion on this statement between factors. Factor 1 ranks this at -1, which suggests a slight feeling of disagreement. Factor 2 ranks this at a 0, which indicates it being of not great importance, whereas for Factor 3, this is valued highly, with a ranking of +4. This illustrates, as suggested by (Morgan-Davies *et al.* 2012), that for some, economic incentives are indeed important, but this is not a main driver for all. It also further depicts the large difference in values between Factors 2 and 3. Participants loading onto Factor 3 would often comment that, "It is all about the money", which is clearly not demonstrated to be the case for Factors 1 and 2.

Factors 1 and 3 have many similarities, which is embedded in a primary belief that woodland creation within this area would be a positive development and there is mutual understanding that this would be beneficial to the environment and society as a whole. Secondly, both factors accept that changes are imminent and embrace this as a positive development. From this point, the similarities separate into two essentially different viewpoints, which are value-driven and fundamentally based on intrinsic and extrinsic viewpoints.

5.4.3 Future opportunities

The results presented in this chapter suggest that three different and clearly defined viewpoints (factors) exist on the topic of woodland creation in the Howgill Fells NCA among stakeholders. Our study has addressed a gap in research, by offering insight into the perspectives, feelings and emotions of stakeholders. This has improved our understanding for why planting trees in the uplands of Cumbria are difficult and offered suggestions for improvement and opportunities for moving forward, presented below.

1. On a local scale within the Howgill Fells NCA there is a strong feeling of conflict between stakeholders, which is embedded in value-driven feelings and the tree planting consultation approach. The results here can be used to open up a discussion locally with acknowledgement that this an issue, whereby more research and resources are needed to clarify the issue. This may assist and inform the discussions which are currently being carried out in the area with regards to whether stakeholders wish to engage with further planting schemes or withdraw from doing so.

2. The findings from our study offer insights that are relevant to policy makers within woodland creation and tree planting on a broader scale. This is clearly a topic which is strongly fuelled by feelings, emotions, past experiences and values, especially within stakeholders belonging to Factor 1 ('*Not enough is done to protect the environment*') and Factor 2 (*'Changing the landscape is changing us')*. It is therefore not surprising that these conflict between each other due to differentiation in values, but especially with Factor 3 *('Let's not let our emotions get in the way'),* which includes stakeholders from the local governmental environmental agencies. The results from our study suggest that more consideration towards such perspectives would be beneficial to include in consultation processes. The strong pragmatic and economic focus held within Factor 3 are an important element to consultation processes, but more

understanding and acceptance of the broad spectrum of perspectives within this topic would be beneficial, if collaboration and compromise are to be reached.

3. It has been suggested that farmers are against tree planting and woodland creation. However, any opposition against planting trees in the Howgill Fells NCA was, as suggested by the results, mainly embedded in feelings, emotions and past/current experiences with consultation processes and governmental agencies, not the trees and woodlands *per se*. This is a key output from this study which could benefit from further research, to specify and identify areas of focus and improvement in the consultation process. Such investigation could be carried out by further analysis of the Q-methodology data from this study.

4. Where previous research has often focussed on farmers, landowners and woodland owners, as the stakeholders with land available to plant trees on, our research has explored the perspectives of all instrumental stakeholders equally, including local agencies, woodland agents and NGOs. This has shown that such stakeholders hold an equally important role in enabling or disabling consultation processes. By doing so, new barriers and opportunities have been identified on the topic of woodland creation in the uplands of Cumbria.

The findings presented and discussed here have increased our understanding for stakeholder perspectives on woodland creation in the uplands of Cumbria. The key outputs are that there is strong conflict within this topic, leading an impression of negativity and the sense that there is a reluctance to engage with tree planting. The findings suggest, however, that stakeholders are generally not against planting trees, but a strong divergence of feelings and values has created conflict and disagreements, which the findings suggest are further fuelled by past experiences and consultation processes. These findings are preliminary and offer great potential for further research to unravel this complex topic.

The next chapter, will combine and discuss how the findings from chapters 4 and 5 complement each other and meet the aims and objectives. The chapter also offers suggestions for moving forward within the subject of woodland creation in the uplands of Cumbria.

6. THESIS DISCUSSION & CONCLUSION

This thesis has explored the impacts and perspectives of woodland creation in an upland area of Cumbria, UK. At the beginning of the study, thirteen preliminary semi-structured interviews were held with woodland sector stakeholders (chapter 3). From these discussions themes emerged concerning woodland creation in Cumbria, including:

- The impact of a change from grassland primarily used for grazing to woodland, especially in relation to ecosystem services (ES) such as:
  - *Climate regulation*
  - *Water related services*
  - *Nature-based recreation*
  - *Cultivated goods (farming)*

- Uncertainty exists with regard to optimum levels of woodland in a given area
- Recognition that stakeholder perspectives are highly conflicted and are a significant element that can act as a barrier to woodland planting

From these preliminary interviews it became clear that there was a need for a transdisciplinary approach in order to fully understand the complexity of the topic. It was also apparent that a rounded, holistic view of this complex topic is currently lacking. This has been further reinforced by the fact that it has been impossible for every single participant within this study, both preliminary interviews in chapter 3, stakeholders offering guidance and advice as part of the TESSA modelling in chapter 4 and the Q-methodology study in chapter 5, to speak about woodland planting in the uplands of Cumbria, without consideration of all three themes. These themes are interrelated. Exploring one of the abovementioned themes on its own, therefore, would have been insufficient, since knowledge gained from exploring one theme of the topic directly impacts the two others. This is exemplified by statements from participants that include, *"But it all depends on how much woodland we're talking about"(2)*, "*The debate of woodland planting around here, gets all wrapped up in discussions about details amongst ourselves – no one can get along and therefore nothing happens"(51)* or *"People are so unsure about the impacts of making such changes and that causes discussions and arguments" (42).*

The Q-methodology stakeholder subjectivity study in chapter 5 confirmed this. The Q statement, *"Planting trees in the uplands of the NCA is difficult… there are so many opinions and values*" became the top consensus statement amongst all participants and, *"A big barrier to tree planting around here is the disagreement amongst ourselves/stakeholders"* the third highest.

In addition, impacts of changes to services provided by the current landscape and how this would change for current land use and potential future land use change with higher levels of woodland was viewed as highly difficult to assess, which thus raises concerns.

The interrelation of these three closely tied elements can therefore become a barrier for woodland planting in upland Cumbria, whereby picking one strand out of a ball of such intertwined elements for examination would leave important questions unanswered. As such, one would not be able to address the overall objectives of this study and, equally importantly, the study would not be of much value in terms of adding knowledge that can be applied.

Given the interrelated and complex nature of the topic, a 'twin-track' approach was adopted for this study, focussing on stakeholder perspectives and ecosystem goods and services:

- A site-specific **ecosystem service assessment** of the goods and services which are of most concern and relevance to local stakeholders was presented in chapter 4 and particularly addressed Aim 1 and Objectives 1.2, 1.3, 1.4, 1.5 and 1.6 by a TESSA ecosystem service assessment. Furthermore, this assessment addresses the uncertainty regarding optimum levels of woodland in a given area.

- An analysis of **stakeholder perspectives** to gain further understanding for the underlying values and feelings which are embedded in this topic was presented in chapter 5. In particular this addressed Aim 2 and Objectives 2.2, 2.3 and 2.4 by a Q-methodology human subjectivity factor analysis.

The results of these two interrelated 'research tracks' are discussed in detail in their respective chapters. This final section of the thesis will bring the two tracks together, discuss why such an interdisciplinary approach is useful, and make recommendations for further research and future woodland creation in the uplands of Cumbria.

The rapid TESSA ecosystem services assessment addressed the theme of impacts caused by increasing levels of woodland creation. The assessment offered a detailed insight into the theme of how the four indicators of climate-regulation, water-related services, nature-based recreation and cultivated goods would deliver services to society under each of the woodland creation scenarios. Subsequently, the results from each indicator were combined and displayed visually to demonstrate how the combined proportional differences might be reflected in the landscape (Figure 35). This demonstrated that the largest proportional differences can be found within the higher levels of woodland creation: a 50% - 75% level of woodland cover. A large amount of carbon could potentially be stored and greenhouse gases sequestrated at this level, with benefits mitigating climate regulation. However, these are the only additional benefits to be expected at this level. Nature-based tourism would, at these levels, deliver the same level of ecosystem service as it currently does under the current state of the NCA and no 'extra' benefits would therefore result from creating more woodland from this ecosystem service, according to the results. Sheep farming in particular would almost inevitably decline under higher woodland cover, with clear socio-economic implications for the farming community.

In the lower percentage scenarios (10 – 25%) of woodland creation, few detrimental impacts are to be expected in comparison to current goods and services delivered in the NCA's current state, especially at the 10% woodland level. The results indicate that at the 10% level, nature-based tourism would be at its highest positive outcome. In addition to providing a service to society, this could be of interest to hill farmers seeking to diversify and provide a much needed extra income alongside having to decrease their livestock production. Very low levels of adverse impacts would be expected at the 10 – 25% level, compared to the current state of the NCA. Additionally, the positive outcomes from climate-regulation and nature-based tourism would be beneficial to society and stakeholders within the NCA. Based on these considerations and results, woodland creation at levels higher than between 10 – 25% would not be recommended. Although climate regulating services would benefit, it would have too large an impact on the other ES assessed,, especially cultivated goods which are of particular importance to the study area. This was specifically identified by the stakeholder perspective Q-methodology study in chapter 5.

The knowledge gained from this assessment aids the understanding of two of the three elements of importance within this topic identified in the preliminary interviews in chapter 3. This knowledge can then be taken onboard by stakeholders and help shape and inform future perspectives and decision making. Without a deeper understanding of the perspectives of stakeholders any changes could be difficult to implement.

6.1.1 The importance of recognising emotions

The results from the Q-methodological study indicated that there are three main factors (viewpoints) of woodland creation within the Howgill Fells NCA. These were identified and titled as, Factor 1: '***Not enough is done to protect the environment'***

Factor 2: ***'Changing the landscape is changing us'***

Factor 3: '***Let's not let our emotions get in the way***'

Each of these viewpoints are described and discussed in detail in chapter 5.

Factors 1 and 3 have many similarities, embedded as they are in a primary belief that woodland creation within this area would be a positive development beneficial to the environment and society as a whole. Both factors also accept that changes to land management and grant schemes are imminent and embrace this as a positive development. From this point of agreement, the similarities separate into two essentially different viewpoints which are value-driven and fundamentally based on intrinsic and extrinsic viewpoints. For the stakeholders whose viewpoints lie within either Factor 1 or 2, emotions are what dominate their viewpoints. Factor 3 (which includes foresters, policy influencers and farmers with highly diverse businesses) on the other hand, has a strong opposition to letting feelings get in the way of what they perceive as important within the topic.

Considering that creating new woodland requires collaboration between the many diverse stakeholders, dismissing feelings as less important highlights a problem of divergence and conflict. Two-thirds of the stakeholders (Factor 1 and 2) held viewpoints that are highly driven by intrinsic values and feelings. These people are farmers, NGO's, environmental advisers and interest groups. One-third of the stakeholders (Factor 3) have the viewpoint that feelings are of less importance. This Factor consists of the stakeholders that are instrumental in delivering woodland creation, which identifies an important element and underlying cause for conflict amongst stakeholders within the topic of woodland creation. Previous research has explored the connection between economic incentives and regulation (Madsen 2003; Langpap 2006; Church & Ravenscroft 2008), ownership and typologies (Eves *et al.* 2013) of farmers and land owners in particular to gain an understanding of how to increase woodland creation (Ma *et al.* 2012). None of this research, however, has investigated the role of emotions or taken a critical reverse look at the influence of the people who are instrumental in delivering tree planting schemes in the process. This supports the suggestion of Lawrence *et al.* 2014, that some stakeholder groups, such as agents, managers, community woodland groups and local authorities are often neglected in research on this topic. Furthermore, Buijs and Lawrence (2013) suggest that this oversight may potentially also arise from a perspective that feelings and emotions in forestry are perceived as irrelevant. Results from this study support this perspective and this is indeed a key finding of the study, which suggests that this acts as a barrier against constructive dialogue among stakeholders. Practitioners must engage with a wide range of stakeholders and the acceptance of differences is vital, even if considered irrational. Currently, feelings are perceived as irrational and irrelevant to Factor 3, which causes a barrier, whereas for Factors 1 and 2, feelings are fundamental to the debate.

6.1.2 The importance of ecosystem services

Interestingly, the stakeholder perspective analysis carried out in chapter 5 also suggested that ecosystem services are a source of conflict and disagreement amongst participants. Many participants commented or asked questions as part of sorting the Q statements, which were about ecosystem services in particular. Distrust of the relevance of water-related services or climate change and how actions that were taken in the Howgills would actually have an impact on their local area, were especially found with Factor 2. Factor 1 agreed (+3, +4) with the Q statements surrounding benefits relating to ecosystem services and tree planting – table 27. However, Factor 3 strongly agreed (+5) that woodlands should be planted with future generations in mind, and it would appear that this consideration is connected to economic incentives, not least because the remaining ecosystem services statements are given little importance (0 and +1). The TESSA assessment provides site-specific answers to these questions, which could facilitate further dialogue of the relevance of ecosystem services within the topic of creating new woodland within the study area. For example, an opportunity exists for improving climate change mitigation within the uplands of Cumbria. According to our results, planting more woodland would lead to a large increase in both carbon storage and GHG sequestration, which as a result would aid climate change mitigation. Considering the world's current climate change challenge, then our results provide a direct site-specific indicator for considering how changes in land use may assist overcoming this challenge.

A key point to take away from this part of the study is that, although participants disagreed on the relative value of ecosystem services, within the context of woodland creation in the uplands of Cumbria, ecosystem service became less important to them. This is particularly relevant among stakeholders within Factors 2 and 3. Considering the level of importance ecosystem services were given in the preliminary interviews in chapter 3, this is noteworthy. It can therefore be concluded that the importance of ecosystem services may be given a high level of attention in policy and research context, and by stakeholders within Factor 1, but that for many stakeholders involved with the topic this is of interest but of less importance within the greater context. We can therefore conclude that concerns regarding ecosystem service impacts are in fact not as severe as suggested, but may be used as a barrier for tree planting in public discussion.

The perspectives on ecosystem services again highlights the interrelated nature of this topic and the benefit of applying a 'twin-track' approach. By adding a deeper qualitative assessment of stakeholder perspectives, we broaden our understanding of the relevance of the TESSA assessment and can direct necessary knowledge towards the relevant recipients and decision makers.

6.1.3 Concerns for changes ahead

The Q-methodology study illustrated that the viewpoint of Factor 2 has little similarities with those of Factors 1 and 3. This is important and not surprising since, although Factors 2 and 3 have conflicting views on intrinsic/extrinsic values, they both consider what is important to be at a broader theoretical scale, whereby for Factor 2, it is personal. This is a significant point, because for stakeholders loading onto Factor 2 woodland creation symbolises change that will not only change the landscape, but also themselves, their way of life and culture. The stakeholders believe that beneficial environmental impacts are to be had by woodland creation, but there is a strong element of scepticism with regard to the extent of the benefits. Additionally, the environmental elements of this topic are overpowered by stronger concerns of what the landscape ought to be used for (S38; +5), a worry of changes ahead (S41; +4) and strong feelings that, although they are the primary user group (perceived by themselves), they are not listened to or consulted on these changes (S44; +5, S6; +2), *"I wish they would just listen more"* (09). There was strong consensus among all 3 factors on this last statement.

Concerns for changes to lifestyle and culture are closely linked to the NCA´s production of cultivated goods, specifically livestock production. Considering the abovementioned results from the Q-methodology study alongside the TESSA assessment adds important knowledge and considerations, which can be used to understand the impacts caused to cultivated goods. The TESSA assessment indicated that woodland creation at and above the level of 25% would considerably decrease livestock production. The traditional herding and hefting of livestock, which underpins parts of the cultural identity of area would also be expected to decline. Considering the close link the provision of cultivated goods has to the local cultural identity and community, as identified in the Q-methodology study, creating woodlands above this 25% level is likely be received with concerns, disapproval and, as a consequence, rejection. The combined interrelated results from the Q-methodology study and the TESSA assessment therefore suggest that the production of cultivated goods acts as a barrier to higher levels of woodland creation in the study area.

6.1.4 Stakeholder engagement and participatory processes

The results suggest that consultation processes are an important element within the topic of woodland creation, due to the level of attention it received during the Q – methodology analysis by Factor 2 stakeholders, which expressed a strong need for inclusion and 'to be listened to'. Stakeholders of Factor 3 provide a strong pragmatic and economic focus on consultation processes, and Factor 1 stakeholders an intrinsic value and appreciation of the protection of the environment. This broad spectrum of perspectives can be beneficial in collaboration, but positive outcomes are only to be reached if inclusion, understanding and compromises are made. The focus, however, should not just be on understanding one specific group of stakeholders, as is often done, but also other relevant parties. Consultation processes aim to facilitate woodland creation, but the findings currently suggest that some consultation processes within the study area are having the opposite effect and are, in fact, acting as a barrier.

The TESSA approach of ES assessment in strong collaboration with stakeholders may therefore prove to be beneficial. The four commons within the Howgill Fells NCA are currently participating in planting schemes at three different stages, as described in chapter 3. A good opportunity exists, therefore, for further exploration of the importance and nature of this collaboration. Q-methodology, as a method, would be a suitable approach to take since the methodology satisfies both the forestry industry's need for quantitative objectiveness and the need for subjectivity of participants' underlying values and feelings towards woodland creation. Such in-depth investigation is needed of the stakeholder consultation processes and the impacts of outcomes caused by individuals. Some of the comments offered by participants loading onto Factor 2 raises concerns. Participants said that they felt, *"Bullied into the scheme"* (24, 51), *"Sick of meetings"* (30) and *"Only took part to keep the peace"* (08, 51). As this was commonly voiced, it suggests that a reappraisal of the consultation processes would be beneficial. Much of the negative attitudes towards woodland creation identified (Bell 1999; Stubbs 2011; Fox 2012; Eves *et al.* 2013; Holstead *et al.* 2017) may be rooted in and instigated by the consultation process itself, which the findings of this study allude to. This needs to be explored by further analysis of the data used for this study.

6.1.5 Interrelation and interdisciplinary approaches

This importance and value of the interrelated nature of this study is exemplified by for example focussing on the nature-based recreation results within the TESSA modelling, this directly addresses the concern and perspective that, *"If we change the way the landscape looks, tourists will stop coming",* which were identified in chapter 3 and further explored by the Q methodology study in chapter 5. With the knowledge from the Q-methodology study, we know this is a concern for some stakeholders (Factor 2) and this can be directly addressed by the results of the TESSA assessment, which showed that no negative impact to the tourist trade is to be experienced if woodland levels are kept under 75%. This shows the value of an interrelated and interdisciplinary study like this. It has identified a concern from one qualitative angle, addressed it with an empirical approach and is therefore able to take further steps in terms of making the results directly applicable. The assessment of each of the TESSA indicators, will aid understanding and help overcome different concerns from different stakeholders.

TESSA as an ecosystem service assessment tool has thus been useful in identifying and quantifying site-specific changes in key goods and services. But to become implementable, meaningful and useful, the findings have benefitted from a qualitative understanding. The TESSA results very much support the, "*Not enough is done to protect the environment*" and *"More trees planted for the greater good!"* related perspective found within Factor 1, as well as the pragmatic extrinsic values within Factor 3. As explained above, he TESSA findings may, however, be of interest and relevant for particular questions and concerns raised from participants loading onto Factor 2, in particular with regard to cultivated goods and nature-based recreational tourism.

Using new interdisciplinary approaches also have the benefit of exploring the unknown, which may yield surprising results, such as, for stakeholders within Factor 2, fundamentally for them planting trees in the uplands of Cumbria is not subject to quantifiable reasoning, but feelings. These feelings are dominated by frustration and concern for the changes ahead and what the land ought to be used for, i.e. pastoral farming. This insight was not identified by the TESSA assessment, but via the Q-methodology analysis and has therefore offered a much deeper understanding of this topic.

6.1.6 Implementation of results

The interrelated findings from both the TESSA assessment and the stakeholder perspective analysis are particularly useful at a local level. For stakeholders creating new woodlands within the study site, the TESSA assessment and Q – methodology analysis offers site-specific insight to questions and concerns raised in the preliminary scoping study. The TESSA assessment suggests that the lower levels of woodland creation scenarios (10 – 25%) are to be recommended, due to an expected overall benefit on all four indicators, without any large detrimental impacts. As the woodland creation scenarios increase in percentage, an increasing detrimental impact is to be expected to cultivated goods in particular, which is the production of livestock. Livestock production is embedded within the culture and history of the area and the Q-methodology analysis highlighted this area of the topic to be closely linked to strong feelings by participants of Factor 2 in particular. If woodland creation is to increase beyond the 25% level, the results would suggest that this could create strong conflict between local stakeholders.

6.1.7 Additional considerations

People are not against trees per se

Previous research and common anecdotal opinion within Cumbria suggests that many landowners and particularly locals from a farming community do not want to increase woodland levels within the uplands of Cumbria. The findings from the Q-methodology suggest that this is not correct and, in fact, that the opinion is much deeper rooted in concerns for the changes ahead, consultation processes, history and cultural identity. Recognition of these concerns and improving dialogue on the topic would lead to an improved opportunity for future woodland creation within the uplands of Cumbria.

Creation of multifunctional woodlands

Within the study area there is interest and support for the planting of woodlands of a multifunctional character, i.e. woodlands which are beneficial for nature, the landscape, but also for production of timber and fuel. The current woodland being planted is of a scrubby type, which many participants commented upon as, *"Isn't good for anything"*. Current Forestry Commission grants schemes do not support small scale fragmented planting and there is a viewpoint that Forestry Commission planting would not be well received within the study area. One forestry official commented that the area was a, *"No-go area"*. As a result, tree planting is carried out by Natural England and of a very different character compared to what the Forestry Commission offers. The findings from this study suggest that there is potential for the creation of multifunctional woodlands within the landscape of upland Cumbria. Additionally, amongst the forestry sector there exists an opportunity for Forestry Commission planting within the study area, but this is currently hindered by the Forestry Commission grant scheme and perceived opinions.

Changes to forestry policy

The current Countryside Stewardship woodland creation scheme does not allow economic support for smaller woodland areas of <3ha. to be created. The results from our study suggests that there are concerns regarding preserving the cultural upland landscape and the potential loss of cultivated goods. This would occur if large areas of grassland currently used for grazing are changed to woodland. It would therefore be recommended to adjust the minimum area size for planting, to accommodate the upland area's specific circumstances in particular.

6.1.8 Future research

This research applies a case study approach and is therefore useful and particularly relevant to the uplands of Cumbria. Other regions of upland areas in the UK are undergoing similar challenges and the opportunities and barriers presented here will also be applicable to such areas. There should be consideration, however, for the caveats and limitations discussed in chapter 4 and 5. The underlying site-specific data used for the TESSA assessment would need adjusting to local conditions if the model is used elsewhere. Equally, the perspectives obtained as part of the Q-methodology study provide us with subjectivity insights relevant to this particular case study, which are influenced by site-specific past experiences, history, local culture and identities. The research does, however, provide a useful model and methodology that offers a broader and deeper insight into site-specific impacts and perspectives of woodland creation projects in Cumbria.

The findings also suggest, that the development of a new assessment tool or the further development of the TESSA assessment tool would benefit from adding qualitative stakeholder perspective analysis aspects to it. Without the insight of the Q-methodology study, the results of the TESSA assessment would have been less meaningful and the study would not have been able to make the recommendation of keeping below the 25% woodland level in order to avoid conflict and thus increase the chance of successful woodland creation.

The results also present us with additional unanswered questions and opportunities for further research. The preliminary scoping study interviews identified the unknown impacts to the four ecosystem services indicators of woodland creation to be a barrier for woodland creation in upland Cumbria. The TESSA findings have provided insight that help overcome these barriers, but further research would be beneficial to assess to what extent this is correct. A natural next step is to present the results from this study to stakeholders to determine whether greater knowledge and understanding of the expected impacts would change perspectives.

Additionally, the Q-methodology study has provided interesting and useful insights of stakeholder perspectives of consultation processes. Much research focus is on understanding farmers, woodland owners etc, but perhaps this focus should be redirected, with more focus on the people implementing the consultation processes. This was carried out by a factor analysis of the whole data set combined. The concerns of stakeholders who feel that current consultation processes are oppressive, drawn-out and causing conflict suggests that these processes would benefit from a reappraisal of their current approach and value. This could be carried out by further analysis of the data used for this study.

6.2 Summary

This transdisciplinary research explored impacts and stakeholder perspectives of woodland creation in the uplands of Cumbria. It has identified that three interrelated elements are important to topic; 1. impacts to ecosystem services such as: climate regulation, water-related services, nature-based recreation and cultivated goods (farming). 2. Uncertainty regarding optimum levels of woodland in a given area and 3. Recognition that stakeholder perspectives are highly conflicted and are a significant element that can act as either a barrier or assistance to woodland planting.

An interdisciplinary approach has been taken to assess and gain understanding for the topic and highlighted that stakeholders are not in principle against the expansion of woodland in the study area per se, but that planting new woodland in Cumbria is highly complex and conflicted topic embedded in concerns for changes and a loss of cultural identity along with a woodland creation consultation culture which dismisses feelings as irrational.

This study suggests that the importance of ecosystem goods and services may be given a high level of attention in policy and research context, and by stakeholders within the advisory, forestry and landscape management sector, but that for many stakeholder involved with the topic this is of interest, but of less importance within the greater context.

The findings also suggest that a 10 – 25% increase in woodland in the Howgill Fells NCA would be most beneficial level, considering all four ecosystem goods and services assessed. This is based on consideration of impacts of climate change, water-related services, nature-based recreational tourism and cultivated goods. Analysis of stakeholder perspectives also indicate that lower levels of woodland within the area would be preferred, mainly linked to the likely low impact on production of cultivated goods (livestock) which is linked to a strong cultural identity in the area.

Finally, the study recommends the need for a reappraisal of consultation processes, as these have been identified as causing conflict amongst stakeholders. Understanding emotions, attitudes and perceptions is a vitally important part of the challenge of creating new woodlands in the uplands of Cumbria. Even if such views may appear irrational or ill-informed, practitioners must continue to engage with a wide range of stakeholders and develop approaches rooted in mutual understanding, participation and collaboration.

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APPENDIX I – Scoping study participant list

Participant ID	Profession	Interview details
P1	Director – Cumbria Woodlands	15/12/14 - Meeting
P2	Senior Conservation Officer	15/12/14 - Meeting
P3	Managing Director -Cumbria Farmers Network	15/01/15 - Meeting
P4	Woodland officer – Forestry Commission	11/01/15 - Meeting
P5	Woodland officer – United Utilities	11/2/15 - Meeting
P6	National Park Lead strategy advisor	18/02/15 - Meeting
P7	Area Director – Forestry Commission	31/03/15 - Meeting
P8	Senior Conservation Officer – RSPB	12/02/15 - Meeting
P9	Partnership Manager – Woodland Trust	31/03/15 - Meeting
P10	Lead advisor – Natural England	04/04/15 - Meeting
P11	Lune Rivers Trust	20/03/15 - Meeting
P12	Woodland inspirations ltd. - Woodland consultant	17/12/15 - Meeting
P13	Director – Forest Carbon	26/03/15 – Phone meeting
P14	Director – Cumbria Farm Environment Partnership	31/02/15 - Meeting
P15	Academic	03/03/15 - Meeting

APPENDIX II – Equations used in chapter 4

Equation ID & reference	Purpose	Equation	Scaling coefficients
1 **(Verplanke & Zahabu 2009)**	Above-ground carbon stock – woodland habitats. Determining number of sampling plots needed in woodland habitats	$n = \frac{(N\ x\ s)^2}{\frac{N^2\ x\ E^2}{t^2} + N\ x\ s^2}$	n = number of plots required N = total area in ha, divided by 0.05ha (area of the plot) S = standard of deviation of the mean carbon stock E = mean carbon stock (from preliminary 9 plots), multiplied by the desired precision at 0.1 (10%) t = sample statistics, t-distribution 95% confidence levels, set at 2
2 **(Muukonen 2007)**	Above-ground biomass estimates for Sitka spruce (*Picea sitchensis*), Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), Beech (*Fugus sylvatica*) and Oak (Both Quercus robur and *petraea*)	$Biomass = Exp\ (\beta_0 + \beta_1)\ x\ \frac{dbh}{dbh + \beta_2}$	Species: β_0 β_1 β_2 *Picea abies* -1.694 10.825 11.816 *Pinus sylvestris* -2.688 10.745 8.062 *Quercus spp.* -0.604 10.677 15.900 *Fagus spp.* 0.006 10.933 21.216
3 **(Jenkins *et al.* 2003)**	Above-ground biomass estimates for Larch (*Latrix decidua*)	$Biomass = Exp\ (-2.0336 + 2.2592\ x\ Lndbh)$	
4 **(Schroeder *et al.* 1997)**	Above-ground biomass estimates for general hardwood – used for any hardwood species where species specific equations were not obtainable	$Biomass = 0.5 + \frac{(25{,}000\ x\ dbh^{2.5})}{(dbh^{2.5}\ x\ 246{,}872)}$	

5 **(Anderson-Teixeria & DeLucia 2010)**	**Below-ground carbon stock - Grassland**	$Bg_{carbon} = (area(ha)\ x\ 14)\ x\ 0.47$	**Where:** Bg_{carbon} is Below-ground carbon
6 (Mokany *et al.* 2006)	Below-ground carbon stock - Woodland	$Bg_{carbon}\ (t) =$ $(total\ above\ ground\ biomass\ (t)\ x\ conversion\ factor\ x\ 0.5$	Where: Bg_{carbon} is Below-ground carbon IPCC conversion factors: Other broadleaf above-ground biomass 75-150 t/ha-$^{1.}$ = 0.23 conifers above-ground biomass 50-150 t/ha-^{1} = 0.29
7 (Nieveen & Schipper 2009)	Carbon sequestration in bog habitat estimates	$C_{seg} =$ $((latitude\ x\ 0.0436) - 2.7302)\ x\ site\ area\ (ha)$	Where: C_{seg} is carbon tonnes per year sequestered in the bog
8 (IPCC 2006)	CO_2 emisions in organic soil	$t\ C/ha/y^{-1} =$ $area\ in\ ha\ x\ emission\ factor$	IPCC emission factor: Drained organic soil in grassland dominated habitats in cold temperate regions -0.25
9 IPCC 2006	CH^4 emissions for cattle and sheep	$CH^4 emissions = EF_{(t)}\ x\ \frac{(N(_t)}{1000}$	Where: $EF_{(t)}$ is emissions factor for that specific species population (cattle = 57, Sheep = 8), kg CH^4head^{-1}y^{-y} $N_{(t)}$ is number of animals of specific species on site

APPENDIX III – Q methodology terminology

Concourse	The discourse or 'breadth and depth of opinion' on the topic.
Exemplar	A Q sort that loads significantly on only one factor and thus exemplifies the view represented by that factor.
Factor	A viewpoint. The factor is created by merging the exemplar Q sorts for each factor.
Factor Array	A 'best estimate' physical representation of the factor.
Item	A statement relating to the discourse.
P set	The 'person set' of study participants.
Q sample	The sample of items selected to represent the concourse.
Q set	The Q sample transcribed on to a set of cards and used in the Q sorting process.
Q sort	The result of the ranking procedure whereby each item is allocated a score. The Q sort represents the opinion of the individual sorter.
Q sorting	The process whereby items are ranked on a grid.

APPENDIX IV – Nature-based recreational tourism questionnaire

Interview question for visitors to the Howgills NCA

Site: **Researcher:**

Interview date: Time/location/weather:

Resident/visitor: First part of postcode:

How many people in group: Age/Gender:

Mode of transport: car/walk/bicycle/horse/public transport/Caravan/other

Have you visited before and how often do you come?

Yes No in the past 1-2 p/y 3-5 p/y 5+ p/y

What is your primary reason for visiting?

Appreciating/viewing nature/landscape

Exercise, sports or hobbies (running, walking, dog walking, biking, fishing etc.)

Visiting towns/shopping

Time with family or friends

Other ____

Would (*insert state)* make you:

	More likely to visit again	Make no difference to me visiting again	Less likely to visit again
10%			
25%			
50%			
75%			
100%			

Do you have a preference for a certain percentage? ________________________

Do you have a preference for woodland of a certain type?

No Conifer Broadleaved Mixed Productive Nature/recreational

Have you spent or planning to spent money during this visit? Yes No

NB. This include meals, drinks, transport, souvenirs, accommodation etc.

If yes, how much? _____________________________ per person / per group

APPENDIX V – Q participant list

Participant ID	Profession/Organisation	Included in study
1	Partnership Manager/Woodland Trust	Yes
2	Director/Weasdale Tree Surgery	Yes
3	General public with common rights	Yes
4	Woodland Agent for landowner	No
5	Farmer (T)	Yes
6	Farmer (T)	Yes
7	Farmer (B)	Yes
8	Farmer (B)	Yes
9	Howgill Campsite owner	Yes
10	Farmer (T)	Yes
11	Farmer (L)	Yes
12	Farmer (B)	Yes
13	Farmer (B)	Yes
14	Lead Advisor/Natural England	Yes
15	Farmer (R)	Yes
16	Farmer (R)	Yes
17	Orton Parish Council	Yes
18	General public with common rights	Yes
19	General public with common rights	Yes
20	Farmer (B)	Yes
21	Farmer (B)	Yes
22	Farmer (B)	Yes
23	Friends of the Lake District	yes
24	Farmer (R)	yes
25	Retired Farmer - rent out land	yes
26	Retired Farmer - rent out land	yes
27	Farmer (R)	yes
28	Farmer (T/R)	No
29	Farm Scheme local advisor	Yes
30	Farmer (R)	Yes
31	Farmer (L/R)	Yes
32	Farmer (T)	Yes
33	Farmer (R)	Yes
34	Farmer (R)	Yes
35	Farmer (T)	Yes
36	Ramblers Association	Yes
37	Westmorland Dales Hidden Landscapes Partnership	Yes
38	Independent Forestry Advisor	Yes
39	Open spaces	Yes
40	Conservation Manager/Wildlife Trust	Yes

Participant ID	Profession/Organisation	Included in study
41	Director Cumbria Woodlands	Yes
42	Landowner	Yes
43	Lead landscape advisor/Natural England	Yes
44	General public with common rights	Yes
45	General public with common rights	Yes
46	General public with common rights	No
47	Pub owner	Yes
48	Yorkshire Dales National Park	Yes
49	Local Paraglider Association	Yes
50	Farmer (B)	Yes
51	Cumbria County Council	Yes
52	Forestry Commission	Yes
53	Forestry Commission	Yes
54	Cumbria Commoners Federation	Yes
55	Pub Owner	Yes
56	Farmer (B)	Yes
57	Farmer (R)	Yes
58	Farmer (R)	Yes
59	Cycling company	Yes
60	Researcher	No

Appendix V displays all participants within the study. Farmers participating all had grazing rights from one or more of the four common land associations within the study site. Their association to which commons, is displayed by: Tebay (T), Brant Fell (B), Ravenstonedale (R) and Lonsdale (L). The last column indicates if a participant was included in the Q-methodology study. If not, this was due to being 'compounded sorts', as explained in chapter 5.

APPENDIX VI – Q-set

Statement ID	Statement
1	New woodlands in the uplands should be planted with consideration to flood protection
2	Farmland in the uplands should be used for agricultural production, not woodland planting
3	New woodlands in the uplands should be planted with consideration to water resource management
4	New woodlands in the uplands should be created with equal benefit to the environment, economy and society
5	New woodlands in the uplands should be planted with consideration to climate change
6	The tree planting consultation process between landowners/farmers, advisors and governmental departments is not good enough
7	New woodlands in the uplands can positively contribute to alternative and renewable energy sources
8	More woodlands in the NCA would negatively impact tourism and therefore the local economy
9	We need more resources on the ground for helping people get into woodland planting in the uplands
10	Planting trees in the uplands of the NCA is difficult.. There are so many opinions and values.
11	Economic incentives for tree planting are too low
12	Tree planting incentive programmes (grants/schemes) are too complex
13	There are concerns about uncertancies, such as payments, risk of planting failures and impacts
14	A big barrier to tree planting around here is the disagreement amongst ourselves/stakeholders
15	There is not enough information given about tree planting opportunities
16	Opinions towards woodland creation are heavily influenced by managers, agents and regulators
17	Opinions towards woodland creation are heavily influenced by family members, friends and neighbours
18	New woodlands in the uplands could help with creating a timber resource for the future
19	New woodlands in the uplands should be coniferous for production and the economy
20	New woodlands in the uplands should be mixed species and multifunctional
21	We should promote creation of productive woodlands in the uplands, as this provides employment opportunities in remote rural communities
22	New woodlands in the uplands should be native species for wildlife and people
23	New woodlands in the uplands would be beneficial for nature, wildlife & biodiversity
24	Enough is already done to protect and enhance the upland environment
25	There has been too much planting of woodland with native only species
26	More woodland in the uplands would be beneficial to the hill farmers in terms of caring and shepherding for livestock, shelter and shade
27	We have worked so hard to make the uplands suitable for farming... seems a real shame to now change that back
28	More woodlands would negatively affect the way of life for people deriving a living from the land
29	New woodland could help diversify the income to a business relying on upland areas for income
30	There is little consideration to landowners/managers/farmers trying to make a living from the land
31	More woodland in the uplands could encourage more outdoor leisure activity
32	The rights of people to enjoy the beauty of the landscape is more important than making profits from the land
33	It is important to have woodlands in the uplands – it is good for our mental and physical health
34	More woodland in the uplands would help in creating a sense of wilderness
35	Increasing woodlands on the fells of the NCA would negatively change the identity and local cultural heritage
36	I support creation of new woodlands, but it has to be done in tune with the landscape
37	The characteristic landscape of the fells in the NCA would be ruined if there were more trees up there
38	The use of the land for pastoral farming is more aesthetically pleasing than woodland on the fells
39	Woodlands should be planted with future generations in mind
40	A lot of the recent planting in the uplands has been of scrub species... It's no good for man nor nature
41	I am concerned about a negative irreversible change in land use that tree planting would entail
42	We have enough woodland in the uplands of the Howgill Fells NCA
43	Tree planting schemes are too short in duration
44	When planting trees in the NCA, we need to respect the rights of the commoners/landowner
45	Some woodland planting in the NCA is ok, just not too much
46	It is a waste of time planting trees up on the Howgill fells - they will struggle to grow
47	It is difficult to combine the management of upland farming with woodland creation on the fells of the NCA

APPENDIX VII – Q Results

Participant ID	Factor 1	Flag	Factor 2	Flag	Factor 3	Flag	h2
1	0.56	Flagged	-0.47		0.28		0.61
2	0.32		-0.25		0.53	Flagged	0.45
3	0.42	Flagged	-0.37		0.36		0.45
4	-0.63	Flagged	-0.19		-0.22		0.49
5	0.46		-0.03		0.61	Flagged	0.59
6	0.51		-0.16		0.61	Flagged	0.66
7	-0.35		0.60	Flagged	-0.08		0.49
8	0.11		0.23		0.47	Flagged	0.29
9	0.09		0.58	Flagged	0.41		0.51
10	0.60	Flagged	0.00		0.39		0.51
11	0.36		0.16		0.68	Flagged	0.62
12	-0.25		0.83	Flagged	0.00		0.75
13	0.03		0.67	Flagged	0.22		0.50
14	0.63	Flagged	-0.45		0.32		0.69
15	-0.28		0.77	Flagged	-0.02		0.67
16	-0.21		0.50	Flagged	-0.16		0.32
17	0.81	Flagged	-0.30		-0.09		0.75
18	0.61	Flagged	0.03		0.37		0.51
19	0.68	Flagged	-0.27		0.46		0.74
20	0.53		0.15		0.51		0.56
21	0.62	Flagged	0.08		0.49		0.63
22	-0.12		0.74	Flagged	-0.02		0.57
23	0.74	Flagged	-0.26		0.29		0.70
24	0.00		0.65	Flagged	0.09		0.43
25	-0.36		0.58	Flagged	-0.34		0.58
26	-0.11		0.69	Flagged	-0.34		0.60
27	-0.13		0.76	Flagged	0.05		0.60
28	0.35		0.33		0.29		0.32
29	0.57		-0.14		0.58	Flagged	0.68
30	0.16		0.31	Flagged	0.24		0.18
31	-0.14		0.57	Flagged	0.05		0.34
32	0.31		0.43	Flagged	-0.01		0.27
33	0.30		-0.08		0.51	Flagged	0.36
34	0.52	Flagged	0.05		0.00		0.27
35	0.39		-0.23		0.57	Flagged	0.54
36	0.25		0.42	Flagged	-0.14		0.26
37	0.08		-0.35		0.75	Flagged	0.69

38	0.45		-0.35		0.64	Flagged	0.73
39	0.72	Flagged	0.13		-0.05		0.53
40	0.65	Flagged	-0.43		0.28		0.69
41	0.26		-0.15		0.61	Flagged	0.46
42	0.04		0.09		0.49	Flagged	0.25
43	0.78	Flagged	-0.29		0.10		0.70
44	0.64	Flagged	-0.25		0.40		0.63
45	0.64	Flagged	0.00		0.21		0.46
46	0.25		0.50		-0.48		0.54
47	0.71	Flagged	-0.25		0.37		0.70
48	0.62	Flagged	-0.20		0.41		0.59
49	0.68	Flagged	-0.05		0.18		0.50
50	0.53	Flagged	0.13		0.39		0.45
51	0.43		0.48	Flagged	0.10		0.43
52	0.47		0.03		0.62	Flagged	0.60
53	0.44		-0.28		0.69	Flagged	0.74
54	0.39		0.26		0.53	Flagged	0.50
55	0.41	Flagged	0.38		0.20		0.35
56	0.06		0.57	Flagged	-0.13		0.35
57	-0.20		-0.05		0.82	Flagged	0.72
58	0.08		0.34		0.71	Flagged	0.62
59	0.60	Flagged	-0.61		0.26		0.80
60	0.43		-0.48		0.43		0.60
% Expln Var	21		16		17		
EV	12.6		16.6		10.2		

Table shows the loadings of each Q-sort (participant ID column) against the three rotated factors with exemplified Q-sorts flagged and compounded Q-sorts identified in green. Participant 4 loaded as bi-polar on factor 1 (identified in red) and disregarded along with the compounded Q-sorts from further analysis. The last column indicates the communality of each Q-sort, i.e. how much it holds in common with all the other Q-sorts (Watts & Stenner 2012). The last two rows allow for further understanding of the variance within the data. The percentage explained variance (% Expln Var) indicates the strength and explanatory influence of a factor and the total variance between all three factors should be >35% to be regarded as valid according to (Kline 2014). The % Expln Var here is 54%. Factor Eigenvalues (EV) are indicated in the last row and each factor should have an EV >1.00 to be valid (Kline 2014)

APPENDIX VIII – Extraction criteria & other equations used in chapter 5

Factor extraction criteria from Brown (1980)

Criteria	Equation	Comments
1. Factor Eigenvalues	$EV = V \times \frac{no.of\ Q\ sorts}{100}$	V = variance Factor eigenvalues (Kaiser-Guttman criterion) account for the variance of each factor. EV is widely accepted as the most commonly used criteria for the decision of how many factors to include in the analysis (Watts & Stenner 2012; Paige & Morin 2016) and ideally, one should extract factors with an EV of 1.00 or above (Kline 2014). Anything less would account for data variance equivalent to less than a single Q-sort. The EV criteria should be applied with consideration for the additional recommended criteria. In fact, some have commented that too much focus on the EV alone can, in large data sets, lead to an overly large amount of factors being included (Brown 1993b).
2. >2 sig. loading rule		This criteria requests that at least two sorts load at a correlations significant level. Which for this study is 0.39.
3. Factor variance	$\%\ expln\ var = 100 \times \frac{EV}{no.of\ Q\ sorts}$	Factor variance are two measures that are closely related and together indicate the strength and explanatory influence of a factor. The total factor variance (all factor variances together) should exceed 35% to be considered valid (Watts & Stenner 2012).

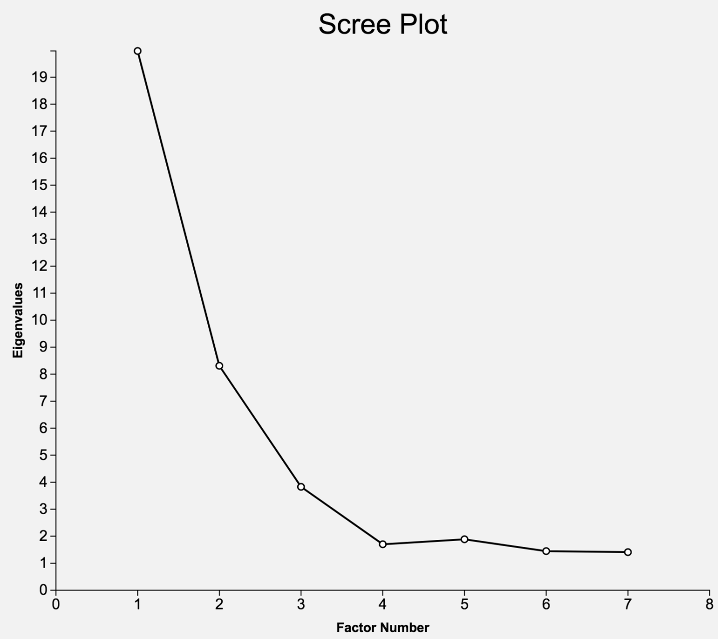
<table>
<tr><th>Criteria</th><th>Equation</th><th>Comments</th></tr>
<tr><td>4.

Cum % expln var</td><td></td><td>Communality is an indicator of how much each Q-sort holds in common with each other within a factor. A high communality indicates a highly representative Q-sort for that factor as a whole and this should exceed 35% to be regarded as valid (Watts & Stenner 2012).</td></tr>
<tr><td>5.

Humphrey's rule</td><td>$SE = 1 \div (\sqrt{no.}\, of\ statements$</td><td>SE = Standard error

Humphrey's rule states that, "a factor is significant if the cross-product of the two highest loadings exceeds twice the standard error" (Fruchter 1954). A less rigid approach is also acceptable, by only applying the standard error as a cut-off point (Watts & Stenner 2012). For this study, this amounts to a standard error of <u>0.30.</u> Humphrey's rule was thereafter applied to each factor as illustrated in table below. Factors fulfilling this criteria is marked by a *.

<table>
<tr><th></th><th>2 highest loadings on each factor</th><th>Cross-product</th></tr>
<tr><td>Factor 1</td><td>0.85 x 0.83</td><td>0.70*</td></tr>
<tr><td>Factor 2</td><td>0.72 x 0.69</td><td>0.50*</td></tr>
<tr><td>Factor 3</td><td>0.58 x 0.57</td><td>0.33*</td></tr>
<tr><td>Factor 4</td><td>0.35 x 0.31</td><td>0.11</td></tr>
<tr><td>Factor 5</td><td>0.36 x 0.35</td><td>0.13</td></tr>
<tr><td>Factor 6</td><td>0.22 x 0.27</td><td>0.06</td></tr>
<tr><td>Factor 7</td><td>0.33 x 0.26</td><td>0.09</td></tr>
</table>
</td></tr>
</table>

6. Cattells's Scree test (Cattell 1966)		The Cattell's Scree test is an additional resource in deciding on how many factors to retain. This test is traditionally and often used (Watts & Stenner 2012) in factor analysis, but was designed to assist PCA factor extraction, not CFA, and should therefore be tested against a PCA (Cattell 1966) and only considered a minor additional criteria to guide factor extraction in a CFA. The Scree test plots the EV's on a line graph. This follows the guidance on the number of factors to retain being determined by the point on the graph where between two factor, the line changes gradient (Cattell 1966) – Figure below illustrates a Scree test carried out on the seven preliminary factors. Everything to the right of this point is considered 'factorial scree' and disregarded (Kline 2014). 

Other equations used in chapter 5

Equation ID & reference	Purpose	Equation	Comments
10 (Brown 1980)	Significance level	$\alpha = 2.58\ \times\ (1\sqrt{no.}of\ statements$	α = significance level set at 0.01
12 (Spearman 1927)	Factor weights	$Factor\ weight = \dfrac{f}{(1-f^2)}$	f = factor loading
13 (Brown 1980)		$Z\ score = \dfrac{\sigma}{(\chi\ -\ \mu)}$	μ = mean of total weighted scores σ = standard deviation of total weighted scores for all items χ = total weighted score for item 1

APPENDIX IX – Crib sheet for interpretation

Example of crib sheet used for Factor 1 interpretation

Items ranked at +5
-
-
-
Items ranked higher by factor 1 than any other factor
-
-
-
Items ranked lower by factor 1 than any other factor
-
-
-
Items ranked at -5
-
-
-
Additional items of importance

APPENDIX X – Research timeline

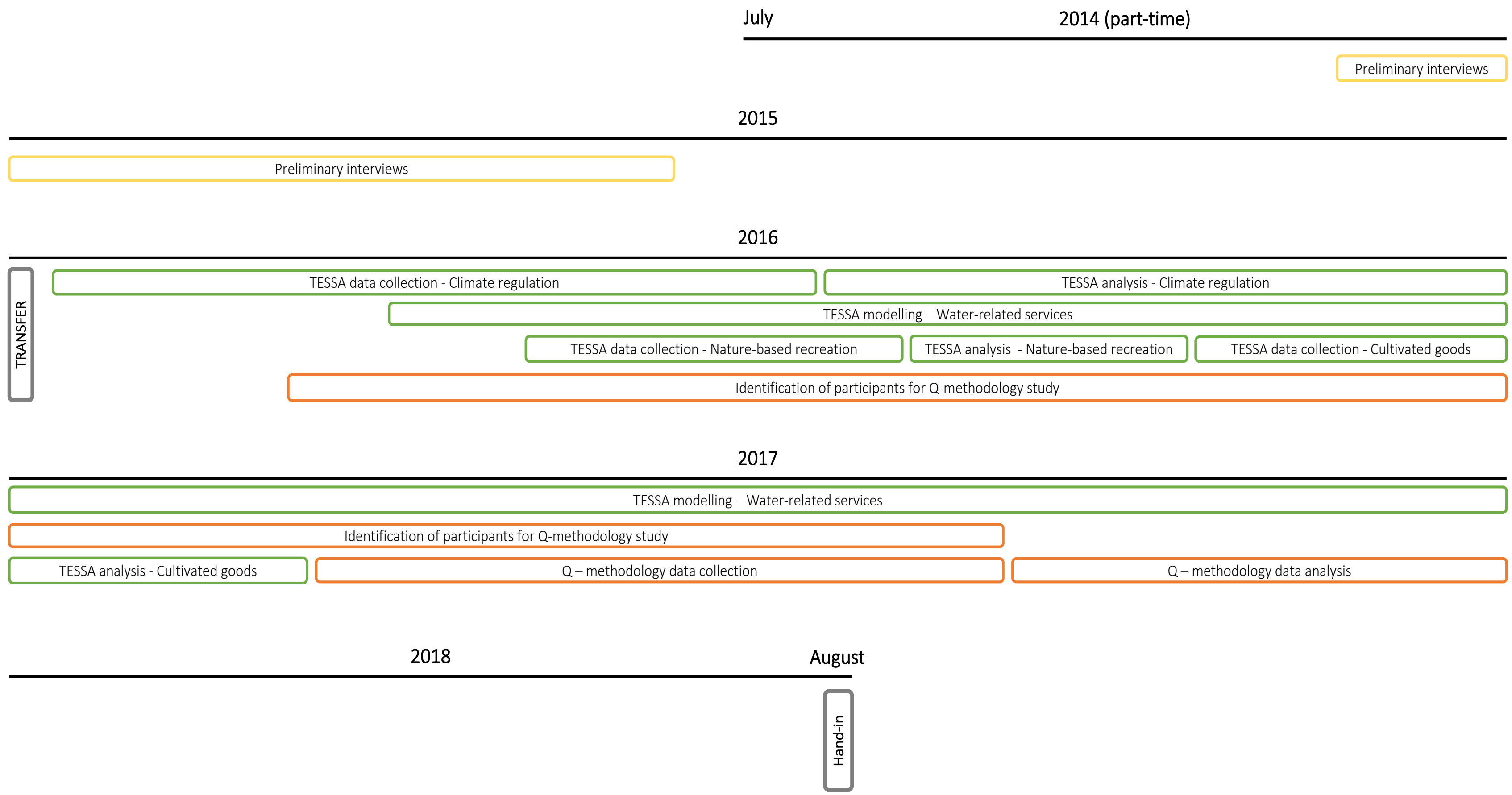


Figure shows a complete timeline of when separate parts of the study was carried out. Chapter 3 – preliminary interviews are illustrated in yellow. The TESSA assessment element are illustrated in green and finally, orange illustrates the Q-methodology elements.