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To what degree can Natural Flood Management truly be considered ‘natural’?

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Abstract

Natural Flood Management (NFM) is a strategy that aims to reduce flood risk by working with natural catchment features and processes. This study analyses the concept of NFM, by focusing on its definition and by exploring what is meant by the word ‘natural’ in the context of environmental restoration. A mixed-methods approach was adopted through the use of GIS mapping, palaeoenvironmental reconstruction and semi-structured interviews to assess the extent to which four selected NFM sites in the UK can truly be considered ‘natural’. The analysis showed that due to the differing definitions of NFM in common usage, it was not possible to declare an NFM site as being completely ‘natural’; however, the long-term environmental data demonstrated that Pott Shrigley and Crompton Moor were more ‘natural’ than Coalburn and Glenderamackin. Interviews with NFM industry professionals evidenced that flood management related nomenclature can be a point of confusion, and further highlighted the need for all stakeholders to have shared expectations of what an NFM project will bring. This study also illustrates how NFM may evolve with future climate projections, and therefore questions the extent to which ‘Natural’ Flood Management is the most suitable term to describe it.

Keywords: Natural Flood Management, tree planting, flooding, Nature-based Solutions, Working with Natural Processes

Contents

List of Abbreviations

BNG	Biodiversity Net Gain
BP	Before Present
cal.	Calibrated
CAP	Common Agricultural Policy
CBFM	Catchment Based Flood Management
CSO	Combined Sewer Overflow
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
ELMS	Environmental Land Management Schemes
EU	European Union
FCERM	Flood and Coastal Erosion Risk Management
FRM	Flood Risk Management
FRMP	Flood Risk Management Plan
FWMA	Flood and Water Management Act
GIS	Geographic Information System
IUCN	International Union for Conservation of Nature
LULC	Land Use Land Cover
NbS	Nature-based Solutions
NFM	Natural Flood Management
NGO	Non-Governmental Organisation
NRW	Natural Resources Wales
NTAG	National Technical Advisory Group
OS	Ordnance Survey
RBMP	River Basin Management Plan
RCP	Representative Concentration Pathway
SEPA	Scottish Environmental Protection Agency
SFM	Sustainable Flood Management
SuDS	Sustainable Drainage Systems
UKCP18	United Kingdom Climate Projections 2018
WFD	Water Framework Directive
WWF	World Wildlife Fund
WwNP	Working with Natural Processes

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

Natural Flood Management (NFM) involves techniques that aim to work with the environment, by restoring, enhancing and altering natural catchment features, to manage the sources and pathways of floodwaters (SEPA, 2016). This counters the use of traditional, hard-engineered defences that aim to prevent flooding, by working with the environment, rather than against it. NFM has grown in popularity over the last decade and has become a key component of the UK's flood management strategy (Dadson *et al*., 2017). However, NFM sits within a range of flood management related nomenclature, which can be a point of confusion, thus complicating its delivery. There is no singular definition of NFM, which leaves the concept open to interpretation, and often results in different expectations of what NFM will deliver. This study will investigate one interpretation of NFM; namely that it should restore the natural landscape for flood mitigation benefits and evaluate how truly 'natural' NFM is considered to be.

NFM aims to reduce flood risk by slowing the flow of water across the landscape using a range of different techniques (Wren *et al*., 2022). These include, for example, tree planting, leaky barriers, offline storage, and river channel restoration. A number of NFM projects across the UK have proved to be successful, including the Defra pilot project 'Slowing the Flow at Pickering' (Defra, 2011). Here, it was estimated that the NFM measures, namely woodland creation, debris dams and offline storage, reduced the flood peak of the Boxing Day 2015 flood event by 15-20% (Slowing the Flow Partnership, 2016). No properties on Beck Isle were flooded during this event, despite having been flooded by previous events of a similar magnitude (Slowing the Flow Partnership, 2016). This evidences the effectiveness of NFM, and demonstrates its importance both within flood management, and also at a community level. Despite this, NFM is not yet fully incorporated into the flood management agenda due to a range of barriers, which have been identified in the literature. These include a lack of catchment-scale evidence, limited funding, and poor cooperation between stakeholders (Wingfield *et al*., 2021). One issue that has not been addressed in the literature, however, is the terminology surrounding this approach to flood management, including what is meant by the word 'natural'. This study aims to explore the concept of NFM, its definition, and whether it truly meets its goals, through the following aim and objectives.

1.1 Aim and Objectives

Aim: To evaluate the degree to which Natural Flood Management (NFM) can truly be considered 'natural' and to consequently assess the importance of restoring the 'natural environment' as a flood management technique.

Objective 1: Map the land cover of each NFM site from the mid-1800s to the present, to determine whether NFM interventions are representative of the historic environment.

Objective 2: Analyse palaeoenvironmental proxy data to determine whether NFM interventions are representative of the mid-Holocene environment.

Objective 3: Conduct interviews with flood management stakeholders to assess the current understanding of how 'natural' NFM is and the importance of its 'naturalness' within flood management.

Objective 4: Evaluate the significance of the term 'natural' within NFM.

This research is necessary because NFM is being more frequently encouraged by organisations such as the Environment Agency and Defra, including Defra's 25 Year Environment Plan (Defra, 2018a). Therefore, a robust and shared understanding of the concept is important as a basis to ensure successful implementation. Whether or not NFM truly restores the 'natural' environment, the approach needs to be fully understood for it to become a part of mainstream flood management. This will be equally important in supporting the Environmental Land Management Schemes, which will replace the EU Common Agricultural Policy and encourage adoption of methods like NFM on private land. Furthermore, this project takes a novel approach by incorporating methods that are not usually used in conjunction with one another. These are GIS mapping, palaeoenvironmental reconstruction and semi-structured interviews, combining spatial, quantitative and qualitative techniques. The results of this research will provide a comprehensive evaluation and unique insight into NFM.

1.2 Thesis Structure

Chapter 2: Literature Review

Here, the foundations of the literature surrounding flood management in the UK will be outlined, with an in-depth focus on the nomenclature and definition of NFM. The successes and challenges of NFM will be explored, providing examples of published studies to establish its place within flood management. Finally, the gaps in this research field will be identified, justifying the importance of this study.

Chapter 3: Methodology

A methodological framework will be introduced in Chapter 3, including an overview of the study sites, and descriptions of the data collection and analyses. The limitations of the selected methods will also be addressed.

Chapter 4: Results

Results from Objectives 1 to 3 will be presented here, which will include the historical land cover maps, taxa representative of the mid-Holocene and the codes from the interviews. The general trends and findings will be analysed.

Chapter 5: Discussion

This chapter will bring together the results from Objectives 1 to 3 in order to address Objective 4: to evaluate the significance of the term 'natural' within NFM. It will start by comparing the land cover and palaeoenvironmental analysis from Objectives 1 and 2, and will then use the results of the interviews to explore these outcomes further. The remaining interview themes will follow this, with reference to how 'natural' NFM is considered to be throughout. The findings will be discussed in the context of the wider literature examined in Chapter 2.

Chapter 6: Conclusion

The final chapter will draw upon all elements of this research to address the degree to which NFM can truly be considered 'natural'. The limitations of the study will be acknowledged and recommendations for future research will be made.

This chapter has briefly introduced Natural Flood Management and some of the issues surrounding its definition and aim. It has outlined the goal of this research, as well as justifying its importance in the context of the current and future flood management agenda. Finally, the structure of the thesis has been defined, and the forthcoming chapters have been summarised.

CHAPTER 2: LITERATURE REVIEW

This chapter synthesises the literature surrounding flood management in the UK, with a particular focus on NFM. The review starts by outlining flood risk in the UK and the way that it is managed through government policy. It then focuses on the terminology used within flood management and begins to contextualise the place of NFM within the broader nomenclature. Literature published on NFM is explored further to build a picture of what is already known, and where developments need to be made.

2.1 UK Flood Risk

Flooding is a major natural hazard faced by the UK; for example, the Environment Agency reports that 1 in 6 people in England are at risk of flooding from rivers and the sea (Environment Agency, 2022). The main factors affecting UK flood risk are those related to climate change and Land Use/Land Cover (LULC) change; both of which can increase the likelihood of fluvial, pluvial, coastal and groundwater flooding (Miller and Hutchins, 2017). This section will explore the effect of changing climate conditions on flood risk in the UK by the mid to late 21st century, and the factors that will influence it.

2.1.1 Climate Change

As a result of climate change, it is expected that a warmer atmosphere, and its ability to hold more moisture, will lead to more frequent and intense precipitation events (Kundzewicz *et al*., 2005). Although rainfall projections across the UK are varied, it is generally accepted that winter rainfall will increase (Met Office, 2022; Prudhomme *et al*., 2013). Kendon *et al.* (2022) report that UK winters between 2012 and 2021 were 26% wetter than the 1961-1990 average, and the Environment Agency (2021a) states that winter rainfall could increase further, by up to 13% in England by 2080. Figure 2.1 shows the projected winter precipitation anomaly in England for the period 2060-2079 based on the 1981-2000 average (Met Office, 2023). The maps demonstrate the projections under different Representative Concentration Pathways (RCPs), and at varying probabilities. Across the RCP scenarios, the 50th percentiles indicate that winter rainfall is expected to increase by up to 20% based on the 1981-2000 average. This is likely to exacerbate flooding from both fluvial and surface water sources (Miller and Hutchins, 2017). It was noted as early as Horton (1933) that antecedent conditions play an important role in the outcome of a heavy rainfall event. For instance, if precipitation has already occurred, the ground may be saturated and therefore not receptive to any further infiltration. This could create runoff via overland flow and increase the likelihood of both pluvial and fluvial flooding (Bennett *et al*., 2018). On the other hand, it is projected that summers in England will become drier; Figure 2.2 shows that average summer precipitation could be up to 40% less than current levels by 2079, when reviewing the emissions scenarios under the 50th percentile (Met Office, 2023). If drought conditions precede an intense rainfall event, this could lead to flash flooding, as water cannot infiltrate the dry land (Archer and Fowler, 2018). Therefore, it is not only the projection of increased rainfall that is of concern, but also the antecedent environmental conditions that may exacerbate an event.

Met Office
Hadley Centre

Winter precipitation anomaly in England
for 2060-2079 minus 1981-2000

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Figure 2.1: *Winter precipitation anomaly in England for 2060-2079 (Met Office, 2023)*

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Figure 2.2: *Summer precipitation anomaly in England for 2060-2079 (Met Office, 2023)*

2.1.2 Land Use Land Cover: Urbanisation

LULC change is another factor contributing to changing flood risk in the UK (Sofia *et al*., 2017). Urbanisation is one of the primary drivers of LULC change as cities have grown over time (Howe and White, 2003). Due to increased demand for housing and other urban infrastructure, floodplains have been built on, which reduces the capacity for natural flood storage (Potter *et al*., 2016). The urban landscape itself also increases the risk of flooding, as impervious surfaces prevent water from infiltrating, forcing it to runoff into the nearest watercourse (Miller and Hutchins, 2017). This has been researched since the early 20th century, and a study by Leopold (1968) identified that urbanisation was the most "forceful" land use change affecting runoff in a catchment. Similarly, Hollis (1974) found that urban expansion of Canon's Brook in Essex – resulting in 16.6% of the catchment being impervious – caused mean monthly maximum floods to increase by 220%. Many contemporary studies demonstrate similar findings, for example Rose and Peters (2001) found that an urbanised catchment in Atlanta generated more runoff than similarly sized rural catchments. In the UK, Putro *et al*. (2016) reported an upward trend in annual and seasonal runoff in selected urban catchments within the Thames basin, compared to rural catchments. It is evident that removing naturally occurring processes within the water cycle increases flood potential, as the drainage system facilitates faster movement of runoff into the nearest watercourse, therefore increasing peak flows and subsequently flooding (Miller and Hutchins, 2017).

It is not only the urban landscape that increases flood risk, but also the infrastructure located within it. Pluvial flooding occurs when rainfall-generated runoff creates a flood prior to reaching the watercourse, which can be a result of an overwhelmed drainage system, or faults in the network such as burst pipes (Kaźmierczak and Cavan, 2011). Linked with this, combined sewer overflows (CSOs) are common in cities and rural areas. They are prompted by a need to reduce the amount of water in the combined drainage system by releasing wastewater into rivers (Hawkes, 2023). However, this increases river levels, affects water quality and enhances the risk of fluvial flooding (De Vleeschauwer *et al*., 2014). Grey infrastructure in cities is designed to transport water out of the system as quickly as possible, but over time this has caused more problems. Runoff is able to enter rivers faster due to the drainage network and impermeable surfaces, which increases fluvial flood risk. Not only this, but the infrastructure itself is less efficient than when it was first built. Increased water in the system, caused by population rise and additional rainfall due to climate change, means that systems cannot cope, thus leading to faults and the need for CSOs (Li *et al*., 2020). In 2022, there were 301,091 monitored spill events totalling 1,754,921 hours in duration (Environment Agency, 2023). In order to alleviate this increased flood risk, green infrastructure, such as Sustainable Drainage Systems (SuDS), has been encouraged since the Pitt Review was published in

2008. This will be explored further in Subsection 2.2.2.

2.1.3 Land Use Land Cover: Agriculture

LULC change is not limited to urban areas; it is also seen in rural settings. Since the end of the second world war, up until the early 21st century, agriculture has undergone intensification to increase production, which resulted in land management changes (Posthumus *et al*., 2008). Drivers for this were social and technological changes, but also the EU Common Agricultural Policy (CAP), which subsidised farmers for increased production (Pe'er *et al*., 2020). This intensification included physical land changes, such as using floodplains for agricultural production, which removed rivers' natural overflow storage (Howe and White, 2003). Similarly, riparian buffer zones were removed, reducing the capacity for runoff storage (O'Connell *et al*., 2007). In terms of farming techniques, heavy machinery was frequently used, causing soil compaction, and reducing the ability of water to infiltrate, thus leading to increased runoff (Howe and White, 2003). In addition to this, leaving fields bare in winter facilitates runoff in a similar way, as the ground becomes hard and water cannot infiltrate, simultaneously reducing water quality through increased sediment loads in rivers (Howe and White, 2003). All of these factors lead to increased flood risk, as less water is stored in the landscape. Figure 2.3 summarises some of the LULC changes discussed in this subsection.

Figure 2.3: *Agricultural LULC changes. (a) pre-war agricultural landscapes. (b) post-war land modifications. (Taken from O'Connell et al., 2007)*

This section has illustrated the current and future picture of UK flood risk, with acknowledgement of the factors exacerbating the problem. A combination of climate change projections and LULC change increases uncertainty, demonstrating the need for strategic future planning. The next section will examine UK policy related to flood risk management.

2.2 Flood Risk Management Policy

Effective policy concerning Flood Risk Management (FRM) is fundamental to ensure that the UK is better protected and prepared for flooding. Werritty (2006) acknowledged the paradigm shift in UK FRM from structural defences to a more sustainable approach. This section will explore the policies relating to that paradigm shift, with a focus on current and future policy changes.

2.2.1 Early 21st Century Policy

Flood management in the UK has evolved over time, particularly since the turn of the 21st century. The Water Framework Directive (WFD) 2000/60/EC prompted focus on water management, both in terms of quality and quantity; its implementation of River Basin Management Plans (RBMPs) was one of the first steps towards a more joined up approach to FRM. The overarching aim of the WFD was for all water bodies in the EU to achieve "good" status and restoration was encouraged as a way of meeting this target. In this context, river restoration refers to restoring natural processes and channels, which could be on floodplains or through the removal of hard-engineered structures, for example (Environment Agency, 2013). River restoration has, therefore, been entwined into policy since the early 2000s. It is noted that the WFD was updated post-Brexit to become the Water Environment Regulations (2017), which extended the river restoration goals. After the 2007 summer floods in the UK, the Pitt Review appraised FRM and within its 92 recommendations, advised that "legislation should be a single unifying Act that addresses all sources of flooding, clarifies responsibilities and facilitates flood risk management" (recommendation 28) (Pitt, 2008). This resulted in the Flood and Water Management Act (FWMA) (2010), which aimed to address the shortcomings identified by Sir Michael Pitt. The Pitt Review also acknowledged that greater emphasis should be placed on working with natural processes (recommendation 27), which has led to changes in the way that flooding is managed (Pitt, 2008). The guidance document on Working with Natural Processes to Manage Flood and Coastal Erosion Risk highlights both the move away from structural defences and the drive towards a joined-up approach to FRM (Environment Agency, 2010).

Despite the recommendations from the Pitt Review and subsequent guidance documents, around a decade later, Wingfield *et al.* (2019) suggested that a lack of policy-relevant research has hindered the move towards holistic catchment flood management. They reviewed the evidence surrounding NFM and acknowledged that such measures were not being implemented as often as they could be. They state that although some NFM projects have received government support (e.g., Holnicote, Somerset and Belford, Northumberland), the approach remains fragmented and has not yet been fully adopted as a FRM strategy. This is further evidenced by the Review of Policy for Development in Areas at Flood Risk, which advises an integrated approach to flood management and encourages “making as much use as possible of Natural Flood Management techniques” (Defra, 2021a). It appears that there has been a drive to incorporate NFM into policy in recent years, but it still requires development and consolidation before it can become a widespread intervention (Black *et al*., 2021).

2.2.2 Policy Developments Since 2018

Looking towards the future, the UK government has created policies and strategies to address current and future environmental issues, which are linked together by the Environment Act. In 2018, Defra published its 25 Year Environment Plan, which sets out actions to “leave the environment in a better state than it was found” (Defra, 2018a). One of the goals is to reduce the risk of harm from environmental hazards, such as flooding and drought. NFM is suggested as a way of doing this, and working with the environment is strongly recommended through the likes of tree planting and peatland restoration (Defra, 2018a). This focus on NFM is encouraging, and addresses some of the shortcomings identified in the past. Additionally, the 25 Year Environment Plan emphasises the importance of implementing SuDS to reduce flood risk (Defra, 2018a). In 2023, the government confirmed Schedule 3 of the FWMA (2010), which includes the requirement for new developments to include SuDS that have been authorised by a SuDS Approving Body (Defra, 2023a). This goes some way to address criticisms raised by industry experts, regarding the length of time it took for Schedule 3 to be implemented (Nguyen, 2023). The use of SuDS further highlights the shift away from hard-engineered structures to softer strategies that aim to work with the environment rather than against it.

Linked with this, the Environment Act (2021) states that new developments granted planning permission under the Town and Country Planning Act (1990), from November 2023, must deliver a Biodiversity Net Gain (BNG) of 10% on or near the new site (Defra, 2023b). While this is not directly related to flood management, a number of NFM activities can be used as a way to achieve BNG, for example, tree planting not only facilitates rainfall interception, but also creates habitats and wildlife corridors (Natural England, 2022). This demonstrates how environmental targets can be met holistically, by recognising the multiple benefits of different activities. Subsection 2.5.2 will investigate this further.

Another policy related to FRM is the National Flood and Coastal Risk Management (FCERM) Strategy (Environment Agency, 2020). As part of the FWMA (2010), the Environment Agency is under a statutory duty to develop, apply and monitor this strategy for England. This is supplemented by the FCERM Strategy Roadmap, which outlines the actions planned for between 2021 and 2026 (Environment Agency, 2021b). As with the aforementioned policy, NFM is prioritised as a way of mitigating flood risk, highlighting its growing importance and acceptance as a strategy. The roadmap states that risk management authorities will double the number of NFM projects delivered as part of the FCERM Investment Programme, in a bid to make greater use of Nature-based Solutions (NbS) to enhance flood resilience and nature recovery (Environment Agency, 2021b). At a local level, Flood Risk Management Plans (FRMPs) are statutory plans that set out how to manage flood risk in nationally identified flood risk areas (Environment Agency, 2022).These are divided into river basin districts, and the current plans cover the period 2021-2027. Complementary to the FCERM Strategy Roadmap, FRMPs encourage the uptake of NFM and also highlight the importance of collaborative working amongst stakeholders (Environment Agency, 2022). Therefore, the profile of NFM has been raised; an improvement on previous policy, though with results yet to be seen.

Further plans are presented by the Environmental Land Management Schemes (ELMS), which replace the EU CAP post-Brexit. Land managers will be paid to manage their land in an environmentally sustainable way in order to meet the goals of the 25 Year Environment Plan (Defra, 2021b). This includes the Sustainable Farming Incentive, Local Nature Recovery and Landscape Recovery. Although ELMS are not planned to be launched until 2024, it is expected that the likes of large-scale tree planting and peatland/salt marsh restoration – techniques that can alleviate flood risk – will be part of the Landscape Recovery scheme (Defra, 2021b). Globally, the “30 by 30” initiative aims to conserve 30% of land and sea for biodiversity and will be a driver in reversing the decline of nature (Natural England, 2023). The UK has incorporated this into the Nature Recovery Network with the goal of restoring and recovering habitat-rich sites (Defra, 2022). Environmental restoration will, therefore, play a key role in future policy.

2.3 Flood Management Terminology

This section concentrates on the terminology used in flood management. Previously, it was highlighted that FRM policy should be joined-up in its approach; a barrier to this is perhaps the varying terminology used to describe similar management practices. While the focus will be on NFM, an assessment of the broader nomenclature will be undertaken to determine whether there have been changes over time, and the extent to which any terminological changes have impacted on flood management. Specific terminology will also be explored in more depth to contextualise the aim of this research.

2.3.1 Flood Risk Management Nomenclature

Lashford *et al.* (2022) discuss the rise of terminology relating to 'sustainable catchment-wide flood management'; a phrase that the authors suggest should be used to unify flood management. The paper notes thirteen different terms that describe similar concepts within FRM, reflecting the long-standing fragmented approach to its governance. The phrase Sustainable Flood Management (SFM) is used widely in the literature and is generally accepted to be an umbrella term that encompasses a range of flood management techniques, including NFM (Lane, 2017; Lashford *et al.,* 2022). This terminology was developed in Scotland in the early 2000s, as a result of the EU WFD 2000/60/EC, which was transposed into Scots law as the Water Environment Water Services Act (2003). This placed a duty on promoting and incorporating SFM when addressing the issue of flooding. However, the concept of SFM was not clearly defined when the Act was passed, reinforcing the complications with FRM policy outlined by the previous subsection. Although defined a year later by the Scottish Executive's National Technical Advisory Group (NTAG) on Flooding, Howgate and Kenyon (2009) acknowledge that there are varying definitions of SFM – some that focus on natural processes and others that place emphasis on resilience. The ambiguity of the definition questions the extent to which policy can be implemented successfully. This is comparable with research undertaken by Salama (2007) regarding the use of the term 'sustainability'. While a slightly different research field, Salama identified that sustainability is defined differently depending on the context (e.g., environment, architecture, tourism etc.) and how this causes confusion when discussing sustainable development. He states that because of the fragmentation, "the true essence of sustainable development is rarely met" (Salama, 2007). Defining a concept clearly is therefore important to ensure it has a shared understanding.

As stated, SFM is seen as a general term incorporating various FRM practices. The roots of NFM can be traced back to a Scottish WWF report (2007), perhaps indicating a connection with SFM as both terms were developed in Scotland around a similar time. Bracken *et al.* (2016) also identify NFM as a sub-field of SFM, which specifically works with natural and morphological processes. However, Lane (2017) states that NFM is a sub-set of Catchment-Based Flood Management (CBFM), which focuses on natural approaches to manipulating river flow. While both concepts appear to be similar, there is discrepancy as to where NFM fits within the nomenclature. This is further exemplified by the term Working with Natural Processes (WwNP). Wingfield *et al.* (2019) state that the term WwNP lacks clarity due to its interchangeable use with the term NFM. This is exemplified by the WwNP Evidence Directory, which suggests that the two terms have the same meaning, but that WwNP is the preferred phrase (Burgess-Gamble *et al.,* 2018). However, Lane (2017) distinguishes between NFM and WwNP, stating that WwNP is more holistic and considers a range of environmental benefits, not just those limited to flood management. Lashford *et al.* (2022) take a slightly different stance and imply that NFM is part of the more general term WwNP. Again, there is a slight disagreement in the literature regarding the similarities and connections between different flood management terminology. It seems that terms are viewed subjectively amongst authors, however, it is feasible that a lack of unifying vocabulary could make it difficult to implement integrated approaches, particularly if one term is interpreted differently by multiple people.

Another concept that fits within FRM nomenclature is Nature-based Solutions (NbS). These are "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature" (IUCN, 2022). NbS are often associated with their co-benefits, for example, restoring forests may reduce flood risk downstream, enhance biodiversity and provide carbon storage (Seddon *et al*., 2020). Therefore, NbS are not exclusively concerned with flood management, but their co-benefits certainly extend to flood mitigation. NbS are often incorporated in urban areas, such as green roofs, which not only retain water, but also increase biodiversity and contribute to reducing the effect of the urban heat island (Huang *et al*., 2020; Kabisch *et al*., 2017). However, conflict arises from the WwNP Evidence Directory, which describes NbS as an alternative term to NFM (Burgess-Gamble *et al.,* 2018). Yet, Bark *et al.* (2021) state that NFM is actually an example of NbS, suggesting NbS is a broader term. To complicate matters further, Castellar *et al.* (2021) assess the conceptualisation of NbS but make no reference to NFM. Instead, they discuss NbS in the context of creating ecosystem services and addressing urban challenges through green infrastructure. Similarly, Huang *et al.* (2020) consider NbS in relation to FRM but do not directly refer to NFM; they, instead, emphasise the role NbS can play in mitigating pluvial flooding. After reviewing the literature, it is unclear as to whether NbS and NFM are considered to be the same, or whether there is any connection between them. However, it is logical to assume that NbS are much broader than NFM, as they relate to the enhancement of a fuller range of ecosystem services, whereas NFM focuses on flood mitigation. The differing viewpoints certainly complicate FRM and help to demonstrate why policy lacks unity and integration.

2.3.2 Defining Natural Flood Management

The previous subsection analysed the relationship between NFM and other FRM nomenclature. The definition of NFM will now be explored in depth to determine how it can be interpreted, and whether this has an impact on its application. After reviewing both academic and grey literature, there is no singular definition that is used by all authors or organisations, already hinting towards some inconsistencies. The definitions used by academics and organisations can be found in Tables 2.1 and 2.2; common key words have been highlighted for further discussion. These definitions were obtained by searching the term ‘Natural Flood Management’ in Google and Google Scholar, in addition to searching within documents produced by flood management organisations in the UK.

Table 2.1: *Definitions of Natural Flood Management from academic literature. 'Based on' refers to definitions that have been quoted from, or share similarities with, already-published definitions. Key words are highlighted.*

Source	Definition
Bark *et al.*, 2021 (Based on SEPA's definition)	NFM involves "techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters".
Black *et al.*, 2021	Natural Flood Management (NFM) aims to take advantage of and work with natural processes to reduce flood risk, whilst delivering wider improvements in environmental quality and societal benefits in river catchments.
Connelly *et al.*, 2020 (Based on EA's definition)	These measures include techniques, such as land use management and river restoration, that can be implemented to 'help to protect, restore and emulate the natural functions of catchments, floodplains, rivers and the coast'.
Cooper *et al.*, 2021	The overall essence of the concept is to holistically apply general flood management and hydrological principles to develop techniques at any scale within the catchment, which either replicate or enhance natural processes to demonstrably reduce flood risk.
Dadson *et al.*, 2017	NFM seeks to restore or enhance catchment processes that have been affected by human intervention. These activities aim to reduce flood hazard, while also sustaining or enhancing other potentially significant co-benefits including enhanced ecosystem services (aquatic, riparian and terrestrial) such as greater biodiversity, improved soil and water quality, carbon sequestration, reduced soil erosion, greater agricultural productivity and improved public health and well-being.
Ellis *et al.*, 2021 (Based on SEPA and EA's definitions)	NFM aims to reduce flood risk by protecting, restoring and emulating the natural hydrological and morphological processes, features and characteristics of catchments using environmentally sensitive and beneficial techniques to manage sources and flow pathways of flood waters.

Garvey and Paalova, 2022 (Based on Dadson *et al's.,* 2017 definition)	NFM 'seeks to restore or enhance catchment processes that have been affected by human intervention' in order to mitigate flood risk by 'slowing the flow' of water from the upper catchment to downstream settlements where flood risk may be high.
Holstead *et al.,* 2017 (Based on Wentworth's, 2011 definition)	The alteration, restoration or use of landscape features to reduce flood risk.
Lane, 2017 (Based on SEPA's definition)	Natural Flood Management involves techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters. These techniques include the restoration, enhancement and alteration of natural features and characteristics, but exclude traditional flood defence engineering that works against or disrupts these natural processes.
Lashford *et al.* 2022 (Based on SEPA's definition)	". . . involves techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters. These techniques include the restoration, enhancement and alteration of natural features and characteristics, but exclude traditional flood defence engineering that works against or disrupts these natural processes."
Nicholson *et al.,* 2019 (Based on Wentworth's, 2011 definition)	The alteration, restoration or use of landscape features to reduce flood risk.
Waylen *et al.,* 2018	NFM aims to slow the flow of water through the landscape, so entails working with new groups for catchment-scale co-ordination of land-use and river management.
Wells *et al.,* 2020	FRM measures which work with natural hydrological processes to retain and slow water within the upper catchment, while creating wider benefits beyond FRM such as habitat creation, diffuse pollution reduction, and sediment capture.
Wilkinson *et al.,* 2019 (Based on SEPA's definition)	Natural Flood Management (NFM) is promoted as a method that can reduce flood risk by the alteration, restoration or use of landscape features.
Wingfield *et al.,* 2019	Natural Flood Management harnesses natural hydrological processes to slow water flowing through the landscape, thereby mimicking natural environmental conditions.

Table 2.2: *Definitions of Natural Flood Management from grey literature. Key words are highlighted.*

Source	Definition
Environment Agency, 2017 (England)	Natural Flood Management (NFM) helps manage flood and coastal erosion risk. It does this by protecting, restoring and emulating the natural processes of catchments, rivers, floodplains and coasts.
Government POSTnote (Wentworth, 2011)	The alteration, restoration or use of landscape features.
Natural Resources Wales, 2021	Natural Flood Management is a means of working with natural processes by implementing nature-based interventions to help reduce the risk of flooding.
NFM Manual (Wren *et al.*, 2022)	The aim of NFM is to restore or mimic the natural functions of catchments, floodplains, rivers and the coast, to reduce the risk of flooding from all sources.
SEPA, 2016 (Scotland)	Natural Flood Management involves techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters. These techniques include the restoration, enhancement and alteration of natural features and characteristics, but exclude traditional flood defence engineering that works against or disrupts these natural processes.
WWF, 2007	It works with the catchment's natural defences to slow the flow upstream and increase water storage in the whole catchment.

The earliest definition of NFM comes from the Scottish WWF and is introduced in A Manual for the Natural Management of River Floods (WWF, 2007). It states that NFM “works with the catchment’s natural defences to slow the flow upstream and increase water storage in the whole catchment” (WWF, 2007). This definition puts emphasis on the river catchment as a whole and describes how NFM can benefit the entire system. The document was published just a few years after the Scottish Water Environment Water Services Act (2003) was established, which stressed the importance of a joined-up approach to FRM. It is therefore plausible that when NFM was originally defined, it was based on the need for integrated catchment-based flood management. Although the catchment-based approach is now a common feature in flood management practices, it began to be recognised as a concept when the WFD 2000/60/EC was created. It is likely that this was brought into Scottish policy and subsequently later infiltrated into the first definition of NFM.

The most widely adopted definition across both the academic and grey literature is from the Scottish Environmental Protection Agency (SEPA). Here, NFM is defined as “…techniques that aim to work with natural hydrological and morphological processes, features and characteristics to manage the sources and pathways of flood waters. These techniques include the restoration, enhancement and alteration of natural features and characteristics” (SEPA, 2016). This definition is more specific compared to that of the WWF, however there is less emphasis on the catchment-based approach. It could be suggested that the concept of NFM has changed over time and is now more focused on working with natural hydrological processes. It is noteworthy that the original definition and the current most widely adopted definition come from Scotland (Scottish WWF and SEPA). Much of the work surrounding NFM has been undertaken in Scotland, and Waylen *et al.* (2018) acknowledge the Scottish Government’s support of non-structural approaches to FRM. Although NFM projects are taking place throughout the UK, Scotland seem to be pioneering both the concept itself, and its definition.

Despite Scotland’s leadership role, it is worthwhile to compare the definitions produced by the devolved nations. The NFM definitions from SEPA, the Environment Agency (EA) and Natural Resources Wales (NRW) can be seen in Table 2.2. A definition from Northern Ireland could not be sourced. The three definitions appear similar, in that they address the issue of flooding and emphasise that the concept is natural. However, when focusing on the word natural as an adjective, what follows is different depending on the source of the definition. SEPA mention “natural features and characteristics”, whereas the EA and NRW refer to “natural processes”. While these may seem similar, features and processes refer to different elements of a river catchment; features might include a river, woodland, and wetlands, whereas processes could be precipitation, runoff and interception. This makes it unclear as to what the aim of NFM truly is, which could complicate its delivery. When observing the other definitions in Tables 2.1 and 2.2, some refer to “natural functions” of river catchments (Connelly *et al.*, 2020; Wren *et al.*, 2022), which is closely related to the aforementioned “natural processes”. The aim of NFM differs depending on the noun that follows the word natural – either the aim is to restore/protect/emulate the features in the catchment or the way in which the catchment operates. It is unjust to declare one definition as correct, however, as the concept of NFM originated in Scotland, it perhaps suggests that the original intention was to focus on natural features. Despite this, when considering what restoring natural features or processes could entail, the results are in fact similar. Restoring natural features could include floodplain restoration or catchment woodland creation. However, restoring natural processes, such as flooding or water storage, could also involve floodplain restoration (to allow flooding) and woodland creation (to store water). This interpretation suggests that the differing definitions of NFM could produce the same result. One singular definition would reduce any discrepancies and potentially make NFM implementation easier.

When exploring the definitions further, Tables 2.1 and 2.2 highlight some common key words, including “restoration/restore” and “natural”. Defining these words could offer an interpretation as to what the aim of NFM should be. Restore means to “return something to an earlier good condition or position”, and natural – “as found in nature and not involving anything made or done by people” (Cambridge Dictionary, 2022a; 2022b). This considered, it could be suggested that NFM should convert the landscape back to its original condition prior to any LULC change. However, this is reliant on the remainder of the definition – restoring natural features may differ from restoring natural processes/functions, though they undeniably rely on one another for the catchment to operate. Simultaneously, restoring a process of a river catchment, such as flooding, may require the restoration of a natural feature – a floodplain. The features and processes operating in a catchment are therefore intrinsically linked. While restoring the ‘natural’ landscape may not be the sole intention of NFM, the fact that its definition can be interpreted in such a way demonstrates the need for clarity. Further to this, Lane (2017) acknowledges that some NFM measures may not be strictly ‘natural’, and that interventions labelled as ‘NFM’ are ‘natural’ to varying degrees. Using the example of impounded storage, Lane (2017) describes the measure as “rarely natural in its nature”, due to its hard-engineered structure. Implementing NFM becomes a challenge when there is no overarching definition, and, therefore, different interpretations of what is expected of NFM, which can limit its successful application. A clearer definition, and evidence as to what NFM should involve, may encourage more frequent application. It would therefore be beneficial for this to be communicated through FRM policy and early discussions with all stakeholders: while there is encouragement to incorporate NFM, its precise purpose could be better explained.

2.3.3 Defining Restoration

The previous subsection reviewed flood management related terminology and explored the importance of the words ‘restore’ and ‘natural’. However, it is also valuable to examine restoration baselines and how they are defined. Burger *et al*. (2007) challenged whether a restored habitat should mimic an ideal, desired or previous ecosystem and questioned to what time period an environment should be restored. Similar difficulties may be encountered in the context of NFM; the aim is to restore natural features and processes, but the definition does not state when this restoration baseline should be. Shuker *et al*. (2015) acknowledged that restoration is limited by a lack of comparative pre-restoration data, which makes it difficult to restore a particular environment to a given time period. Further to this, Lee *et al.* (2014) describe the ‘Baseline Problem’ and acknowledge the difficulties with setting a reasonable and responsible baseline for restoration. This demonstrates how restoring the environment is not objective and cannot be generalised; baselines differ depending on the context. With the lack of clarity surrounding this, Soga and Gaston (2018) reviewed the concept of Shifting Baseline Syndrome (SBS), whereby an absence of past information about historical conditions distorts people’s interpretations of a baseline. Although a different context to NFM, Pauly (1995) acknowledged that marine scientists tend to perceive fish stocks at the beginning of their careers as an unaffected baseline condition, which demonstrates how an environmental baseline can be subjective, despite a ‘baseline’ being quite objective in its nature. Higgs *et al*. (2014) questioned the relevance of historical factors in a period of rapid environmental and cultural change and challenged their role in restoration ecology. They go on to describe two versions of restoration: restoration v1.0, which refers to traditional, historical based goals and restoration v2.0, which uses historical knowledge as a guideline instead of a template (Higgs *et al*., 2014). Figure 2.4 illustrates this concept in an attempt to expand on the traditional ideas of environmental restoration to better suit current needs.

This subsection has examined some of the issues with defining a baseline for restoration and questions the extent to which NFM can truly restore the environment for flood mitigation purposes. This research will use the mid-Holocene as a baseline, which represents the period 5000-7000 BP and depicts a landscape before human intervention. The selected NFM sites will be compared to the mid-Holocene to consider the extent to which this baseline is suitable.

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Figure 2.4: *Restoration v1.0 and v2.0 taken from Higgs et al., 2014*

2.4 Semantic Change

Section 2.3 demonstrated how the definitions of NFM and restoration can be interpreted in different ways, but it is also noteworthy to review other terminology within the broader environment related nomenclature that may have undergone semantic change. A lack of clarity surrounding particular words and definitions could lead to difficulties with target setting and implementation. For example, Castellar *et al.* (2021) explored the use of the phrase Nature-based Solutions, with a focus on the word 'nature'. They suggest that the notion of NbS is vague, which can cause confusion amongst those involved. The authors describe nature as an "empty signifier", implying that the word has been overused and its meaning has changed over time. The concept of empty signifiers stems from Brown (2016), who studied the word 'sustainability'. He declared that the word has "no precise content" due to its overuse and misuse, which enables decision makers to make "empty gestures" by using the term. Castellar *et al*. (2021) explored the meaning of the word nature and found that the "green factor" is commonly associated with it, referring to the presence of vegetation. They acknowledge that interventions, such as porous asphalt, may emulate natural processes (water infiltration), but because this lacks the "green factor", it is not typically considered as 'natural'. This is significant when defining the concept of NbS, as it suggests that interventions should appear to be visually natural by including an element of greenery. Due to the different interpretations of the word nature, the term NFM could, too, be subject to semantic change and interpretation.

2.5 NFM Case Studies

The previous section outlined how NFM, and other related terminology is defined, and explored where NFM fits within the general flood management nomenclature. This section will focus on examples of NFM, by reviewing some of the case studies discussed in academic and grey literature. It will explore the types of NFM, and the successes and challenges of established projects.

2.5.1 Types of NFM

NFM takes various forms, which are dependent on the catchment type and desired outcome. Generally, the aims of NFM are to reduce runoff and store water within rivers and their floodplains (SEPA, 2016). This illustrates the concept of 'slowing the flow', which seeks to reduce the speed at which water moves within a catchment (Dadson *et al.*, 2017). SEPA (2016) outlines the main NFM techniques, which are highlighted in Table 2.3. Examples of such techniques will be discussed in relation to specific NFM studies.

Table 2.3: *Examples of NFM divided into measure groups and linked to their main action (adapted from SEPA, 2016)*

Group	Measure Type	Main Action
Woodland Creation	• Catchment Woodland • Floodplain Woodland • Riparian Woodland	• Runoff Reduction • Runoff Reduction/Floodplain Storage • Runoff Reduction/Floodplain Storage
Land Management	• Land and Soil Management Practices • Agricultural and Upland Drainage Modifications • Non-floodplain Wetlands • Overland Sediment Traps	• Runoff Reduction • Runoff Reduction • Runoff Reduction • Runoff Reduction/Sediment Management
River and Floodplain Restoration	• Riverbank Restoration • River Morphology and Floodplain Restoration • Instream Structures (e.g., woody debris dams) • Washlands and Offline Storage Ponds	• Sediment Management • Floodplain Storage/Sediment Management • Floodplain Storage • Floodplain Storage

The concept of the catchment-based approach was introduced in Subsection 2.3.1 and is applicable when incorporating NFM measures into the landscape. It is reported by Wren *et al.* (2022) that NFM tends to be more successful when a combination of techniques is used across the catchment, which is the case for most examples in the literature. Table 2.4 outlines a selection of NFM case studies identified by the WwNP Evidence Directory and within the general NFM literature (Burgess-Gamble *et al*., 2018). It is noted that these case studies are not wholly representative of all NFM projects, however, they provide an insight into some of the successes and challenges of projects across the UK.

Table 2.4 demonstrates that most of the selected case studies incorporate more than one NFM measure, excluding Coalburn and Tarland Burn. Of the case studies in Table 2.4, tree planting is one of the most popular measures, which is often combined with leaky dams and offline storage, exemplified by Belford Burn, Eddleston, the Holnicote Estate, Pickering, and Sussex Flow Initiative. The repeated implementation of these measures implies their perceived effectiveness. Evidence from the Holnicote Estate supports this; debris dams, offline storage and woodland were created between 2012 and 2014 and no flooding was experienced by nearby vulnerable villages during the winter 2013/14 storms, despite them being regularly flooded in the past (National Trust, 2015). In a similar instance, NFM at Pickering (debris dams, bunds, and riparian woodland) performed successfully during rainfall events in both 2012 and 2015, reducing flood risk from a 25% annual chance to just 4% (McAlinden, 2016). Further to this, Eddleston incorporated a total of four different NFM techniques, including tree planting, leaky barriers, offline storage, and river channel restoration. Black *et al.* (2021) concluded that the combination of leaky barriers and riparian tree planting was most successful in increasing lag time; up to a 7.3-hour increase in the smaller catchments. This demonstrates the importance of combining techniques within a catchment, which appears to increase the chance of success. In smaller areas where only riparian tree planting was incorporated, Black *et al.* (2021) found that there was no significant increase in lag time. In this example, the combination of leaky barriers and tree planting could mean that the two measures were more beneficial than tree planting alone, or perhaps that leaky barriers were effective enough themselves, though this would require further investigation. In any case, the studies reinforce the notion that using a number of different NFM techniques provides valuable results.

Despite the aforementioned successes, some case studies required amendments to their study designs. For example, at Tarland Burn, a small bund was created on a major overland flow pathway, which had a capacity of 250m^3 and the aim to minimise sediment-rich overland flow reaching the nearby villages (Wilkinson *et al*., 2019). However, just two years after installation, the bund overflowed during storm Frank in 2015, as the upstream soils were fully saturated. Wilkinson *et al.* (2019) go on to suggest that a larger network of ponds would be more successful, ensuring that there is still capacity within the network during peak flows. The suggestion was based on the NFM at Belford Burn, which incorporated multiple offline storage ponds and reduced local peak flows during small, flashy events (Nicholson *et al*., 2019).

Despite the pond network at Belford, it was still noted that larger rainfall events required more storage space, highlighting the need for combined NFM measures that function together in the catchment (Nicholson *et al*., 2019). Iacob *et al.* (2017) modelled the Tarland catchment and suggested that coniferous afforestation would be successful in reducing increased flows under future climate projections. Coniferous trees were found to have higher evapotranspiration rates than deciduous trees; this, with increased interception, implies that coniferous trees may be more successful in reducing peak flows than deciduous trees (Iacob *et al.,* 2017). However, it should be noted that *Pinus sylvestris* (Scots pine) is the only conifer native to the UK that has any significant presence (Woodland Trust, 2023a). Therefore, it is questionable as to whether an intervention involving large-scale planting of coniferous trees can be termed 'Natural' Flood Management if the species planted are not native. This highlights the points raised in Subsection 2.3.2, and demonstrates how describing something as 'natural', that is inherently not, makes the term NFM problematic. Regardless of how NFM is interpreted, this case study emphasises the need to account for site context, in order to achieve the most effective results.

Focusing on tree planting as a popular NFM measure, the NFM Handbook (SEPA, 2016) and NFM Manual (Wren *et al*., 2022) outline the different types of tree planting for NFM, namely: catchment woodland, cross-slope woodland, floodplain woodland and riparian woodland. Each type is used for a different purpose, depending on the project aim and characteristics of the catchment. For riparian woodland, SEPA (2016) suggests planting broadleaved species to increase channel roughness and encourage infiltration. However, for upland catchment woodland, conifers are advised, to reduce greater runoff volumes (Forest Research, 2022). This reinforces the importance of contextual factors when planting trees and highlights some potential reasons as to why an NFM site may not be wholly restored to its 'natural' state. In cases where non-native species have been planted, the aim may be to emulate natural processes for the purpose of flood mitigation. It should be noted that all tree planting activities must comply with the UK Forestry Standard, which includes a designated practice guide for designing and managing woodland to reduce flood risk. Within the practice guide, it is recognised that tree type, species and spacing can affect the ability of the trees to reduce flood flows, and it goes on to provide guidance on each of these factors (Forest Research, 2022). In terms of tree type, the guide states that canopy interception of conifers is typically twice that of broadleaves, and conifer soils have greater capacity to absorb rainwater, thus reducing runoff (Forest Research, 2022). Similarly, modelling of the Tarland catchment also revealed that conifers would be more beneficial. However, the practice guide acknowledges that broadleaves should be used in riparian habitats, due to their greater potential for below-ground floodwater storage (Forest Research, 2022). As previously addressed, this reinforces the notion that NFM is not just a method to restore the landscape, but should be driven by site suitability (Forest Research, 2022). Tree spacing is another factor influencing the flood mitigation potential of tree planting. Hydraulic roughness increases as trees are planted closer together, therefore, the practice guide suggests spacing of 5 metres or less (Forest Research, 2022). If wider spacing is necessary, ground vegetation and shrubs also contribute to roughness, which can be planted in between the trees (Forest Research, 2022). This highlights the logistical considerations that have to be made when implementing NFM. In many cases, landscape restoration may not be suitable for the site, as the main aim of NFM is to reduce flood risk.

Table 2.4: *Examples of NFM case studies from the literature and Working with Natural Processes Evidence Directory*

NFM Project	**Tree planting** (Catchment, riparian, cross slope, or floodplain)	**Leaky barriers/woody debris dams**	**Offline storage** (Ponds, bunds, swales)	**River channel restoration**	**Sediment traps**	**Total**
Belford Burn, Northumberland (Barber and Quinn, 2012; Nicholson *et al*., 2019; Wilkinson *et al*., 2019)		✓	✓		✓	**3**
Coalburn, Northumberland (Birkinshaw *et al*., 2014; McIntosh, 1995; Robinson, 1998)	✓					**1**
Eddleston, Scottish borders (Black *et al*., 2021; Wren *et al*., 2022)	✓	✓	✓	✓		**4**
Holnicote Estate, Somerset (Burgess-Gamble, 2018; National Trust, 2015; Wren *et al*., 2022)	✓	✓	✓			**3**
Pickering, North Yorkshire (Defra, 2011; McAlinden, 2016)	✓	✓	✓			**3**
Sussex Flow Initiative, East Sussex (Manning-Jones *et al*., 2021; Turley and Southgate, 2018)	✓	✓	✓	✓		**4**
Tarland Burn, Northeast Scotland (Iacob *et al*., 2017; Wilkinson *et al*., 2019)			✓			**1**
Total	**5**	**5**	**6**	**2**	**1**	

2.5.2 Multiple Benefits of NFM

The previous subsection focused on the flood mitigation outcomes of NFM, however there are additional benefits that NFM can also provide. In the WwNP Evidence Directory, Burgess-Gamble *et al.* (2018) state that such projects should achieve multiple environmental benefits. Figure 2.4 exemplifies those that are commonly cited, demonstrating that flood risk reduction is often not the only factor considered when implementing NFM. Due to the focus on tree planting in this research, this subsection will explore the multiple benefits of woodland creation.

Iacob *et al*. (2014) examined a range of NFM studies and determined their effect on different ecosystem services. After assessing the ecosystem service categories of provisioning, regulating, cultural and supporting, they found that woodland creation increased carbon sequestration (regulating), improved water, soil, and air quality (regulating), and enhanced biodiversity and nutrient cycling (supporting). In addition, social benefits such as tourism and recreation – associated with the cultural ecosystem service category – were identified as being provided by woodlands, demonstrating the wide-ranging impacts that trees can have. Within both the NFM Handbook (SEPA, 2016) and NFM Manual (Wren *et al*., 2022), similar benefits are acknowledged through the implementation of woodland NFM, including carbon capture, recreational activities, and habitat connectivity. In fact, when reviewing the effects of woodland expansion on ecosystem services, Burton *et al*. (2018) found the strongest evidence towards biodiversity gains, further supporting the multiple benefits approach. The UK Forestry Standard states that it is a Good Forestry Practice Requirement for woodlands to achieve diverse structure of habitat, species, and age of trees (Forestry Commission, 2017). BNG is relevant here, as NFM can be used to achieve the 10% net gain that is required of new developments. Although increasing biodiversity has long been a benefit of NFM, the more recent focus on BNG requires that such projects have a quantifiable outcome. Therefore, the notion of using woodlands for both flood management and other environmental and social benefits is well-established within the literature and policy.

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Figure 2.5: *Multiple benefits of NFM (The Flood Hub, 2023)*

2.6 Barriers to NFM Implementation

While the previous section discussed case study examples of NFM, it is widely acknowledged that there is a range of barriers preventing such strategies from being implemented on a larger scale. The main barriers identified are evidence gaps, poor governance and lack of funding, little cooperation between stakeholders, and public perception. Wells *et al.* (2020) identify a positive feedback loop, presented in Figure 2.6, which offers an explanation as to why NFM is not yet wholly incorporated into flood management. It suggests that a lack of evidence demonstrating the effectiveness of NFM means that a cost-benefit ratio cannot be calculated, thus reducing funding opportunities for new projects (Wells *et al*., 2020). Subsequently, NFM is not implemented as widely as it could be. Many of these factors are also acknowledged by other authors, and the connections between them will be explored in this section.

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Figure 2.6: *Positive feedback loop on barriers to NFM (Wells et al., 2020)*

2.6.1 Catchment-Scale Evidence

Thus far, NFM has primarily been implemented at small, local scales, therefore, evidence that it works in larger catchments is currently lacking (Wilkinson *et al*., 2019). This is frequently cited as one of the main barriers to NFM (Lavers *et al*., 2022; Waylen *et al*., 2018; Wells *et al*., 2020; Wilkinson *et al*., 2019). Semi-structured interviews undertaken by Waylen *et al*. (2018) demonstrate that there is uncertainty around the effects of NFM measures on catchment hydrology, but also uncertainty regarding modelling, noting that it is easier to model the effects of hard-engineered flood defences than NFM, due to the incomplete scientific evidence base for NFM. Furthermore, a report published by Defra (2020) acknowledged that modelling is expensive and complex, which might limit the possibility of collating robust evidence that NFM could work on a larger scale. However, research on catchment-scale modelling is starting to emerge – Lavers *et al*. (2022) studied the effect of NFM on the Stour catchment in Warwickshire. While this is a step forward, Lavers *et al*. (2022) found that the impact of attenuation created by upstream NFM on the downstream peak response actually decreased at larger hydrological scales. This suggests that NFM may not be effective in larger catchments, creating another barrier to its widespread implementation. Despite this, the evidence is not yet conclusive and requires further investigation – circling back to the ‘lack of evidence’ barrier initially identified. Lacking evidence means NFM is not being implemented on a large scale, yet evidence cannot be gathered without implementation. Due to the uncertain effects of NFM on a catchment-scale, funding has not been concentrated on this area of flood management, limiting opportunities for modelling and/or experimental studies.

2.6.2 Funding

As highlighted in the previous subsection, much of the literature acknowledges the dependence of funding on evidence that NFM is effective (Wells *et al*., 2020). The main funding-related barrier identified is that there is simply a lack of money available for NFM projects. Semi-structured interviews conducted by Waylen *et al.* (2018) revealed that none of the respondents thought there are enough resources for new projects. A similar response was received by Wells *et al.* (2020) and Holstead *et al.* (2017), who reported that land managers faced financial restraints when installing NFM. If the monetary support is not there for land managers, they are unlikely to support NFM being implemented on their land. Focusing on the community level, Wingfield *et al.* (2021) conducted surveys with Catchment Partnerships, who ranked funding as one of the most significant barriers. This suggests that charitable bodies have experienced difficulties with securing funding for NFM schemes. Contrastingly, Wingfield *et al.* (2021) also surveyed people working in Flood Risk Authorities and found that funding was not ranked as highly compared to other barriers. It was established that the two groups (Catchment Partnerships and Flood Risk Authorities) acquire funding from different systems, perhaps explaining the different ranking. Wingfield *et al.* (2021) emphasised that Flood Risk Authorities are generally required to meet specific targets using money from public funding. If NFM does not meet those conditions, it is unlikely to be supported as a flood management option. This is likely to explain why Flood Risk Authorities ranked the difficulty of demonstrating flood risk reduction higher than funding – they are required to show that NFM works for it to be funded. This reiterates the problem identified by Wells *et al.* (2020) in Figure 2.6; for progress to be made, it has to be proved that NFM is effective.

However, due to the multiple benefits outlined in Subsection 2.5.2, funding for some NFM activities may be more widely accessible. For example, tree planting initiatives, such as the Northern Forest, have dedicated funding associated with them (Woodland Trust, 2023b). Therefore, while it may be more difficult to access funds for solely NFM-related projects, focusing on the multiple benefits of activities like tree planting, could be the key to securing funding. This does, however, restart the debate around terminology. For example, if the purpose of a project is to increase habitat connectivity, but also has the benefit of mitigating flood risk, it is questionable as to whether it should be termed NFM. A scheme like this with multiple benefits may be better termed a Nature-based Solution, thus encompassing all benefits. The difficulties with defining such terms may lead to confusion if there are set funding streams for specific activities. Therefore, funding for larger scale projects with the aim of providing multiple benefits, may increase the profile of NFM, generating interest and funds for subsequent projects.

In addition to the multiple benefits approach, funding for projects using 'Green Finance' is becoming more readily available, as the UK's Green Financing Programme was launched in 2021 (HM Treasury, 2022). Green Finance uses private investment for nature-based activities; an example of this is the Wyre Catchment NFM project (Green Finance Institute, 2023). Through a combination of private and public investment, 70ha of measures were planned for the Wyre catchment pilot project in 2019 (Green Finance Institute, 2023). The aim of this pilot project was to assess the feasibility of funding such schemes with private loans and investments, which could be expanded in future as a more reliable source of resources. There is a growing interest in funding for activities involving NFM and NbS, though Green Finance still requires development and consolidation as an approach.

2.6.3 NFM Governance

One of the most common barriers to NFM is poor cooperation and a lack of clarity surrounding responsibility. Wells *et al.* (2020) state that NFM is not fully represented in English legislation, which makes funding and monitoring more difficult. This is supported by Wingfield *et al.* (2021) who reported that the main barrier to NFM was a lack of government commitment and conflicting messaging. This has led to confusion around who is responsible for funding, installing, and monitoring NFM, and whether these should be managed by different organisations (Bark *et al*., 2021; Waylen *et al*., 2018; Wells *et al*., 2020). A survey undertaken by Bark *et al.* (2021) showed that 95% of respondents acknowledged the need for actions and changes, including a consistent modelling and appraisal methodology; a reflection of there being little shared understanding of how to implement NFM. Waylen *et al.* (2018) acknowledge the difficulty with planning NFM measures across local authority borders, yet it is necessary to consider whole catchments, whether they are constrained to one local authority or not. The debate of who is responsible for NFM is also explored by Wells *et al.* (2020), who came to similar conclusions that local borders may cause issues. Some respondents placed responsibility with Lead Local Flood Authorities, whereas others believed Non-Governmental Organisations should take charge. This is a reoccurring theme in the literature and demonstrates that NFM needs clear and improved governance for it to be effective.

The overall responsibility for NFM was not the only barrier identified; communication and cooperation between organisations delivering and managing NFM also requires improvement.

Wilkinson *et al.* (2019) state that engagement with land managers is essential for NFM schemes to work effectively, and Garvey and Paavola (2022) define land managers as the key to project success, since a vast number of NFM projects are located on private land. Despite this emphasis on the importance of good relationships, it is acknowledged by Defra (2020) and Waylen *et al.* (2018) that relationships between land managers and external organisations are poor. For NFM to be effective, there must be cooperation between all stakeholders, otherwise the approach becomes fragmented.

2.6.4 Land Managers' Understanding of NFM

Land managers are one of the main stakeholder groups involved in NFM, therefore their input and cooperation is essential for NFM to work (Lavers *et al.*, 2022). However, relationships between land managers and other stakeholders are often difficult. It is important to consider the issues from both perspectives; Holstead *et al.* (2017) explored farmers' perceptions of NFM in Scotland due to poor uptake. Their survey revealed that 59% of respondents knew nothing about NFM. A similar theme was identified by Wells *et al.* (2020), who found that 2-in-3 land managers had not heard of NFM, nor did they understand its aim. Without knowledge or understanding of NFM, land managers are unlikely to allow NFM schemes on their land. When farmers were asked why they were against NFM, the most common responses were insufficient advice, lack of funding, high land value and tradition (Holstead *et al.,* 2017). 60% of farmers who had not installed NFM said that tradition was one of the main reasons, and 16% avoided implementing NFM so as not to be labelled a 'slipper farmer' (farmers who do not use their land for agricultural purposes, but still claim subsidy payments) (Holstead *et al.,* 2017). Defra (2020) also concluded that the difficulty in changing farmer mindset was a key barrier to implementing NFM. The concept of 'tradition' is noteworthy here in terms of the environmental conditions in question. Over time, land that was previously forested has been cleared for agriculture. The truly 'natural' landscape is, therefore, definitively not farmland. However, this questions exactly what is meant by 'traditional' and suggests the need for a baseline to refer back to, but this baseline, or 'natural' state, appears to be subjective. While land managers may not share this perception, it highlights complications with terminology.

Positive engagement with land managers is required to ensure they have sufficient knowledge and advice to be more accepting of implementing NFM measures on their land. Lavers and Charlesworth (2018) concluded that early engagement with land managers and acknowledgement of their input was essential for NFM to be successful. They highlight that farmers often have local knowledge of key runoff pathways and erosion points, which are important to pinpoint when considering different NFM techniques. The research undertaken in the Warwickshire-Avon catchment provides an exemplar of how to work with upstream farmers when investigating NFM options to reduce downstream flooding (Lavers and Charlesworth, 2018). The project was a collaborative effort between researchers and land managers, demonstrating that relationships with land managers do not have to be a barrier in every case. Future NFM interventions should take a similar approach to maximise the number of land managers willing to be involved, therefore increasing the evidence base on NFM.

2.6.5 Public Perception of NFM

Along with land managers, support from the public is necessary for the success of NFM. NFM projects often have the aim of reducing flood risk to downstream communities, and Garvey and Paavola (2022) acknowledge that communities are a key driving force to NFM becoming more widespread. While much of the research on barriers to NFM states that public perception is an issue, those studies did not actually consult the public. Instead, the majority of studies report what NFM professionals believe public perception to be. This area of stakeholder attitudes requires further research to gain a thorough understanding of how people view NFM. Despite this, the studies that conducted interviews with NFM professionals explored how the public may perceive NFM, which came with mixed results. Wells *et al.* (2020) interviewed FRM practitioners and reported that communities with an NFM scheme may have too much reliance on it, particularly during larger flood events, whereas downstream communities may have a negative view of NFM due to the time it takes to benefit downstream settlements. Wingfield *et al.* (2021), however, analyse the different responses of those working in Flood Risk Authorities and Catchment Partnerships. The former ranked public perception as a significant issue, with particular focus on resistance to change and negative media portrayal, whereas the latter did not rank public perception as significant a barrier. The explanation for this was that Catchment Partnerships may have had more success communicating with local communities, but there was no evidence to substantiate this (Wingfield *et al.,* 2021). Research by Waylen *et al.* (2018) concluded that NFM may not be perceived as secure as traditional defences, particularly due to the lag time between installation of NFM and demonstrated successes. This links with the aforementioned findings of Wells *et al.* (2020) – if benefits are not seen straight away, the public may view NFM negatively. While these are all valid and plausible ideas of the public's perception, research should be focused on those living in communities at risk of flooding. This will indicate where communities may be more receptive to NFM and where more engagement is needed.

2.6.6 Causality Dilemma

This section has outlined the main barriers to NFM mentioned in the literature, including catchment-scale evidence, funding, governance, land managers and public perception. Figure 2.6 was introduced at the beginning of the section and emphasised the reliance on evidence that NFM is effective for funding to be allocated. However, as several barriers have been identified, it is questionable what the root of the positive feedback loop actually is, creating a causality dilemma. Figure 2.7 instead focuses on the issue of poor governance as the main barrier, which leads to reduced funding, decreased opportunities for NFM to be implemented and therefore a negative perception, ultimately meaning that NFM is not fully integrated. It is clear that all of the barriers link with one another and share a causal relationship, but for this positive feedback loop to be intercepted, changes need to be made to at least one of the barriers. This research aims to contribute to such an endeavour.

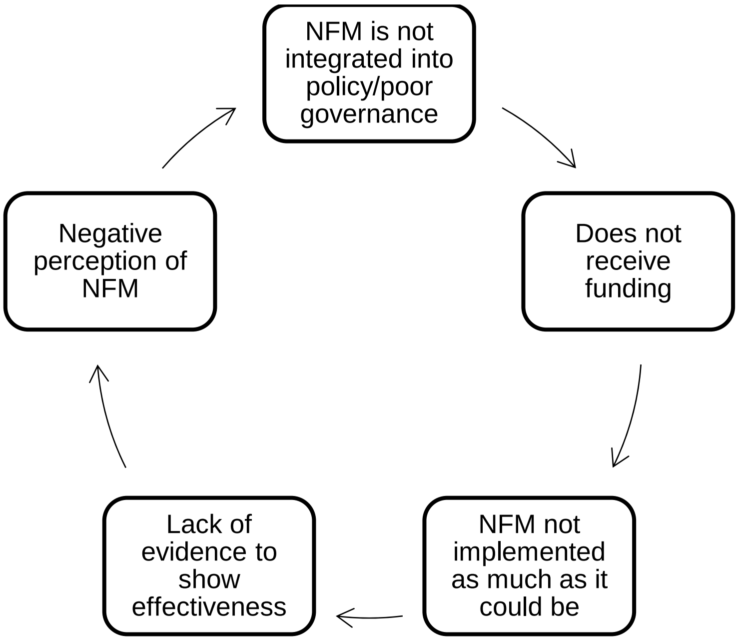

Figure 2.7: *Alternative positive feedback loop on barriers to NFM*

2.7 Conclusion

This chapter has analysed the current literature surrounding flood management, specifically NFM, with a particular focus on the nomenclature. However, it is recognised that there is scope to develop the current research further. NFM is becoming better established in the literature and is starting to be consolidated as a FRM approach, but the concept is continuously evolving. This project will aid the development of NFM by exploring its definition and what is meant by ‘natural’. Section 2.3 of this literature review recognises that the terminology surrounding flood management is complicated, but previous studies have not explored this in depth, nor have they investigated the actual aim of NFM. Therefore, this research will address those issues, by examining what is meant by ‘natural’ in the context of NFM. By improving understanding of the nomenclature, the perception of NFM and similar activities should become clearer, which will ensure shared expectations amongst all stakeholders and allow for more widespread implementation.

CHAPTER 3: METHODOLOGY

Chapter 3 describes the methodological approach to the project. This chapter will introduce the study areas and how they were selected, explain and justify the approach taken to data collection for each objective, and describe the data analysis. Figure 3.1 illustrates the methodological framework used for this research, setting out the objectives and data collected to meet each one, along with some of the linkages between them. The project takes a mixed-methods approach by using both quantitative and qualitative data, which ensures robust and thorough results (Caruth, 2013). The combination of GIS, palaeoenvironmental reconstruction, and interviews is not one that is commonly used in this field of research, thus providing novel insights into the concept of NFM. As discussed in the literature review, NFM is not a hypothesis or theory that can be proved or disproved; it is a concept, therefore the mapping and pollen analysis demonstrate some ways in which the word natural can be interpreted, and the interviews provide an insight into how NFM is viewed amongst professionals. This project is framed by a pragmatic approach, which was deemed suitable due to the philosophy that pragmatism seeks solutions through diverse methods, which are specific to the research question (Saunders *et al*., 2009). After reviewing the literature surrounding NFM, issues regarding terminology, implementation and flood management policy were identified as ongoing challenges. The pragmatic approach allows for holistic research, by considering the strengths of both quantitative and qualitative methods. This has resulted in a detailed analysis, exploring the concept of NFM, while also providing answers to the research question on how 'natural' NFM is considered to be. Combined with the examination of terminology in the literature review, the research methods enable investigation of the extent to which this 'naturalness' is important to NFM as a flood management technique.

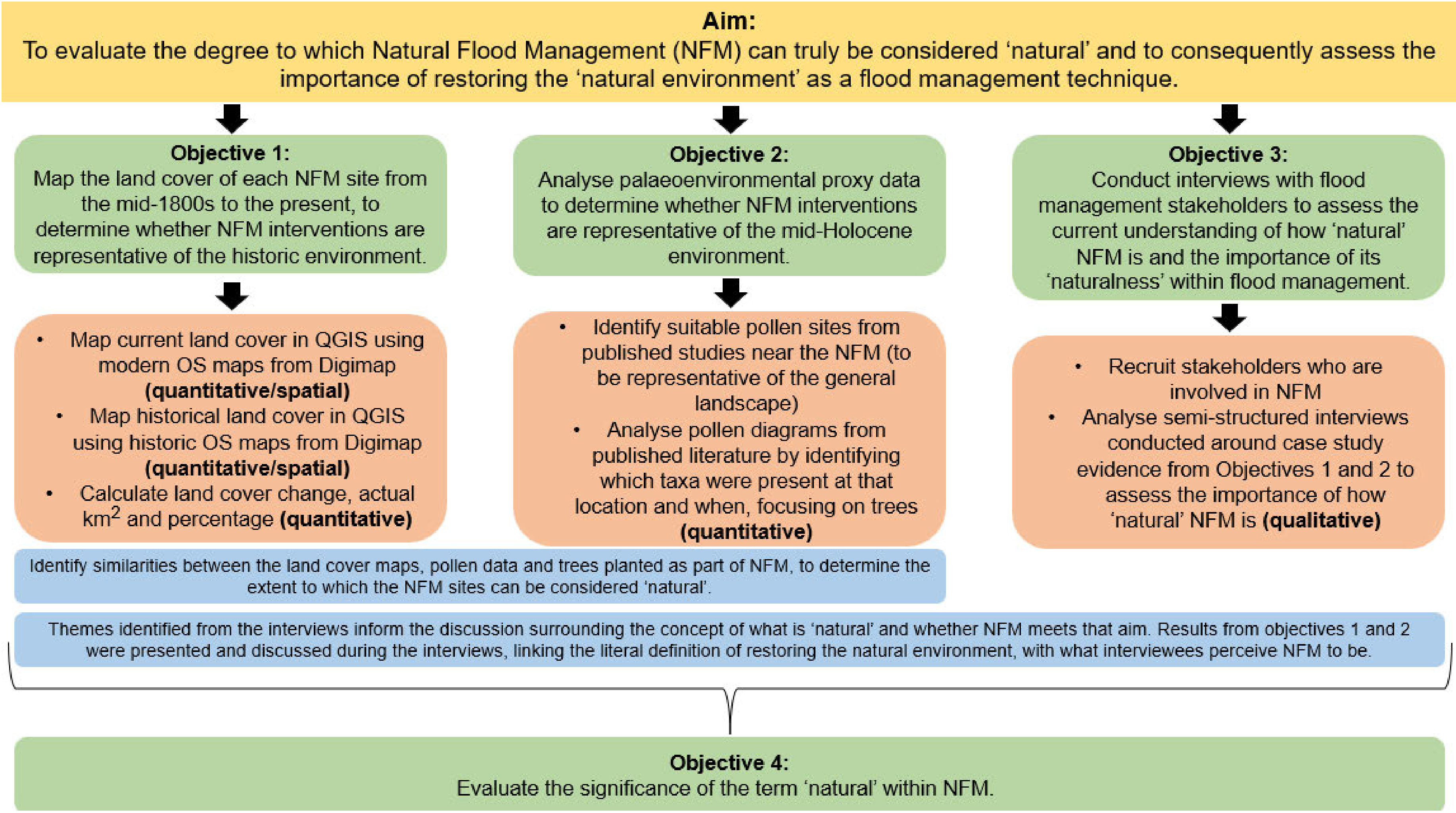

Figure 3.1: *Methodological framework including data collection for Objectives 1-4*

3.1 Study Site Selection

3.1.1 NFM Sites

Initial research into possible NFM study sites in the UK was carried out by reading literature describing NFM case studies, such as those mentioned by Wilkinson *et al*. (2019), Wingfield *et al*. (2019), and the Natural Flood Management Manual (Wren *et al*., 2022). Figure 3.2 shows the process of researching NFM projects, and how these were narrowed down to a shortlist of eight potential sites. NFM schemes involving tree planting were focused on to ensure consistency with the mapping and palaeoenvironmental data in Objectives 1 and 2. The nature of the palaeoenvironmental reconstruction means that pollen grains are analysed to give an overview of the vegetation found in the selected area at a given point in time (Simpson, 2019). Subsection 2.5.1 demonstrated tree planting as a popular type of NFM, therefore, it was reasonable to compare this to the pollen analysis. The palaeoenvironmental data provides an overview of what the environment was like prior to written records. After further reading and research, a list of eight potential NFM sites was compiled in Table 3.1 and presented in Figure 3.3.

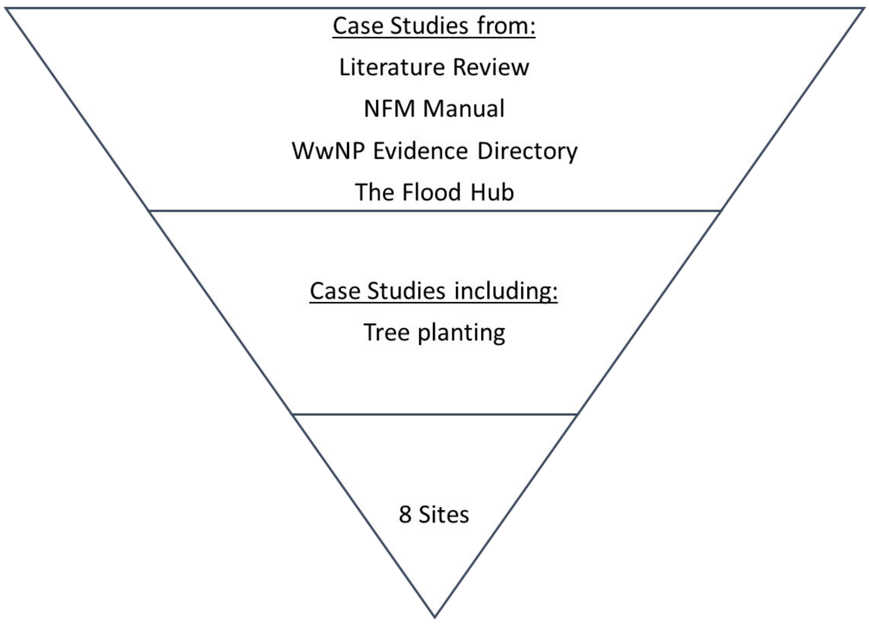

Figure 3.2: *Process of researching NFM sites*

Table 3.1: *Eight potential NFM sites identified within the literature*

NFM Site Name	NFM Site Location
Broughton Hall Estate	Skipton
Coalburn	Northumberland
Crompton Moor	Oldham
Glenderamackin	Keswick
Holnicote Estate	Somerset
Kendal	Kendal
Pott Shrigley	Cheshire
Smithills Estate	Bolton

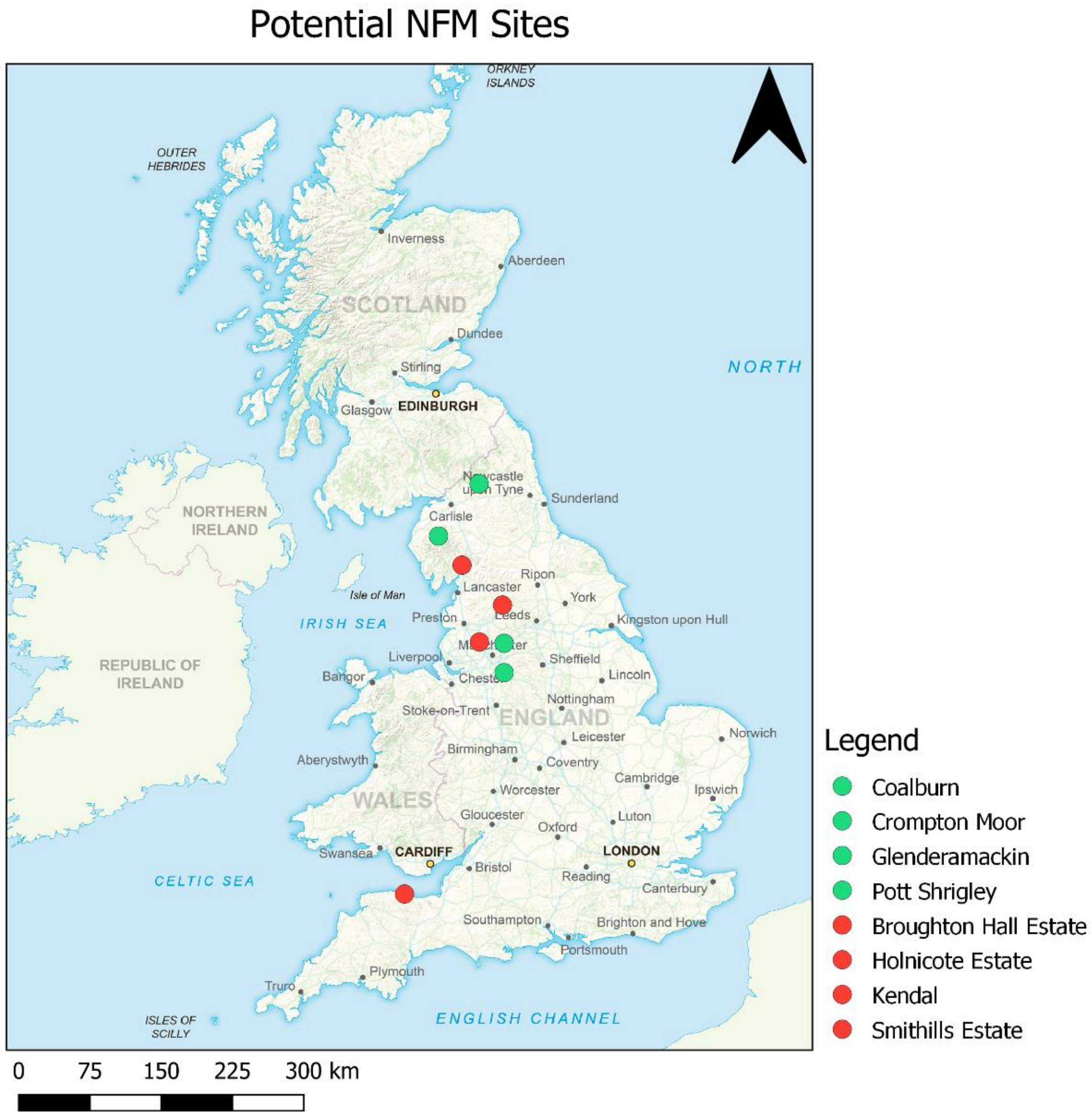

Figure 3.3: *Map of the potential NFM sites. Green points are sites that were used and red points were rejected after following the methodology in Figure 3.4.*

These eight sites were investigated further to determine their suitability for the research, by following the first part of the flow diagram in Figure 3.4. The process of contacting people to gain more information was required for all eight of the potential sites. Contact details were sought from public websites that gave information about the NFM projects. For a site to be applicable, the tree species and planting locations had to be known for comparisons to be made with the results of the historic land cover mapping and palaeoenvironmental data analysis. Responses regarding four of the sites were received (Coalburn, Crompton Moor, Glenderamackin and Pott Shrigley), providing a list of the species that were planted and maps with the planting locations. However, for these sites to be confirmed, they had to align with the availability of pollen sites. The methodology for selecting those is outlined in the next subsection.

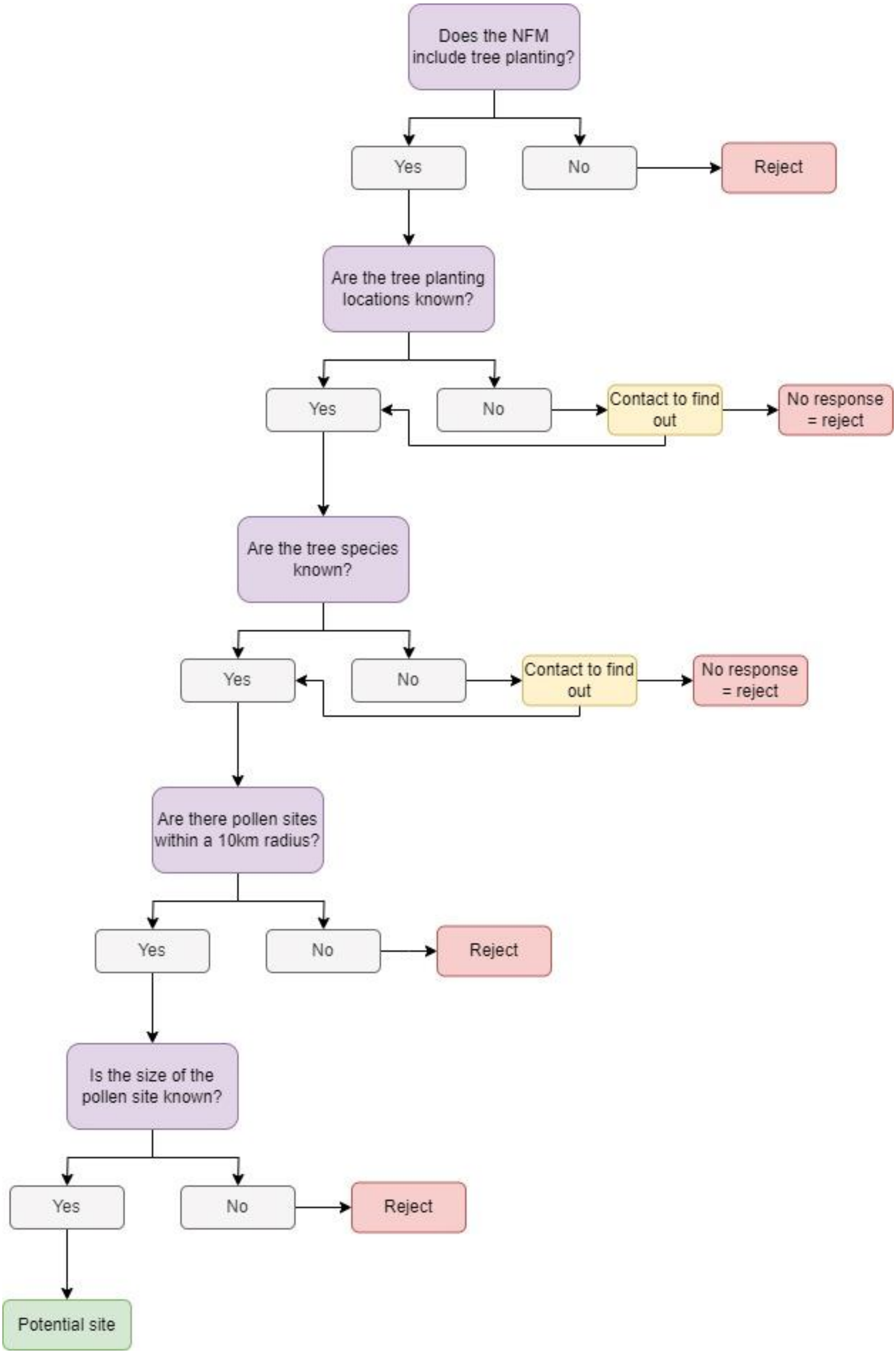

Figure 3.4: *Flow diagram describing NFM site selection and pollen site selection*

3.1.2 Pollen Sites

The selection of the final study sites was reliant on the availability of pollen data. Prior to receiving responses regarding the tree planting at the NFM sites, the available pollen data were investigated. To do this, literature reviews by Suggitt *et al.* (2015) and Payne *et al.* (2016) were accessed, which compiled lists of published studies that included pollen data and diagrams from the UK. These detailed the coordinates of each site, which were then plotted into QGIS using CSV files, along with the locations of the potential NFM sites. This indicated the proximity of pollen sites to the NFM, though this remained tentative until the precise tree planting locations were known. The second part of Figure 3.4 (see above) details the remainder of the process.

3.1.3 Pollen Source Areas

Figure 3.4 highlights the importance of the distance between the NFM and sedimentary basins from which pollen records were obtained, and the actual size of the basins themselves. A maximum radius of 10km was allowed for the distance between the potential NFM and pollen sites, because the greater the distance between them, the less reliable the environmental reconstruction becomes (Sugita, 1994). Spatially, the pollen record can be considered fragmented and lacking across the UK, due to data collection being somewhat ad-hoc. Therefore, the distance radius had to be large enough to identify any pollen sites at all, though it is noted that this may cause generalisations, which are discussed further in Chapter 4. Linked to this, the size of the actual pollen site was also required. Pollen accumulates, and is preserved in, sedimentary basins such as lakes and mires, and research by Jacobson and Bradshaw (1981) and Sugita (1994) shows that the size of the basin is important in determining the spatial area represented by the pollen record. The 'pollen source area' therefore determines how representative the pollen data are of the environment surrounding the NFM site. Generally, larger basins accumulate pollen from larger spatial areas, and Sugita (1994) used a simulation approach to determine representative pollen source areas for a range of basin sizes. Table 3.2 summarises his findings.

Table 3.2: *Relationship between sedimentary basin size and their estimated pollen source areas. Information taken from Sugita (1994).*

Radius of Sedimentary Basin	Estimated Pollen Source Area (radius)
2m (forest hollow)	50-100m
50m (small lake)	300-400m
250m (medium lake)	600-800m

The intention was to follow Sugita's methodology and apply the estimated pollen source areas to the pollen sites for this project. However, not all papers included information on the size of the sedimentary basin, therefore, several different methods had to be used to obtain this information, which tended to result in an estimate. Some papers included diagrams of the coring transects, which were labelled with the basin diameter, so these could reliably be used to calculate the radii. Those sites included Butterburn Flow (NFM: Coalburn) and Danes Moss (NFM: Pott Shrigley). For other sites, measurements of basin radii were taken using Google Earth Pro or OS maps. The diameter of Little Tarn (NFM: Glenderamackin) was measured using Google Earth Pro; the measurement of the longest axis of the lake was taken and halved for the radius. OS maps were explored for the remaining sites, whereby map contours were used to determine whether there was a basin around the coring site; if so, the diameter of this was measured and halved for the radius. Alternatively, the vegetation type of some sites was clearly distinguishable; for instance the core at Calvert Trust Land (NFM: Glenderamackin) was taken in marshland, therefore the radius of the marshy area was measured instead. Figures 3.5 to 3.8 show these processes.

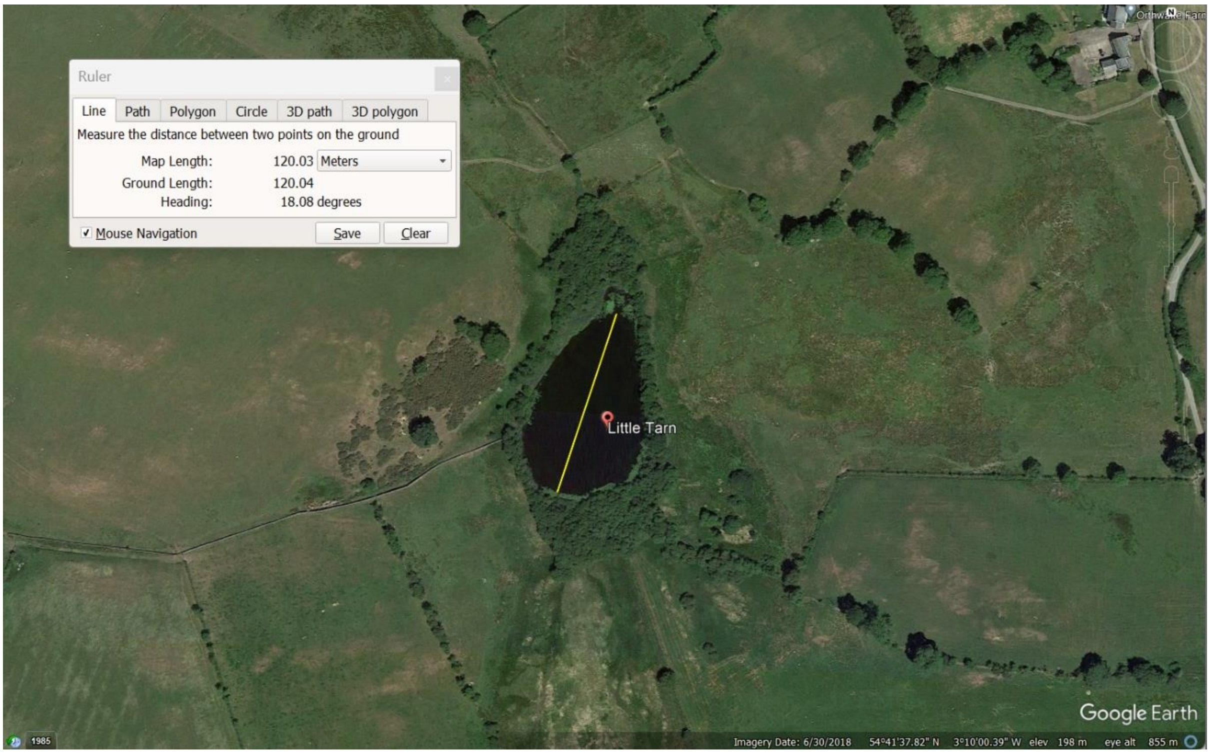

Figure 3.5: *Measurement of the longest axis of Little Tarn (NFM: Glenderamackin) using Google Earth Pro*

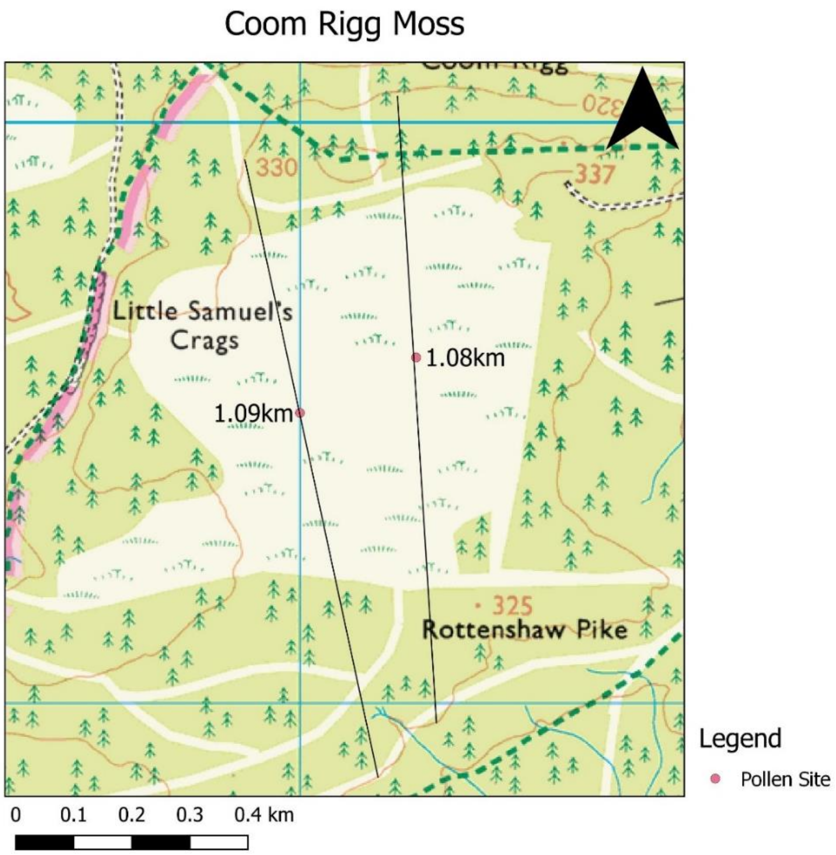

Figure 3.6: *Coom Rigg Moss (NFM: Coalburn) estimated diameter using contours to create a basin*

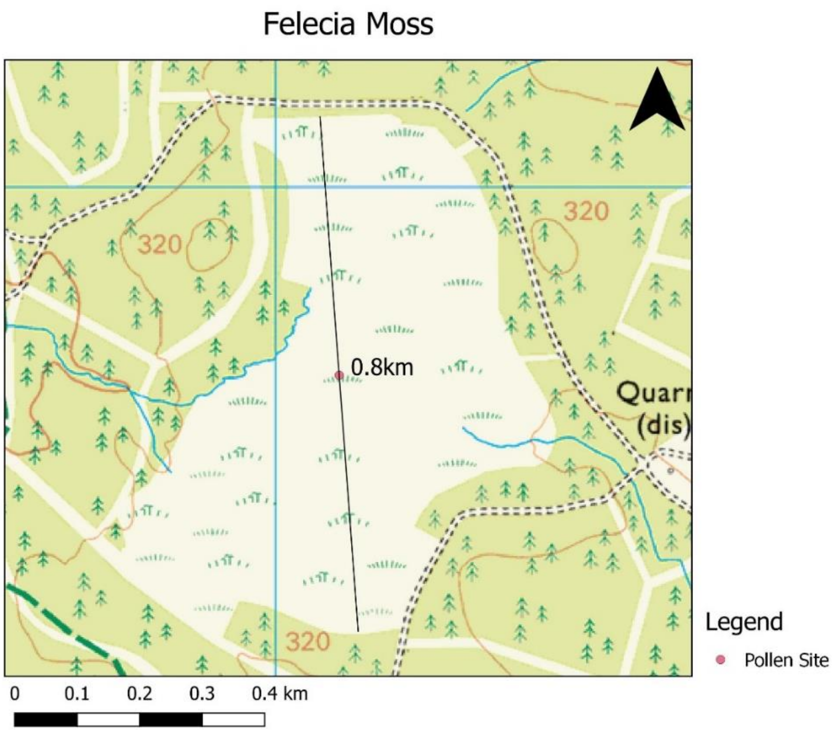

Figure 3.7: *Felecia Moss (NFM: Coalburn) estimated diameter using extent of rough grassland from which the core was obtained*

Calvert Trust Land

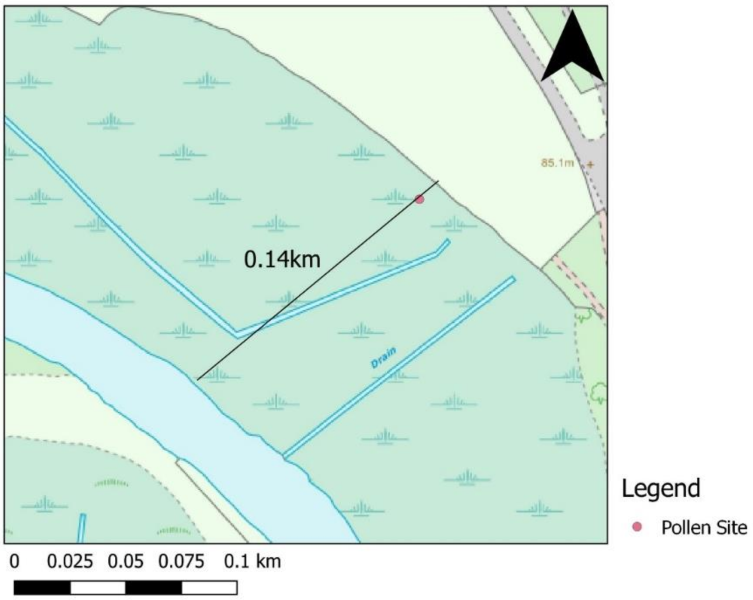

Figure 3.8: *Calvert Trust Land (NFM: Glenderamackin) estimated diameter using extent of marshland from which the core was obtained*

However, several pollen cores were not located within a basin or a distinguishable type of land cover, rather they were taken in large areas of peatland. This made it difficult to take any accurate measurements, as any potential basins could only be identified using coring transect data, which were not available for these sites. Therefore, the pollen source areas of these sites could not be estimated using Sugita's (1994) methodology. Instead, conclusions drawn by Jacobson and Bradshaw (1981) were studied and applied to the remaining sites. They defined local, extra-local and regional pollen in relation to the surrounding landscape and their findings can be seen in Table 3.3. It is generally accepted that larger sedimentary basins have larger pollen source areas, demonstrated by their definition of regional pollen as potentially originating hundreds of metres away from the basin (Jacobson and Bradshaw, 1981). Figure 3.9 provides further evidence that sites with larger diameters (up to 1000m) are dominated by regional pollen, whereas smaller sites mainly represent local and extra-local pollen. Jacobson and Bradshaw (1981) also acknowledge that peat deposits are most beneficial for regional palaeovegetational reconstructions. Therefore, for the remaining study sites where the diameter was unknown, the assumption was made that the large peatland areas would represent the regional vegetation. It is acknowledged that closer accuracy would be beneficial, particularly due to the distances between the NFM and pollen sites. However, there were no other suitable pollen sites available.

Table 3.3: *Jacobson and Bradshaw's (1981) definitions of pollen source areas*

Pollen Site Type	Estimated Pollen Source Area
Local pollen (small hollows)	Plants growing within 20m of basin
Extra-local pollen (small lakes)	Plants growing 20-100m+ from the basin
Regional pollen (peatland)	Plants growing 100m+ from basin

Figure 3.9: *Local, extra-local and regional pollen defined by basin size (Jacobson and Bradshaw, 1981)*

3.1.4 Representative Distance

Table 3.4 details the final pollen sites, including the estimated pollen source areas for each site based on Sugita's (1994) model. The largest radius that the model includes is 250m, therefore sites larger than this could not be mapped, but instead rely on the assumption that larger sites represent regional vegetation (Jacobson and Bradshaw, 1981). Figures 3.10 and 3.11 show the estimated pollen source areas and proximity to the NFM sites of Coalburn and Glenderamackin respectively. The pollen source areas, however, do not cover the NFM sites, which was expected due to the distance between them. A larger pollen source area, or one closer to the NFM sites, would provide greater confidence about the surrounding mid-Holocene vegetation. Despite this, due to there being no pollen sites closer to the NFM, these sites are considered to provide a reasonable approximation of past vegetation cover, given the relatively short distances involved, and ecological similarities between the pollen and NFM sites.

It should also be noted that some pollen may be over or underrepresented in the pollen cores; the amount of pollen a plant produces, along with the type of pollination, can contribute to this (Lowe and Walker, 2014). For example, a review by Broström *et al.* (2008) recognised that some taxa are consistently high pollen producers, such as *Alnus* (alder), *Betula* (birch) and *Pinus* (pine), but also that some are low pollen producers, including *Fraxinus* (ash), *Salix* (willow) and *Ulmus* (elm). It is possible that the lower pollen producers may be underrepresented, which should be considered when evaluating how 'natural' an NFM site is, when comparing it to the mid-Holocene vegetation. While generalisations such as this cannot be avoided, the analyses for this section will remain tentative to account for any potential biases in the pollen data.

Table 3.4: *Final selected pollen sites. *Basin diameter could not be obtained. Peatland assumed to represent regional vegetation, see Subsection 3.1.4 for details.*

NFM Site	Pollen Site	Associated Paper	Pollen Grid Reference	Approximate Basin Radius	Estimated Pollen Source Area	Distance between NFM and Pollen Site
Coalburn	Butterburn Flow	Hendon and Charman, 2004	NY681766	200m	600-800m	1.98km
	Butterburn Flow	McClymont *et al*., 2008	NY681766	200m	600-800m	2.18km
	Butterburn Flow	Yeloff *et al*., 2007	NY678770	200m	600-800m	2.12km
	Coom Rigg Moss	Hendon, 1998	NY690795	545m	Regional	1.07km
	Coom Rigg Moss	Mauquoy and Barber, 1999	NY692796	540m	Regional	1.12km
	Felecia Moss	Mauquoy and Barber, 1999	NY721777	400m	Regional	2.82km
Crompton Moor	Black Heath	Ryan and Blackford, 2010	SE041144	*	Regional	9.56km
	Castleshaw Moor	Brayshay, 1998	SE004115	*	Regional	5.04km
	Rishworth Moor	Bartley, 1975	SD988173	*	Regional	7.88km
	Soyland Moor Site C	Williams and Switsur, 1985	SD974170	*	Regional	7.21km
	Soyland Moor Site D	Williams and Switsur, 1985	SD974181	*	Regional	8.27km
Glenderamackin	Calvert Trust Land	Hodgkinson *et al*., 2000	NY236272	70m	300-400m	8.82km
	Derwent Water (Cannon Dub)	Hodgkinson *et al*., 2000	NY262189	*	Regional	8.80km
	Little Tarn	Hodgkinson *et al*., 2000	NY249338	60m	300-400m	10.49km
Pott Shrigley	Danes Moss	Leah *et al*., 1997	SJ905715	650m	Regional	9.81km

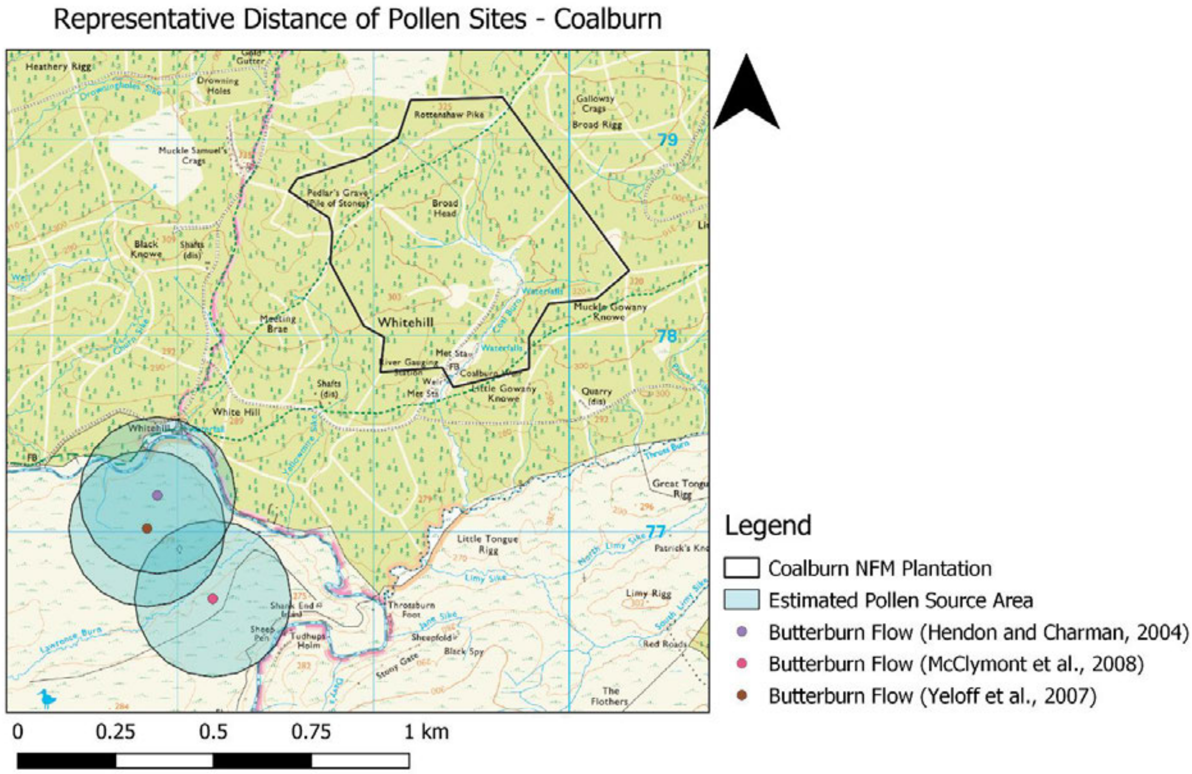

Figure 3.10: *Estimated pollen source areas of Coalburn pollen sites*

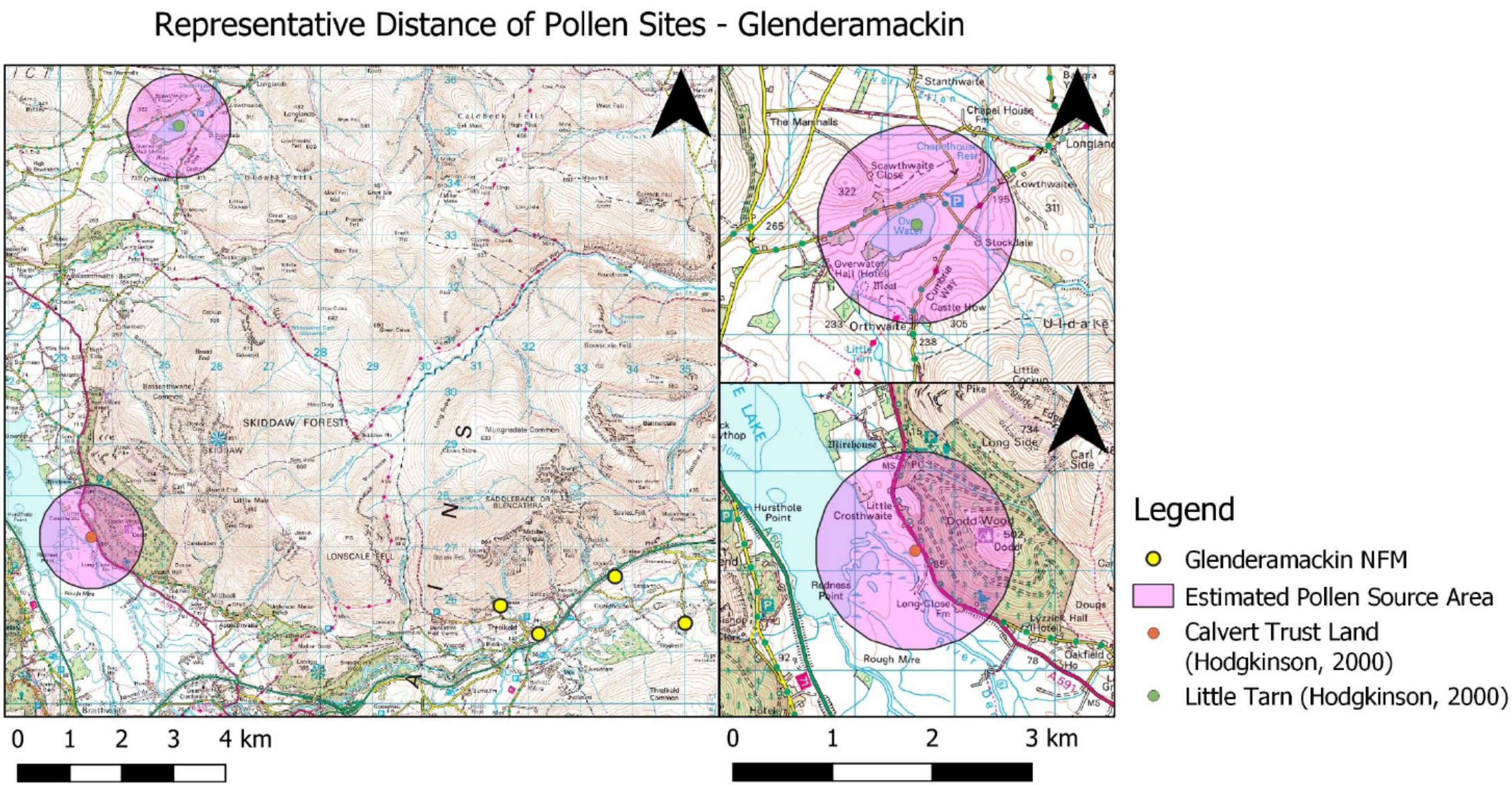

Figure 3.11a: *Estimated pollen source areas of Glenderamackin pollen sites.* **Figure 3.11b:** *Close up of Little Tarn pollen source area.* **Figure: 3.11c** *Close up of Calvert Trust Land pollen source area.*

3.2 Study Areas

The final NFM sites for this project are Coalburn, Crompton Moor, Glenderamackin and Pott Shrigley. These were selected based on the methodology outlined in the previous section, and as mentioned in Subsection 3.1.1, each NFM site included tree planting as a flood management approach. The final sites are located within a satisfactory proximity of pollen sites, as described in Subsection 3.1.4. Figure 3.12 locates the NFM sites and Table 3.5 gives more information about each of them, including their size and the tree species planted.

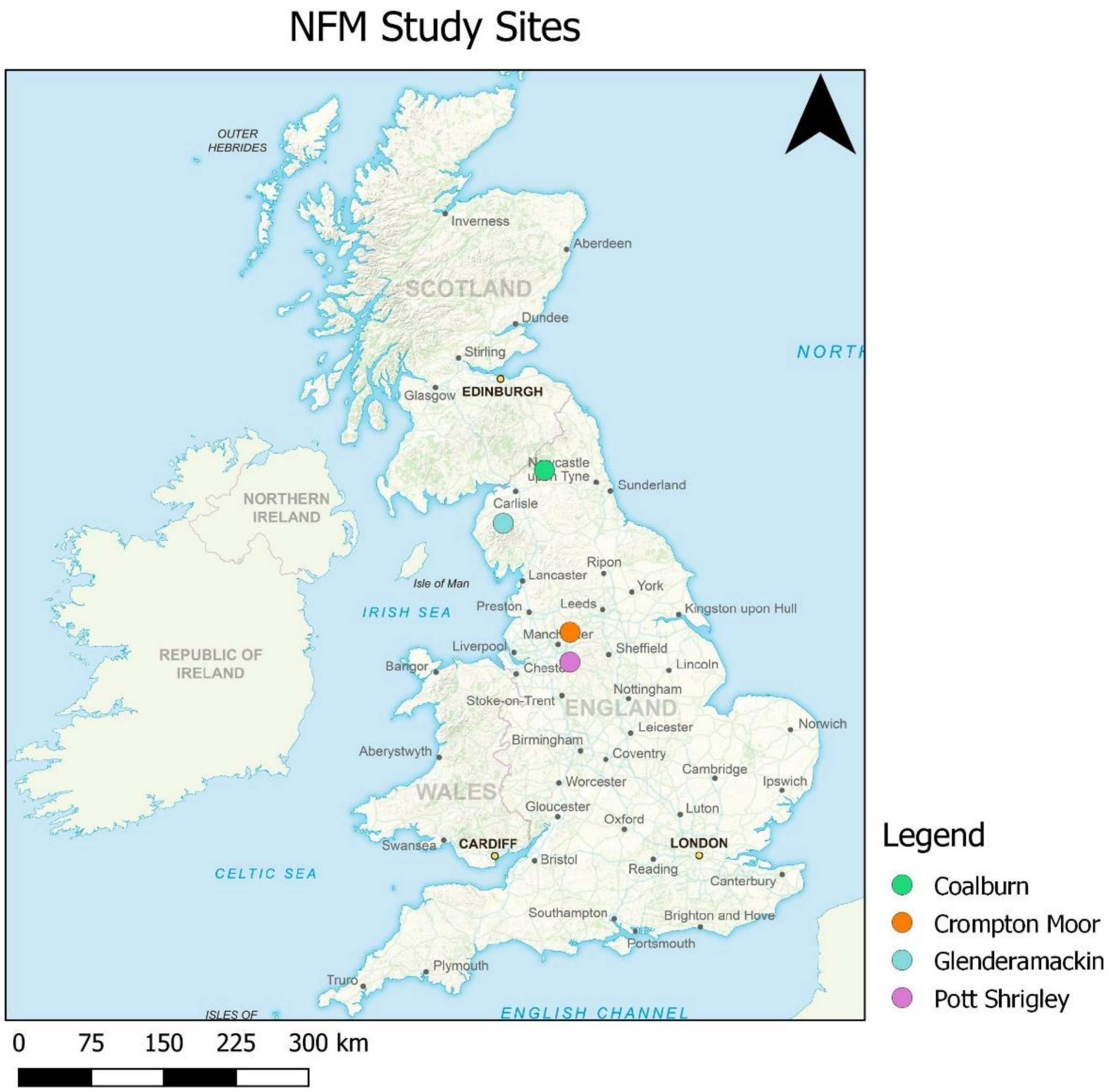

Figure 3.12: *NFM site locations*

Table 3.5: *Overview of NFM study sites*

NFM Site	Location	Grid Reference	Site Size	Species Planted	Common Name
Coalburn	Northumberland	NY694783	150ha	*Pinus contorta* *Pinus sylvestris* *Picea sitchensis*	Lodgepole pine Scots pine Sitka spruce
Crompton Moor	Oldham	SD955106 SD952103 SD951102 SD958099	2.6ha	*Alnus glutinosa* *Malus sylvestris* *Betula pubescens* *Salix caprea* *Ulex* *Viburnum opulus* *Crataegus* *Carpinus* *Quercus robur* *Sorbus aucuparia* *Quercus petraea* *Betula pendula*	Common alder Crab apple Downy birch Goat willow Gorse Guelder rose Hawthorn Hornbeam Pedunculate oak Rowan Sessile oak Silver birch
Glenderamackin	Keswick	NY336264 NY350255 NY321253 NY314 258	23.5ha	*Prunus spinosa* *Viburnum opulus* *Crataegus* *Corylus* *Sorbus aucuparia*	Blackthorn Guelder rose Hawthorn Hazel Rowan
Pott Shrigley	Cheshire	SJ959797 SJ960795	2ha	*Quercus robur* *Betula pubescens* *Salix cinerea* *Crataegus* *Corylus* *Ilex* *Sorbus aucuparia* *Quercus petraea* *Betula pendula*	Pedunculate oak Downy birch Grey willow Hawthorn Hazel Holly Rowan Sessile oak Silver birch

3.2.1 Coalburn

Coalburn is located in the Kielder Forest, Northumberland, (Figure 3.13). It is the largest of the four study sites at 150 hectares and is the longest running hydrological research catchment in the UK (Robinson, 1998). Kielder is the largest human-made forest in northern Europe, having undergone afforestation since 1926 (McIntosh, 1995; Robinson, 1998). The area was previously dominated by open hills before it was deforested for agricultural use and then replanted to facilitate timber production in the early 20th century (McIntosh, 1995). The Coalburn catchment project was established in 1967, and the original intention was to study the hydrological impacts of afforestation, however, the research has continued, and the effects of tree felling are now being studied (Birkinshaw *et al*., 2014; Robinson, 1998). The area was ploughed and drained in 1972 and then afforested in 1973, mainly comprising of Sitka spruce, Lodgepole pine and Scots pine (Robinson, 1998). Initial evidence showed an increase of 50-100mm in annual streamflow, which was the opposite of what was expected (Birkinshaw *et al*., 2014). It was suggested that extensive ploughing had lowered the water table, thus reducing losses by evapotranspiration (Robinson, 1998). Despite this, from around 1996 when the trees reached maturity, annual streamflow decreased by 250-300mm compared to pre-afforestation (Birkinshaw *et al*., 2014; Robinson, 1998).

As stated, Coalburn was established in the late 1960s, which predates the concept of NFM, therefore the planting was not referred to as NFM at the time. However, the catchment is now considered to be an example of NFM and is frequently cited as this in the literature, (Cooper *et al*., 2021; Iacob *et al*., 2012; Kay *et al*., 2019; Xiao *et al*., 2022) hence its suitability for inclusion as an NFM site in this research.

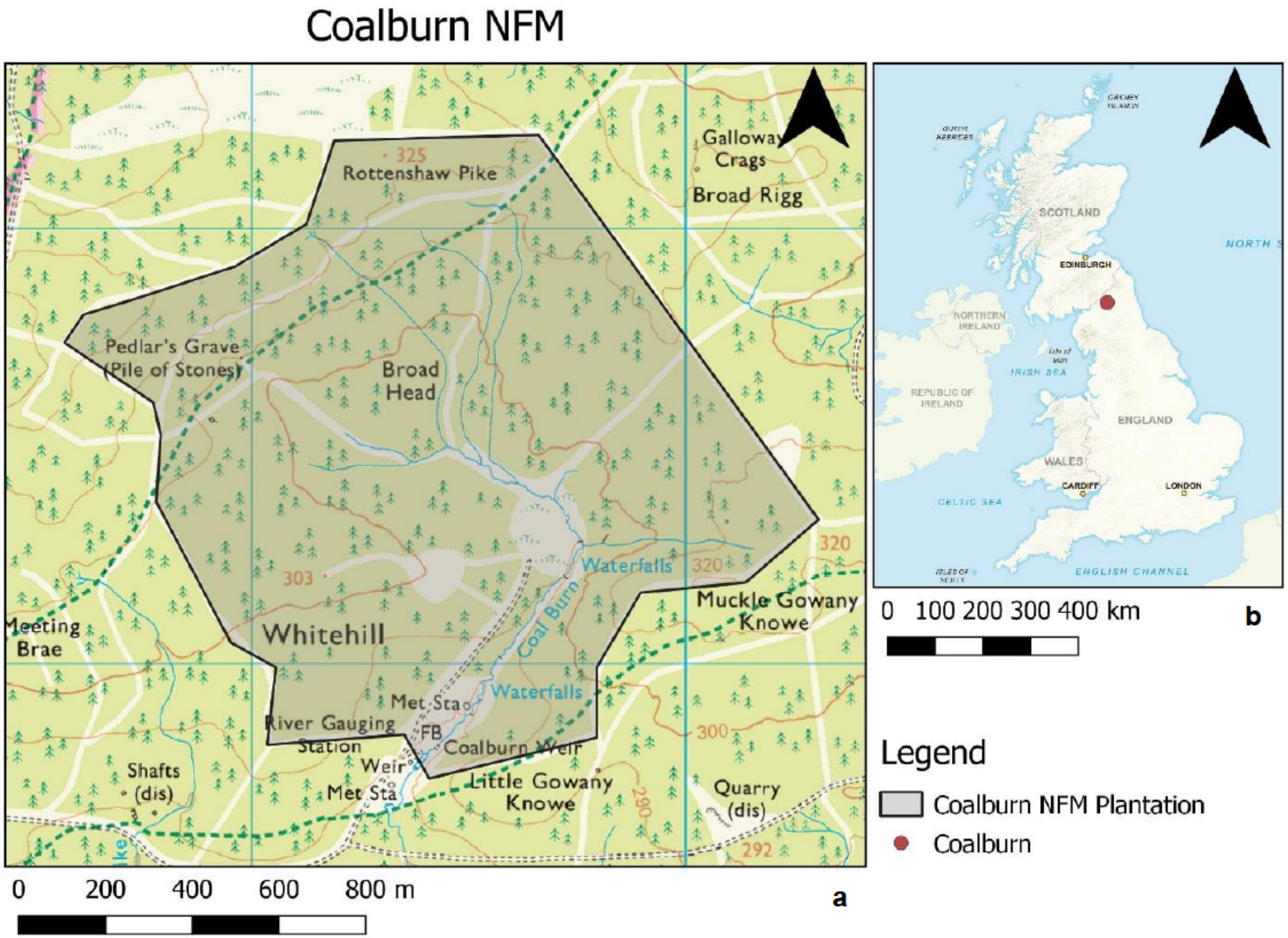

Figure 3.13a: *Detail of Coalburn NFM site.* **Figure 3.13b:** *Location of Coalburn within the UK.*

3.2.2 Crompton Moor

Crompton Moor is situated in Oldham, Greater Manchester, and the areas of NFM are shown in Figure 3.14. The landscape of Crompton Moor is made up of peatland and mixed woodland, and a selected area is also designated as a Site of Biological Importance due to its peat bog habitats (Natural Course, 2020; Oldham Council, 2022). Several NFM measures have been incorporated at Crompton Moor, including leaky dams, peatland restoration and tree planting, to reduce downstream flood risk (Friends of Crompton Moor, 2020). This research will focus on the element of tree planting that took place at Crompton Moor between January 2018 and March 2020 (Natural Course, 2020). Around 4000 trees were planted across four locations, totalling approximately 2.6ha. Table 3.5 details the range of tree species that were planted. The NFM intervention is expected to attenuate approximately 1000m^3 of water, which would otherwise have run-off, potentially resulting in downstream flooding (Natural Course, 2020).

This NFM project is part of Manchester City of Trees; a community forest within the wider Northern Forest (Northern Forest, 2019). The Northern Forest is a scheme that aims to plant 50 million trees across the north of England, which is expected to have a number of benefits including reducing the risk of flooding (Northern Forest, 2019). Some of these tree planting projects, including Crompton Moor, are part of the wider delivery of NFM and so their focus is on reducing flood risk.

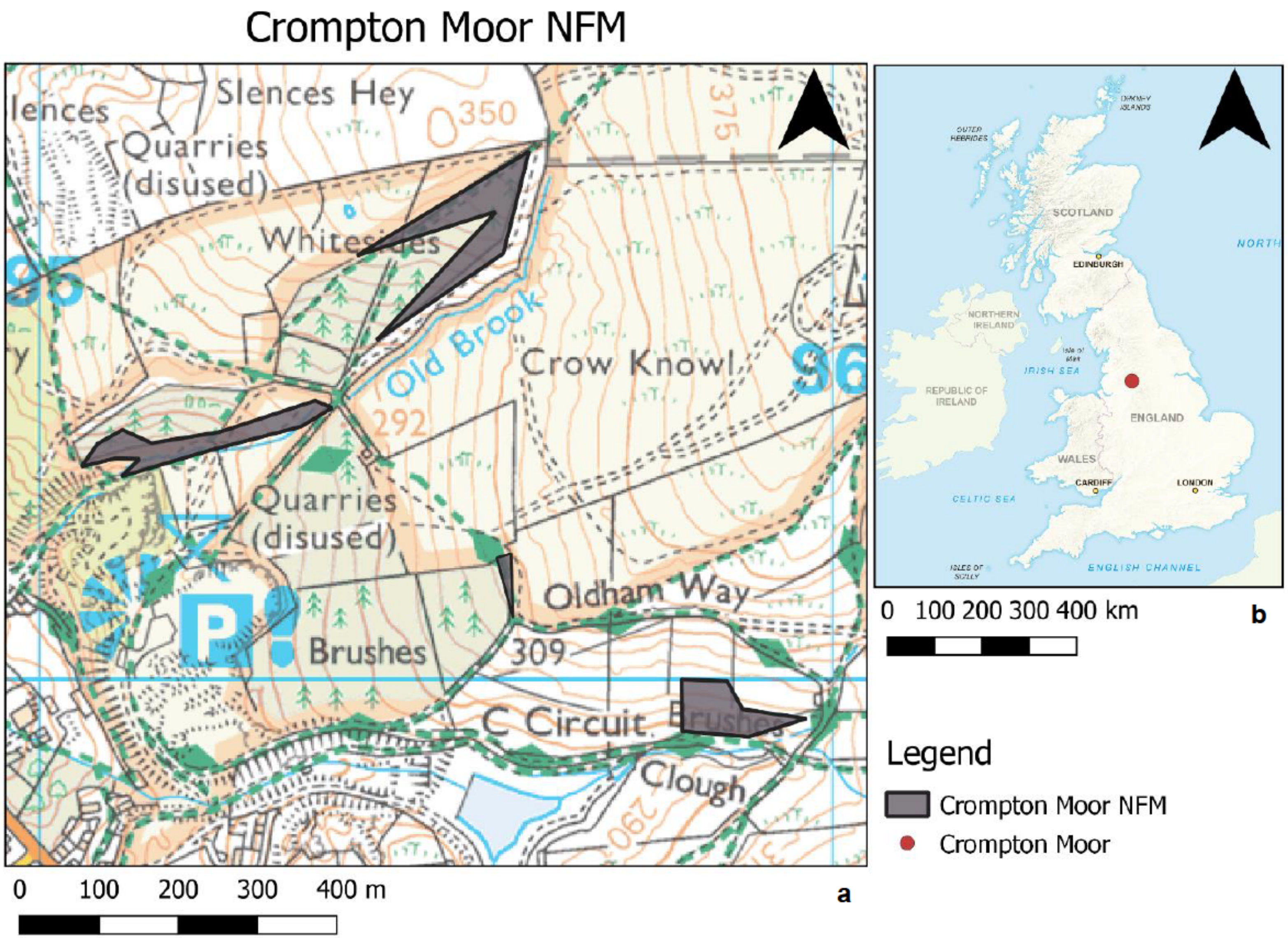

Figure 3.14a: *Detail of Crompton Moor NFM site.* **Figure 3.14b:** *Location of Crompton Moor within the UK.*

3.2.3 Glenderamackin

Figure 3.15 shows the NFM tree planting sites in the Glenderamackin catchment near Keswick. The river Glenderamackin is a tributary of the river Greta; the catchment covers around 100km^2 and encompasses the upstream watercourses of Keswick (West Cumbria Catchment Partnership, 2022). Situated in the Lake District National Park, Glenderamackin is a mountainous catchment, but also includes urban areas within the small towns. The area is vulnerable to flooding and was most notably affected in 2005, 2009 and 2015 (Spencer *et al*., 2018). Despite attempts to protect the area from flooding using hard-engineered structures, the focus has shifted to NFM in recent years. The West Cumbria Rivers Trust delivered a suite of NFM interventions between 2018 and 2022, including tree planting, pond creation and the installation of leaky barriers. The project was funded by Defra and the Green Recovery Challenge Fund in a bid to reduce downstream flooding (West Cumbria Rivers Trust, 2021a). This included 23.5ha of tree planting; the species and locations of which can be seen in Table 3.5. Glenderamackin is set to receive more catchment interventions as part of the Natural Environment Readiness Fund, with the aim to reduce peak flows by 5-15% through further NFM strategies (West Cumbria Rivers Trust, 2021b). These should not only provide further flood risk protection to Keswick, but also restore parts of the natural environment within the Lake District.

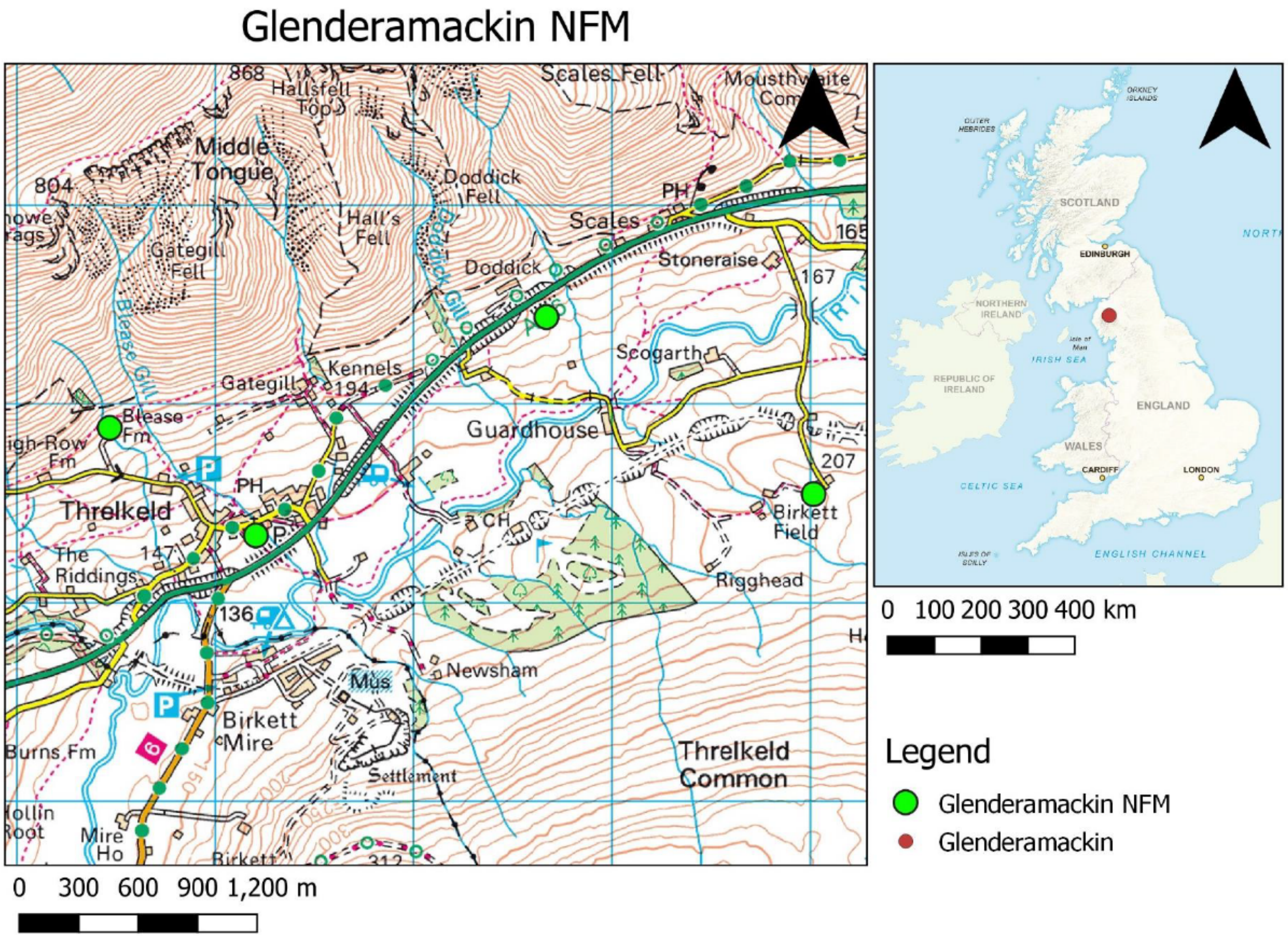

Figure 3.15a: *Detail of Glenderamackin NFM site.* **Figure 3.15b:** *Location of Glenderamackin within the UK.*

3.2.4 Pott Shrigley

The smallest of the sites is Pott Shrigley, a village in Cheshire. The land cover of this site is rural and dominated by agriculture. Multiple NFM measures were put in place in 2021 to slow the downstream flow of the river Dean, in order to protect nearby properties (Sanders, 2021). These included leaky dams and upland tree planting. 4000 trees were planted in total across two locations at Bakestonedale Moor and Bakestonedale Farm (Figure 3.16) and the tree species are listed in Table 3.5 (Mersey Rivers Trust, 2021). The combination of upland relief and historical grazing of this area exacerbates flood risk due to increased runoff, therefore the aim of the trees is to create a buffer by attenuating $1200m^3$ of water (Mersey Rivers Trust, 2021). Like the NFM at Crompton Moor, the trees planted at Pott Shrigley were provided by City of Trees, within the wider Northern Forest project (Mersey Rivers Trust, 2021). The secondary aim of the tree planting at Pott Shrigley is to increase biodiversity, habitats and food sources for invertebrates, birds, and mammals (Mersey Rivers Trust, 2021). It is intended that the range of tree species will provide shelter both for animals, and for other plants and tree species to colonise once the vegetation has established (Mersey Rivers Trust, 2021).

Pott Shrigley NFM

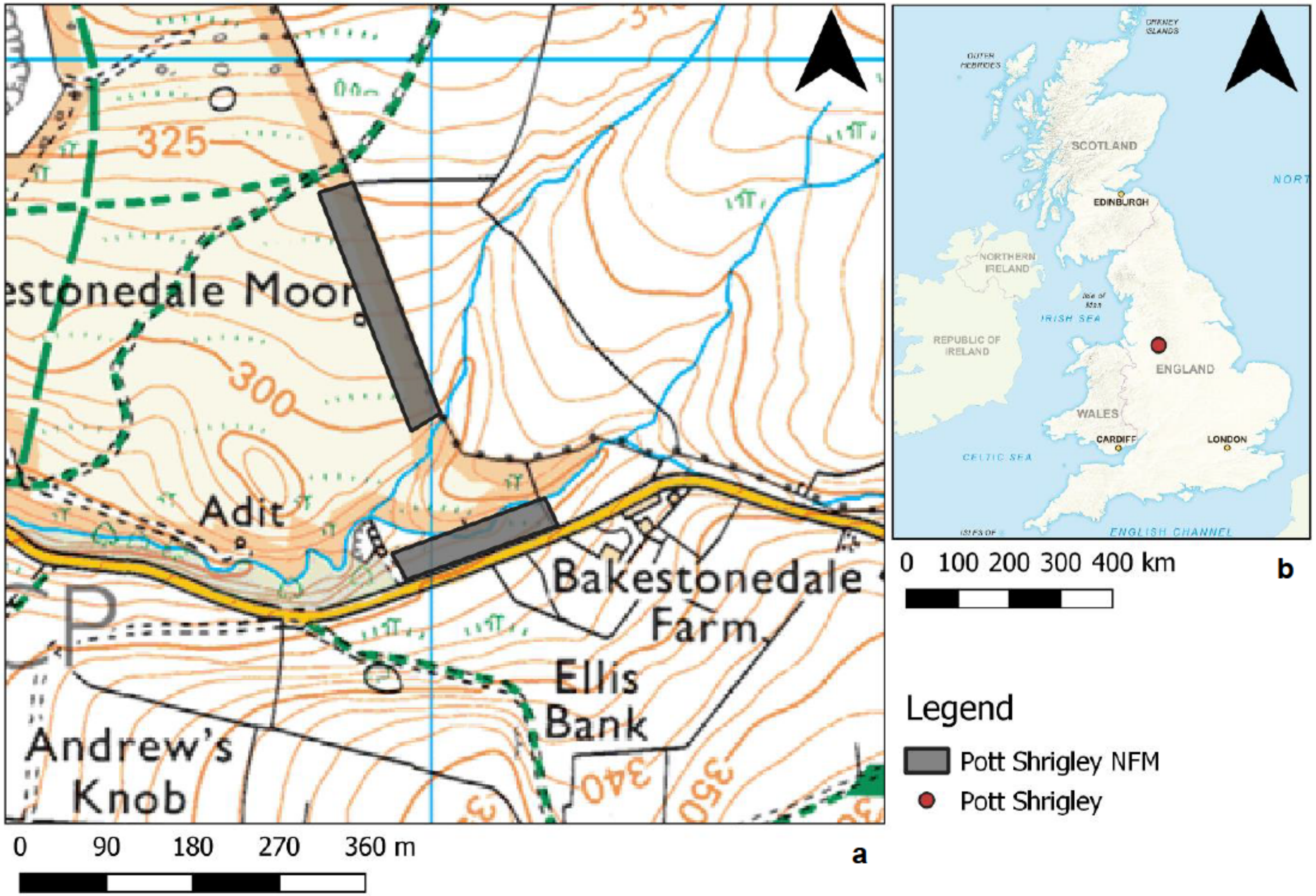

Figure 3.16a: *Detail of Pott Shrigley NFM site.* **Figure: 3.16b:** *Location of Pott Shrigley within the UK.*

3.3 GIS Mapping: Objective 1

3.3.1 Mapping

In order to meet the first objective, the current and historical land cover of each NFM site was mapped in QGIS (Version 3.28 Firenze). This required digitisation of OS maps, but prior to this, the data availability of the historic maps was assessed using Digimap (Edina, 2023a). Table 3.6 demonstrates the map availability and those that were selected as a result. The chosen maps attempt to minimise overlapping of the time periods and mostly favour the 1:10,000 scale due to availability. However, there were fewer data available for Glenderamackin, therefore the 1:2500 scale was selected to cover approximately the same, or similar, time periods as the rest of the sites. Land cover elements at the 1:10,000 and 1:2500 scales were compared using maps of the NFM sites where both scales were available at a similar time. These used the same legend for the main land cover categories, therefore it was deemed appropriate to use the 1:2500 scale for Glenderamackin, where 1:10,000 was unavailable. For the current land cover maps, OS VectorMap Local was used for each NFM site, which is at the 1:10,000 scale and represents January 2023, so is the most up to date available map.

After the maps were selected, the files were downloaded from Digimap for each time period. Figure 3.17 highlights the process of digitising the maps. Individual elements were identified using a historical OS map legend, and shapefiles were created to represent these. To begin with, individual buildings were digitised, but this method did not represent the whole urban area. Therefore, the area surrounding the buildings was also digitised to symbolise a village or farm buildings, for example. Because these areas were not completely 'urban', particularly in the older maps, they were labelled as 'discontinuous urban fabric', due to them being low density, semi-urban areas. Once the whole map had been digitised, the symbology was edited to make for easier comparisons. This methodology was repeated for each map.

It is acknowledged that while the historic OS maps demonstrate land cover, they do not provide any further detail about the tree taxa that were present. The classification of coniferous, non-coniferous or mixed woodland was relied upon to determine the type of trees that were present in the maps. The analyses, therefore, had to be tentative to account for this. The use of historic estate maps and documentary sources was considered, as these typically label land cover more specifically. However, due to availability and time constraints, this was deemed to be out of the scope of this research.

Table 3.6: *Historic OS map availability on Digimap. CS = County Series map, NG = National Grid map. Green = full map available, Red = no map or incomplete data. Ticks = selected data.*

	CS 1846-1899	CS 1853-1904	CS 1888-1914	CS 1894-1915	CS 1903-1950	CS 1906-1939	CS 1924-1951	CS 1922-1969	NG 1943-1995	NG 1948-1977	NG 1958-1996	NG 1969-1999
	1:10560	**1:2500**	**1:10560**	**1:2500**	**1:10560**	**1:2500**	**1:2500**	**1:10560**	**1:2500**	**1:10560**	**1:10000**	**1:10000**
Coalburn	✓				✓					✓	✓	
Crompton Moor	✓				✓					✓	✓	
Glenderamackin		✓		✓						✓	✓	
Pott Shrigley	✓				✓					✓	✓	

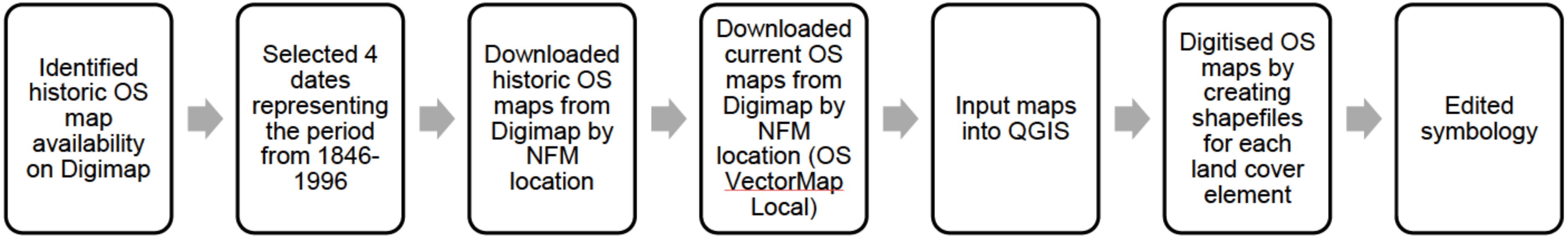

Figure 3.17: *Process of selecting, downloading and digitising OS maps*

3.3.2 Quantifying Land Cover

In order to allow for comparisons, the land cover elements from both the current and historical GIS maps were quantified, in terms of both actual area and percentage cover. To do this, the spatial area for each land cover class was generated in the attribute table in QGIS and converted to kilometres squared. To ensure the correct area had been generated, one of the land cover elements was selected and converted to a KMZ file and then opened in Google Earth Pro. The area tool in Google Earth Pro was used to verify that the area was the same, thus confirming that this method was suitable. As the measurements were valid, the remaining land cover elements were quantified in QGIS, and the land cover area was calculated in MS Excel. This method was repeated for the remaining current and historical maps. The change in percentage cover between each land cover element for the specific sites was calculated to show the change over time. These results can be found in Section 4.1.

3.4 Pollen Analysis: Objective 2

3.4.1 Pollen Diagrams

The second objective was met by interpreting the pollen diagrams from the sites discussed in Subsections 3.2.1-3.2.4. First, the pollen diagrams were obtained from the selected papers. The aim was to use data taken from the mid-Holocene – pre-human influence – to gauge as accurately as possible what the 'natural' state of the landscape was like (Hodder *et al*., 2009). Woodbridge *et al.* (2014) acknowledge the impact of land clearance by humans during the Neolithic period from 6000-5300 cal. BP (calibrated years before present). Therefore, it was intended for the pollen diagrams to represent the mid-Holocene (*c*. 6000 cal. BP), to only account for the 'natural', undisturbed vegetation. However, this was not always possible, due to some of the palaeoenvironmental data representing later time periods. Because these were the only data available, the earliest time period was analysed, and the potential influence of human activity on the vegetation was noted. This still gives an indication as to what the environment was like during the Holocene before maps and written records were available.

The pollen diagrams were interpreted by identifying which taxa were present in the mid-Holocene. It should be noted that the palaeoenvironmental data only identified pollen to a genus level, therefore precise species could not be detected. This limited the comparison between the NFM species and the mid-Holocene taxa to an extent, but it was accepted that the genus provided enough detail for this research. Vegetational changes that the authors attributed to human activity were also noted, to be discussed in relation to how 'natural' the NFM is in Chapter 5. If the diagrams were divided into zones, these were summarised to give an overview of environmental change. The results sections of the selected papers supported these interpretations. Due to the focus of this research being on tree planting, only tree taxa were recorded, though other vegetation was also mentioned in the analyses to contextualise the environment. When analysing the palaeoecological data, the dates were taken into consideration as different dating systems were used, which meant the sites were not easily comparable. Most of the pollen diagrams were radiocarbon dated, however: not all dates were calibrated; some included a range; and some used the BC/AD system (see Table 3.7). For the studies that provided raw, uncalibrated dates, the calibration software CALIB 8.2 was used to calibrate them for consistency (Stuiver and Reimer, 1993). The software provided several different results, therefore, those with the highest confidence levels were selected. The dates were given as an estimated range, so the midpoint between them was calculated and rounded to the nearest ten, however it is acknowledged that the exact date could actually be anywhere within the range. The diagrams that were dated in BC/AD were converted to represent years before present (BP). The tree taxa present in the pollen diagrams during the mid-Holocene were tabulated and are presented in Chapter 4.

Table 3.7: *Dating systems used in the pollen diagrams*

NFM Site	Pollen Site	Dating System	Associated Paper
Coalburn	Butterburn Flow	BC/AD	Hendon and Charman, 2004
	Butterburn Flow	BC/AD	McClymont *et al*., 2008
	Butterburn Flow	BC/AD	Yeloff *et al*., 2007
	Coom Rigg Moss	Calibrated	Hendon, 1998
	Coom Rigg Moss	Calibrated	Mauquoy and Barber, 1999
	Felecia Moss	Calibrated	Mauquoy and Barber, 1999
Crompton Moor	Black Heath	Calibrated	Ryan and Blackford, 2010
	Castleshaw Moor	Uncalibrated	Brayshay, 1998
	Rishworth Moor	Uncalibrated	Bartley, 1975
	Soyland Moor Site C	Uncalibrated	Williams and Switsur, 1985
	Soyland Moor Site D	Uncalibrated	Williams and Switsur, 1985
Glenderamackin	Calvert Trust Land	Uncalibrated	Hodgkinson *et al*., 2000
	Derwent Water (Cannon Dub)	Uncalibrated	Hodgkinson *et al*., 2000
	Little Tarn	Uncalibrated	Hodgkinson *et al*., 2000
Pott Shrigley	Danes Moss	Uncalibrated	Leah *et al*., 1997

Although the pollen record provides a valuable insight into the taxa present over time, the impact of widespread disease should be addressed. Dutch elm disease is an example of this, which occurred around 5000 BP and is recognised by declines in elm pollen when analysing pollen diagrams (Perry and Moore, 1987). It is generally accepted that the elm decline was caused by a combination of climatological and human factors, and was therefore considered when interpreting the pollen data for this project (Parker *et al*., 2002). Because the aim was to understand the 'natural' landscape before human influence, any indication of declining elm pollen signposted the potential for human activity, allowing for a more cautious analysis.

3.5 Interviews: Objective 3

3.5.1 Philosophical Approach and Positionality

The consideration of both quantitative data (Sections 3.3 and 3.4) and qualitative data (Section 3.5) reflects the pragmatic approach taken in this research. In order to meet Objective 3 – to conduct interviews with flood management stakeholders to assess the importance of 'naturalness' within NFM – an interpretivist approach was required. This was due to the subjectivity and diverse opinions caused by the semi-structured interviews (Alharahsheh and Pius, 2020). Although NFM is an established strategy, Chapter 2 highlighted that there are varying definitions of it. Certainly, the interviews revealed that individuals' perceptions of what NFM is differed between participants. The interpretivist approach allowed for an exploration of the participants' views and thoughts on NFM, including the benefits and barriers to its implementation. Saunders *et al*. (2009) emphasise that the purpose of interpretivist research is to enhance understandings, which aligns with the aim of this project in the context of NFM.

Additionally, positionality was taken into account. Positionality is relevant as it shapes each part of the research process, from formulation of the research question through to the conclusions drawn from the results (Coghlan and Brydon-Miller, 2014). Focusing on the interviews, it is recognised that, being a master's student, I did not have as much experience on the applied side of NFM compared to the interview participants, who were experts in their field. This could have impacted the responses as it is possible that the interviewees may have responded differently to a more experienced researcher or person working in industry. Although NFM is not typically a controversial topic, the aim was to challenge the perception and definition of NFM, which could have evoked negative responses due to the participants working in the flood management sector. At the start of the interviews, the intentions to explore the concept of NFM and reflect on the project data were outlined to the participants, to ensure a shared understanding of the project aim. Linked with this, Wingfield *et al*. (2021) acknowledged the importance of the researcher's opinion when conducting interviews – in their case on the barriers to NFM implementation. Like Wingfield *et al*. (2021), bias was minimised when interviewing NFM stakeholders, by remaining neutral and asking balanced questions (Robson and McCartan, 2016). This intentional focus in the interview approach aimed to ensure that the participants' responses were as authentic as possible. Despite this, it is recognised that it was difficult to remain completely neutral, due to the research question being driven by an opinion. The choice of interviewing NFM professionals was motivated by the desire to challenge the concept of NFM, which may have resulted in differing opinions, had the interviews been conducted with a different audience. Therefore, even though the interviews were as impartial as possible, it is accepted that there may be some bias due to assumptions.

3.5.2 Participant Recruitment

The aim of the interview process was to assess understanding of how 'natural' NFM is perceived to be by NFM practitioners, and the importance given to restoring the 'natural' environment as a flood management technique. Therefore, potential participants were required to have prior knowledge and experience of NFM to allow for in-depth discussions. In order to recruit participants, emails were sent either to people working in flood risk management, who were already known to the researcher, or to generic email addresses of organisations involved in NFM, which were sought via internet research. Follow up emails were sent after one week to those who had not responded. Seven interviews were scheduled throughout April 2023; there was no predetermined sample size, but due to this being only a third of the data collection, seven was deemed to be an appropriate starting number at this point in time. Contacts of other potential participants were noted in the event that more data were required. It had been decided beforehand that while data interpretation was ongoing, data saturation would be monitored (Fusch and Ness, 2020). Once the seven interviews were completed, it was noted that the same themes had continued to reoccur, and no new insights were emerging. Hence, data saturation had been achieved and a larger sample size was therefore deemed unnecessary.

As stated, the participants were selected due to their connection with NFM, which included people from consultancies, NGOs, and research backgrounds. To gain a more holistic view of NFM, it perhaps would have been beneficial to also interview people from the farming industry, due to NFM being frequently implemented on privately-owned land. However, since there are already published studies engaging with land managers (Holstead *et al*., 2017; Lavers *et al*., 2022; Wells *et al*., 2020), the focus of this research was centred on those involved in NFM delivery.

Prior to the interviews, each participant was asked to read an information sheet and informed consent form, which outlined what to expect of the interviews and required agreement to be audio recorded. Ethical guidelines set by the University were followed at all times. Once informed consent was received, the participants were sent a general overview of the interview structure, as well as some basic information about the project. All seven interviews took place online using MS Teams and were scheduled for one hour, however they ranged between 33 and 63 minutes. The interviews were recorded using MS Teams and verbal consent was requested prior to starting recording.

3.5.3 Interview Process

Semi-structured interviews were conducted for this project, which aimed to facilitate open discussions on the topic of NFM. This approach was also taken by Holstead *et al*. (2017), Waylen *et al*. (2018) and Wells *et al*. (2020) when interviewing participants about the barriers to NFM uptake. Semi-structured interviews were deemed most appropriate to obtain comprehensive responses, and, in contrast to questionnaires for instance, allowed for follow-up questions based on the participants' answers (Adams, 2015). Structured interviews would not have been suitable due to the participants having different backgrounds and therefore potentially slightly different perceptions of NFM. The open, conversational nature of the interviews facilitated a more in-depth exploration of individual responses.

Prior to the interviews, a topic guide was created to provide a general structure and to highlight the main areas to be discussed. Kallio *et al*. (2016) acknowledged the importance of creating a topic guide for semi-structured interviews and stated that doing so contributes to objectivity, reducing the chance of bias. This also ensured that the approach to all of the interviews was consistent, and allowed the subject of NFM to be explored completely with each participant. Waylen *et al*. (2018) describe using a topic guide in their methodology, which was informed by the literature, and a similar approach was taken in this project. Figure 3.18 details the main topics that were to be discussed in the interviews, and the full topic guide with examples of questions can be found in Appendix B. There was no obligation for the topics to be followed in any particular order, but the initial questions surrounding job roles and knowledge of NFM were always asked first (Bark *et al*., 2021). This provided a baseline and allowed the interviewer to gauge the direction the interview might take. The remainder of the interview was based on the participant's responses and topics were addressed as they were mentioned. The final topic of all of the interviews was based on the data presentation from Objectives 1 and 2 of this project. Figure 3.19 details the information that the participants were shown and the researcher provided an explanation of how the data were obtained. Each participant was asked the same question after being presented with the data: "Taking into account the data from this project, to what extent do you think NFM can be considered 'natural'?". As before, discussions after this were based on the participants' individual responses.

- Introductions
  - Job role
  - Interaction with NFM
- Defining NFM and exploring the concept
- NFM changes over time
- Barriers to NFM uptake
- Approach to flood management
- The future of flood management
- Presentation of project data

Figure 3.18: *Simplified topic guide for the semi-structured interviews*

NFM Site X

NFM Species

- Downy birch
- Silver birch
- Hawthorn
- Hazel
- Holly
- Common oak
- Sessile oak
- Rowan
- Grey willow

Historical and Current Land Cover

- Agriculture/pastures
- Non-coniferous trees
- Rough grassland

Early to Mid-Holocene Tree Taxa from Pollen Analysis

- Alder
- Birch
- Hazel
- Pine
- Oak
- Elm

Figure 3.19: *Data presentation slide shown to the interview participants. Yellow highlighting shows similarities between the three pieces of data, which was also shown to the participants.*

3.5.4 Post-interview Analysis

The interviews were transcribed manually using MS Word, and all participants' personal information was anonymised, as agreed in the informed consent. Participants were assigned a number, which will be referred to throughout the remainder of this work. Once transcribed, the files were uploaded into NVivo 1.5 software in preparation for coding. Thematic analysis was undertaken manually, by reading through the transcripts and identifying the main, reoccurring themes throughout all of the interviews. Particular language and reference to certain topics often formed the basis of these themes, due to their regular occurrence and thus significance. This ensured that the context was considered when analysing the data, aligning with the interpretivist approach, by acknowledging the subjective nature of semi-structured interviews. Waylen *et al*. (2018) and Wells *et al*. (2020), identified codes and sub-codes in their data on barriers to NFM, which were based on themes from their topic guides. They also coded new themes that had not previously been identified in the topic guide, but frequently occurred amongst different participants. A similar approach was taken in this project, in that the codes were first based on the main questions, then sub-codes allowed for common themes to be included that were not part of the original topic guide.

When presenting the results of the interviews, the data were analysed in terms of their content. This involved quantifying the codes and sub-codes to identify those that occurred most frequently. This provided a basic analysis of the most popular themes overall and the results are presented in Chapter 4.

3.6 Conclusion

This chapter has outlined the methodological approach to collecting and analysing the data for the project. This includes contextualisation of the study sites, GIS mapping, palaeoenvironmental reconstruction, and interviews. Limitations with the chosen methodologies have also been identified throughout this chapter and have been taken into consideration when analysing the results. The next chapter presents the results from each objective, and considers how they can be used in conjunction with one another, in order to evaluate the extent to which NFM can be considered 'natural'.

CHAPTER 4: RESULTS

The results from each part of the data analyses are summarised in this chapter, and the overall trends and findings will be identified. Figure 4.1 outlines the results for each objective, demonstrating the connections between them. Chapter 5 will then synthesise these data, along with the literature explored in Chapter 2, to evaluate the significance of the term 'natural' within NFM.

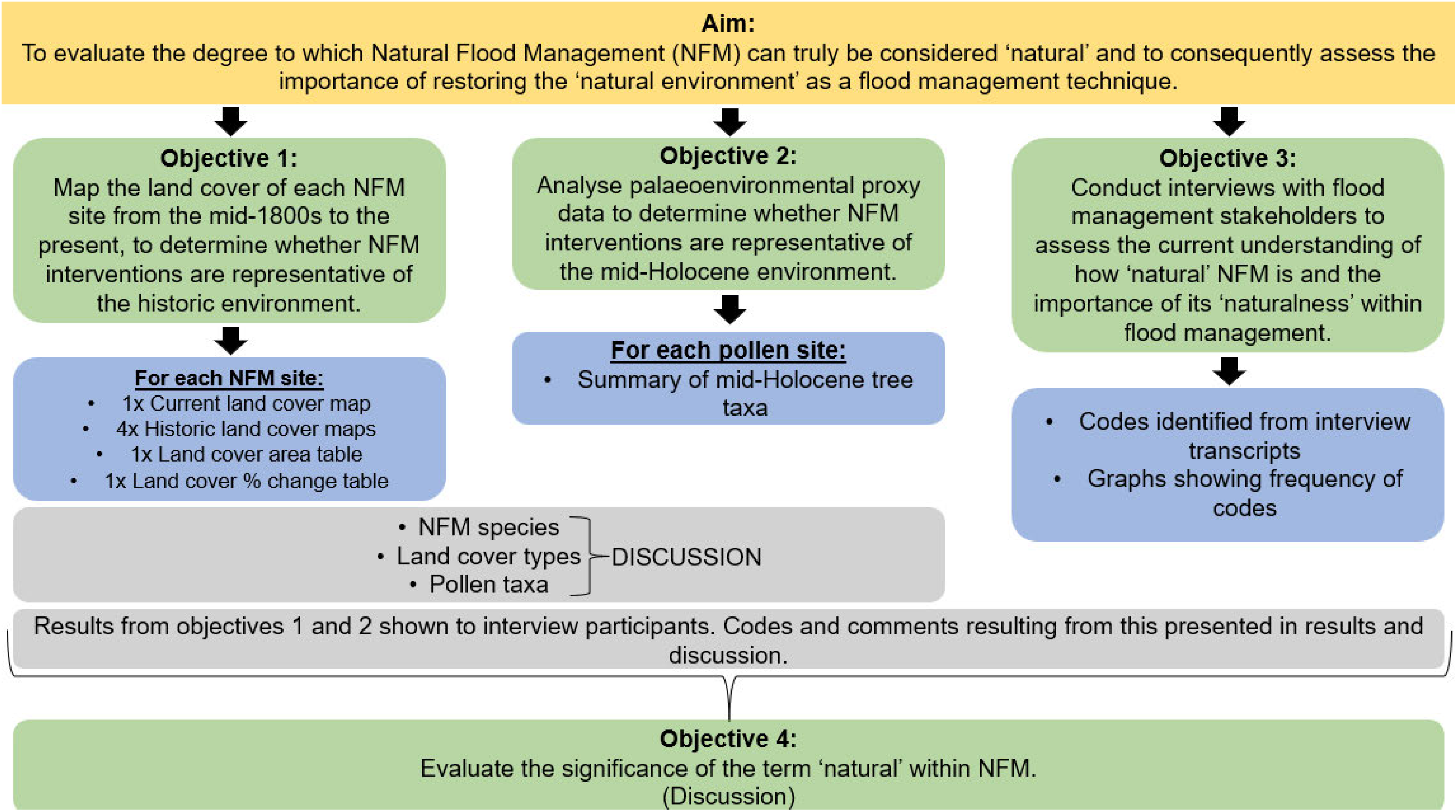

Figure 4.1: *Framework for presentation of results linked with the relevant objectives*

4.1 Land Cover (mid-1800s to present)

In order to meet Objective 1, maps representing the land cover of approximately the last 170 years are presented for each NFM site. This includes four historic maps taken at semi-regular intervals from the mid-1800s to the late 20th century, and one map demonstrating the current land cover (2023). In addition to these, two tables are presented for each site, which outline the area of each land cover type and the change in percentage cover over time.

4.1.1 Coalburn

The land cover at Coalburn remains visually similar for approximately the first 100 years, as it is dominated by rough grassland from Figure 4.2 to 4.4 (beginning 1846 and ending 1977). Figures 4.5 and 4.6 (1958-1996 and 2023) exhibit a change in the landscape, as coniferous trees become the main land cover type and rough grassland declines, to be found only in patches. Table 4.1 shows that coniferous trees cover 5.00km^2 and 4.91km^2 of the total area in Figures 4.5 and 4.6 respectively, having previously not been present at all. The establishment of woodland coincides with the tree planting that was part of the Coalburn hydrological research during the 1970s, which is now referred to as NFM (Robinson, 1998). It is noted that this seemingly sudden change in land cover was, in fact, human-induced and therefore not a natural change. This will be explored further in Subsection 5.1.1. Overall, Figures 4.2 to 4.6 demonstrate that Coalburn has experienced a considerable shift in land cover in a relatively short space of time, from being 98% rough grassland in 1846-1899, to 94% coniferous trees in 2023.

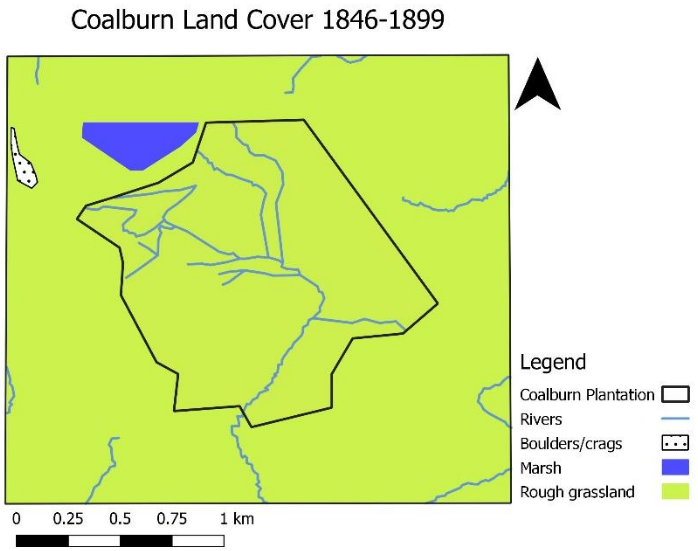

Figure 4.2: *Coalburn land cover 1846-1899 (EDINA, 2010a)*

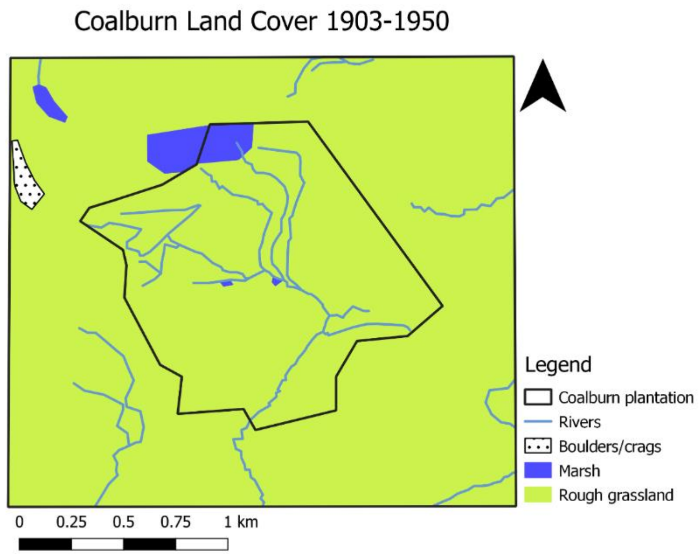

Figure 4.3: *Coalburn land cover 1903-1950 (EDINA, 2010a)*

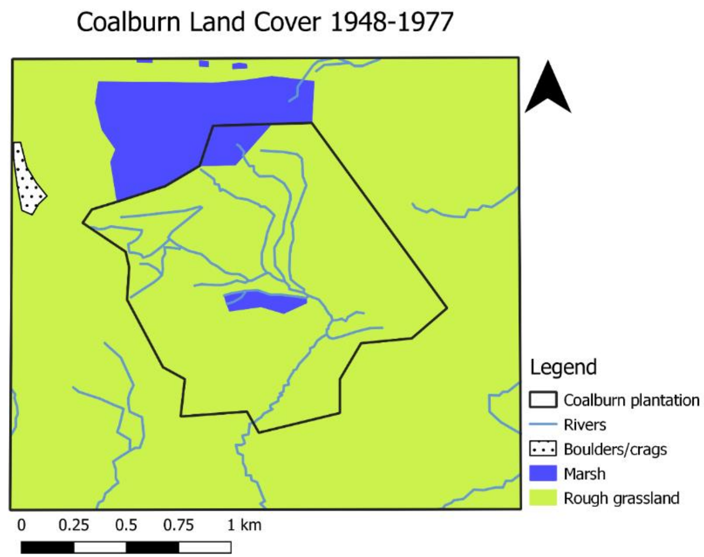

Figure 4.4: *Coalburn land cover 1948-1977 (EDINA, 2010a)*

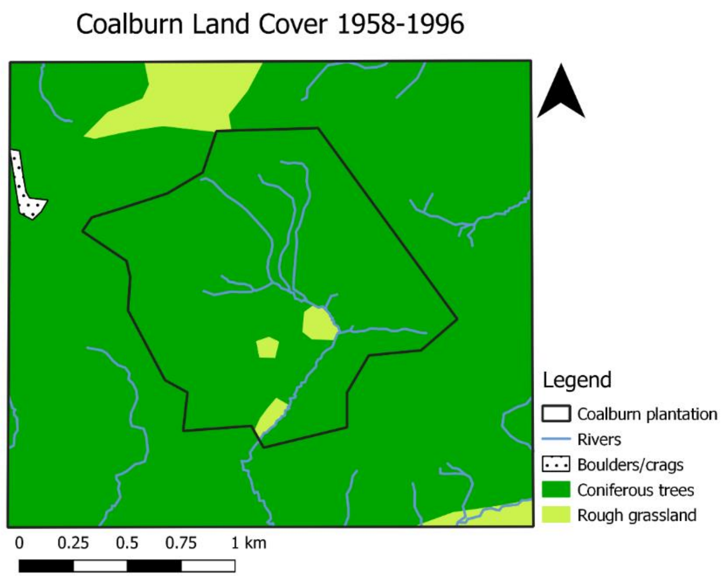

Figure 4.5: *Coalburn land cover 1958-1996 (EDINA, 2010a)*

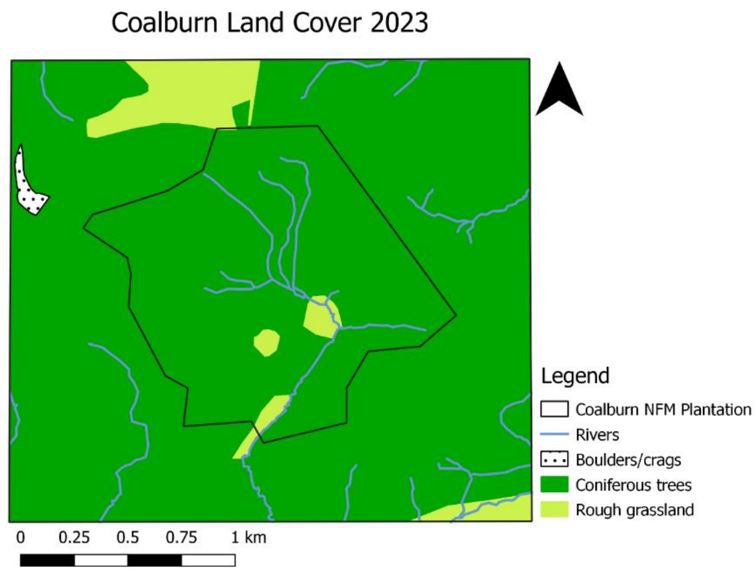

Figure 4.6: *Coalburn land cover 2023 (EDINA, 2023b)*

Table 4.1: *Coalburn land cover area (km^2)*

	1846-1899	1903-1950	1948-1977	1958-1996	2023
Boulders/crags	0.02	0.02	0.03	0.02	0.02
Marsh	0.09	0.11	0.42	0.00	0.00
Rough grassland	5.13	5.10	4.79	0.26	0.31
Coniferous trees	0.00	0.00	0.00	5.00	4.91

Table 4.2: *Coalburn percentage land cover (with change in percentage). Boulders/crags not included as typically a fixed structure.*

	1846-1899	1903-1950	1948-1977	1958-1996	2023
Boulders/crags					
Marsh	1.62%	2.10% *(+0.48%)*	8.01% *(+5.91%)*	0.00% *(-8.01%)*	0.00% *(0%)*
Rough grassland	98.09%	97.47% *(-0.62%)*	91.50% *(-5.97%)*	5.03% *(-87.47%)*	5.82% *(-0.79%)*
Coniferous trees	0.00%	0.00% *(0%)*	0.00% *(0%)*	94.60% *(+94.60%)*	93.82% *(-0.78%)*

4.1.2 Crompton Moor

Over time, the land cover at Crompton Moor has been dominated by rough grassland and pastures, with rough grassland being the main land cover class up to 2023 (Figures 4.7 to 4.11). Pastures showed an initial increase from 1846-1899 to 1903-1950 (Table 4.4), but then decreased until 2023. Figures 4.7 to 4.10 demonstrate the presence of a quarry, which expanded most significantly between 1846-1899 and 1903-1950 (Table 4.4), before it became disused and no longer present by 2023 (Figure 4.11). Discontinuous urban fabric showed a gradual increase from Figure 4.7 to 4.10, reflecting the growth of the town, but decreased in 2023 by 50%.

The most significant change occurs in Figure 4.11 due to the introduction of woodland to Crompton Moor. The previous maps are devoid of any trees, making the presence of coniferous trees, non-coniferous trees, and mixed woodland in 2023 notable. The non-coniferous trees appear to replace most of the area previously used for the quarries, and the coniferous trees and mixed woodland are located close to the watercourse. This is potentially a result of the NFM tree planting that took place between 2018 and 2020 (Natural Course, 2020). Additionally, much of the area that was pastures becomes coniferous trees, as pastures decline by 89%, therefore it is likely that this sudden increase in woodland is a result of tree planting. Chapter 5 will evaluate the extent to which this can be considered natural (Subsection 5.1.2).

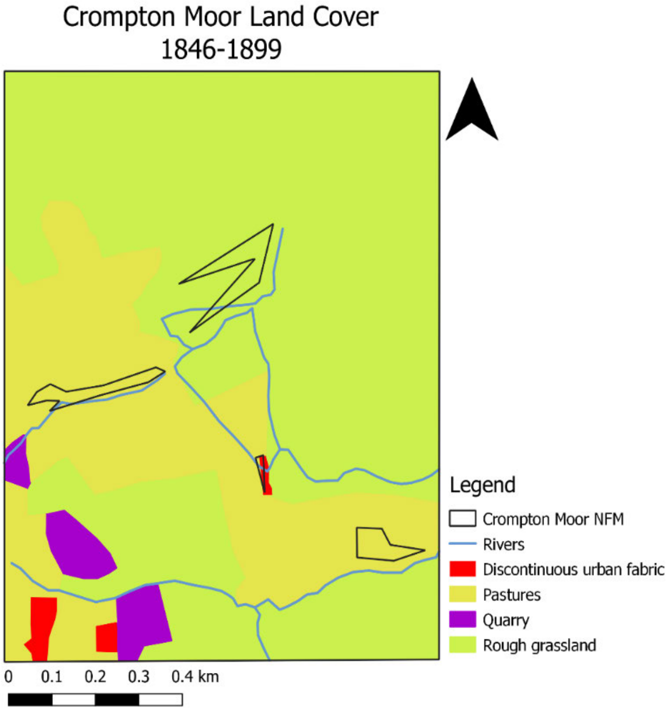

***Figure 4.7:** Crompton Moor land cover 1846-1899 (EDINA,2010b)*

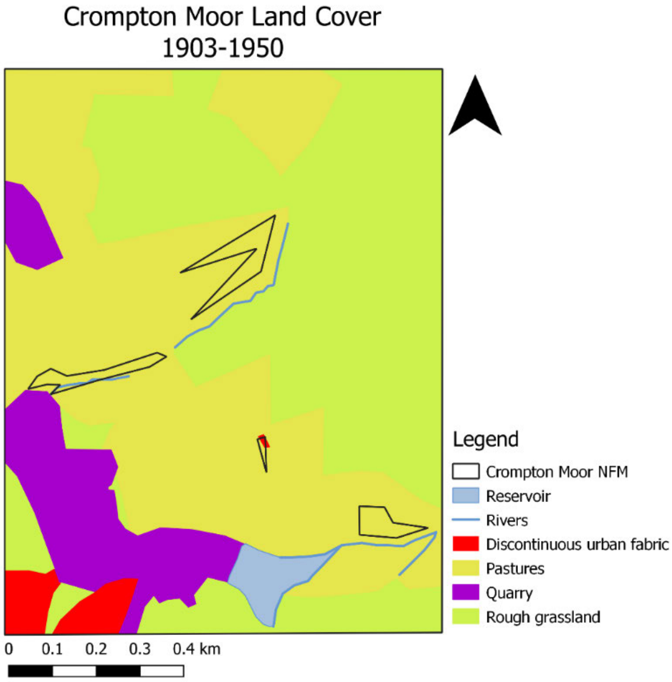

Figure 4.8: *Crompton Moor land cover 1903-1950 (EDINA, 2010b)*

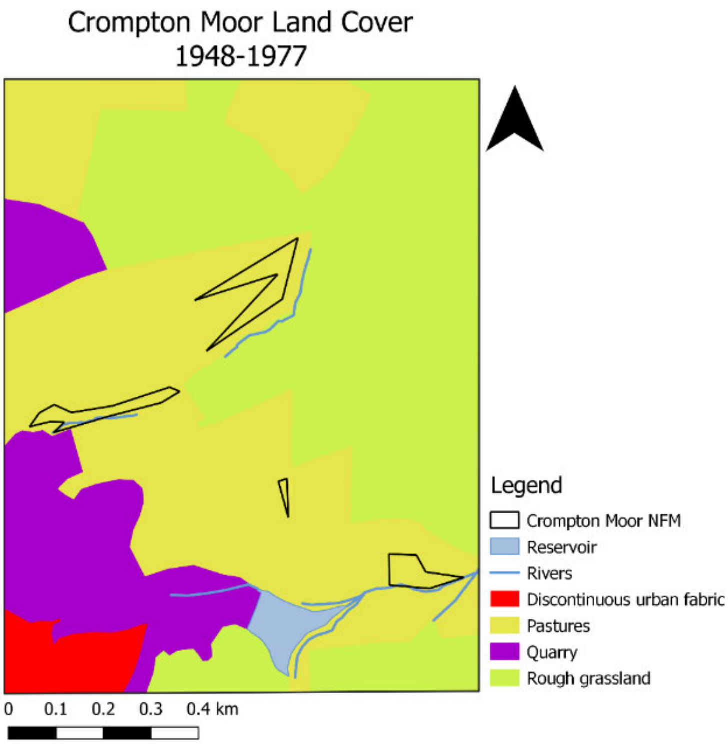

Figure 4.9: *Crompton Moor land cover 1948-1977 (EDINA, 2010b)*

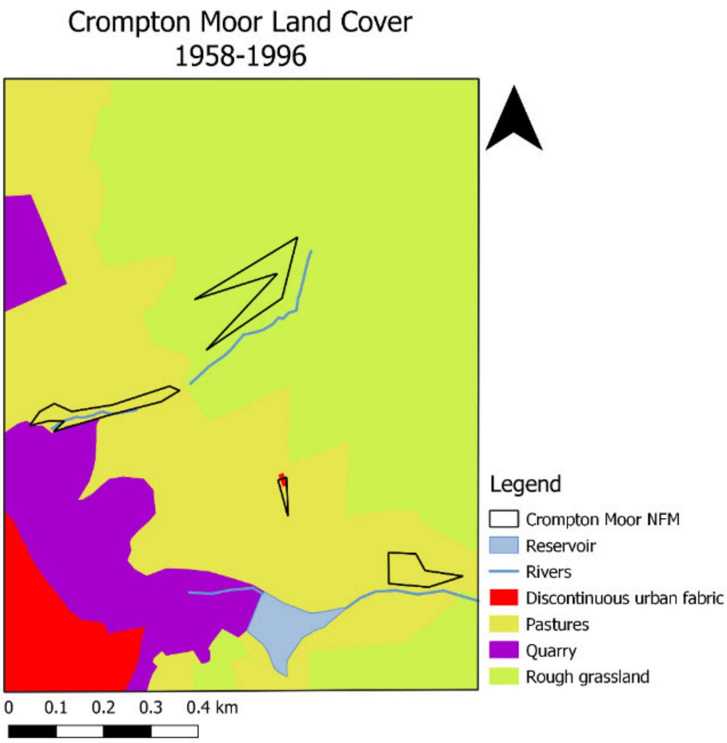

Figure 4.10: *Crompton Moor land cover 1958-1996 (EDINA, 2010b)*

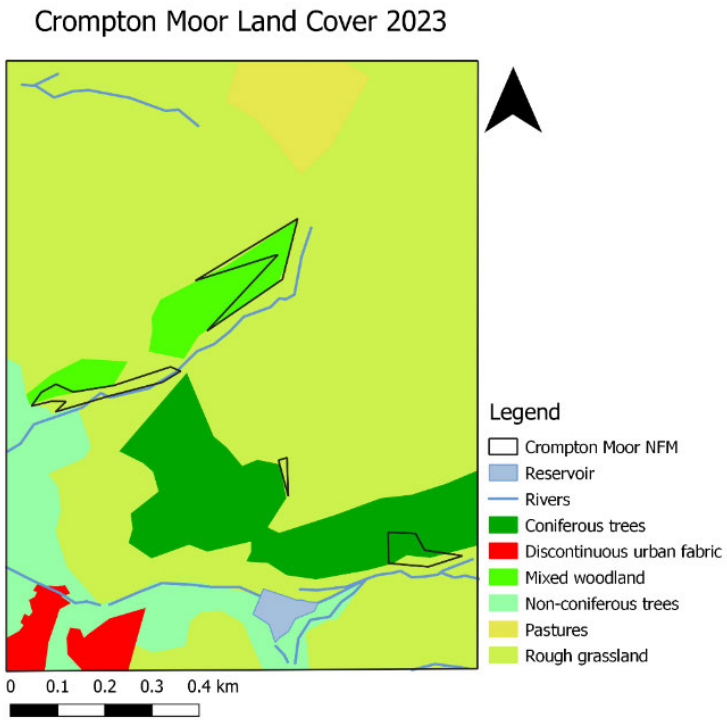

Figure 4.11: *Crompton Moor land cover 2023 (EDINA, 2023c)*

Table 4.3: *Crompton Moor land cover area (km^2)*

	1846-1899	1903-1950	1948-1977	1958-1996	2023
Coniferous trees	0.00	0.00	0.00	0.00	0.14
Discontinuous urban fabric	0.01	0.03	0.04	0.06	0.03
Mixed woodland	0.00	0.00	0.00	0.00	0.05
Non-coniferous trees	0.00	0.00	0.00	0.00	0.11
Pastures	0.37	0.54	0.52	0.43	0.05
Quarry	0.04	0.14	0.18	0.15	0.00
Reservoir	0.00	0.02	0.02	0.02	0.01
Rough grassland	0.88	0.56	0.55	0.64	0.92

Table 4.4: *Crompton Moor percentage land cover (with change in percentage). Reservoir not included as typically a fixed structure.*

	1846-1899	1903-1950	1948-1977	1958-1996	2023
Coniferous trees	0.00%	0.00% *(0%)*	0.00% *(0%)*	0.00% *(0%)*	10.65% *(+10.65%)*
Discontinuous urban fabric	0.91%	2.39% *(+1.48%)*	3.00% *(+ 0.61%)*	4.48% *(+1.48%)*	2.26% *(-2.22%)*
Mixed woodland	0.00%	0.00% *(0%)*	0.00% *(0%)*	0.00% *(0%)*	3.54% *(+3.54%)*
Non-coniferous trees	0.00%	0.00% *(0%)*	0.00% *(0%)*	0.00% *(0%)*	8.36% *(+8.36%)*
Pastures	28.23%	42.13% *(+13.90%)*	39.93% *(-2.20%)*	33.00% *(-6.93%)*	3.55% *(-29.45%)*
Quarry	2.84%	10.45% *(+7.61%)*	13.59% *(+3.14%)*	11.75% *(-1.84%)*	0.00% *(-11.75%)*
Reservoir					
Rough grassland	68.02%	43.44% *(-24.58%)*	42.34% *(-1.10%)*	49.64% *(+7.30%)*	71.07% *(+21.43%)*

4.1.3 Glenderamackin

The main land cover type at Glenderamackin in Figures 4.12 to 4.16 is pastures, though rough grassland is also quite extensive. Woodland is present throughout the mapped period, and despite some fluctuations, non-coniferous trees are the dominant tree type in Figures 4.12, 4.13, 4.14 and 4.16 (see Table 4.5). The actual coverage of trees is quite sporadic at Glenderamackin and the variation in total cover over time could point towards both clearance and planting. The patch of mixed woodland to the south of Glenderamackin in Figure 4.15 is replaced almost exactly with coniferous trees in Figure 4.16, though it is likely that this is the result of a mapping error. However, it is clear that some tree planting has taken place in this area due to the transition from rough grassland in Figures 4.12 to 4.14 (1853-1904 to 1948-1977), to woodland in Figures 4.15 and 4.16 (1958-1996 to 2023). The extent to which these land cover changes can be considered representative of the natural environment will be examined in Subsection 5.1.3.

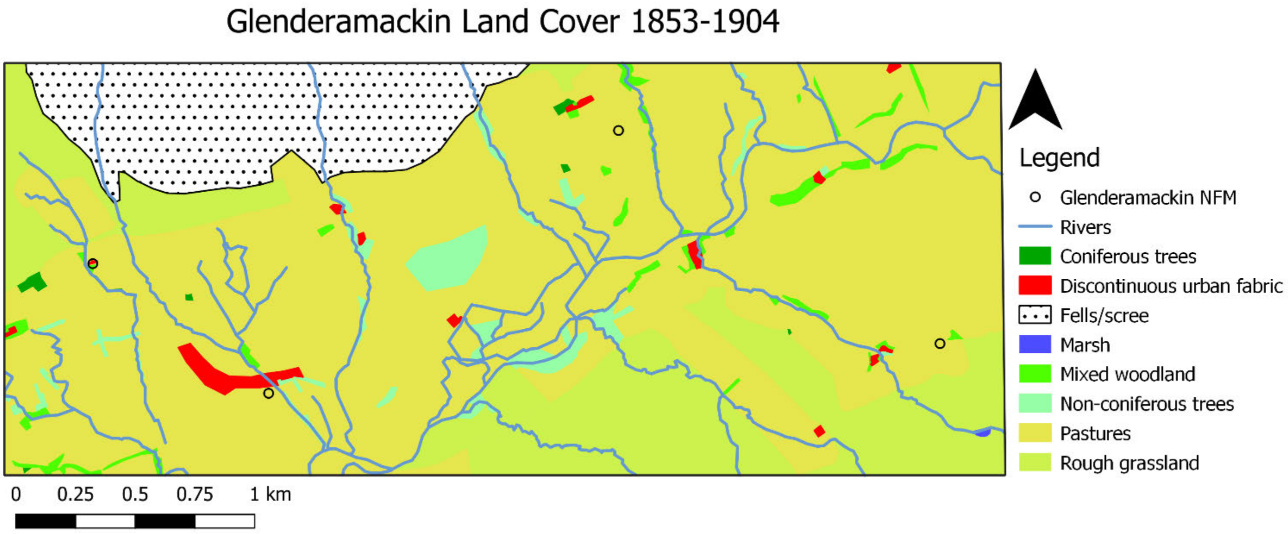

Figure 4.12: *Glenderamackin land cover 1853-1904 (EDINA, 2010c)*

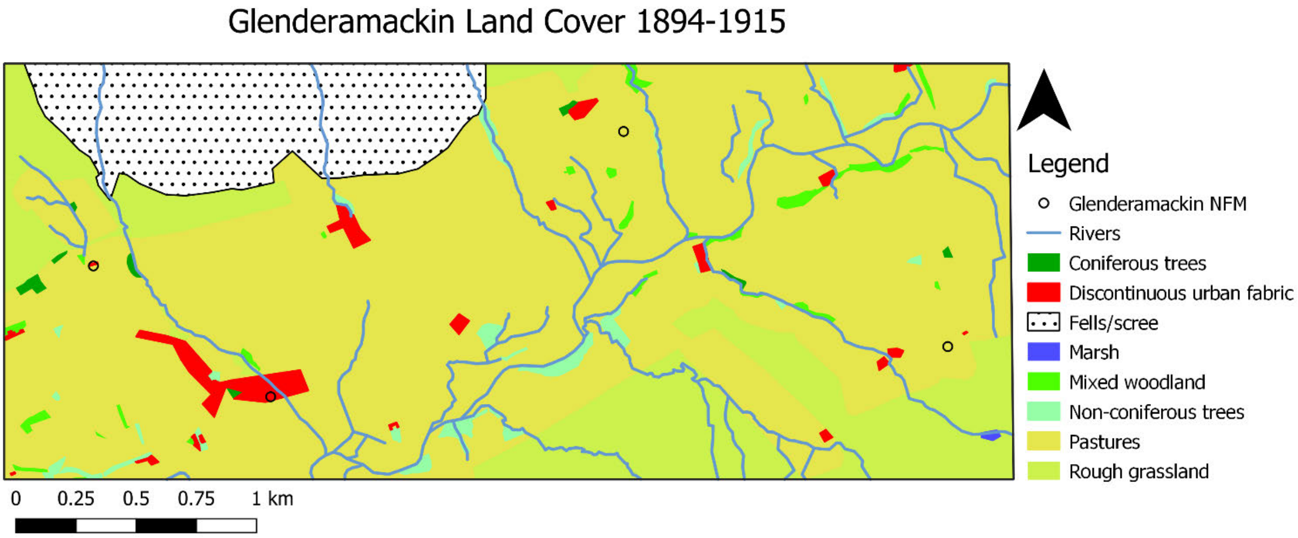

Figure 4.13*: Glenderamackin land cover 1894-1915 (EDINA, 2010c)*

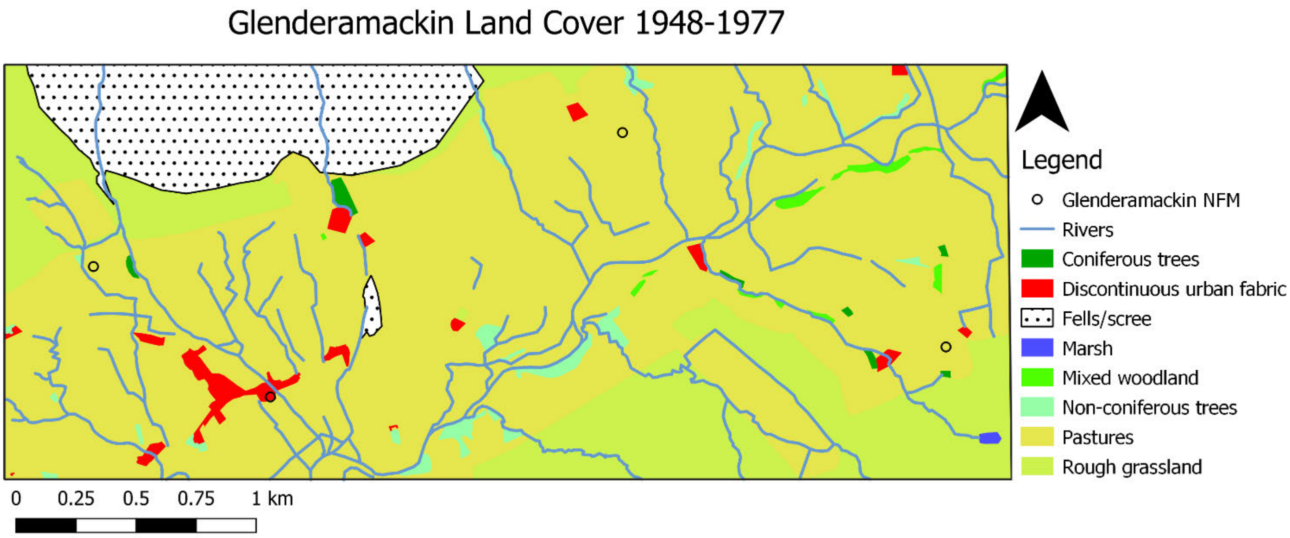

Figure 4.14: *Glenderamackin land cover 1948-1977 (EDINA, 2010c)*

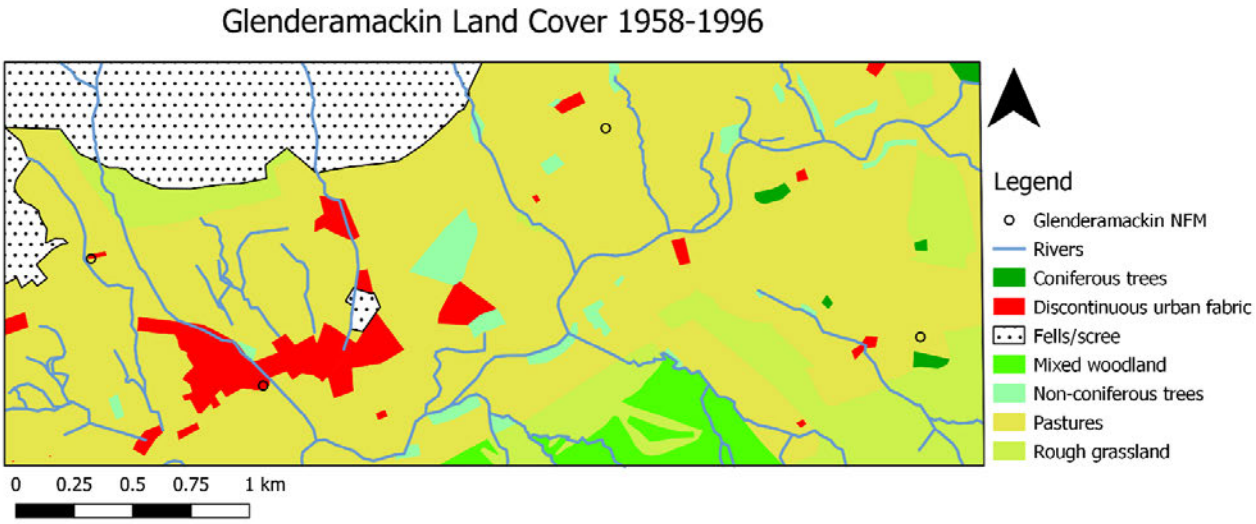

Figure 4.15: *Glenderamackin land cover 1958-1996 (EDINA, 2010c)*

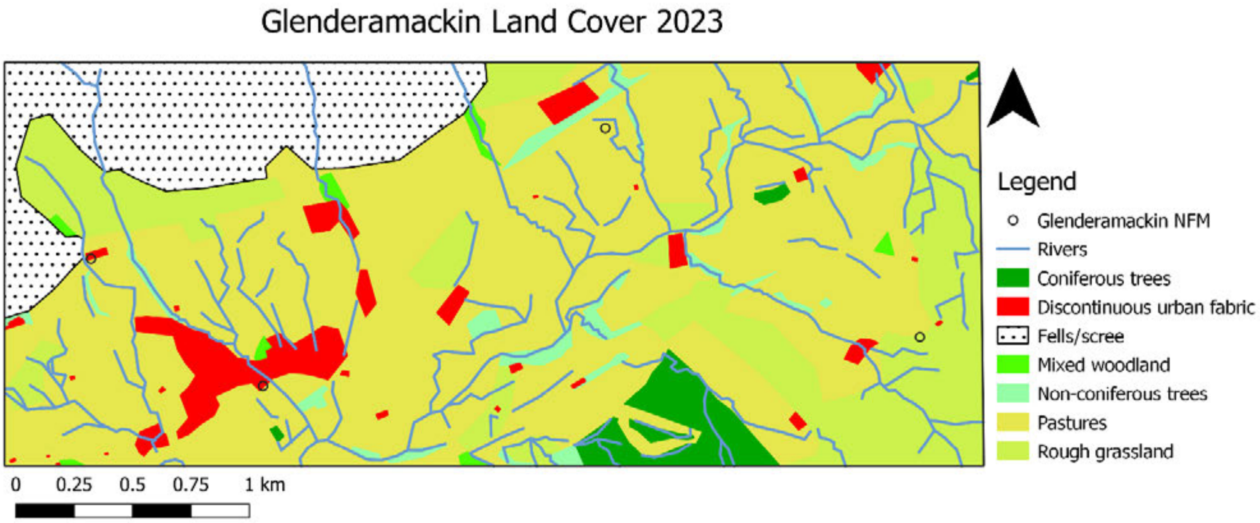

Figure 4.16: *Glenderamackin land cover 2023 (EDINA, 2023d)*

Table 4.5: *Glenderamackin land cover area (km²). Note: Due to rounding, some figures appear as 0.00.*

	1853-1904	1894-1915	1948-1977	1958-1996	2023
Coniferous trees	0.02	0.02	0.02	0.03	0.20
Discontinuous urban fabric	0.05	0.10	0.09	0.31	0.27
Fells/scree	0.83	0.82	0.78	0.90	0.97
Marsh	0.00	0.00	0.00	0.00	0.00
Mixed woodland	0.11	0.07	0.04	0.22	0.05
Non-coniferous trees	0.17	0.10	0.09	0.18	0.18
Pastures	4.78	4.99	5.02	4.73	4.33
Rough grassland	1.28	1.14	1.20	0.87	1.24

Table 4.6: *Glenderamackin percentage land cover (with change in percentage). Fells/scree not included as typically a fixed structure.*

	1853-1904	1894-1915	1948-1977	1958-1996	2023
Coniferous trees	0.26%	0.25% *(-0.01%)*	0.27% *(+0.02%)*	0.36% *(+0.09%)*	2.76% *(+2.40%)*
Discontinuous urban fabric	0.70%	1.38% *(+0.68%)*	1.27% *(-0.11%)*	4.34% *(+3.07%)*	3.77% *(-0.57%)*
Fells/scree					
Marsh	0.03%	0.04% *(+0.01%)*	0.05% *(+0.01%)*	0.00% *(-0.05%)*	0.00% *(0%)*
Mixed woodland	1.55%	0.97% *(-0.58%)*	0.48% *(-0.49%)*	3.08% *(+2.60%)*	0.63% *(-2.45%)*
Non-coniferous trees	2.29%	1.31% *(-0.98%)*	1.21% *(-0.10%)*	2.47% *(+1.26%)*	2.47% *(0%)*
Pastures	66.04%	68.94% *(+2.90%)*	69.31% *(+0.37%)*	65.30% *(-4.01%)*	59.84% *(-5.46%)*
Rough grassland	17.66%	15.81% *(-1.85%)*	16.61% *(+0.80%)*	11.99% *(-4.62%)*	17.13% *(+5.14%)*

4.1.4 Pott Shrigley

Throughout the period 1846-2023 (Figures 4.17 to 4.21), the main land cover types at Pott Shrigley are rough grassland and pastures. Rough grassland generally decreases and pastures generally increase, until 2023 when the trend reverses (Table 4.8). Despite pastures and rough grassland dominating the land cover, non-coniferous trees are also present from the start of the historical mapping. However, they show a continuous decline, with the greatest decreases between 1846-1899 and 1903-1950 (47%), and 1903-1950 and 1948-1977 (49%). The maps visually show this decline as the area of non-coniferous woodland shrinks and is replaced by rough grassland. Changes to the built environment are negligible; quarries are present in Figures 4.18 and 4.19 but these become disused and are subsequently removed by Figure 4.20. Overall, the land cover at Pott Shrigley remains fairly consistent over time.

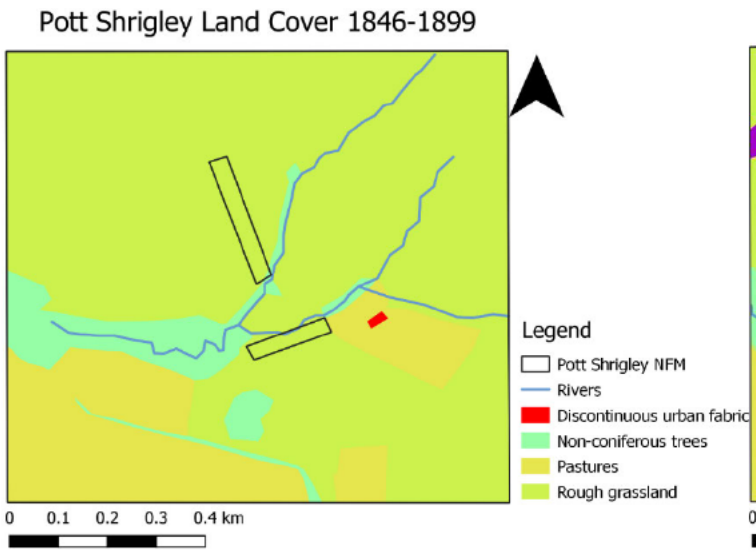

Figure 4.17: *Pott Shrigley land cover 1846-1899 (EDINA, 2010d)*

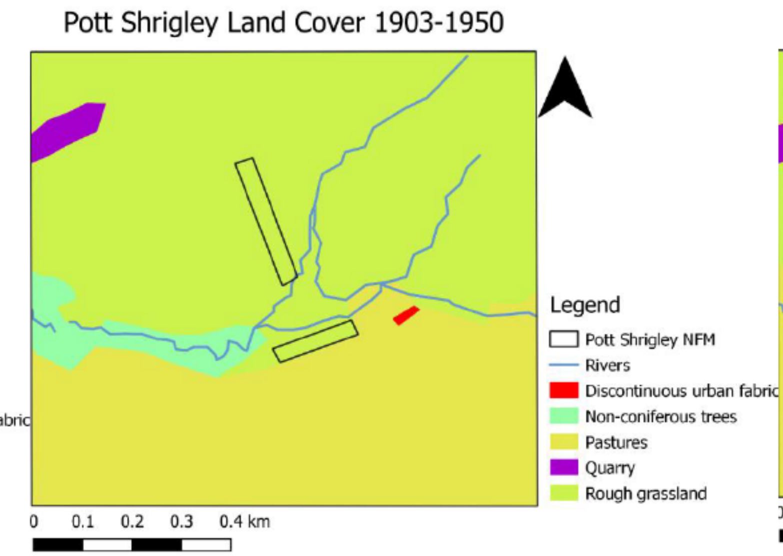

Figure 4.18: *Pott Shrigley land cover 1903-1950 (EDINA, 2010d)*

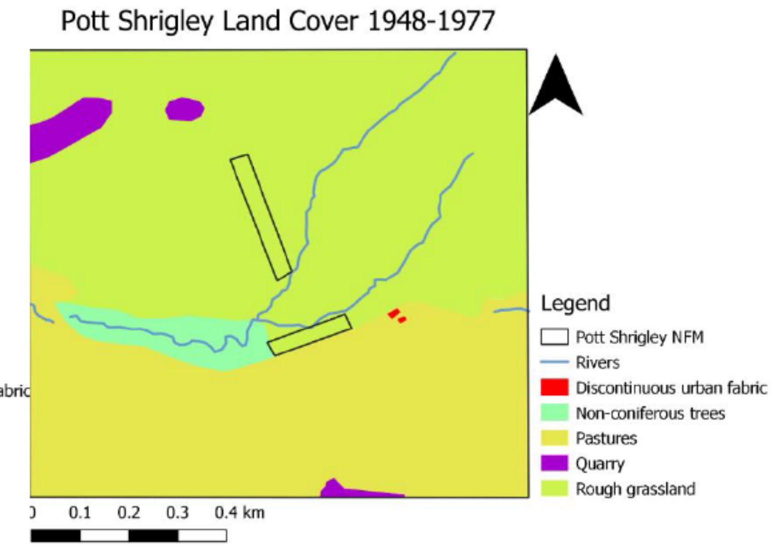

Figure 4.19: *Pott Shrigley land cover 1948-1977 (EDINA, 2010d)*

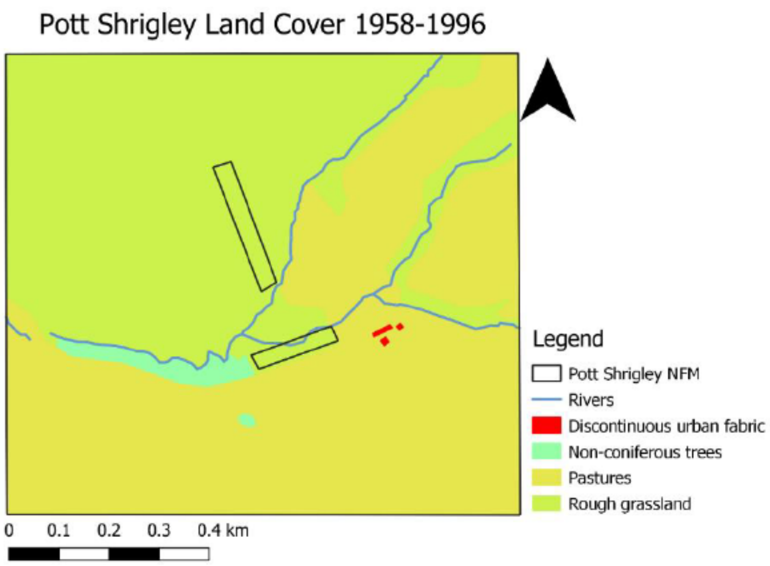

Figure 4.20: *Pott Shrigley land cover 1958-1996 (EDINA, 2010d)*

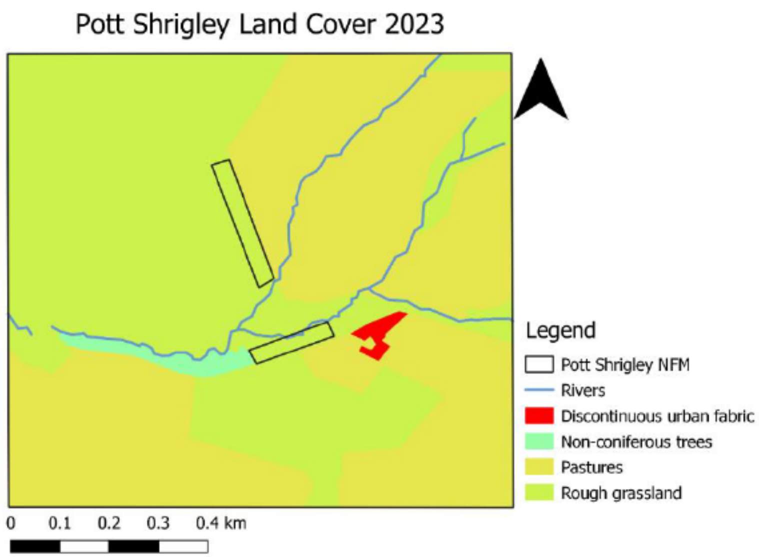

Figure 4.21: *Pott Shrigley land cover 2023 (EDINA, 2023e)*

Table 4.7: *Pott Shrigley land cover area (km^2). Note: Due to rounding, some figures appear as 0.00.*

	1846-1899	1903-1950	1948-1977	1958-1996	2023
Discontinuous urban fabric	0.00	0.00	0.00	0.00	0.01
Non-coniferous trees	0.07	0.04	0.3	0.02	0.1
Pastures	0.17	0.35	0.35	0.49	0.48
Quarry	0.00	0.01	0.02	0.00	0.00
Rough grassland	0.70	0.55	0.55	0.44	0.45

Table 4.8: *Pott Shrigley percentage land cover (with change in percentage)*

	1846-1899	1903-1950	1948-1977	1958-1996	2023
Discontinuous urban fabric	0.06%	0.08% *(+0.02%)*	0.05% *(-0.03%)*	0.06% *(+0.01%)*	0.50% *(+0.44%)*
Non-coniferous trees	7.56%	4.00% *(-3.56%)*	3.35% *(-0.65%)*	1.72% *(-1.63%)*	1.48% *(-0.24%)*
Pastures	18.12%	36.75% *(+18.63%)*	36.94% *(+0.19%)*	51.87% *(+14.93%)*	50.30% *(-1.57%)*
Quarry	0.00%	1.01% *(+1.01%)*	1.96% *(+0.95%)*	0.00% *(-1.96%)*	0.00% *(0%)*
Rough grassland	74.26%	58.15% *(-16.11%)*	57.70% *(-0.45%)*	46.35% *(-11.35%)*	47.72% *(+1.37%)*

4.2 Mid-Holocene (*c.* 7000-*c.* 5000 BP) Land Cover

Interpretations of pollen sequences from locations close to each NFM site are presented in this section, including a summary of the general trends and analysis of environmental change over time. The data are representative of the Holocene, which ranges from *c.* 11,700 years before present (BP) to the current day (Roberts, 2014). The aim was to focus on the mid-Holocene (7000-5000 BP), as this period is most characteristic of the British Isles' natural vegetation, prior to anthropogenic change (Roberts, 2014). By the mid-Holocene, the environment had adjusted to post-glacial conditions and represents what the landscape could be like today without the impact of humans. However, it was not always possible to focus on 7000-5000 BP, as the time periods covered by the various pollen sequences differ. The time period represented by each sequence will be clarified in the relevant subsection and, for later periods, the potential impact of humans will be noted if necessary. A table is presented at the end of each subsection to summarise the tree taxa found in that area during the mid-Holocene. Comparisons between the results of Objectives 1 and 2, with the taxa planted as part of the NFM, will be made in Chapter 5.

4.2.1 Coalburn

4.2.1.1 Butterburn Flow

The earliest pollen data from the sites around Coalburn come from Butterburn Flow, where the sequence begins approximately cal. 5000 BP. At this time, Yeloff *et al.* (2007) identified *Alnus* (alder), *Quercus* (oak), *Ulmus* (elm), *Betula* (birch) and *Corylus* (hazel), indicating the existence of deciduous woodland around Butterburn Flow during the mid-Holocene. These taxa were established in the UK as the Holocene climate warmed after the last glacial period, evidenced by Birks' (1989) isochrone maps of Holocene tree spreading. It is suggested that the taxa Yeloff *et al.* (2007) found would have been established between 10,000 and 7000 BP in the British Isles. For the purpose of comparisons with the land cover maps and NFM species from Objective 1, the taxa in Table 4.9 will be considered as representative of the mid-Holocene. While it cannot be certain that humans had not changed the landscape by this point, these are the earliest data that could be sourced for Coalburn.

Hendon and Charman's pollen data from Butterburn Flow (2004) represent 1800-1978 AD, and reveal the presence of *Picea* (spruce) and *Pinus* (pine) during this period. This coincides with the plantations of Kielder and Spadeadam Forests, indicating that these taxa have been introduced into the area. Neither were present at the earliest time period covered by pollen sequences from Butterburn Flow; therefore they have not been included as part of the 'natural' tree taxa in this study.

4.2.1.2 Coom Rigg Moss and Felecia Moss

The pollen cores taken at Coom Rigg Moss and Felecia Moss represent the mid to late-Holocene (4500-150 cal. BP) and therefore must be viewed cautiously in terms of how 'natural' they are, due to the increasing human influence on vegetation from the Neolithic onwards. At *c.* 4500 cal. BP, Hendon (1998) reported a decline in *Alnus* pollen and a rise in Cyperaceae (sedges) and Poaceae (grasses) at Coom Rigg Moss. This signals disturbance in the area, giving way to a more open landscape.

The aforementioned rise in *Pinus* in the early to mid-20th century at Butterburn Flow is also observed at Coom Rigg Moss (Hendon, 1998) and Felecia Moss (Mauquoy and Barber, 1998) around the same time. It is clear that *Pinus* has been introduced into the area as it was not found in any local pollen sequences in the mid-Holocene. This will be explored further in Chapter 5.

Table 4.9: *Tree taxa representing the mid-Holocene environment of Coalburn, to be compared with the results of Objective 1*

Estimated Time Period	Tree Taxa	Common Name
c. cal. 5000 BP (Yeloff *et al*., 2007)	*Alnus*	Alder
	Betula	Birch
	Corylus	Hazel
	Quercus	Oak
	Ulmus	Elm

4.2.2 Crompton Moor

4.2.2.1 Black Heath

Black Heath represents the earliest pollen sequence from the area around Crompton Moor, beginning *c.* 7000 cal. BP (Ryan and Blackford, 2010). At this point in time, pollen assemblages were made up of >90% shrub and arboreal pollen, with *Betula* and *Corylus* woodland being the primary vegetation. *Pinus*, *Quercus*, *Alnus* and *Salix* (willow) were also present, highlighting the predominantly wooded landscape. This is in line with trends in the British Isles at the beginning to middle of the Holocene, as deciduous trees migrated and re-established populations following deglaciation (Birks 1989). These tree taxa are recorded in Table 4.10 and will be further discussed in Chapter 5.

Notably, at *c.* 5260 cal. BP, Ryan and Blackford (2010) acknowledge evidence of *Gelasinospora,* a fungus which is linked to burnt ground and is therefore indicative of burning. It is suggested that this could have been a key tool in Mesolithic management to improve grazing, highlighting the possibility of human activity and the potential influence of this on vegetation (Ryan and Blackford, 2010).

4.2.2.2 Castleshaw Moor

Castleshaw Moor's pollen diagram characterises the environmental conditions around Crompton Moor from *c.* 5830-*c.* 2670 cal. BP (Brayshay, 1998). At *c.* 5830 cal. BP, 81% of the total land pollen was tree and shrub, with the greatest proportion being *Corylus*. The landscape was predominantly scrub woodland: also present at this time was *Betula*, *Pinus*, *Quercus*, *Ulmus* and *Salix*. This was typical of the British Isles during the mid-Holocene and the taxa are therefore included in Table 4.10 (Birks, 1989).

4.2.2.3 Rishworth Moor

Bartley (1975) published pollen data obtained from Rishworth Moor, representing the period *c.* 6270-*c.* 1830 cal. BP. The beginning of the diagram aligns with the elm decline, which occurred around 5000 BP, and explains the decrease in *Ulmus* pollen seen at this time (Edwards and MacDonald, 1991). Around the same time, *Quercus*, *Alnus* and *Corylus* were present at high frequencies – between 30 and 70% of total tree pollen – indicating the presence of a woodland environment near the site. These mid-Holocene tree taxa are recorded in Table 4.10. After this, Bartley (1975) reports an increase in Poaceae, highlighting the presence of open grassland. For the remainder of the pollen diagram (*c.* 4490-*c.* 1830 cal. BP), disturbance indicators begin to dominate, such as Cyperaceae, *Plantago lanceolata* (ribwort plantain) and *Rumex acetosella* (sorrel). This implies the introduction of agriculture to the area, as forest was cleared to make way for cereal production, likely coinciding with the onset of the Iron Age (Bartley, 1975).

4.2.2.4 Soyland Moor Sites C and D

The earliest time periods that Soyland Moor sites C and D represent are *c.* 7570-*c.* 7120 cal. BP respectively (Williams and Switsur, 1985). At Site C, typical post-glacial woodland taxa including *Corylus*, *Pinus*, *Ulmus* and *Quercus* are present (*c.* 7570 cal. BP). While the area was dominated by woodland vegetation, disturbance indicators are also present, such as Brassicaceae (mustards), *Rumex* (dock) and Apiaceae (celery, carrot, parsley family), suggesting the presence of open ground. The pollen sequence from Site D represents a similar vegetation composition at *c.* 7120 cal. BP with increasing *Corylus* and the presence of herbaceous vegetation, though this is less diverse compared to Site C. Soyland Moor experienced typical, deciduous woodland vegetation during the mid-Holocene, before being subjected to disturbance and therefore the opening of forest.

Table 4.10: *Tree taxa representing the mid-Holocene environment of Crompton Moor, to be compared with the results of Objective 1*

Estimated Time Period	Tree Taxa	Common Name
c. 7570 – *c.* 7120 cal. BP (Williams and Switsur, 1985)	*Corylus*	Hazel
	Pinus	Pine
	Quercus	Oak
	Ulmus	Elm
c. 7000 cal. BP (Ryan and Blackford, 2010)	*Alnus*	Alder
	Betula	Birch
	Corylus	Hazel
	Pinus	Pine
	Quercus	Oak
	Salix	Willow
c. 6270 cal. BP (Bartley, 1975)	*Alnus*	Alder
	Corylus	Hazel
	Quercus	Oak
	Ulmus	Elm
c. 5830 cal. BP (Brayshay, 1998)	*Betula*	Birch
	Corylus	Hazel
	Pinus	Pine
	Quercus	Oak
	Salix	Willow
	Ulmus	Elm

4.2.3 Glenderamackin

The data published by Hodgkinson *et al.* (2000) assessed the palynological potential of a range of pollen sites in Cumbria. Data from three of these sites are analysed below. Although the results are only preliminary, they still provide some indication of land cover during the mid-Holocene. The cores discussed in this section are estimated to represent the period 10,000 BP to the present day (Hodgkinson *et al*., 2000). As this was a preliminary study, no radiocarbon dating was carried out, and these dates are only estimates based on biostratigraphy, therefore conclusions drawn from this section are tentative.

4.2.3.1 Calvert Trust Land

The beginning of the core at Calvert Trust Land is estimated to represent the early Holocene period, around 10,000-9000 BP (Hodgkinson *et al.*, 2000). Tree and shrub pollen makes up 84% of total pollen here, including *Betula*, *Corylus*, *Salix* and *Juniperus* (juniper). Birks' isochrone maps (1989) indicate that *Betula* and *Corylus* were present in the north of the British Isles from 10,000-9000 BP, correlating with Hodgkinson *et al.*'s findings (2000). Similarly, Chiverrell *et al.* (2023) found that *Juniperus* and *Salix* were present on the Isle of Man from *c.* 11,200 cal. BP. The Isle of Man is at a similar latitude to the sites near Glenderamackin; therefore, it can be assumed that the beginning of the core taken from Calvert Trust Land represents the early Holocene period. While the desired study period is the mid-Holocene, it is interesting to note the taxa identified as part of the early Holocene, when foundations for the evolving landscape were established. However, these taxa will not be included in Table 4.11.

4.2.3.2 Derwent Water

The core from Derwent Water is believed to represent the period 7000-6000 BP (Hodgkinson *et al*., 2000). The surrounding woodland was composed of *Corylus*, *Betula*, *Pinus*, *Quercus* and *Ulmus*, with the additional presence of Poaceae, indicating some open ground around this time. The deciduous tree taxa represented by the pollen diagram are typical of this time period and are similar to those identified in the early Holocene at Calvert Trust Land and Little Tarn (see below). This demonstrates some continuity within the landscape, highlighting the continual presence of woodland from the early to the mid-Holocene, as the pioneer vegetation transitioned to a climax community. These taxa have therefore been included in Table 4.11.

4.2.3.3 Little Tarn

The beginning of Little Tarn's pollen core, at 6.25m depth, is thought to represent the early Holocene period (10,000-9000 BP) based on the presence of *Corylus*, *Quercus*, *Ulmus* and *Pinus*, which spread across the UK during the early Holocene (Hodgkinson *et al*., 2000). It is suggested that 6.25m-4.75m of the pollen core represents 7000 cal. BP, when *Alnus* pollen reached 24% and *Ulmus* pollen exhibited a decline. Between 2.25m and 0.3m, a secondary woodland of *Betula* and *Corylus* replaced the *Quercus* and *Alnus*, which could be related to earlier clearance during the Bronze Age (4000-2500 cal. BP) (Hodgkinson *et al*., 2000). After this, however, herbaceous vegetation and cereal pollen dominated, indicating an extensively cleared landscape, likely due to human activity. The majority of the genera identified in the mid-Holocene at Little Tarn were also found at Derwent Water 7000-6000 BP, indicating their continued presence over a long period of time.

Table 4.11: *Tree taxa representing the mid-Holocene environment of Glenderamackin, to be compared with the results of Objective 1*

Estimated Time Period	Tree Taxa	Common Name
c. 7000 cal. BP (Hodgkinson *et al*., 2000)	*Alnus*	Alder
	Betula	Birch
	Corylus	Hazel
	Quercus	Oak
	Tilia	Lime
	Ulmus	Elm
c. 7000 – 6000 BP (Hodgkinson *et al*., 2000)	*Alnus*	Alder
	Betula	Birch
	Corylus	Hazel
	Pinus	Pine
	Quercus	Oak
	Ulmus	Elm

4.2.4 Pott Shrigley

4.2.4.1 Danes Moss

Danes Moss was the only pollen site that met the requirements to be considered representative of the mid-Holocene environment at Pott Shrigley. The core is divided into two zones, the earliest representing *c.* 7510 cal. BP. This zone is characterised by woodland taxa, which experiences peaks and troughs throughout the period, namely *Alnus*, *Betula*, *Corylus*, *Pinus*, *Quercus* and *Ulmus* (Leah *et al*., 1997). These are recorded in Table 4.12.

The second zone *c.* 3370 cal. BP generally indicates an overall decrease in tree pollen and an increase in shrubs/herbs; with the likes of Ericales (heathers) being indicative of disturbance or woodland clearance due to humans (Leah *et al*., 1997). Microscopic charcoal concentrations significantly increase in Zone 2, which is suggestive of burning and may reflect land clearance caused by fires. *Betula*, *Ulmus* and *Pinus* decline here, supporting this theory. This, however, is simply a generalisation of the landscape; correlations with other pollen sites are needed to corroborate the evidence for mid-Holocene land cover in the area around Pott Shrigley.

Table 4.12: *Tree taxa representing the mid-Holocene environment of Pott Shrigley, to be compared with the results of Objective 1*

Estimated Time Period	Tree Taxa	Common Name
c. 7510 cal. BP (Leah *et al*., 1997)	*Alnus*	Alder
	Betula	Birch
	Corylus	Hazel
	Pinus	Pine
	Quercus	Oak
	Ulmus	Elm

Sections 4.1 and 4.2 have outlined the results of the land cover maps from Objective 1 and the pollen analyses from Objective 2. The discussion in Chapter 5 will begin by comparing the results from both objectives with the tree species planted as part of the NFM. The extent to which the tree planting can be considered to be representative of the 'natural' environment will also be evaluated. The results of the interviews will be discussed in relation to the importance of this 'naturalness' within NFM.

4.3 Stakeholder Interviews

This section summarises the results of the seven interviews by highlighting the main themes identified in the data analysis. Specific quotations have been presented to examine the codes in more detail and to analyse the extent to which stakeholders thought that NFM can be considered 'natural'. The main themes have been focused on in this section, and Chapter 5 will examine the quotations in more depth. Along with the results from the previous sections, the interviews will also be further discussed in the next chapter to address Objective 4, which looks to evaluate the significance of the term 'natural' within NFM.

4.3.1 Participant Demographics

In order to contextualise the results of the interviews, Table 4.13 outlines the job titles of the participants, as described by themselves during the introductory interview questions. The list is in no particular order and the titles are not assigned to participant numbers to ensure anonymity. As discussed in Chapter 3, the interview participants were selected based on their experience of working with NFM. The job roles identified in Table 4.13 are therefore reflective of this, though the types of job vary. Most participants had roles in senior positions, demonstrating their knowledge and experience of working in flood management. The participants' expertise ranged from early career research to involvement in the sector for over 20 years. However, the participants also had varying backgrounds, either industrial or a combination of industrial and academic. This provided an insight into how NFM is viewed by both academic researchers and practitioners across different water management-related industries. The demographic of the interviewees was therefore strategically selected to ensure educated and diverse responses.

Table 4.13: *Job titles described by the participants*

Job Titles
Environmental Scientist
Partnerships Manager
Science Group Leader
PhD Student
Environment Lead
Drainage and Wastewater Planning Lead
Senior Flood Risk Consultant

4.3.2 Thematic Analysis

Table 4.14 shows the codes and sub-codes that were identified when the interview transcripts were analysed, first manually and then in NVivo (see Chapter 3). These have been linked to the themes from the topic guide that was followed during the interviews (see Appendix B). It is noted that some references by interviewees were included in multiple codes/sub-codes.

Table 4.14: *Codes and sub-codes from the interview analysis, linked to topic guide themes*

Codes	Sub-Codes	References	Topic Guide
Approach to dealing with NFM	Bottom-up approach	10	Approach to flood management
	Fragmented approach	23	
	Landscape scale restoration	8	
	Top-down approach	11	
	Total	**52**	
Perception	Declining focus on flooding in NFM	12	Defining NFM and exploring the concept
	Expectation of NFM	15	
	Greenwashing	8	NFM changes over time
	NFM discourse	10	
	Total	**45**	
Terminology	Actual definition	6	Defining NFM and exploring the concept
	Hierarchy	6	
	NFM/NbS concept	7	
	Other terminology	17	
	Total	**36**	
Policy	CAP/ELMS	11	Approach to flood management
	Policy challenges	9	Barriers to NFM uptake
	Policy change	11	The future of flood management
	Total	**31**	
Perceived 'naturalness' of NFM/NbS		**26**	Defining NFM and exploring the concept
Multiple benefits		**24**	Approach to flood management Defining NFM and exploring the concept
Barriers	Funding	6	Barriers to NFM uptake
	Land manager interaction	3	
	Perception	4	

	Politics	3	
	Understanding of NFM	7	
	Total	**23**	
The future	Future flood management strategy	6	The future of flood management
	Responding to future climate change	15	
	Total	**21**	
Funding		**20**	Approach to flood management Barriers to NFM uptake The future of flood management
Environmental change	Climatic change	4	Approach to flood management
	Landscape change	10	
	Total	**14**	
NFM data comments	'Naturalness' of site X	8	Presentation of project data
	Suggestions for NFM	6	
	Total	**14**	
Land managers		**11**	Approach to flood management Barriers to NFM uptake
Project timescale	Long timescale	6	NFM changes over time
	Short timescale	3	
	Total	**9**	

The code with the highest number of references is 'approach to dealing with NFM' (52). This has been divided into four sub-codes, and the most frequently cited of those is 'fragmented approach' (23). The approach to dealing with flood management was covered in all of the interviews, as it was part of the topic guide, and questions were asked regarding the current state of flood management. The three quotations below are taken from the 'fragmented approach' sub-code and have been selected due to their similarities.

"Then we're going to go down, as we always do, silos." (Participant 1)

"There's some areas within flood risk management where we're still perhaps sat in a silo and if we're sat in silos then we're not all pulling in the same direction." (Participant 4)

"I also think that it's a very siloed working, so from someone putting in a development plan through to it being put in place, there's just so many different stakeholders it just kind of gets passed over and there's not much collaboration." (Participant 6)

Siloed working and a lack of cooperation was often mentioned when discussing the approach to flood management, as demonstrated by the quotations above. It is noted that all but one participant referred to flood management as being fragmented, reinforcing this shared opinion amongst professionals. When asked what could be done to improve the approach to flood management, participants were encouraged to consider top-down and bottom-up approaches, such as policy change and community engagement. The references for each of these are not categorised into positive or negative opinions but were coded when the type of approach was mentioned. Overall, participants tended to decide that a combination of both was required to make flood management more successful. The quotations below highlight the importance of both approaches.

"I'm a great believer in government setting policy that works." (Participant 1)

"If we've got that overarching policy persuasion to almost give a bit more weighting behind why we should be doing it [NFM] *and the importance of it, I think we would see a greater uptake."* (Participant 4)

"If the local community and the local landowners aren't supportive, it's [NFM] *not going to happen, so you've also got to have that bottom-up approach, you have to get the buy in, you have to build these partnerships."* (Participant 5)

"I'm a firm believer that I think bottom-up approaches are the best, but when it comes to these things, there needs to be money, there needs to be the resource, there needs to be expertise." (Participant 6)

These quotations demonstrate the importance of effective government policy and availability of funding, as well as the support of local communities and land managers when it comes to implementing NFM. While some participants may have favoured one approach over another, all tended to agree that they should work in collaboration with one another.

Another prevalent theme from the topic guide was 'defining NFM and exploring the concept', which related to several of the codes identified in Table 4.14. Terminology was frequently discussed, with a total of 33 references. Chapter 2 referred to the complexities surrounding flood management nomenclature, which was also examined in the interviews, as participants were asked whether NFM is the best term to describe it. A sample of responses can be seen below.

"There are so many acronyms flying around, once one gets a hold, it's very difficult to shake it." (Participant 3)

"Historically we've had Working with Natural Processes, for a bit we tried to combine it [NFM] *with Nature-based Solutions, which isn't quite right because it's not that… We always revert back to NFM anyway."* (Participant 4)

The quotations reflect the difficulty in defining and using different flood management-related terminology, and the two participants above agreed that it would be difficult to change the way NFM is described, due to its already-established profile in the flood management community. Despite this, there was general agreement that the flood management nomenclature can be a point of confusion, which reiterates what was found in the literature review. The concept of what is 'natural' was explored further with the interviewees when discussing the term NFM, and most participants noted that the methodologies of NFM and NbS are not always entirely 'natural'. This relates to the code 'perceived 'naturalness' of NFM/NbS', which was cited 25 times and exemplified by the following quotations.

"We were talking about bunds, I would say they are definitely artificial, they are essentially mini reservoirs, they're dams placed in the environment which did not necessarily occur in the form that they are placed." (Participant 3)

"If you're looking at something like tree planting, if you're not working with native tree species, then is that actually natural because you're introducing something that's never quite been seen before." (Participant 4)

"It's almost like there is this wee door of, can we just push anything through, and you think we would have to draw the line and say there needs to be some actual natural features to call something a Nature-based Solution." (Participant 6)

"When you refer to Natural Flood Management up in Pickering, let's say, and then you see effectively a reservoir that has a headwall of very artificial material covering about 100m in width, that generates storage close to 10,000 cubic metres of water, that's not the most natural of features." (Participant 7)

Interestingly, participants identified examples of NFM, such as bunds, tree planting and reservoirs, and discussed the extent to which they can be considered natural. The examples above reflect the consensus that measures involving some kind of artificial material, or non-native species, are not typically accepted as being natural, yet they remain examples of NFM and NbS. Participant 6 noted that there could be an attempt to label structures as being natural when they definitively are not, which could complicate what is defined as NFM or a NbS.

Following on from this, participants were presented with a case study example of the data from this project and were asked to what extent they thought the NFM scheme could be considered natural. It is noted that the data were related to tree planting, therefore the responses differed slightly to the previous quotations, which discuss the 'naturalness' of NFM in general. While participants agreed that the case study could be considered natural due to the similarities between the data, some commented on other factors that should be considered.

"I think that we can say it's partially natural yes, but without having a longer record of what's been there historically, we can't quite go as far as saying it's fully natural." (Participant 4)

"I can see you're using a tree that's appropriate for that location, that's been used in the past, but of course, the proof is in the pudding in how it's delivered." (Participant 7)

One comment stemming from this discussion was that the land cover maps did not go into sufficient detail to confirm that the intervention is fully natural. As recognised in Chapter 3, a limitation of the historic OS maps was that they did not provide any more specific detail regarding the tree species present at a given time period. Therefore, the data provided perhaps did not give the participants enough evidence to make an informed decision. Other comments referred to the actual delivery of NFM and suggested that while efforts may be considered natural, the way they are delivered could change that. This links back to previous quotes about physical structures and artificial materials being included in the term NFM. None of the participants decided that the NFM case study example could be considered fully natural, thus questioning whether NFM is the best description of the management technique. This will be explored in relation to Objectives 1 and 2 in the next chapter.

4.3.3 Interview Response: Barriers to NFM

Section 2.5 of the literature review addressed the common barriers to implementing NFM. While it is recognised that the aim of this research is to determine how 'natural' NFM is considered to be, the barriers were prevalent themes in both the literature and the interviews. Therefore, this subsection is being included within Chapter 4, as the discussions of the barriers were less closely tied to Objective 4 – to evaluate the significance of the term 'natural' within

NFM – which will be examined in Chapter 5. The interview participants were asked what they perceived the barriers to NFM to be, and their answers were split into the following codes: funding, challenges with land managers, perception, politics and understanding of NFM. These will be discussed in the following subsections, in response to the observations from the literature review.

4.3.3.1 Funding

One of the main barriers identified in Chapter 2 was limited funding opportunities (Holstead *et al*., 2017; Waylen *et al*., 2018; Wells *et al*., 2020; Wingfield *et al*., 2021). This barrier was also mentioned by the interview participants, highlighting that this is an ongoing issue. Below are four of the quotations taken from the interview responses, which demonstrate concerns around the money available for NFM.

"Funding, and funding streams, for the implementation of NFM at the moment [is] *a barrier. There's only a certain amount of organisations that can access the funding to implement things on the ground."* (Participant 4)

"Funding's been a bit of a barrier. One of the big changes over time has been the degree, the growing acceptance, that NFM can make a contribution and the funding that comes in to support that." (Participant 5)

"There's barriers around funding, so actually sometimes it's because they're [NFM measures] *more expensive, but they do bring more benefit, but in the first instance obviously that's a bit of a barrier."* (Participant 6)

The discussion around funding in Subsection 2.6.2 was driven by Wells *et al*'s., (2018) positive feedback loop on the barriers to NFM, which stated that funding is dependent on evidence that NFM is effective. Without this evidence, NFM projects are less likely to be funded, making their implementation more difficult. Participant 5 acknowledged this, but commented on the fact that there has been growing acceptance over time that NFM can contribute to flood risk management. Participant 6 expands further on the issue by stating that NFM projects may be more expensive, which could hinder their funding. The actual cost of NFM measures was not acknowledged by other participants, and while this does not mean that the other interviewees would disagree, it could mean that Participant 6 has a different experience of working with NFM. It was noted in Chapter 2 that Wingfield *et al.* (2021) recognised the two different types of participants in their study, and stated that their different rankings of NFM funding as a barrier could have been due to their differing experiences. Similarly, Participant 4 noted that access to funding is not linear, and so organisations may not receive the same level of funding. It seems that similar problems with funding are continually occurring, as the results of the interview data from this project align with the published literature. Although there may be some improvements, the interview discussions suggest that money for NFM projects is still lacking.

4.3.3.2 Challenges with Land Managers

As discussed in the literature review, NFM is often implemented on privately-owned land, which makes cooperation with land managers essential for its success. Subsection 2.6.4 identified three main issues with, and faced by, land managers, namely limited knowledge and awareness of NFM, resistance to change, and a lack of money (Holstead *et al*., 2017; Wells *et al*., 2020). During the interviews, the participants were asked what they thought were the barriers to NFM implementation, and five out of seven interviewees named challenges with land managers as one of them. The selection of quotations below highlights this issue.

"We have problematic relationships with landowners. As much as land is owned as an asset, very often the farmer will own land and they want a return from it, because that's how they earn their living." (Participant 1)

"There's a barrier from a landowner perspective in terms of getting people on board to implement NFM, to accept NFM on their land, and that needs [to be] *incentivised."* (Participant 5)

"There is a concern that some farmers think 'well I'm not getting any money from any of this [NFM], *let's remove all these hedgerows that I've put in and let's plough right up to the watercourse, let's try and get as much money as I can from the land in the short-term economics.'"* (Participant 7)

The predominant challenge identified by these quotes is the potential for land managers to lose income due to productive land being used for NFM. Participant 7 provides the example of removing hedgerows and ploughing up to the watercourse as a way that land managers might attempt to maximise their profits, while either removing or denying the potential for NFM measures. A similar theme was identified by Holstead *et al*. (2017) who reported that a lack of funding and high land value were some of the main reasons that farmers were against NFM measures being installed on their land. It is noteworthy that the participants in this research identified similar issues that land managers themselves identified in the research by Holstead *et al*. (2017), highlighting NFM professionals' presumed awareness of land managers' opinions. Of course, the above quotations did not come directly from land managers, therefore they must be viewed with caution. However, the fact that the same ideas have arisen suggests that NFM professionals have some level of understanding regarding the issues faced by land managers. It should also be acknowledged that Holstead *et al*'s. (2017) interviews with land managers were conducted in 2011. The interviews from this research were conducted 12 years later, and while the participants were a different type of stakeholder, the same issues were identified. This suggests that any change has not been significant, and that land managers still require the same support they did over a decade ago. It would be beneficial to conduct updated interviews with land managers themselves to determine whether there has been any change from their perspective.

4.3.3.3 Politics

Governance of NFM was established as a barrier within the literature review, and six out of seven interviewees stated that the approach to NFM has been disjointed in the past. The 'fragmented approach' code demonstrates the participants' thoughts on how NFM has been governed over time. Most commented on working in silos and a lack of communication between stakeholders, which agrees with research by Bark *et al*. (2021) and Waylen *et al*. (2018), who recognised that communication needed improving. The following quotations mirror the findings of the aforementioned authors.

"There's certainly a lot more scope to link up plans and strategies. Just thinking about it from a forestry perspective, we've got a lot of support for woodland expansion and we've got forest plans, but we haven't really linked those up with the flood plans." (Participant 5)

"One of the things we have is this orphaned Natural Flood Management system, where they get put in place and then they're just sort of like, alright whose responsibility is this now?" (Participant 6)

"What we need is an integration of solutions, that provide the greatest outcome across the appropriate scale." (Participant 7)

Participant 5 gives the example of forest plans for woodland expansion but goes on to say that these plans are not joined with those related to flooding, demonstrating a lack of communication between stakeholders. It was acknowledged in Subsection 2.5.2 of the literature review that NFM provides multiple benefits, most of which require input from different stakeholders if they are to be fully realised. Therefore, integrated working is essential to gain the desired outcome of the NFM project, to, as stated by Participant 7, "provide the greatest outcome across the appropriate scale". Along with this, Participant 6 questioned who is responsible for the monitoring and maintenance of NFM, which was also established as a problem by Wells *et al*. (2020). Despite these criticisms, two participants acknowledged that improvements have been made to NFM governance over time, as demonstrated by the quotations below.

"Sometimes it [approach to flood management] *has been quite disjointed in its history."* (Participant 3)

"I think we're more joined up than we were, so I've been in industry for 7 years now and I would say that over the past 3 or 4 years, I think we're getting much stronger and better at partnership working." (Participant 4)

These comments indicate that the approach to NFM is becoming more holistic, with Participant 3 emphasising its fragmented nature in its "history". While this view was not shared by all participants, it certainly suggests that there have been some positive changes in recent years. The differences in opinion are likely to be due to experiences of NFM, perhaps influenced by different job roles. Although a different subject, Wingfield *et al.* (2021) noted the difference in opinion between participants who worked in different sectors. This does, however, highlight the need for more cooperative working, if stakeholders have contrasting views. The interviews certainly identify that there is scope for the approach to NFM to be more joined up.

To conclude, this subsection has identified the common barriers to NFM as described by the interview participants. These barriers were similar to those found in the wider literature, and the majority of comments agreed with the findings of other researchers. It seems that there have been minor improvements in the approach to NFM through more joined-up working, but the barriers of funding and challenges with land managers have made little progress. These issues are perhaps related and could be resolved through better allocation of funding to land managers. There are clearly ongoing issues with NFM and its governance, which need to be addressed to enable its widespread application, and cooperation amongst all stakeholders.

The interview results give a profound insight into how NFM is viewed amongst flood management professionals, and also address the common challenges that have inhibited widespread implementation of NFM thus far. Encouraging uptake was discussed in detail, concluding that a combined approach of government policy and community engagement is necessary, in addition to collaborative working amongst all stakeholders. The discussions also provide context for Objectives 1 and 2, and consider both the extent to which NFM is truly 'natural' as well as the importance of its 'naturalness' in flood management.

4.4 Conclusion

Chapter 4 has presented and analysed the results from this project, namely the land cover maps from 1846 to 2023 (Objective 1), mid-Holocene pollen diagrams (Objective 2) and interview codes (Objective 3). The barriers to NFM have also been addressed, and discussed in the context of those identified in the literature review. The next chapter will begin with an overview of each NFM site to discuss how 'natural' the NFM is, with consideration of the land cover change and mid-Holocene tree taxa. This will then be combined with the interview data to facilitate a wider discussion, linked with the findings of the literature review, in order to achieve Objective 4 – to evaluate the significance of the term ‘natural’ within NFM.

CHAPTER 5: DISCUSSION

In order to assess the extent to which the NFM at Coalburn, Crompton Moor, Glenderamackin and Pott Shrigley can be considered ‘natural’, this chapter will first compare and contrast the results from Objectives 1 and 2 with the tree taxa planted at each site. The concept of what is meant by natural will then be explored using the definitions that were examined in the literature review, in the context of the NFM case studies investigated here. This will be linked to the interviews with NFM professionals, to comprehensively evaluate how ‘natural’ NFM is. The remainder of the discussion will analyse the themes identified from the interviews, with reference to the reviewed literature and the importance of ‘naturalness’ within NFM.

5.1 Land Cover Comparison

5.1.1 Coalburn

The hydrological research catchment at Coalburn was established in 1967 and tree planting began in 1973; a project now referred to as NFM (Birkinshaw *et al*., 2014). The species planted were *Picea sitchensis* (Sitka spruce), *Pinus contorta* (Lodgepole pine) and *Pinus sylvestris* (Scots pine), all coniferous trees. Table 5.1 includes these, and names the types of land cover identified in the GIS maps, in addition to the mid-Holocene tree taxa detected by the pollen diagrams. The highlighted taxa demonstrate similarities between the NFM species and past land cover data; however, it should be recognised that coniferous trees were only identified in the historical maps from 1958-1996 (Subsection 4.1.1), which is around the time the Coalburn study began. Therefore, the presence of coniferous trees is assumed to be the NFM plantation itself and not the natural landscape. Prior to this, much of the area was dominated by rough grassland and marsh, which are distinctly different land cover classes to coniferous trees. Furthermore, the tree taxa identified as being present during the mid-Holocene do not match the genera of the species that were planted as part of the NFM. Focusing on the species level of the NFM, both *Picea sitchensis* and *Pinus contorta* are non-native to the UK, therefore neither would have been found around Coalburn prior to the NFM plantation, unless deliberately introduced (Mason, 2015). While *Pinus sylvestris* is native to the UK, *Pinus* was not present in the pollen diagrams, demonstrating its absence in the area during the mid-Holocene. Using SEPA’s (2016) definition of NFM examined in Chapter 2, the NFM at Coalburn does not definitively restore natural landscape features, as none of the planted species were found at, or around, the site, prior to the intervention.

When introducing Coalburn in Chapter 3, it was acknowledged that the plantation predates the concept of NFM, and therefore was not classed as such at the time. It is perhaps unjust to state that Coalburn is not wholly ‘natural’ if that was not the main intention when research at the site began in 1967. As mentioned, Coalburn is a hydrological research catchment, with the aim to study hydrological impacts of afforestation, which differs from the purposes of the other study sites (Robinson, 1998). Nonetheless, multiple papers label Coalburn as NFM, which justified its inclusion in this project (Cooper *et al.*, 2021; Iacob *et al.*, 2012; Kay *et al.*, 2019; Xiao *et al.*, 2022). If Coalburn does not meet the definitive aim of restoring the natural environment for the purpose of flood mitigation, its labelling as NFM becomes problematic. However, it was found that the mature trees reduced annual streamflow by 250-300mm, thus meeting the aim of managing sources and pathways of flood waters (Birkinshaw *et al.*, 2014). It is therefore questionable whether restoring 'natural' features truly matters in the context of flood mitigation. It is perhaps sufficient that the Coalburn catchment reduces flood risk by mimicking the natural processes of interception and infiltration, even though it does not entirely restore the natural features that have been in the area historically. This demonstrates the complexities surrounding the definition of NFM identified in Chapter 2 and reinforces the importance of site context when labelling the intervention.

Table 5.1: *Land cover comparison of Coalburn, using data from objectives 1 and 2. Commonalities highlighted. Dates next to land cover types show when present.*

NFM Species			**Land Cover Type (1846-2023)**	**Tree Taxa (Mid-Holocene)**	
Species	**Common Name**	**Native?**		**Species**	**Common Name**
Picea sitchensis	Sitka spruce	Non-native	Coniferous trees **(1958-2023)**	*Alnus*	Alder
Pinus contorta	Lodgepole pine	Non-native	Marsh **(1846-1977)**	*Betula*	Birch
Pinus sylvestris	Scots pine	Native	Rough grassland **(1846-2023)**	*Corylus*	Hazel
				Quercus	Oak
				Ulmus	Elm

5.1.2 Crompton Moor

The NFM at Crompton Moor comprises of four planting locations, which include the species mix summarised in Table 5.2. Those that share a common genus with the mid-Holocene tree taxa have been highlighted (*Alnus*, *Betula*, *Quercus* and *Salix*), as well as the land cover type 'non-coniferous trees' from the GIS maps. It must be acknowledged, however, that non-coniferous trees were only present at Crompton Moor in the 2023 map, demonstrating their absence during the mid-19th to late-20th century. The occurrence of coniferous trees and mixed woodland in the 2023 map suggests that these trees may have been part of a planting scheme and could indeed be the NFM trees themselves. If this is the case, then non-coniferous trees have not been continuously present over time. Despite this, four of the NFM tree taxa were also identified in the pollen diagrams, which demonstrates some similarity between the NFM intervention and the 'natural' environment. It is probable that the typical deciduous woodland of the mid-Holocene was cleared by humans and the landscape therefore significantly altered over time, perhaps explaining the absence of tree cover demonstrated by the GIS maps until 2023 (Bartley, 1975). 55% of the NFM taxa are representative of the Holocene taxa, which implies that it is natural to an extent and suggests some consideration of including natural species. The remaining NFM taxa, namely *Carpinus*, *Crataegus*, *Malus*, *Sorbus* and *Viburnum,* were not detected during the mid-Holocene, suggesting they have not been present around Crompton Moor, though they are all non-coniferous and native to the UK. Interestingly, *Carpinus* is only native to southern Britain, and would not have been found naturally as far north as Crompton Moor (Woodland Trust, 2023c). This questions precisely how 'natural' something needs to be for it to be considered a 'natural feature'. However, while the taxa may not specifically replicate the past environment, they could perhaps be considered representative due to their 'natural' presence elsewhere in the UK, and their ability to mimic natural processes. This demonstrates the complexities with labelling schemes as 'NFM', as noted in Chapter 2.

The definition of what is natural in the context of NFM should be examined here in relation to Crompton Moor. SEPA's definition (2016) of NFM is to "restore, enhance and alter natural features and characteristics to manage sources and pathways of flood waters". Crompton Moor meets the aim of restoring natural features to an extent, as similarities in tree taxa have been detected. Many of the other definitions identified in Chapter 2 refer to "natural processes" instead of "natural features", which can also be recognised in the case of Crompton Moor. The Environment Agency's definition (2017) of NFM states that it "…protects, restores and emulates the natural processes of catchments…". The trees facilitate the natural processes of rainfall interception and infiltration, thus reducing runoff and decreasing flood risk (Cooper *et al*., 2021). Regardless of whether a particular tree species has been present over time, it is clear that this NFM intervention aims to mimic natural processes through tree planting. As identified in Subsection 2.3.2, NFM definitions are contested, making it difficult to understand what the true aim of NFM is. On the one hand, Crompton Moor's NFM restores some natural features (the tree taxa identified in the pollen diagrams), which meets SEPA's definition of NFM, but on the other hand, the trees themselves emulate natural processes to reduce flood risk, following the Environment Agency's definition of NFM. Therefore, the extent to which Crompton Moor's NFM can be considered 'natural' relies on how NFM is defined, highlighting the need to investigate this contextually.

Table 5.2: *Land cover comparison of Crompton Moor, using data from Objectives 1 and 2. Commonalities highlighted. Dates next to land cover types show when present.*

NFM Species			Land Cover Type (1846-2023)	Tree Taxa (Mid-Holocene)	
Species	**Common Name**	**Native?**		**Species**	**Common Name**
Alnus glutinosa	Common alder	Native	Coniferous trees **(2023)**	*Alnus*	Alder
Betula pendula	Silver birch	Native	Discontinuous urban fabric **(1846-2023)**	*Betula*	Birch
Betula pubescens	Downy birch	Native	Mixed woodland **(2023)**	*Corylus*	Hazel
Carpinus	Hornbeam	Native	Non-coniferous trees **(2023)**	*Pinus*	Pine
Crataegus	Hawthorn	Native	Pastures **(1846-2023)**	*Quercus*	Oak
Malus sylvestris	Crab apple	Native	Rough grassland **(1846-2023)**	*Salix*	Willow
Quercus petraea	Sessile oak	Native		*Ulmus*	Elm
Quercus robur	English oak	Native			
Salix caprea	Goat willow	Native			
Sorbus aucuparia	Rowan	Native			
Viburnum opulus	Guelder rose	Native			

5.1.3 Glenderamackin

Table 5.3 shows the similarities between the results of Objectives 1 and 2 for Glenderamackin, demonstrating that only *Corylus* was present in both the NFM taxa and pollen diagrams. Non-coniferous trees have also been highlighted to show the long-term presence of this tree type. However, only 20% of the NFM tree taxa were identified as being present in the mid-Holocene (*Corylus*), with no detection of the genera *Crataegus, Prunus*, *Sorbus* or *Viburnum*. If the aim of NFM is to "restore, enhance and alter natural features and characteristics to manage sources and pathways of flood waters" (SEPA, 2016), the extent to which Glenderamackin truly meets that aim is ambiguous. However, it cannot be ignored that the NFM species are all non-coniferous and native to the UK. Therefore, although they may not have been present around Glenderamackin during the mid-Holocene, this does not eliminate the possibility of them being present in the more recent past. This is a limitation of the historic OS maps; more precise information on tree taxa would allow for a full assessment of how 'natural' Glenderamackin's NFM is.

Despite the above observations, NFM is implemented on a site-by-site basis, therefore, restoring the past environment is not always most beneficial (Wren *et al*., 2022). NFM projects are encouraged to use a mix of tree species to create diversity, including shrub varieties of hazel, guelder rose and rowan (Cumbria Strategic Flood Partnership, 2018). Species such as hawthorn and hazel are also recommended to slow runoff and stabilise riverbanks, supporting the choice of taxa at Glenderamackin (Cumbria Strategic Flood Partnership, 2018). Two of the tree planting sites are located adjacent to watercourses and the remaining two sites are approximately 150m and 250m away from the nearest watercourses (see Chapter 3, Figure 3.15a), therefore reinforcing the species choices. It is likely that these taxa were selected due to their ability to slow the flow and consequently reduce flood risk. This meets the aim of "working with natural hydrological processes … to manage the sources and pathways of flood waters" (SEPA, 2016). Glenderamackin's NFM seems to satisfy part of the definition, through the restoration of natural processes, but does not completely restore the past environment. Defining NFM becomes complicated, particularly when questioning what is meant by 'natural'. While only *Corylus* was detected by the pollen diagrams, this observation does not mean that Glenderamackin's NFM is 'unnatural'. The chosen trees are native and facilitate processes to slow and store water, ultimately reducing the possibility of flooding, which still addresses the intention of NFM. The overall definition of NFM perhaps encompasses the different methods and functions, without creating too narrow a focus.

As discussed, the context of a site is important to consider when planning NFM projects. This aligns with the concept of 'Right Tree, Right Place'; a philosophy often adopted in tree planting activities (Bateman *et al*., 2022). It aims to ensure that the most suitable trees are planted in locations where they will flourish, and provide the desired benefits outlined in the planning stage (GreenBlue Urban, 2021). There are many reasons for planting trees, including carbon storage, timber production and flood mitigation, therefore it is necessary that projects are tailored to their specific goal (Bateman *et al*., 2022). The NFM at Glenderamackin follows the principles of Right Tree, Right Place, due to the consideration of the most suitable tree species to mitigate flood risk near watercourses. Restoring the landscape and using taxa that have been present in the past may not meet the goals of the project, thus emphasising the importance of site context. Again, while this perhaps does not meet the definition of being truly 'natural', it certainly is not unnatural, as it recognises the ecological needs of the catchment whilst also aiming to reduce flood risk.

Table 5.3: *Land cover comparison of Glenderamackin, using data from Objectives 1 and 2. Commonalities highlighted. Dates next to land cover types show when present.*

NFM Species			Land Cover Type (1853-2023)	Tree Taxa (Mid-Holocene)	
Species	**Common Name**	**Native?**		**Species**	**Common Name**
Crataegus	Hawthorn	Native	Coniferous trees **(1853-2023)**	*Alnus*	Alder
Corylus	Hazel	Native	Discontinuous urban fabric **(1853-2023)**	*Betula*	Birch
Prunus spinosa	Blackthorn	Native	Marsh **(1853-1977)**	*Corylus*	Hazel
Sorbus aucuparia	Rowan	Native	Mixed woodland **(1853-2023)**	*Pinus*	Pine
Viburnum opulus	Guelder rose	Native	Non-coniferous trees **(1853-2023)**	*Quercus*	Oak
			Pastures **(1853-2023)**	*Tilia*	Lime
			Rough grassland **(1853-2023)**	*Ulmus*	Elm

5.1.4 Pott Shrigley

The species planted at Pott Shrigley's two NFM locations are presented in Table 5.4, alongside the data from Objectives 1 and 2. The genera shared by the NFM species and mid-Holocene tree taxa, namely *Betula*, *Corylus* and *Quercus*, along with non-coniferous trees, were present in all of the historical maps, indicating the presence of trees in the recent and historical past. 56% of the NFM taxa were detected to a genus level by the pollen diagrams, however, this includes different species of the same genera; *Betula pendula* and *Betula pubescens*, and *Quercus petraea* and *Quercus robur*. This percentage is, therefore, perhaps over-representative of the NFM taxa, and it also recognises a limitation of pollen analysis; pollen diagrams rarely go as far as identifying taxa to a species level. This limits the ability to determine how truly 'natural' the NFM is; however, there has clearly been consideration of native, deciduous species.

The land cover maps for Pott Shrigley, presented in Subsection 4.1.4, showed the presence of non-coniferous trees between 1846 and 2023. However, this area declined over time, leaving just 20% of the original non-coniferous coverage. The reduction is likely to be a result of land clearance, perhaps influenced by the nearby Bakestonedale Farm, as non-coniferous trees were generally replaced by pastures. This could have been a result of the EU CAP. Although the UK did not join the EU until 1973, the early 20th century saw rise to agricultural intensification in order to maximise production (Pe'er *et al.*, 2020). It is plausible that the non-coniferous trees at Pott Shrigley were removed to increase productive farmland, as incentivised by CAP. This was introduced in Subsection 2.1.3 in the context of LULC change and flood risk. The NFM intervention could therefore be a response to the previous land clearance, by regenerating trees that have potentially been cleared over time. Although the exact tree taxa from the land cover maps are unknown, the restoration of non-coniferous trees could be seen as being 'natural', due to their prior long-term presence. The two NFM planting sites are located next to watercourses and are within close proximity to the non-coniferous trees that were identified in the land cover maps. This could, therefore, be an extension of the already present woodland, to restore some of the natural processes that may have been altered by land clearance.

Table 5.4: *Land cover comparison of Pott Shrigley, using data from Objectives 1 and 2. Commonalities highlighted. Dates next to land cover types show when present.*

NFM Species			**Land Cover Type (1846-2023)**	**Tree Taxa (Mid-Holocene)**	
Species	**Common Name**	**Native?**		**Species**	**Common Name**
Betula pendula	Silver birch	Native	Discontinuous urban fabric **(1846-2023)**	*Alnus*	Alder
Betula pubescens	Downy birch	Native	Non-coniferous trees **(1846-2023)**	*Betula*	Birch
Corylus	Hazel	Native	Pastures **(1846-2023)**	*Corylus*	Hazel
Crataegus	Hawthorn	Native	Rough grassland **(1846-2023)**	*Pinus*	Pine
Ilex	Holly	Native		*Quercus*	Oak
Quercus petraea	Sessile oak	Native		*Ulmus*	Elm
Quercus robur	Common oak	Native			
Salix cinerea	Grey willow	Native			
Sorbus aucuparia	Rowan	Native			

5.1.5 Land Cover Comparison Summary

The previous subsections facilitated discussion regarding the 'naturalness' of each NFM site, determined by similarities between the data from Objectives 1 and 2, and the NFM tree species. None of the sites were declared fully 'natural', due to contextual factors, the different interpretations of NFM's definition, and the ambiguity of what is meant by natural. Despite this, there were clear elements of 'naturalness' identified across some of the sites, when using similarities in taxa over time as a measure of naturalness in this context. According to such an understanding of 'naturalness', Pott Shrigley can be seen as the most 'natural' of the four study sites. Here, 56% of the NFM taxa were also identified in the pollen diagrams, along with the presence of non-coniferous trees throughout all of the historical maps. Subsection 5.1.4 discussed the limitations of the data but concluded that the NFM at Pott Shrigley can certainly be deemed natural to a considerable degree. When comparing this to the other NFM sites, Crompton Moor appears to be almost as 'natural' as Pott Shrigley, due to 55% of the NFM taxa matching genera from the pollen diagrams. However, non-coniferous trees were only present in the current land cover map (2023), therefore it cannot be certain that these trees have existed continuously at Crompton Moor. The question of what is meant by 'natural' is relevant here. If natural is defined as "as found in nature and not involving anything made or done by people" (Cambridge Dictionary, 2022b), then Crompton Moor's NFM can be determined as semi-natural, due to over half of the taxa being present during the mid-Holocene, which would be prior to any human activity. Regardless of whether non-coniferous trees were present in the historical maps, the existence of the same genera during the mid-Holocene demonstrates that 55% of Crompton Moor's NFM taxa can be considered 'natural', due to them being identified before any human intervention took place.

According to the above definition of 'naturalness' (using the same tree taxa that have been present over time), Glenderamackin and Coalburn were the least definitively 'natural' of the study sites. Glenderamackin's NFM only shared one common genus with the mid-Holocene taxa (*Corylus*) and none of Coalburn's NFM taxa were identified by the pollen diagrams. The respective subsections discussed how this affected the 'naturalness' of the NFM sites, resulting in different interpretations of NFM's definition. When focusing on restoring, emulating, and mimicking natural processes, both Coalburn and Glenderamackin met that aim, due to the selected species facilitating processes such as infiltration and interception. Therefore, Coalburn and Glenderamackin can be considered 'natural' due to their restoration of natural processes, but perhaps not in terms of their features. This reinforces the complexities of both the definition and practices of NFM, which were identified in Chapter 2. The examples of Coalburn and Glenderamackin illustrate that restoring the natural landscape is not the sole intention of NFM, and emphasise the importance of site context when considering the most suitable intervention.

The concept of Right Tree, Right Place was explored in Subsection 5.1.3 and is relevant when considering the NFM taxa. The projects had the purpose of reducing flood risk, therefore the most suitable trees were selected to meet that aim. For Coalburn, coniferous trees were selected in order to research their hydrological impact, despite none of the chosen species having been naturally present in the area in the past. Conifers are reported to have higher interception losses throughout the year compared to broadleaves; studies show that 25-45% of annual rainfall is lost by interception from conifers, whereas this is just 10-25% for broadleaves (Calder *et al*., 2003; Nisbet, 2005). The use of conifers at Coalburn reinforces the concept of Right Tree, Right Place, as the species have been carefully selected to analyse their impact on runoff. Coalburn is an upland catchment, therefore the site context is likely to have affected the species choice. Calder and Newson (1979) stated that every 10% of upland catchment covered by mature coniferous trees, would create a potential 1.5-2% reduction in water yield, supporting the suitability of conifers at Coalburn. In this case, it was more beneficial to plant trees based on their characteristics, rather than on what is considered to be definitively natural.

While coniferous trees were favourable at Coalburn, the remaining three NFM sites only included broadleaved species. Crompton Moor, Glenderamackin and Pott Shrigley all included multiple NFM techniques, whereas Coalburn only used tree planting. Therefore, the requirements of these NFM sites were slightly different. The sites are much smaller than Coalburn and focus on riparian and floodplain woodland, compared to Coalburn's catchment woodland. These have different purposes, so it is not surprising that different tree species have been used. Catchment woodland aims to increase interception of rainfall and enhance soil infiltration and water storage, whereas riparian woodland often consists of trees planted in strips either side of the watercourse, to increase channel roughness and slow the flow of water (Wren *et al*., 2022). This reinforces the importance of considering site context and highlights the concept of Right Tree, Right Place; while coniferous trees may be more beneficial for interception storage, broadleaved species are more useful in riparian settings.

Guidance on riparian tree planting advises that native, broadleaved species should be planted, not only for the benefits of flood management, but also to support biodiversity (Baker *et al*., 2019). A range of tree taxa can be used, but the most common include alder, birch, hawthorn, hazel, rowan, and willow (Yorkshire Dales River Trust, 2021). All, or some, of these taxa are present at either Crompton Moor, Glenderamackin or Pott Shrigley, reinforcing the expectations of riparian planting. These taxa aim to improve bank stability and reduce erosion, in addition to increasing water uptake through roots, thus slowing the flow of rivers and reducing the risk of flooding (SEPA, 2016). Riparian tree planting, therefore, emulates natural processes and, to a degree, restores the river environment back to its natural state. By interpreting the definition of NFM in this way, Crompton Moor, Glenderamackin and Pott Shrigley certainly meet the aim of restoring natural features and processes, despite not including all of the 'natural' taxa identified by the pollen diagrams.

However, it should be acknowledged that the source areas of the various pollen sites mean that the available data cannot be directly applied to the NFM sites. While the pollen diagrams give a representation of the regional environment, they are unable to specifically identify vegetation found in the selected NFM areas. It is also acknowledged that not all plants produce the same quantities of pollen, and that some pollen grains travel further than others, causing taxa to be over or underrepresented in the pollen diagrams (Lowe and Walker, 2014; Roy *et al*., 2018). Therefore, generalisations about the landscape during the mid-Holocene should be tentative, and the difficulty with making direct comparisons is recognised here. Although this limits the degree to which the NFM sites can be considered truly 'natural', the use of native, broadleaved species demonstrates consideration of taxa typically found in the UK.

This section has analysed the data from Objectives 1 and 2, to evaluate the extent to which the four NFM sites can truly be considered 'natural'. The interpretations demonstrate that each site can be considered 'natural' to an extent, but for different reasons. The difference between 'natural features' and 'natural processes' has been explored, highlighting that all of the sites mimicked natural catchment processes. The importance of site context was emphasised in relation to the concept of Right Tree, Right Place, in order to explain why certain taxa had been used to meet specific purposes. This reinforces that the purpose of NFM is not always to restore the natural environment, but to consider the catchment as a whole and to ensure that the desired targets are met. The following section explores this further, by discussing the interview participants' responses to the preliminary results of this research.

5.2 Interview Response to Data

The results of the interviews were introduced in Chapter 4, which established some of the main themes occurring within the responses. This section will focus on the comments made regarding the project data, where participants were asked to what extent they thought the NFM could be considered 'natural'. All of the participants said that the NFM was 'natural', although nobody agreed to a full extent. Below are some of the responses to this question.

"Well, we're planting the same species, then it must in some way reflect some of that natural process and system." (Participant 2)

“At first glance, you would say that that looks natural.” (Participant 3)

“I think that we can say it’s partially natural, yes.” (Participant 4)

“I can see you’re using a tree that’s appropriate for that location, that’s been used in the past.” (Participant 7)

Participants commented on the similarities between the NFM species and mid-Holocene taxa, demonstrating the consideration of using taxa that have been present in the past when implementing NFM. This goes some way to evidencing the interpretation of NFM in Chapter 2, where it was suggested that restoring the natural environment could mean converting the landscape back to its original condition prior to LULC change. The comments on using the same taxa reflect the importance of understanding the historic and prehistoric landscape to ensure environmental continuity. The notion of planting similar taxa follows SEPA’s (2016) definition of NFM; to restore natural features for the benefit of flood mitigation. However, it is also noted that this, alone, was not enough to declare the example of NFM fully ‘natural’. Participant 4 commented on the ambiguity of the mapped land cover data, stating that non-coniferous trees are not specific enough to be certain that the NFM is fully ‘natural’. This is a limitation of the historic OS maps, but reflects Participant 4’s perception of what is meant by natural. Indeed, a complete record of the historic environment around the NFM site would offer a clearer insight into how ‘natural’ the NFM intervention is, if considering natural to mean the continuous state of the landscape over a long period of time.

Despite this, it was discussed that NFM does not necessarily need to fully restore the environment for it to be ‘natural’; getting as close as possible to the historic landscape is still valuable. A quote from Participant 4 describes this:

“So, if you’re looking at something that’s just a complete monoculture, and we know that historically it has been X, Y and Z species on there, if you can get as close to what we’ve seen in history then that’s a net gain.” (Participant 4)

The phrase ‘net gain’ is mentioned here, which appears to have been used colloquially to describe a positive environmental change. While the participant did not directly reference a specific definition of ‘net gain’, it is worth noting Defra’s definition, which states that it is “an approach to development that aims to leave the natural environment in a measurably better state than beforehand” (Defra, 2018b). This substantiates Participant 4’s example of converting a monoculture to a land cover that is more diverse. In the context of NFM, restoring part of the natural environment is perhaps sufficient. This addresses the point made in Chapter 2, which explained that restoring the whole environment may not be the sole intention of NFM, but the ability to interpret it in this way demonstrates the need for a clear definition. In fact, when participants were asked to define NFM themselves, slightly different responses were received. This is perhaps unsurprising given the number of different definitions sourced from the literature in Subsection 2.3.2. The three quotations below provide some examples, which were taken from the subcode ‘actual definition’.

“[NFM is] *working with natural processes in an attempt to reduce flood risk, using a whole array of techniques.”* (Participant 3)

“It’s [NFM] *like almost trying to work with our natural environment back when we had a sustainable baseline.”* (Participant 4)

“I think it’s [NFM] *about being inspired by, and working with, and trying to enhance nature.”* (Participant 6)

These examples all use the phrase “working with”, and then refer to the natural environment, or processes that occur within it. However, the three definitions vary in their content. Participant 3 specifically includes reducing flood risk, while Participants 4 and 6 only discuss working with the environment. The inconsistency in defining NFM reflects the participants’ personal thoughts on the topic, but also reinforces the number of slightly different definitions that were identified in Chapter 2. The use of the phrase “working with” is likely to stem from ‘Working with Natural Processes’; Participant 3 uses the whole expression itself. This demonstrates the similarity between the terms NFM and WwNP, reinforcing the connections made between the two by the WwNP Evidence Directory (Burgess-Gamble *et al.,* 2018), Lane (2017) and Lashford *et al.* (2022) in Subsection 2.3.1 of the literature review. It could be implied that these participants use the terms NFM and WwNP interchangeably, suggesting they have similar meanings that are understood by those working in the sector. However, as the phrase “working with” was only mentioned here by three of the seven participants, it cannot be assumed that NFM and WwNP are used interchangeably by all. Individuals’ perceptions of NFM will be discussed further in Subsection 5.3.1.

Interestingly, only one of the above quotations mentions looking to the past, which Participant 4 describes as a “sustainable baseline”. The notion of a baseline is significant in this research, due to the comparisons between NFM data from the present day, with land cover data over the last 200 years, and taxa from the mid-Holocene. The results of this project evidence the difficulty with defining a baseline, and question how far back one should go to determine the ‘natural’ landscape (Hodder *et al*., 2009). Participant 4 summarised this in the following quotation:

“It’s very site specific, I think, in terms of where you’re trying to revert back to. And I think it’s all part of understanding what is your baseline in your catchment. Of course, that’ll be vastly

different from a catchment in the West Midlands, that's been highly industrialised over the past 200 years, to something slap bang in the highlands of Scotland. Those two are going to be vastly different in terms of what you should be looking at." (Participant 4)

Here, Participant 4 compares an urbanised catchment with a rural catchment and highlights the importance of site context. According to Participant 4, landscape restoration within an urban area is ultimately more difficult due to the scale of land-use transformation. Schulz and Schröder (2017) labelled urban infrastructure as a 'spatial constraint' in landscape restoration, due to it being unsuitable for large-scale environmental interventions. Hence, using the mid-Holocene as a baseline to revert back to in an urban area would simply be unachievable. In this case, making smaller changes may be more impactful, and could be achieved by looking back to the more recent past; Klaus and Kiehl (2021) use the example of restoring remnant rivers as a small-scale restoration technique in urban areas. For a rural catchment, on the other hand, it may be easier to use the mid-Holocene as a baseline, due to fewer 'spatial constraints' from infrastructure (Klaus and Kiehl, 2021). For instance, the new Landscape Recovery Scheme – part of ELMS – focuses on landscape-scale restoration, which would not be possible in urban areas (Defra, 2021b). Particular environments, therefore, have different requirements for restoration, which highlights the fluidity of a 'natural' baseline. Participant 4's comment about catchments' individual baselines demonstrates Lee *et al*'s. (2014) 'Baseline Problem', whereby restoring the environment is an arbitrary concept. The context of a site, and the aim of the project, are both vital when determining precisely what the restoration should entail. This further complicates the part of the definition of NFM that states it should restore natural features, due to the restoration baseline being unclear.

Further comments were made about site context and the impact that this may have on implementing NFM. While participants recognised the importance of using taxa that have been present in the past, they acknowledged that this may not provide the desired outcome. Quotes from Participants 3 and 5 illustrate the importance of looking at both what is happening now, and what may be beneficial in the future.

"So, in terms of the naturalness of NFM, there might be circumstances where planting non-native, or unnatural to that environment, trees, might arguably give a better result in terms of flood risk management." (Participant 3)

"I think you need to be careful about trying to restore, while some organisations do very much promote trying to restore past ancient woodland and native species, you need to be mindful that conditions are changing and that the mix of species involved could well change." (Participant 5)

Both participants refer to site conditions/circumstances, which may influence the suitability of certain species. Interestingly, Participant 3 refers to using non-native species for the benefits of flood risk management, which questions how ‘natural’ an intervention like this could be. This was explored in Subsection 5.1.1 in relation to the non-native species used at Coalburn, however, the use of conifers was justified due to their higher evapotranspiration rates compared to broadleaves (Iacob *et al.,* 2017). The use of non-native species could make the term ‘natural’ within NFM problematic; it is difficult to justify labelling something as ‘natural’, if those species have never been found in a particular area before. However, some definitions of NFM refer to restoring, emulating, or mimicking natural processes (Environment Agency, 2017). If non-native species mimic natural catchment processes, then they could be considered ‘natural’ in that context. This debate demonstrates that NFM is not just about environmental restoration, but that it considers the catchment context in order to facilitate the desired flood management benefits.

This section has examined the interview responses to the project data, through the evaluation of the term ‘natural’ within NFM. The initial quotations demonstrated that the participants believed the example NFM data to be ‘natural’, but there were often caveats to their responses. These were primarily due to the lack of a full environmental history, the difficulty in defining a suitable baseline, and the importance of implementing NFM on a site-by-site basis. The discussions revealed that there is no simple answer when trying to determine how ‘natural’ an NFM intervention is, and that this relies on knowledge of contextual factors. Despite this, interviewees acknowledged the importance of interventions being ‘natural’, whether through restoring, emulating or mimicking natural features or processes. The following subsections will discuss the interview data in more depth, focusing on the main themes that arose, and will compare these results with those found in the literature review where applicable.

5.3 Interview Themes

This section will discuss the main themes that were coded from the interview responses. Although the primary focus was on the terminology surrounding NFM and what is meant by ‘natural’, other valuable discussions were had regarding the approach to implementing NFM. These insights contribute to the ongoing research on NFM and will be addressed in the following subsections, while also making comparisons with the previously published literature that was discussed in Chapter 2.

5.3.1 Terminology and Perception

The terminology surrounding flood management is a key element of this research and featured considerably in the literature review. A number of similar, yet different, terms were identified, including Catchment-Based Flood Management (CBFM), Natural Flood Management (NFM), Nature-based Solutions (NbS), Sustainable Flood Management (SFM) and Working with Natural Processes (WwNP) (Lane, 2017; Lashford *et al*., 2022). Different authors seemed to have different ideas about what such terms mean, which makes understanding the overlaps, connections and differences between them more difficult. Similar conversations were had with the interview participants when exploring the concept and perception of NFM. Expectations were often discussed in relation to the terminology surrounding flood management, hence the evaluation of both topics in this subsection. Initial conversations generally focused on the broader terminology surrounding flood management, including analysis of where NFM fits in the nomenclature. The following quotations describe the terms as being part of a hierarchy.

"We have Working with Natural Processes at the top of the hierarchy." (Participant 3)

"The reason I refer to all three there [NbS, NFM, SuDS], *but started with Nature-based Solutions, is that what I've found particularly across the urban and rural landscape, is that Nature-based Solutions is becoming more of the umbrella term internationally."* (Participant 7)

Interestingly, while Participants 3 and 7 both referred to there being an overall term, their choices of terminology differ; Participant 3 placed WwNP at the top, whereas Participant 7 chose NbS. The literature review identified a similar inconsistency, whereby Lane (2017) stated that WwNP is a holistic term, yet Bark *et al*. (2021) determined NbS to be the broader term. This suggests that, even amongst industry experts, perceptions of these terms differ. To add further complication, Participant 6 stated that such terms are actually used interchangeably, as demonstrated by the quotation below.

"I'm talking about them interchangeably [NFM, NbS, WwNP], *and I think that's because, partly, we get the point, we know what we're talking about."* (Participant 6)

Participant 6's use of the plural pronoun "we" suggests there is a perception of a shared understanding amongst NFM professionals as to what these terms mean, therefore justifying their use interchangeably. It appears that the terminology surrounding flood management is subjective and perhaps depends on the situation in which it is being used. Participant 6 illustrates this in the following quote.

"If you're speaking to a group of engineers, they probably understand blue-green infrastructure in terms of 'that is things that are grass and water', whereas if you're speaking to environmental scientists about Nature-based Solutions, they maybe understand that a bit more because they're used to sitting in the ecology space." (Participant 6)

The different contexts suggested in this quote reinforce the notion that the terminology is subjective, depending on who is using it. Participant 6 emphasises the importance of recognising how people's perceptions may differ, depending on the sector in which they work. This reinforces the need for early conversations with all stakeholders, to establish the precise aim of the project, and to ensure that there is a shared understanding. Earlier comments about working in silos are apparent here and demonstrate how collaborative working could be improved.

Linked with this, a recurring theme within the interviews was the multiple benefits of NFM, and the declining focus on the purpose of flood management alone. In fact, Participant 1 stated that NFM should be used "as a way to leverage wildlife restoration". Although this opinion was not shared by all of the participants to the same extent, the following quotes support the notion that NFM is used for purposes other than flood mitigation.

"More often than not, I've found that the flood risk management side of NFM is rapidly eclipsed by people's enthusiasm for the wider benefits." (Participant 3)

"Quite a few projects now have to achieve a Biodiversity Net Gain, so people are going to think, alright so what we'll need to do is Natural Flood Management. If we're putting a scheme in, we need Natural Flood Management to deliver our Biodiversity Net Gain." (Participant 3)

"There's a lot of support for Natural Flood Management in the sense of using habitats, natural-type measures, to soften more traditional, engineered-based approaches, and so looking at the wider benefits rather than necessarily contributing physically to reducing the flood risk in any significant and material way." (Participant 5)

Participants were keen to discuss the multiple benefits of NFM, which were also highlighted in Subsection 2.5.2 of the literature review. However, it seems that these benefits are becoming the main focus, and the purpose of flood mitigation is becoming less significant. Participant 3 describes the use of NFM to meet BNG targets, which not only showcases how beneficial NFM is, but also reflects that the wider benefits of NFM are perhaps now better understood. Considering the broader focus of NFM, participants were asked whether they thought 'NFM' was still the most suitable way to describe the concept.

"As soon as people latch onto an acronym, you don't necessarily completely digest what an acronym is about and what it should enshrine." (Participant 3)

"I think as we evolve through time, it [NFM] *goes through cycles of trying to be called something else, but we always revert back to NFM anyway."* (Participant 4)

Interestingly, Participants 3 and 4 defended the use of the term NFM, due to its frequent use and shared understanding amongst professionals. However, they both acknowledged the difficulty with changing mindsets, describing how people "latch onto acronyms" and "revert back to NFM" regardless of what NFM actually entails. The frequent adoption of acronyms within the general flood management nomenclature is likely to be due to their simplicity and ease of remembrance. Research by Radović and Manzey (2019) found that acronyms are useful when learning and remembering concepts, reinforcing the recurrent use of the acronym NFM. Considering this, it seems that even if interventions are not directly related to the flood management element of NFM, they are still labelled as such due to their similarity and the simplicity of the acronym itself. Participant 3 compared the acronyms NFM and WwNP, suggesting that people may refer to NFM more often because it is easier to say, thus reinforcing the sentiment that people may not consider what NFM really means.

"It's far harder to say WwNP than NFM, which I think is precisely why it's [NFM] *got such traction, because it just trips off the tongue so easily."* (Participant 3)

This issue demonstrates the link between the terminology itself and the perception or understanding of what NFM is. On the one hand, labelling activities as NFM that do not exclusively address flood management may not be an issue if there is a shared understanding of what is meant, though this is highly subjective and dependent on the knowledge of those involved in the project. This reiterates Participant 6's earlier quote – "we know what we're talking about" – where they assume that those involved understand what they mean. Therefore, it is perhaps of no consequence whether the 'NFM' in question is truly NFM or not. On the other hand, it is clear from earlier observations that NFM is not always as closely linked to flood mitigation as one might expect. The quotations below exemplify the challenges that the interviewees have faced in terms of stakeholder perception of NFM.

"People will make a presumption about what NFM is going to deliver." (Participant 3)

"If you're posing a scope of works to a client, and we're saying we're going to deliver you a Natural Flood Risk Management study, the outputs of that can be wildly different based on previous studies etcetera. So I think there's a common misconception about what NFM is and what it isn't" (Participant 4)

"The terminology, I think it's not so much a barrier, but I think it's a point of confusion for various stakeholders." (Participant 7)

Participants 3, 4 and 7 acknowledge that different stakeholders may have different perceptions of what NFM is, which makes expectations difficult to manage. It seems that experts in the sector have a shared understanding of NFM and related activities, but this does not extend to stakeholders outside of industry, which could produce unexpected results. It is important to set expectations at the beginning to ensure all stakeholders have a shared understanding of the project. It is arguable that the broader terms NbS and WwNP may be more suitable to describe projects that restore the environment for purposes other than flood management, or when flood management is not the only aim. Using these terms would perhaps encompass all expectations and ensure that stakeholders know what the end results will be. Furthermore, NbS and WwNP are more holistic than NFM in terms of their literal definition. The emphasis on 'working with' in WwNP implies that the intervention should utilise the benefits of the natural processes in question. It does not suggest that natural processes should be restored or emulated, as is expected with NFM. Similarly, the 'nature-based' element of NbS suggests that such solutions should be inspired or influenced by nature. Both terms are less concrete than NFM in terms of their aim, which allows them to be applied to a range of activities, and not just limited to flood management. The results of Objectives 1 and 2 from this research demonstrate that NFM does not wholly restore past environments, whether that be the past 200 years or the environment of the mid-Holocene prior to human intervention. Therefore, the part of the definition that states NFM should restore natural features/processes is rarely truly met, further supporting that the terms WwNP and NbS may be more suitable.

When discussing what is meant by 'natural', the interviews explored different NFM techniques and considered the extent to which such measures could be considered 'natural'. A range of NFM methods were analysed, but bunds were most frequently discussed, as exemplified by the quotations below.

"We were talking about bunds, I would say they are definitely artificial, they are essentially mini reservoirs, they're dams placed in the environment which did not necessarily occur in the form that they are placed." (Participant 3)

"They were applying things like bunds and sediment traps, and most bunds and ponds are generally man-made features, these involve a digger of some sort, forming a structure that then will require a degree of maintenance." (Participant 7)

The use of the words "artificial" and "man-made" to describe techniques that are supposedly 'Natural' Flood Management, questions what the requirement for something to be 'natural' truly is. Participant 3 points out that bunds are unlikely to have historically occurred in the places that they are implemented, which challenges whether this meets the aim of restoring ‘natural features’. This was explored in Section 5.1 when discussing the data from this project, with reference to the differences between ‘natural features’ and ‘natural processes’. It could be said that a bund mimics natural processes through water attenuation, even though it is not necessarily a natural feature. The perception of what is considered ‘natural’ is brought into question here, and the consensus from the interviews was that an artificial structure should not be labelled as ‘natural’. This could lead to the possibility of greenwashing if artificial structures are characterised as being ‘natural’. Linked with this, some participants mentioned that certain techniques may be perceived as ‘natural’, even though they definitively are not. This could limit the ‘natural’ extent of some measures, if there is no regulation for how ‘natural’ a feature should be. Quotations from Participants 6 and 7 exemplify this.

“Artificial grass, you could say, is inspired by normal grass, doesn’t mean it’s a Nature-based Solution.” (Participant 6)

“A reservoir that has a headwall of very artificial material covering about 100m in width, that generates storage close to 10,000 cubic metres of water, that’s not the most natural of features. However, it is working with natural processes to a degree, because it’s trying to encourage connections to floodplains, so I think there are potential accusations of greenwashing.” (Participant 7)

Notably, discussions, such as the above, interpret the question of what is meant by ‘natural’ in a slightly different way to how Objectives 1 and 2 of this project address the concept. The first part of this research aims to determine how ‘natural’ specific NFM interventions are, in terms of the degree to which they represent the ‘natural’ historical landscape, which takes the general definition of NFM very literally. The quotes from Participants 6 and 7, however, focus on the difference between something artificial or human-made, and something that might naturally occur within the environment. Again, the discrepancy between restoring/emulating/mimicking natural features or processes is relevant here, as the examples given by Participants 6 and 7 mimic natural processes, but do not restore natural features. This demonstrates the different perceptions of what is ‘natural’, and reinforces the issues with how NFM can be interpreted. As discussed previously, this could lead to varying expectations of what NFM will deliver, ultimately making its implementation more complicated.

This subsection has explored the interview discussions surrounding flood management terminology, and how this may affect people’s perception of NFM. The participants’ responses demonstrate that much of the nomenclature is subjective, depending on who is using it and for what purpose. In order to foster a joined-up approach, all stakeholders need to have a shared understanding of the project aim, and thus the terminology that is being used. This will become increasingly important in the future, particularly as NFM is being encouraged to mitigate the increased risk of flooding as a result of climate change.

5.3.2 The Future of NFM

The future of flood management was addressed during the interviews, both in terms of flood defence strategy and response to climate change. The topic guide facilitated questions surrounding flood defence and mitigation, while the interview participants themselves generally initiated conversations about restoring past environments in light of climate change. The interviewees were asked whether they thought NFM would become the main flood defence in future, and all of the participants stated that a combination of natural and traditional defences would be necessary. The quotations below exemplify this.

> *"There's no way that we could be storing that volume of water purely using natural processes, the land uptake would be so high, and secondly, we can't quite use the same standard of protection using measures like Natural Flood Management as we can using things like a flood storage reservoir, as an example."* (Participant 4)

> *"I think it's going to be a bit of both* [hard engineering and NFM] *and I think we're kidding ourselves if we kind of put all of our eggs in one basket, but I certainly think it's about making NFM the norm."* (Participant 6)

Participant 4 justifies their opinion by explaining that storing large volumes of water is simply not possible with NFM, and that it does not give the same level of protection as a structured defence, like a reservoir. Along with Participant 6's comment of "putting all of our eggs in one basket", it can be suggested that the interviewees were realistic in their suggestions and acknowledged that using natural processes alone is not the aim of future flood management, but, instead, that NFM will be more frequently implemented. Participants were keen for NFM to become the main type of strategy, which can be supplemented with hard-engineered structures where necessary. One of the barriers identified in the literature review (Subsection 2.6.1) was that catchment-scale evidence of NFM is currently lacking, and the main reason for this was the difficulty with modelling the impact of NFM measures (Defra, 2020; Waylen *et al*., 2018). Considering this, it is unsurprising that the interviewees agreed on a combination of hard engineering and natural measures to protect against future flooding. It is questionable, however, whether using both types of management at the same time can be considered completely 'natural'. While the structured defences may not mean that the 'naturalness' of NFM becomes redundant, it certainly highlights the need for guidelines on what makes something natural. This reinforces the subjective nature of NFM and related terminology that was identified in Subsection 5.3.1.

The concept and definition of NFM were discussed in depth during the interviews, which led to conversations about how NFM should be approached in the future with regard to climate change. While it was widely accepted that NFM should restore and emulate the natural environment, some participants questioned whether this would still be a suitable approach as the climate changes. The quotations below illustrate this.

"It's probably sensible to start moving those bands of species. In 10, 20 years' time, it may be that I start planting Mediterranean species because we are reaching those temperature ranges." (Participant 2)

"People are casting their eye to doing these sort of climate matching techniques to say, where's our future climate likely to compare with, is it north of France or central France or even the Mediterranean, and then plant species that grow successfully there." (Participant 5)

"We're going into very dry spells, so if we're looking at the southeast, we're getting prolonged dry weather. Are there certain trees that might not be suited for that area, and maybe actually applying something that wasn't there before, but is more suited to the climate we're going into, is probably a better solution." (Participant 7)

Such comments highlight the shared understanding amongst participants of the importance of looking towards the future, and indicate the observation that restoring past environments will no longer be feasible. Despite this, it should be recognised that the palaeo record can be used to study how species have responded to climate change in the past (Fordham *et al*., 2020). While it may not be appropriate to use the mid-Holocene as a restoration baseline, palaeoenvironmental data could indicate the suitability of certain species under future climate projections, by demonstrating how they reacted during historic warming periods (Fordham *et al*., 2020). This illustrates the importance of understanding how the environment has changed in the past, in order to make future decisions.

With reference to the above quotations, Participants 2 and 5 suggest that Mediterranean species may be more suitable in future climates, and that these species should be considered within planting schemes. These concerns are also mirrored by the Forestry Commission (2020), which outlines the possible effects of climate change on trees, including increased pests and diseases, heightened drought conditions in summer, and increased risk of wildfires. If native trees are unlikely to thrive in future conditions, planting them now means they will be ineffective in the near future. The interview participants recognised this, with Participant 7 giving the example that some species may not be suitable in the southeast of the UK, if subjected to prolonged dry weather in future. Research suggests that non-native species may be better suited to the projected warmer, drier conditions, which could include planting more southerly species further north (Forest Research, 2022). However, this complicates the delivery of NFM and similar activities because they usually require the planting of native species. It is certainly questionable whether a scheme can be labelled 'natural', if those species have never been found in that area before. It could be argued that non-native trees, nevertheless, facilitate natural processes, consequently meeting NFM's definition of 'mimicking natural processes'. This highlights the different interpretations of NFM, which were also noted in the literature review and earlier in this chapter. In this case, it is arguable that NbS might be a more suitable description of such activities as they are 'nature-based' but perhaps do not take the precise definition of 'natural'. While planting non-native trees may not be the norm yet, the future of NFM requires careful consideration in terms of its implementation and interpretation.

This subsection has demonstrated how the projected impacts of climate change may affect flood management in future. The detailed discussions about this with NFM professionals reflect the consideration of future changes, including how 'natural', or otherwise, these may be. It was accepted that restoring the past environment for flood management purposes is unlikely to be the best solution in future, questioning how relevant the term 'natural' within NFM will be. This demonstrates how the concept of NFM is evolving, thus justifying the need for clear expectations and a shared understanding of what is meant by the selected terminology.

5.4 Conclusion

This chapter has examined the data collected to meet each objective, in order to evaluate the significance of the term 'natural' within NFM. The land cover and mid-Holocene pollen taxa comparisons demonstrated how the definition of NFM can be interpreted, and the extent to which the NFM sites could be considered 'natural' was determined by whether the definition described natural features or natural processes. All of the NFM sites restored and/or mimicked natural processes through water interception and storage, but not all of these planted trees matched the taxa that had been identified as being present during the mid-Holocene, reinforcing the importance of site context. When discussing this with the interview participants, different viewpoints were identified, which often depended on the individuals' perception of what is meant by 'natural' and how they defined NFM. Key differences between natural 'features' and 'processes' were identified, and demonstrated how NFM can be interpreted differently depending on which definition is used. The significance of terminology was highlighted throughout the interview themes, particularly when discussing people's expectations of what NFM will deliver, and how this can present difficulties. Looking towards the future, collaborative working and a shared understanding of a project's aim will be vital in ensuring a holistic approach to flood management. This was highlighted as being particularly relevant with regards to the compromises that may have to be made about what we can consider to be 'natural' under scenarios of future climate change.

CHAPTER 6: CONCLUSION

This chapter will conclude the thesis by summarising the findings of the research objectives, and by stating the contribution that this study has made to research on Natural Flood Management. It will also review the limitations of the project, and make recommendations for future research opportunities in order to further develop knowledge on NFM and related terminology.

6.1 Research Findings

The aim of this project was to evaluate the extent to which NFM can truly be considered 'natural', and to consequently assess the importance of restoring the 'natural environment' as a flood management technique. This aim was achieved through the data collection and analysis of the following objectives.

Objective 1: Map the land cover of each NFM site from the mid-1800s to the present, to determine whether NFM interventions are representative of the historic environment.

Objective 2: Analyse palaeoenvironmental proxy data to determine whether NFM interventions are representative of the mid-Holocene environment.

Objective 3: Conduct interviews with flood management stakeholders to assess the current understanding of how 'natural' NFM is and the importance of its 'naturalness' within flood management.

Objective 4: Evaluate the significance of the term 'natural' within NFM.

The extent to which each NFM site could truly be considered 'natural' depended upon whether NFM's aim was defined and understood as restoring 'natural features' or 'natural processes'. As described in the literature review, these differing aims may result in different outcomes and the four NFM sites demonstrated that. Coalburn was considered the least 'natural' due to none of the NFM tree species being identified as present during the mid-Holocene, or within the historical maps. However, the importance of site context was noted, as the original aim of the Coalburn catchment was to study the effects of coniferous afforestation on runoff rates, thus making its labelling as NFM problematic. Contextual factors were noted amongst the other NFM sites, such as the differing functions of catchment woodland and riparian woodland, which introduced the concept of Right Tree, Right Place. Therefore, there is no distinct answer as to whether an NFM site's afforestation measures can be declared fully 'natural' or not. This prompted an evaluation of the nomenclature surrounding flood management, which was a fundamental topic during the interviews with NFM professionals. The terminology narrative was weaved throughout the discussions, from how it can affect allocation of funding, to the expectations of land managers. It was clear that different perceptions and understandings of NFM may complicate its implementation, therefore demonstrating the importance of discussing these expectations as part of the early consultations when planning new NFM measures.

Looking towards the future, the concept of NFM is likely to continue to evolve, particularly if landscape restoration includes planting non-native species. Of course, this may be necessary under projected climate conditions, but interview discussions questioned whether this can still be labelled as 'natural'. Once again, the debate as to whether NFM should restore natural features or processes becomes relevant, as non-native species may still facilitate mimic the natural processes of water interception and storage. The terms Nature-based Solutions and Working with Natural Processes were considered as suitable alternatives, particularly as many 'NFM' projects are actually used for their multiple benefits, rather than solely focusing on flood management (The Flood Hub, 2023). While the terminology may seem like a trivial issue, it was identified that it can be a point of confusion, if stakeholders have different expectations due to their own perceptions of NFM. At a time when collaborative and joined-up working is being encouraged, discussions with all stakeholders surrounding those expectations are vital, to ensure the desired outcome is achieved.

6.2 Knowledge Contributions

This thesis has contributed to the developing knowledge base on NFM by identifying the need for clear and consistent phrasing when defining and labelling flood management techniques. It has done so through a mixed-method approach, novel to NFM research, which enabled analysis of the concept of what is 'natural' within NFM. With its focus on terminology and the unpacking of NFM as a theoretical construct, this research has highlighted the importance of conceptual clarity, particularly for practical and policy applications of NFM. In order to ensure that NFM projects are effective, their specific goals must be clearly defined from the beginning. Furthermore, there is a need for consistency and clarity in policy for NFM projects to be delivered successfully. The definitions and wording of particular terms may be interpreted differently by different people, resulting in a range of expectations. Clarity will be particularly important for current and future environmental targets, such as the 25 Year Environment Plan and the Environment Agency's goal of establishing 260 NFM projects between 2021 and 2027 (Environment Agency and Defra, 2023). If the aim of these projects is to reduce the risk of flooding, this should be made clear from the outset and the chosen management techniques should be specific to that goal. It was suggested earlier in this thesis that trees planted for other purposes, such as biodiversity, may still be labelled as NFM, despite those trees not being most suitable for flood mitigation. Therefore, using the NFM label in the wrong context may falsely suggest that targets have been successfully met. The findings of this research are particularly relevant for writing policy and setting targets related to NFM and environmental restoration.

6.3 Limitations

Despite the findings of this research, the study was limited by several factors. Initial difficulties were faced when selecting NFM and pollen sites, due to the fragmented pollen record in the UK. It would be beneficial for the pollen record to be expanded, which could supplement landscape restoration projects across the UK. Similarly, the historic OS maps were not specific enough to gain a detailed insight into the types of trees that were present around the NFM sites. This would have allowed for a more confident determination of how 'natural' the selected sites were. The use of estate maps, for example, may have provided more specific land cover information, and therefore could be a fruitful avenue for future research. It is also acknowledged that through its focus on the historic land cover of the NFM sites, this research has taken a very literal interpretation of 'restoring the natural environment' as its conceptual starting point, which was – as demonstrated – just one interpretation of the definition of NFM. The interview discussions were, therefore, necessary to explore the concept in more depth, and to demonstrate the different perceptions of the topic. To develop this further, interviews with other stakeholders would have been beneficial, such as the public or land managers, to allow for a broader discussion on NFM. Due to the scope of this research, however, it was only possible to interview NFM professionals.

6.4 Future Research

Research on NFM is continuously progressing but requires further investigation to ensure its advancement and integration into the flood management agenda. To do this, the limitations of this study should be addressed, namely the expansion of the pollen record in the UK, the use of a wider range of historical data (e.g., estate records), and in-depth interviews with a range of stakeholders, including the general public and land managers, to assess the understanding of NFM in different sectors. This research has revealed that the concept of NFM and the perception of what is natural, are highly subjective and open to interpretation. Because of this, open conversations about the terminology and expectations are necessary to ensure a holistic approach and improved stakeholder support. In order to address environmental policy agendas like the 25 Year Environment Plan, the Environment Act and ELMS, clarity surrounding the aim of NFM will be needed. Flood management nomenclature should, therefore, be reviewed over time, to ensure such activities are meeting their desired aim.

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Appendices

Appendix A: Full Record of Ethical Approval

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Appendix B: Interview Topic Guide

Outline of interview structure. Questions are for guidance purposes; they do not all have to be asked. Follow the order of the interview guide as closely as possible.

Introductions. Introduce yourself, thank them for taking part and remind them of the purpose of the interview.
Share project background slide to explain what the research is about.
Inform the participant you will start recording.

Introductory Questions

Can you introduce your job role and tell me a bit about what you do?
Can you tell me what you know about NFM?
In what capacity have you interacted with NFM?
(Only ask if they have not mentioned explicitly) To what extent is NFM related to your job role?
Can you tell me about the NFM projects you have worked on?

Defining NFM and Exploring the Concept

In your own words, how would you define NFM?
Do you think there is any variation in the definition?
Have you heard it defined differently?
If you were designing an NFM project/in NFM projects you have been involved in, are there any particular criteria you would include? For example, provision of ecosystem services, community benefits, carbon storage etc.
The aim of NFM is 'to restore, enhance and alter natural features and processes to manage the sources and pathways of flood waters'. Do you think that NFM meets its aim? Why/why not?
Do you think 'natural' is the most appropriate description of NFM? Why/why not?
Do you think some types of NFM are more 'natural' than others? Examples: tree planting, debris dams, beavers

NFM Changes Over Time

Do you think there has been an increase in the application of NFM in recent years? If yes, what do you think could be driving this?
Have you seen any changes in the way that NFM has been delivered over the past 10 years?
Do you think the role of NFM within wider flood management has changed over time?

Barriers to NFM Uptake

Do you think there are any barriers to implementing NFM? If yes, what are they?

Have you experienced this in your job role/the projects you have worked on?

Approach to Flood Management

Do you think flood management is generally 'joined up' in terms of its approach? Why/why not?

If there are problems with flood management: What do you think is the best approach to address these problems? Top down or bottom up?

Do you think NFM is the 'way forward' for flood management strategies? In what circumstances would this be the case? Or not the case?

The Future of Flood Management

Do you think we will continue to use hard-engineered structures to mitigate flooding? If yes, how natural is that?

Is restoring the environment and looking back to the past the most effective way of mitigating flooding?

How might flood management change in the future?

Presentation of Project Data

Share data presentation slide and explain the results. Ask the following question.

Given this evidence, do you think 'natural' is the most appropriate description of NFM?

Close the interview. Stop recording.