EXPLORING THE CONTRIBUTION OF LAND MANAGER EXPERTISE WHEN CONSIDERING TREE COVER EXPANSION FOR NATURAL FLOOD MANAGEMENT.

by

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Abstract

Faced with climate and biodiversity crisis, increasing tree cover has become a hot topic and a matter of significant debate. The multiple benefits of increasing tree cover have become a familiar narrative, particularly as part of Natural Flood Management (NFM). However, this increased interest is not reflected in increased tree cover in our landscapes. NFM itself is critiqued for a lack of empirical evidence, and a lack of uptake (of both NFM and tree cover) is linked to 'social barriers'.

NFM can be framed as 'wicked', a challenge in which multiple social, physical and ecological systems are entangled; water flows across socially defined boundaries. Trees are equally complex, crossing generational timescales where socio-ecological interactions may impact outcomes as readily as tree-water interactions. Understanding these interactions and entangled systems involves both interdisciplinary and participatory approaches. This has direct implications for the understanding of landscapes and decision-making at the knowledge-policy interface.

In this thesis, I demonstrate the importance of Land Managers' lived experience and expertise when exploring tree cover expansion for NFM (Trees for NFM). I explore how this impacts their decision-making and how this knowledge sits alongside the knowledge(s) that currently inform environmental decision-making, specifically hydrological modelling. This interdisciplinary, participatory study aims to inform decision-making by developing a better understanding of knowledge production for scaffolding solutions to 'wicked' problems.

In a large case study river catchment, the Trothy in South East Wales, I draw on key concepts and methods of Geography to explore landscape as both place and space. I root this disciplinary rigour and interdisciplinary perspective within a framework of participation and the co-production of knowledge. Working with Land Managers (predominantly but not exclusively farmers) through long, emplaced interviews, participatory

GIS and hydrological modelling, I show the political and practical importance of lived experience. A phenomenological approach builds on current literature of agri-environment decision-making, enmeshing understandings and shedding new light on 'barriers' to uptake. Through this work, I affirm the attribution of Land Managers as relevant experts, exploring and applying their expertise. Using a hydrological model (SHETRAN) as a heuristic, I show the usefulness of modelling whilst situating the output within and recognising its entanglement with the wider relevant knowledges.

Conducting participatory reflexive work throughout, including evaluation and analysis workshops, I recognised a need for a new perspective on knowledge production and decision-making in landscapes. I introduce a concept I call 'drysi gwir', the real puzzle (work or entangled confusion!). I show that the current science-policy interface lacks key pieces of the puzzle. By recognising the importance of heterogeneity and connectivity within landscapes, I can directly reflect on 'barriers' to implementation and the impact this has on knowledge production within the context of environmental challenges. Through the analysis and work with participants, clear recommendations for alternative approaches, including the importance of relationships and the role of facilitation, are developed.

Significant landscape change is occurring, whether chosen or not. Choosing and impacting the direction of change involves a series of wicked challenges. Trees for NFM is a lens through which the decisions about this landscape change can be explored. The view through this lens shows that the current limited knowledge production at the science-policy interface is not meeting the challenge. In this thesis, I directly link landscapes, knowledge production and decision-making. In doing this, I propose ways in which knowledge production and a knowledge-policy relationship can meet the challenge and call for action to make the changes that can enable us to scaffold the solutions to the multiple wicked challenges we face.

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Dedication

For Dylan and Jack,

your future is worth growing trees for.

Contents

I The Challenge **1**

1 Introduction **3**
1.1 Research story . . . 3
1.2 An interdisciplinary thesis . . . 4
1.3 Research aims and contribution . . . 6
1.4 Thesis overview . . . 8

2 Literature Review **13**
2.1 Introduction . . . 14
2.2 Natural Flood Management . . . 16
2.2.1 The development of 'Natural Flood Management' . . . 16
2.2.2 What is 'NFM'? The 'science' and the evidence debate . . . 17
2.2.3 Using Hydrological Models where empirical evidence is unavailable or unattainable . . . 21
2.2.4 Beyond the evidence debate . . . 23
2.3 Trees for NFM . . . 24
2.3.1 Trees-water interactions . . . 24
2.3.2 Using Trees for Natural Flood Management . . . 28
2.3.3 Barriers to tree planting and NFM - focus on land managers 'social barriers' . . . 32
2.4 Decision-making and the importance of participation . . . 36
2.4.1 Drivers that determine uptake of agri-environment schemes . . . 36
2.4.2 Can concepts such as Social Capital and the 'Good Farmer' fully explain decision-making and uptake? . . . 38
2.4.3 Beyond the socio-cultural: How a phenomenological approach can add to understanding . . . 40
2.4.4 Landscapes are 'more-than-human' spaces where humans are not the only actor . . . 45
2.5 Participation, Decision-Making and Knowledge production . . . 48
2.5.1 Postnormal science and wicked problems - re-framing environmental challenges and 'knowing' the problem we're trying to solve . . . 50
2.5.2 Environmental science, policy and expertise: participation and exclusion . . . 54
2.5.3 Farmers are relevant experts . . . 59
2.5.4 Reframing governance, knowledge and participation to scaffold the solution . . . 66
2.6 Entangled systems and participation: summarising the challenge so far . . . 71

3 Interdisciplinary methods **75**
3.1 Theoretical frameworks . . . 76
3.1.1 'Doing' interdisciplinary, participatory research . . . 76
3.2 Methods for an iterative boundary-crossing case study . . . 79
3.2.1 Participation and Ethics . . . 79
3.2.2 A single case study catchment . . . 80
3.2.3 Methodological overview: Stages and process . . . 82
3.2.4 Co-production: Mapping participation throughout the study . . . 84

II The Fieldwork **87**

4 Methods I **89**
4.1 Conducting the Fieldwork . . . 89
4.1.1 Case study selection and data collection . . . 91
4.1.2 Positionality and ethics . . . 93
4.1.3 Semi-structured interviews . . . 94
4.1.4 Participant Mapping . . . 97
4.1.5 Participatory observation . . . 98
4.2 Analytical approach . . . 99

5 Case Study: Dalgylch Afon Trothy **101**
5.1 Catchment Characteristics - Physical . . . 101
5.2 Catchment Characteristics - Trees . . . 110
5.3 Catchment Characteristics - Floods . . . 112
5.4 Catchment Characteristics - Policy and Governance . . . 115

6 Fieldwork in the F/field **117**
6.1 Introduction . . . 117
6.2 The importance of lived experience . . . 118
6.2.1 Lived Experience: Encounters, Topography and multi-natural landscapes . . . 118
6.2.2 Understanding landscapes: Policy interactions and political rhetoric 141
6.3 Complex knowledges and relevant experts . . . 148
6.3.1 Decision-making . . . 148
6.3.2 Experts in their F/fields . . . 155
6.4 Summary and impacts . . . 164

III The Model **169**

7 Methods II **171**
7.1 Hydrological models for NFM . . . 171
7.2 Model choice . . . 172
7.3 SHETRAN; description, setup and application . . . 174
7.4 Model calibration . . . 181

8 Modelling increased tree cover for NFM **187**
8.1 Evaluating the Baseline Model . . . 188
8.1.1 1. How well the model represents catchment hydrology . . . 189
8.1.2 2. An evaluation against observed river levels . . . 190
8.1.3 Baseline Evaluation against Archived data . . . 194
8.2 Alternative Scenarios . . . 194
8.3 Findings . . . 198
8.3.1 No intervention prevents flooding at the maximum peak . . . 199
8.3.2 Increasing woodland planting decreases floodpeak . . . 201
8.3.3 Time to Peak and peak flood dates . . . 207
8.3.4 The 'type' of landscape that is under tree cover, where it is and what is replaced are important (not just the extent) . . . 213
8.3.5 Loss of trees or other management choices have a greater impact per area of change . . . 217
8.4 Reflections and implications . . . 220
8.4.1 Methods . . . 220
8.4.2 Interpreting the model output . . . 221
8.4.3 Limitations and implications . . . 227

IV Synthesis **231**

9 Methods III **233**
9.1 Participatory Workshops . . . 233
9.1.1 Ethics and Methods . . . 233
9.2 Data Analysis . . . 238
9.3 Participant Observation / Researcher Experience . . . 239

10 Co-production of Knowledge **243**
10.1 Introduction . . . 243
10.2 Towards synthesis . . . 244
10.2.1 Evaluation and analysis of model output . . . 244
10.2.2 Evaluation of researcher reflections . . . 252
10.2.3 Analysis and discussion: wider knowledge and political behaviours . 254
10.3 Translating across boundaries . . . 264
10.3.1 Research as intervention: land manager knowledges and learning through participation . . . 264
10.3.2 Co-production and the fluidity of expertise . . . 266
10.3.3 The unsettling experience of translating across boundaries . . . 269

11 Understanding the whole picture: Y drysi gwir **271**
11.1 A holistic and inclusive approach . . . 274
11.1.1 Using temporal extent to build a more comprehensive picture . . . 276
11.1.2 Shedding light on the problem by working with the 'opaqueness' of different data . . . 278
11.1.3 Are we dealing with a false dichotomy when we try to 'integrate' qualitative and quantitative . . . 279
11.2 Entwined systems and entangled data . . . 283

11.2.1 Making knowledge and policy: Exploring the practice of 'making the best decision' through the practices of data collection, analysis and application . . . 285
11.2.2 Governance and 'solving' the drysi gwir of increased tree cover for NFM . . . 292

12 Conclusion **297**
12.1 Endings, beginnings and cycles . . . 297
12.2 Response to aims and contributions to knowledge . . . 298
12.2.1 Objective 1: . . . 298
12.2.2 Objective 2: . . . 299
12.2.3 Objective 3: . . . 300
12.3 Interdisciplinary reflections and future research . . . 302
12.4 Implications and solutions for policy and practice . . . 304
12.4.1 New ways of finding evidence: . . . 305
12.4.2 New ways of governing . . . 306
12.5 Concluding remarks . . . 308

Bibliography **351**

Appendices **353**
I Enlarged Graphs and Figures . . . 355
I.1 Chapter 2. Literature Review . . . 355
I.2 Chapter 3. Methods Overview . . . 359
I.3 Chapter 5. Case Study . . . 361
I.4 Chapter 6. Fieldwork . . . 366
I.5 Chapter 7. Methods II . . . 370
I.6 Chapter 8. Models . . . 372
I.7 Chapter 10. Workshops . . . 385
I.8 Chapter 11. Synthesis . . . 386
II Remote sensed and Secondary data . . . 388
III Participant Maps . . . 392
IV Participant information . . . 395
V Ethics Approval and HRA documentation . . . 396
VI Analytical Mind Maps . . . 415
VII NVivo Coding structures . . . 416
VIII PRD R code . . . 419
IX EPD R code . . . 423
X Alternative landcover maps . . . 426
XI SHETRAN baseline parameters . . . 433
XII We need to talk about death . . . 437
XIII Workshop Datasheet . . . 439
XIV Workshop mind maps . . . 441
XV Summary report for NRW South East Area team . . . 445

List of Abbreviations

AONB - Area of Outstanding Natural Beauty

CaBA - Catchment Based Approach

CCC - Committee for Climate Change

EEC - European Economic Community

FRM - Flood Risk Management

GIS - Geographic Information System

GPS - Geographic Positioning System

LM - Land Manager

NFM - Natural Flood Management

NERC FDRI - Natural Environment Research Council, Floods and Droughts Research Infrastructure

NRW - Natural Resources Wales

NVZ - Nitrate Vulnerable Zone

PGIS - Participatory GIS

PNS - Post-Normal Science

SFS - Sustainable Farming Scheme

SRC - Spearson Correlation Coefficient

WFD - EU Water Framework Directive (2000)

WI - Womens Institute

WILD - Water with Integrated Local Delivery

WWNP - Working with Natural Processes

List of Figures

2.1 A simple model of catchment and discharge 18

2.2 A simple model of Natural Flood Management 19

2.3 An alternative framework / model of Natural Flood Management 20

2.4 Tree - water interactions 25

2.5 'Treescape' - water interactions 26

2.6 NFM wicked features 51

2.7 Wicked features of Trees 52

2.8 A visualisation of the extant linear conception of the science-policy framework 67

2.9 Re-conceptualising a knowledge-policy framework shaped by society and the landscape 68

3.1 Boundaries across the science/policy interface 76

3.2 Overall project flow chart showing iterative stages and feedback loops . . . 82

3.3 Diagrammatic illustration of the number of sites and participants that were engaged with the full study 84

3.4 Distribution of study sites across the catchment, grouped into areas relating to the main tributaries. The 3 sites engaged later in the study are identified as +1 85

4.1 Illustration of the locations of fieldwork and interview sites. The distribution of the 22 fieldwork sites across the catchment. The smaller +1 indicates the 4 sites where interviews did not take place 97

5.1 Location and area of the Trothy River Catchment/Watershed 102

5.2 The river Trothy during high flows, showing two very different bank profiles; photos taken within a 1km stretch *Participant photographs, consent to use granted* . . . 102
5.3 Bedrock of the Trothy River Catchment . . . 103
5.4 Geological structure and parent soil types of the Trothy River Catchment . 104
5.5 Topography from Lidar data of the Trothy River Catchment . . . 105
5.6 White Castle, one of three castles built to defend the southern Welsh / English border; *image authors own* . . . 106
5.7 Registered Land Holdings demonstrating the complex ownership within the Trothy River Catchment . . . 107
5.8 Catchment watershed and River Trothy overlaid with the OS vector data for buildings (see credits and Appendix II) . . . 108
5.9 Categorized Land Cover data from the CEH 2015 dataset (see credits and Appendix II) of the Trothy River Catchment . . . 109
5.10 The historical maps of Skirrid Fawr at the North end of the Trothy Catchment; 1880, 1920, 1960 and 1970 respectively . . . 110
5.11 Photos showing representative 'wooded' features, riparian, small woodland and hedge in the South of the Catchment. Images authors own . . . 111
5.12 (LH) Trothy in Flood, 12th Feb 2014 at 17:10; (RH) The same view standing 6ft further back across the bridge *LH Photo contributed by catchment resident permissions for use granted; RH photo authors own* . . . 112
5.13 The bridge in figure 5.12 showing the extent of the flood waters. *Photo contributed by catchment resident permissions for use granted* . . . 113
5.14 Trothy River Levels . . . 114
5.15 Relevant River Roles and Responsibilities . . . 115

6.1 Abstract showing the relationship between participants' perception/narrative of the relationship between landscape and river, to the distance from and thus experience of the river itself. . . . 122

6.2 The closest line of trees, which could easily be mistaken for an overgrown hedge in this catchment, hides the Trothy. 125
6.3 Histogram showing range and regularity of different angles of slope within the Trothy catchment 127
6.4 Tractor routes drawn by Roger on the maps as he talked 129
6.5 Flood damage to the Trothy wall 140
6.6 Old large Willow fallen across the Trothy 146
6.7 Network of intersecting codes 148
6.8 David's map of potential tree planting 151
6.9 A visualisation of researcher and land manager expertise; how they are integrated and framed. 156
6.10 Trothy river wall and erosion 162

7.1 SHETRAN v4 processes 175
7.2 SHETRAN v4 modules 176
7.3 ETD module processes and order of calculations 177
7.4 VSS module processes based on Figure 5.1, p51 "SHETRAN Water Flow Component, Equations and Algorithms", n.d., data sources in Appendix II and parameters in Appendix XI 178
7.5 OC module processes based on Figure 4.2 p49 SHETRAN waterflow equations 179
7.6 Workflow to develop the baseline model of the Trothy catchment 2013-2014 180
7.7 Workflow to develop the alternative landcover scenarios of the Trothy catchment 181

8.1 The channel network produced by the SHETRAN model against the channel network from the OS maps 189
8.2 The Baseline Hydrograph for the evaluation period Dec 2013 - Feb 2014 . . 190
8.3 Baseline Hydrographs for the 2013-2014 flood events 190
8.4 The Baseline Hydrograph overlaid with the observed NRW levels data . . 191

8.5 The Baseline Hydrograph overlaid with the observed NRW levels data for the flood events . . . 192
8.6 The spatially distributed rainfall used for the SHETRAN precipitation input 193
8.7 The alternative scenarios arranged by group . . . 196
8.8 Shows the peak events, the flood events relate to the Christmas Eve, New Year and February peaks . . . 199
8.9 Flood event Discharge graphs for all scenarios, with a band the range at which flooding may be expected to occur throughout the catchment . . . 200
8.10 Maximum Discharge during the December 2013 flood event . . . 201
8.11 A / Percentage change in Discharge in December. B / Percentage change in Discharge Max . . . 204
8.12 Visualising the relationship between the size of intervention and the variance in peak reduction . . . 205
8.13 Maximum peaks for each scenario in a categoric plot against the flood date. 205
8.14 Shows the maximum peak for each scenario grouped by the day they occurred 206
8.15 Peak events against the impact of increased tree cover . . . 207
8.16 Tree cover interventions change river flood behaviour . . . 209
8.17 Alternative scenarios 63_arable2 and 64_arable3 . . . 210
8.18 Difference between December and February events . . . 211
8.19 Shows the maximum change in discharge for each alternative scenario identified by group . . . 213
8.20 Shows the impact per acre of each group of scenarios . . . 214
8.21 Impact per Area arranged by scenario, in order of size of intervention . . . 214
8.22 Impact per Area boxplot, grouped by scenario groups and by flood date . . . 215
8.23 Impact per Area grouped by flood date, in order of flood size (23rd through to 1st . . . 215
8.24 regroups alternative scenarios by impact per acre percentile . . . 216
8.25 Plots discharge against percentage land cover for the largest other landcover codes used in the SHETRAN scenarios . . . 218

8.26 Shows the Impact per Acre graph with the loss scenarios added back into the data . . . 219
8.27 Shows the linear regression over the percentage change in discharge against the percentage landscape change against . . . 224
8.28 Standardized residuals for scenarios against percentage landscape change . 225

9.1 Baseline scenario Hydrograph from model output including the observed river height data . . . 237
9.2 Early graph of model output maximum flood peak against the percentage of catchment under tree cover for the baseline and all alternative scenarios. This graph was an early analysis of output and does not include all the data used in the analysis described in PartIII . . . 237
9.3 Aerial image of the catchment generated on ArcGIS - credits included . . . 238

10.1 A funnelled floodplain . . . 251
10.2 Intersecting social groups attribute and identify expertise differently . . . 268

11.1 Y drysi gwir: data, analysis and the relations between them situated within Trees for NFM and the wider land management context . . . 275
11.2 Timeline showing the data against selected historical and geographical context . . . 276
11.3 The fuzzy boundaries of soil data (historical use and physical characteristics may situate the soil as it is, soil ecology and future use indicate what it might become) entangle with the fuzzy boundaries of other data sets. . . . 283
11.4 The cyclical nature of knowledge production . . . 285

Part I

The Challenge

Chapter 1

Introduction

1.1 Research story

In 2008, in the UK, technical flood management was found unable to meet the challenges of flooding (Pitt, 2008). The problem across the UK and Europe was reframed as flood risk management, acknowledging the social structures at the root of the challenge. The approaches also reinforced a broader perspective of the benefits of catchment-based management and working with natural processes, including Natural Flood Management (NFM). In 2011, the rapid u-turn on the potential sale of the national forest estate saw a paradigm shift in political support for the benefits of forested landscapes and recognition of how culturally essential trees were in the UK (Independent Panel on Forestry, 2012). This shift in perception ran alongside the calls to tackle the nature and biodiversity crisis, and all of these changes cannot but be framed within the wider understanding of the landscape change we will be forced to undergo in the face of climate change.

As well as a response to climate and nature crisis, trees have been situated as a key catchment-wide intervention for flood management (Environment Agency, 2021b; NRW, 2020a; Trust, 2022). The benefit of tree cover expansion for NFM has become a narrative in itself, regularly mentioned without reference to the evidence (or lack of it). 'Trees for NFM' suggests a simple solution to a 'wicked' problem. However, nothing about trees, even defining them (Ghazoul, 2015; Rackham, 2015) is that simple. In 2018, the Climate

Change Committee (CCC) advised a target for increasing UK tree cover to 17-19%, and the 2019 government election became a bidding ground for the highest tree planting target set; none of these targets have been met (Chris Morris, 2019; Environment, Food and Rural Affairs Committee, 2022). Trees within the UK landscape have become a controversial feature of debates. They have become a narrative that has captured many underlying, unrelated controversies. This may be because of the potential of trees to have a temporal and material impact that extends across decades and systems (Rackham, 2015; Wynne-Jones et al., 2022).

These challenges of Natural Flood Management and tree cover expansion can be framed as 'wicked'; they do not sit within disciplinary or traditional knowledge production frameworks. Yet despite decades of evidence (Wynne, 1996; Wynne and Lynch, 2015), whilst the framing of responsibility (the finger of blame?) has turned to land managers of the rural landscape (Emery and Hannah, 2014), the acknowledgement of expertise, knowledge production and ownership of the 'right approach' has not (Chilvers and Kearnes, 2020). This has stayed resolutely within extant power hierarchies and a science-policy interface that is still firmly 'evidence-based' with a resolute belief in who can produce 'evidence', or what it is (Raymond et al., 2010; Smallman, 2020). Current policy and planning is technocratic and teleological (Wingfield et al., 2019), a process which has encountered significant 'social' barriers (Waylen et al., 2018).

In the light of this complex landscape, a human geographer and a physical geographer walked into a pub. They debated how forested landscapes, an expansion of tree cover across the UK, could be explored and implemented as an NFM intervention. This thesis arose as a response to that conversation.

1.2 An interdisciplinary thesis

The doctoral scholarship program 'The Forest Edge' offered Leverhulme Doctoral Scholarships to researchers "to determine to what extent Forest existence, form, and function emerge from detailed interactions within and across scales, from molecules to individ-

ual organisms, to communities and societies" (Birmingham Institute of Forest Research (BIFoR), n.d.). The Forest Edge program's essence was always to be interdisciplinary, whether through the platform for discussion between diverse disciplinary backgrounds that it provided or through the nature of the research being conducted.

Whilst the literature identifies the necessity of interdisciplinary, participatory approaches (Nesshöver et al., 2017; Pasquier et al., 2020; Rusca and Di Baldassarre, 2019, Tadaki et al., 2015), it also recognises that traditional disciplinary and institutional frameworks are still shaping approaches (Krueger et al., 2016; Oughton and Bracken, 2009). Rusca and Di Baldassarre (2019) find Geography to be an interdisciplinary resource that can overcome perceived methodological and epistemological 'incompatibilities' between natural and social sciences. This thesis very much utilises geography in this way, responding to the concerns of Hadfield-Hill et al. (2020) by 'doing' interdisciplinary practice.

Multiple definitions of the terms interdisciplinary, multidisciplinary and transdisciplinarity have been debated. This interdisciplinary research could be described as transdisciplinary as the knowledge production engages with knowledge(s) beyond those certified institutionally. However, the term 'disciplinary' is reflective of institutional knowledge. I find it suitable only within these environments and, therefore, refer to my work as interdisciplinary and participatory.

I am also responding to Turnhout and Lahsen (2022) by doing science differently in this research. I cross boundaries not just within the scientific institutions but extending beyond them. I draw on Science and Technology Studies and participatory literature such as Chilvers and Kearnes (2020) whilst rooting the work within the Geographical literature exploring place, space and landscape. From its strong foundations across the geographical sciences, I explore the expertise of land managers. I find direct links between landscape, knowledge production and decision-making through their participation. I argue that the key to scaffolding solutions (Andersson and Törnberg, 2018) is reframing the science/knowledge-policy interface and introducing the concept 'drysi gwir' to better frame evidence and the co-production of knowledge. Land Manager expertise is a crucial piece of the 'drysi gwir', the entangled puzzle, a contribution directly impacting

the expansion of tree cover as an NFM intervention and relevant to wider environmental decision-making.

I would not say that (as in Krueger et al. (2016)) this work challenges disciplinary foundations, neither am I trying to 'integrate them'. Instead, I recognise disciplinary expertise, the fuzzy nature of the boundaries between disciplines and the wicked problems rooted there. The aims and objectives of this thesis have not been pre-emptively attributed to one discipline or another, whilst the work conducted builds on rigorously developed disciplinary methodologies.

This work, therefore, starts with a broad mindset. I explore multiple strands of literature to identify the giants on whose work I build before rooting in disciplinary practices to ensure rigorous data collection (always with an eye on that interdisciplinary background). These practices are drawn back together in the analysis, both within the chapters and, most evidently, in Part IV, Synthesis.

1.3 Research aims and contribution

Aim of the thesis:

I aim to explore how land managers' knowledge and expertise inform their decision-making and how compatible/relevant that knowledge is alongside knowledge(s) that currently inform the challenge of tree cover expansion for Natural Flood Management.

Objectives:

- To identify land managers' relevant knowledge and expertise and how this impacts their decision-making and political behaviour.
- Explore the integration/compatibility of different knowledge(s)[1] for decision-making, including land manager knowledge and expertise and hydrological modelling of alternative scenarios, focusing on factors which would inform the efficacy of tree cover expansion for NFM - Trees for NFM.

[1]There is a complex discussion on types of knowledge referred to throughout this thesis. To simplify the grammatical choices this creates, I start each chapter by referring to knowledge(s), then discard the () for the rest of the chapter

- To critique current science/policy interface and decision-making process alongside land manager/model knowledge integration for usefulness in enabling management interventions that i) deliver NFM and ii) are acceptable to multiple stakeholders.

This thesis makes significant contributions to the extant literature within disciplinary fields. For example, I draw on phenomenological approaches to expand the literature on agri-environment decision-making and knowledge production. I argue that the lived experience of a material, living landscape can directly inform knowledge production for developing interventions and inform the decisions of those holding that experience. There is a direct link between landscapes, knowledge production and decision-making, enabling us to explain some current 'barriers to uptake'.

In the physical sciences, through the use of a hydrological model (SHETRAN[2]) as a heuristic model applied to a large river catchment (+140km2), I improve understanding of how increased tree cover might affect catchment hydrology; in particular, showing the importance of heterogeneity of catchment (and event) characteristics.

However, this thesis goes beyond the evidence debates of NFM and trees, recognising the entangled nature of wickedness. Throughout, I argue for a perspective that recognises how these disciplinary findings are inextricable from interdisciplinary threads. The physical, material landscape is integral to understanding behaviours in and the co-production of socio-ecological landscapes. The socio-cultural and land manager expertise are both integral in informing and improving the science of hydrological modelling, from calibration to analysis and interpretation.

This entangled evidence needs a new perspective, and this is the foundation of the 'drysi gwir' - a real puzzle (or tangled confusion!). I argue for a perspective that goes beyond integration to synthesis, seeing all evidence as crucial pieces of a puzzle, where each piece of evidence has an impact, informs and is part of an entangled whole. In exploring this puzzle and crossing many boundaries of knowledge production, my own story has become entangled in this work, and reflexivity is an aspect considered throughout.

Finally, the thesis argument of evidence as key pieces of 'y drysi gwir' has direct

[2]https://https://research.ncl.ac.uk/shetran/

implications for governance and 'evidence-based' policy. Reflections are made on, for example, the roles and responsibilities of different decision-makers, the attribution of expertise and how policy structures and knowledge production respond to the heterogeneity of connected socio-ecological landscapes.

1.4 Thesis overview

Part I - Setting the Scene

Includes:

- Chapter 1 - Introduction,
- Chapter 2 - Literature Review
- Chapter 3 - Interdisciplinary methods

Part one of the thesis sets the scene for the research; it includes this introduction and lays out the relevant literature. The literature review itself is structured into multiple parts, as the interdisciplinary nature of this project crosses multiple disciplinary boundaries. This means that each area of the review touches only on the most relevant areas of the literature, and I have tried in each case to identify where the interested disciplinary specialist may wish to delve deeper. The methodology in this section justifies and lays out the overarching thesis approach, identifying the interdisciplinary frameworks and limitations and is directly relevant to the final part, 'Synthesis'. The more detailed disciplinary methodologies are included at the beginning of each relevant section.

Part II - fieldwork

Includes:

- Chapter 4 - Methods I
- Chapter 5 - Case Study

- Chapter 6 - Fieldwork

In part II, I introduce the first empirical study of the thesis. The methodology is structured around predominantly social science frameworks but also includes the quantitative data case study collection. A coherent approach was developed by using the overall framework of a case study methodology. The case study briefly introduces the catchment (the River Trothy | Avon Trothy, in Monmouthshire, Wales) in both its social and physical characteristics and situating it within the Wales/UK landscape and political context. Further data can be found in the appendices.

The first empirical chapter is Chapter 6 - Fieldwork. The aim of Chapter 6 was to identify farmers' and land managers' relevant knowledge and expertise and how this impacts their decision-making and political behaviour. One of the key terms here is 'relevant', and a substantial part of the chapter is dedicated to understanding the 'relevance' of farmer knowledge within our current frameworks of evidence-based policy, i.e. what knowledge is 'scientifically' relevant. But also to identify knowledge that may not easily bridge this gap whilst still having direct relevance to understanding the suitability and potential efficacy of solutions of increasing trees within the landscape.

Part III - Modelling

Includes:

- Chapter 7 - Methods II
- Chapter 8 - Hydrological Model

The methodology in Chapter 7 identifies and describes the well-evidenced hydrological practices of computational modelling of catchment hydrology. In addition, I identify where knowledge and information from the fieldwork, both qualitative and quantitative, have directly impacted this methodology. These methods lean heavily on the reflexive practices of Critical Physical Geography and Socio-hydrology.

The aim of chapter 8 is to:

- identify what might be learnt from a hydrological model of the catchment from a known flood period, which explores the impacts of different scenarios of tree cover
- and to show how farmer land manager knowledges impacted the building of this hydrological model and alternative scenarios (the importance(+/-) of scientisable knowledge)

Chapter 8 is the second empirical chapter, laying out in detail the process, development and output of the modelling. Applying the SHETRAN hydrological model to the catchment for a known flood event, developing a baseline, and then developing alternative land cover scenarios to explore the impacts on flood peaks. This model is developed and analysed as a heuristic rather than a predictive model. Scenarios were not meant to provide 'flood prevention schemes' but to inform and explore the suitability of different options in relation to particular catchment characteristics.

Part IV - Synthesis

Includes:

- Chapter 9 - Methods III
- Chapter 10 - Co-production of knowledge
- Chapter 11 - Understanding the whole picture: Y drysi gwir
- Chapter 12 - Conclusions

The methodology of Chapter 9 includes two parts: the practice of participatory evaluation and the reflexive approaches of social sciences and critical physical geography, which inform the researcher's analysis and discussion. The researcher's experiences throughout this project are briefly outlined, demonstrating the relevance of researcher practice impacting both the extent and limitations of the approach.

Chapter 10 is the final empirical chapter, and Chapter 11 is the substantive discussion of the thesis. The aim of Chapter 10 is to evaluate the model alongside farmer and land

manager knowledge and expertise and the researcher's expertise. The aim of chapter 11 is to synthesise the research as entangled pieces of a whole puzzle (y drysi gwir) and use this whole picture model to critique how environmental decision-making/policy is currently being made. For this purpose, the chapter is split into two distinct parts: a discussion of the synthesis and co-production of knowledge and the implications of this entanglement of knowledge for decision-making and governance regarding land management and meeting wicked challenges, including tree cover expansion for NFM.

Finally, in Chapter 12, the overarching conclusions and recommendations from the thesis are made.

I begin each chapter with a contents overview and cross-reference different sections of the thesis throughout. Several supporting appendices are referenced, including 'enlarged figures' (Appendix I) so complex graphs may be examined in more detail where desired.

Chapter 2

Literature Review

Contents

2.1 Introduction **14**

2.2 Natural Flood Management **16**

2.2.1 The development of 'Natural Flood Management' 16

2.2.2 What is 'NFM'? The 'science' and the evidence debate 17

2.2.3 Using Hydrological Models where empirical evidence is unavailable or unattainable 21

2.2.4 Beyond the evidence debate 23

2.3 Trees for NFM **24**

2.3.1 Trees-water interactions 24

2.3.2 Using Trees for Natural Flood Management 28

2.3.3 Barriers to tree planting and NFM - focus on land managers 'social barriers' 32

2.4 Decision-making and the importance of participation **36**

2.4.1 Drivers that determine uptake of agri-environment schemes . . 36

2.4.2 Can concepts such as Social Capital and the 'Good Farmer' fully explain decision-making and uptake? 38

2.4.3 Beyond the socio-cultural: How a phenomenological approach can add to understanding 40
2.4.4 Landscapes are 'more-than-human' spaces where humans are not the only actor 45
2.5 Participation, Decision-Making and Knowledge production **48**
2.5.1 Postnormal science and wicked problems - re-framing environmental challenges and 'knowing' the problem we're trying to solve 50
2.5.2 Environmental science, policy and expertise: participation and exclusion 54
2.5.3 Farmers are relevant experts 59
2.5.4 Reframing governance, knowledge and participation to scaffold the solution 66
2.6 Entangled systems and participation: summarising the challenge so far **71**

2.1 Introduction

As an interdisciplinary thesis, this research must take a broad approach to literature. In each of my topics, there are intricate disciplinary questions which could lead (and have led me) down rabbit holes, which while of academic interest, are not relevant to meeting the project aims. This review then takes a wider approach, broadly identifying the key topics and debates relevant to the aims. In section 2.2 I introduce Natural Flood Management (NFM) within the context of an 'evidence-based' UK policy (NRW, n.d., Defra, n.d.-b). By exploring the development of NFM, I introduce the debate around what NFM is, and what evidence is either relevant or 'enough' to support its implementation. I briefly summarise some of the science behind NFM and the challenges with this debate, including a discussion of the hydrological modelling which has often been relied upon to fill in some of those evidence 'gaps'. I then go *beyond the evidence* debate introducing a key topic of

this thesis, entangled socio-physical systems and the ontology of knowledge production for decision-making in the current science-policy interface. Section 2.3 introduces the tree-water system, what is currently known and the gaps that emerge when this is scaled to wooded feature/woodland or forest (identifying some of the bio-physical evidence 'gaps' relevant to the previous section). I then discuss the roots and frameworks of Trees for NFM which have led to a technical approach, framing trees as a functional tool in a physical process. None of the literature reviewed reflects the complexity of tree-water systems identified in the previous section. Within this context, I then explore the 'barriers' that have been identified and are directly relevant to the potential expansion of tree cover for NFM. Controversies and barriers in the literature suggest more complex systems and knowledge production may be impacting decision-making. Section 2.4 Land manager (LM) decision-making, explores the wider agri-environment literature to identify what factors determine LM decision-making, specifically in regard agri-environment uptake. I find that literature often focuses on the socio-cultural to the exclusion of the materiality of landscapes. Emery and Carrithers (2016) found that farmers lived experience and represented landscapes were entangled, this reflects in a way Bender's (1993) call to 'enmesh' or knit together (Bender, 2010) academic approaches. Responding to these findings I draw on phenomenological literature to explore the potential relevance of lived experience to LMs knowledge production and decision-making. Section 2.5 questions assumptions of expertise and knowledge production at the science-policy interface. Science and Technology Studies (STS) literature critiques the institutional frameworks within which decisions in regards to Trees for NFM and wider landscape change are made. This directly reflects on both barriers to and uptake of interventions as well as the design of interventions themselves.

2.2 Natural Flood Management

2.2.1 The development of 'Natural Flood Management'

Since the 1990s it had been recognised that the previous 50 years of technical flood management (TFM) focusing on capital and maintenance works, was ineffective (Newson et al., 2021). The EU Water Framework Directive (WFD)[1], focusing on improvements in water quality, shifted the framework of policy from one of intervention to one of whole basin management. This is reflected in the Land Use Policy Group (LUPG, 2004) report and Royal Society Review paper (Wheater, 2006) which recognise the potential impact of, and lack of evidence for, landscape-scale impacts on catchment hydrology.

In 2007 disastrous summer floods were declared 'the country's largest peacetime emergency since World War II' (Pitt, 2008, pvii). This was swiftly followed by the opportune publication of the EU Floods Directive (FD)[2] in September of the same year. Both the Floods Directive and the Pitt Review, an independent review of the 2007 emergency (Pitt, 2008), reframed the focus of flood management from that of an environmental, physical challenge, to a more social one. The focus was shifted from flood protection to flood risk management (Newson et al., 2021). Whilst both reports also recognised and consolidated the thinking that the framework of management needed to address and manage the whole water basin and wider landscape, this was not the priority. The Pitt review, for example, targets seven recommendations for local authorities in the assessment and development of management plans. Only one of these recommendations (no. 27, Pitt, 2008, pxx) addresses a 'catchment-based approach' to enable 'working with natural processes'. This recommendation is secondary to and referenced as a better approach than the use of sandbags to keep water away from homes.

A strategic approach to these issues may have been to develop a holistic, whole-scale water management delivery approach. Instead, where they have been led by departments with specific objectives and legal targets, or run by academics with different disciplines, the

[1] EU Water Framework Directive, 2000.
[2] EU Floods Directive, 2007.

two approaches to a certain extent developed separately, and within their own frameworks. Catchment-based approaches (CaBA) are rooted in the WFD, targetting water quality and biodiversity improvements (often led by groups that had previously focused on fish stocks such as the Wye and Usk Foundation(Wye and Usk Foundation, n.d.)). NFM or 'Working with Natural Processes' (Environment Agency, 2021b) developed from the FD and an engineered approach to flood protection which was required to shift to Flood Risk Management.

Whilst these approaches overlap, their roots are evident in the frameworks on which they focus, and the way in which stakeholders are identified. The separation of these approaches is additionally evidenced by contemporary calls for the need to integrate water management (Howarth, 2017). This is not just a challenge across quality and quantity Within water quantity there has been little consolidation between the management of floods and droughts (Krueger et al., 2016, Kosow et al., 2022); evidenced in the £38 million being invested from the UKRI Infrastructure fund to develop the 'Flood and Droughts Research Infrastructure'. (CEH, n.d.)

The need for the research infrastructure and monitoring program above highlights a key debate around the implementation of NFM - a lack of empirical evidence to support policy direction and changes (reflecting the technocratic, linear focus that will be critiqued in section 2.5.4). To explore this I shall briefly outline the science behind the evidence, the evidence debate and why alternate framings of NFM suggest the need to move beyond this debate.

2.2.2 What is 'NFM'? The 'science' and the evidence debate

Natural Flood Management (NFM) is a flood management strategy that bases interventions on the principles of Catchment Based Flood Management (CBFM - reducing flood inundation through upstream catchment management rather than local defences) but specifically through 'natural' processes (Lane, 2017b). In setting out to define and examine the concept and evidence base of 'Natural Flood Management'. Dadson et al. (2017) notes immediate difficulties with the concept by hyphening the 'natural' in the title whilst

Lane (2017b) bypasses this discussion by noting that NFM interventions may be "natural to varying degrees". Although both papers recognise the importance of socio-cultural factors and complex catchment characteristics, NFM is framed as a simple physical model. Water enters the catchment as precipitation and at some downstream location is measured as river discharge Q (Figure 2.1).

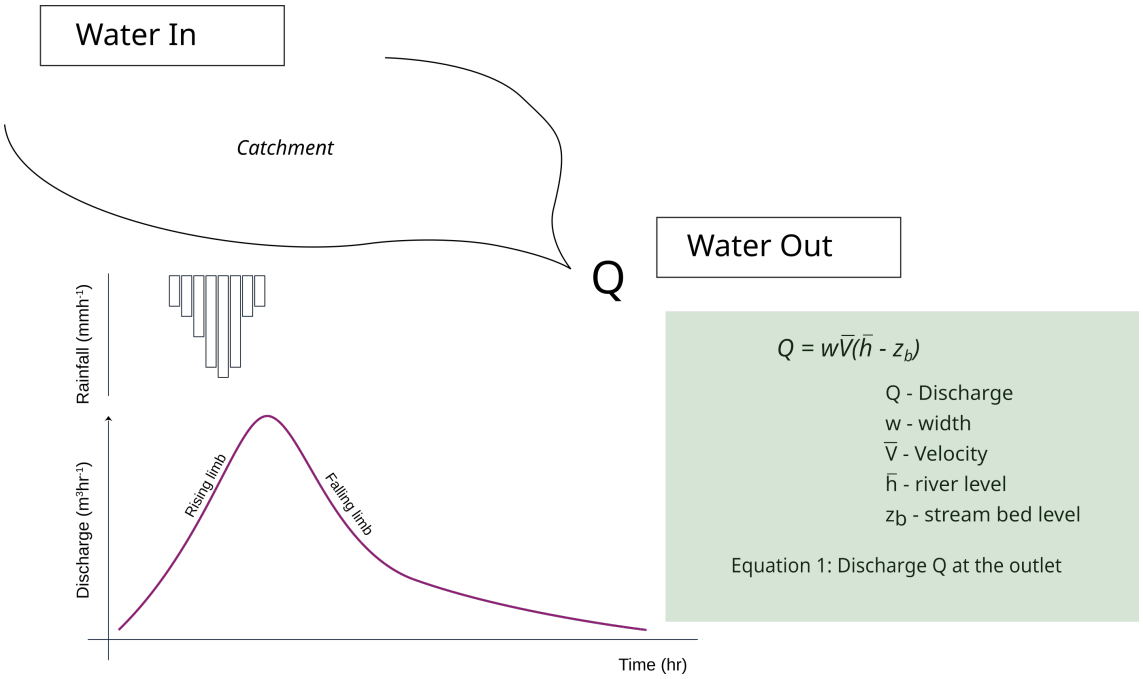


Figure 2.1: a visualisation, hydrograph and equation of the simplified model of the catchment which underlies the development of NFM in the UK. The hydrograph shows the precipitation (columns) and discharge at point Q (line graph). Equation 1. shows the discharge Q depends on the physical characteristics of the river bed (width - w and depth - the difference between water height $\overline{h}$ and stream bed z_b) and the mean river velocity $\overline{V}$.

NFM is treated as a subset of 'Catchment Based Flood Management' (CBFM) which aims to prevent or reduce flooding by preventing the river level reaching some critical height $\overline{h_c}$ (Figure 2.2).

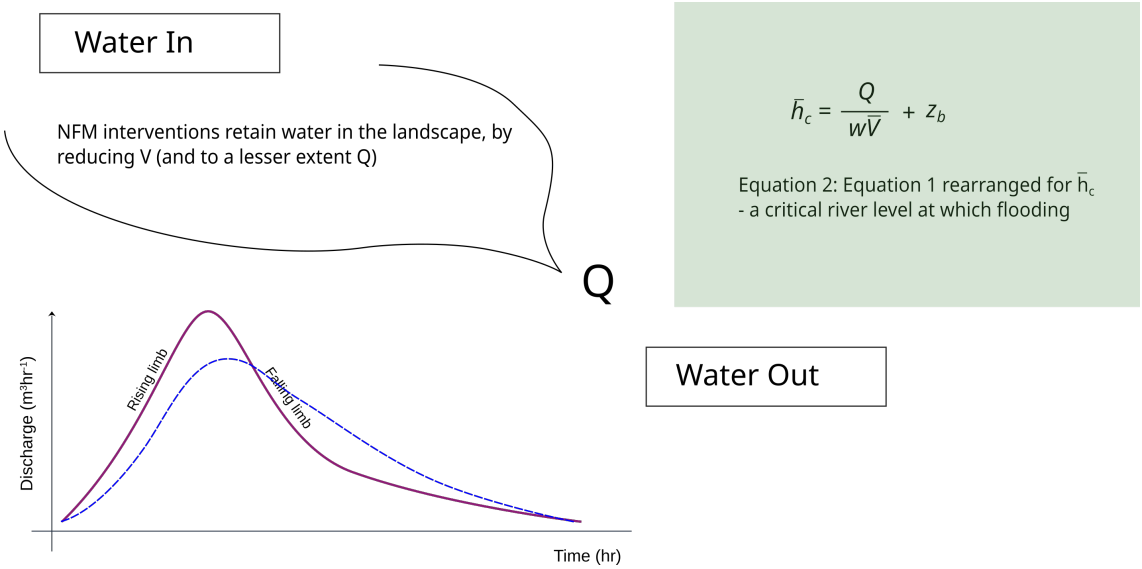


Figure 2.2: The equation rearranged for hc, and the impact of 'slowing the flow', shifting the discharge from the peak to the falling limb of the stormflow hydrograph (Wells et al., 2017, Thomas and Nisbet, 2007)

Interventions focusing on flood sites have historically involved engineered change to physical characteristics (w and z_b) to control river levels $\overline{h}$, including straightening, deepening or building levees (Pitt, 2008, Newson et al., 2021). Reducing Q itself, according to Lane requires work in the catchment or CBFM. Again here historical interventions have focused on engineered solutions (Newson et al., 2021), 'inline' or 'offline' depending on their connection to the river (Lane, 2017b).

NFM approaches seek to manage 1) infiltration and overland flow, 2) conveyance and connectivity and/or 3) storage (Dadson et al., 2017, Lane, 2017b), in ways that reduce $\overline{h_c}$. There are many techniques to address this, however, Lane (2017b) identifies the management of attenuation (the mean river velocity V) or 'slowing the flow' as "the basis of NFM" (Lane, 2017b, p2). The 'natural' in 'natural' flood management is therefore only limited to what one defines as natural.[3]

This framework has formed the basis of the UK evidence base for NFM (Environment Agency, 2021b). One of the key problems evident is the lack of integration with, or

[3]I could actually discuss Trees for flood management, and discard the term 'natural' throughout this thesis, it would not change the type of interventions or how they were implemented. I have retained it as the phrase NFM is that which would be associated with tree planting. There is a lot to be unpicked here but goes beyond the scope of the thesis (and my word count!). To delve into this and the myth of the nature-culture dichotomy I would suggest starting with Castree, 2014 and Latour, 1993

recognition in this model, of the complex multiple systems that make up a 'catchment'[4].

Ellis et al. (2021) reframe NFM as a 'Nature Based Solution' (NBS), as opposed to technical flood management. Whilst this approach requires significantly more complex analysis, it does reframe NFM as part of a more complex system (Figure 2.3)

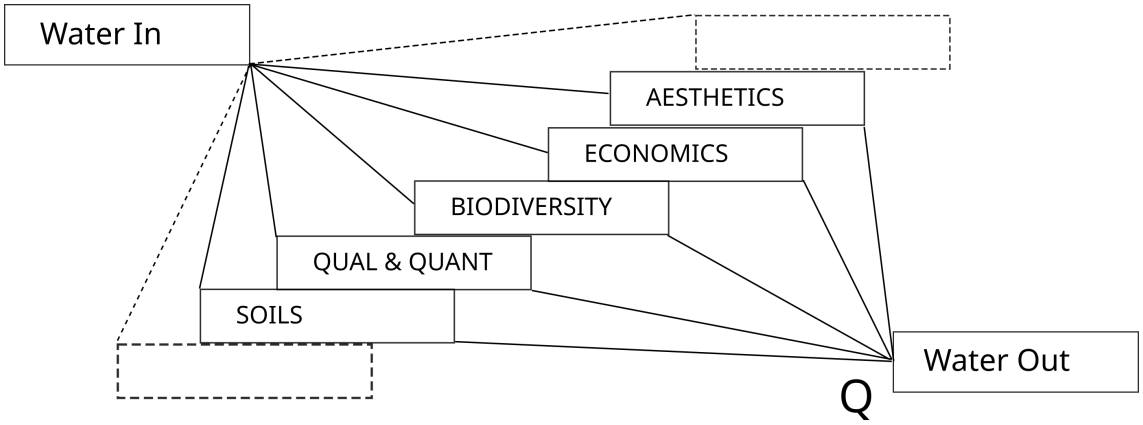


Figure 2.3: An alternative framework / model of NFM based on Ellis et al., 2021. Here the flow of water cannot be dissociated from the many other catchment systems and processes. NFM interventions therefore impact and are impacted by a significantly wider range of characteristics than those defined by the river channel properties

The differences between the Lane (2017b), Dadson et al. (2017) papers and the Ellis et al. (2021) paper demonstrate the potential for interpretation that NFM presents. I would argue that the history and development of natural flood management has created a framework that risks limiting both its application and its use in policy and planning. It can be argued that an integrated catchment-based approach was the intended focus of the findings of the Pitt review (2008). CaBA (and in Europe Integrated River Basin management IRBM, (Giskoumis, 2018)) is part of national strategies (Defra, 2013), however, this is not reflected in how NFM is evidenced or funded (Lane, 2017b; Newson et al., 2021)

[4]another is the identification of a single, often urban focal point for Q. Whilst relevant to this thesis a deep exploration of this is beyond scope and the subject of current research elsewhere

2.2.3 Using Hydrological Models where empirical evidence is unavailable or unattainable

Lane (2017b), Dadson et al. (2017) and Ellis et al. (2021) all critique the lack of supporting evidence for NFM interventions. In the complex system outlined by Ellis et al. (2021) empirical measurements are rarely practical or possible, with time and spatial variation making results hard to generalise (Beven, 2012).

One method of dealing with scenarios where empirical measurements are impractical or impossible is to run hydrological models (Beven, 2012; Oreskes, 2018; Seibert and Bergström, 2022).

Mathematical/computational models as simplified means of representing river basin and hydrological processes have been used before computational methods were possible (Bathurst 2010), the advance of computer technology has significantly increased the complexity of what can now be represented.

Hydraulic models represent the flow of water in either a 1D or 2D space (Hankin et al., 2019). Hydrological models are models which represent the physical processes taking place within a catchment (river basin) (Beven, 2012). Computational models range in complexity; the simplest can be 'black box', lumped or spatially distributed (Davie, 2008). Black box models do not attempt to present or break down the conceptual models but present a direct relationship between runoff and rainfall. Lumped models are more complex and require parameters to be set for catchment characteristics (Beven, 2012) and distributed models go a step further representing the heterogeneity of catchment characteristics and requiring parameters for each identified element (usually some size grid square). The parametrisation of processes and changes to processes is one of the great uncertainties in hydrological modelling and is the source of a wealth of hydrological literature (Benke et al., 2008; Brigode et al., 2013; Hankin, Metcalfe, et al., 2017). This introduces a second distinction between models, whether they are deterministic or stochastic (Beven, 2012). A deterministic model produces one result, whereas a stochastic model takes into account uncertainties and outputs a number of different possible responses. This can be a method-

ological approach, (for example, using the GLUE methodology, (Beven and Binley, 2014)) with multiple model runs being used to create a wide output set. The choice of model and the model methodology depends on multiple factors including the frameworks and knowledge of the modeller (their perceptual model), what the model is for and often, how available it is (Beven and Chappell, 2021; Wagener et al., 2021)

Models can be used for a variety of purposes including as a heuristic where the knowledge and understanding of the catchment are both tested and developed by use of the model (Bathurst et al., 2010; Rangecroft et al., 2018). This can be conceptual or practical, for example identifying spatial locations most likely to have one impact rather than another (Bathurst et al. (2010) explore the potential of landslips for example). They can also be predictive, attempting to identify the most likely outcome of a given change, or event (Seibert and Bergström, 2022; Wagener et al., 2021).

Within Natural Flood Management a full gamut of models are used, and the choice of model depends on a range of criteria. The way in which models are presented does not necessarily clearly demonstrate the assumptions or uncertainties underlying either the conceptual model or the perceptual model on which the model interpretation depends. (Beven and Chappell, 2021).

Literature on modelling has recently challenged the lack of reflection on the perceptual model on which the conceptual model is based (Beven and Chappell, 2021, Wagener et al., 2021). Perceptual models are defined as the hydrologists evolving understanding of the real-world system (Beven, 2012; Beven and Freer, 2001; Wagener et al., 2021) and are often a visual representation. Perceptual models contain uncertainties and gaps where knowledge is missing, whether this be a developing understanding of processes or a lack of clear data describing the underlying processes (Wagener et al., 2021). The importance of understanding the perceptual model is evident in the differences between figure 2.2 and figure 2.3.

At the beginning of this section, I stated that models were useful for evaluating scenarios where time, scale and inherent limitations make empirical measurements either impractical or impossible. However, numerous papers critique the lack of empirical evi-

dence and reliance on modelling in the evaluation of NFM (Carrick et al., 2018; Chappell, 2006; Dadson et al., 2017; Ellis et al., 2021; Lane, 2017b; Waylen et al., 2018). This reflects debates surrounding climate science and leads to questioning what evidence would be good 'enough' for decision-making (Sarewitz, 2004; Wingfield et al., 2019)

2.2.4 Beyond the evidence debate

A commonality to all the current NFM reviews is a continued critique of a lack of empirical evidence (Cooper et al., 2021; Dadson et al., 2017; Ellis et al., 2021; Lane, 2017b) and this lack of evidence is stated as a key barrier to its implementation (Bark et al., 2021; Waylen et al., 2018; Wingfield et al., 2019).

Yet the requirement for this 'evidence' comes from the framing of NFM as a mechanical problem, developing and being compared to engineered or technical flood management. As hinted at in Ellis et al. (2021) and Lane (2017b) conclusions and findings of NFM as 'wicked' (section 2.5.1) a significantly more complex system has been identified underlying this. Literature in Critical Physical Geography (Blue and Brierley, 2015; Colven et al., 2018; Lave, 2015b; Tadaki et al., 2015), Socio-Hydrology (Rangecroft et al., 2020; Rusca and Di Baldassarre, 2019; Wesselink et al., 2017) and the wider geographical literature (e.g. Emery and Hannah, 2014; Kosow et al., 2022) have identified the entangled nature of physical and social systems when tackling water resources and specifically floods. This literature supports a focus on community engagement in Natural Flood Management. They challenge the primacy of scientific knowledge production (Blue and Brierley, 2015) where it does not account for the experience of these communities (Emery and Hannah, 2014) as well as recognising the political importance of engagement (Emery and Hannah, 2014; Tadaki et al., 2015). However, with its roots in Flood Risk Management (FRM), the identification of stakeholders in NFM often falls on communities at risk or institutions that have traditionally delivered Technical Flood Management schemes (Bark et al., 2021; Wingfield et al., 2019). This focus on the 'at risk' communities also frames projects within the context of immediate delivery, rather than long-term change. This means that projects are at risk of focusing their attention on achievable outcomes that reflect again the TFM

approach, engineered projects that mimic natural processes (log damns, offline ponds, bunds etc) rather than social changes to improve resilience (though involvement in these projects has demonstrated increased engagement as a by-product or result (Howgate and Kenyon, 2008), or effective long term monitoring and management of rural catchments.

A few community-led examples stand out including the WILD (Water with Integrated Local Delivery) in South West England (Black et al., 2021) and PontBren in Wales (Wheater et al., 2008; Wynne-Jones, 2016). Neither of these approaches focused entirely or even primarily on NFM.

As NFM has developed, the way in which it has been framed has shifted; from a cheaper and more practical approach to reducing risk at source event (literally in comparison to sandbags, (Pitt, 2008)), to a more integral catchment based approach to water management within a complex socio-physical system. This shift has incorporated a number of factors including recognition of the complex interrelated impacts on systems (Ellis et al., 2021); the importance of a wider stakeholder community, with land managers being integral to delivery (Black et al., 2021; Howgate and Kenyon, 2008; Wynne-Jones, 2017); and the uncertainties that impact the evidence base (Dadson et al., 2017; Wingfield et al., 2019). This last point becomes even more evident when the intervention being considered is trees, a biophysical actor extending our system from the socio-physical to the socio-ecological and significantly extending the time-frame over which intervention is being considered.

2.3 Trees for NFM

2.3.1 Trees-water interactions

A Tree Tree-water interactions have been defined as the first of a cascading and interacting set of systems (IUFRO, 2018). This recognises the importance of the 'social' at an expanded scale although framing the social as distinct from 'natural' systems.

Plants absolutely rely on water and the way in which tree-water interactions occur

has been a matter of close study (Lambers and Oliveira, 2019). These key interactions are shown in Figure 2.4

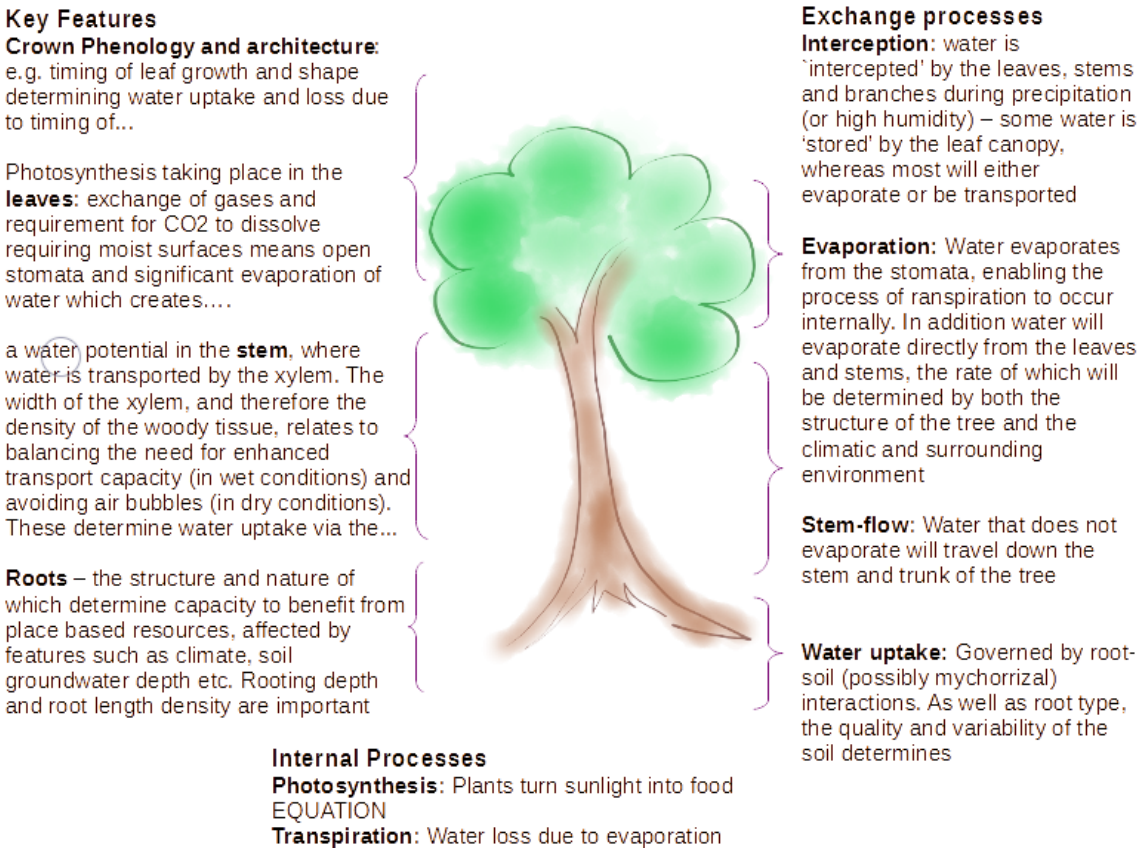


Figure 2.4: Diagram and details adapted from IUFRO, 2018; Lambers and Oliveira, 2019

There are still unknowns, for example, the impact of mycorrhizal networks (Lambers and Oliveira, 2019, Simard, 2021). The potential impacts of which are yet to be well understood, both in terms of the individual tree, or wooded landscapes as ecological communities.

Wooded Landscape / Forest When considering a wooded landscape feature rather than an individual tree, different factors become significant in the way in which trees interact with their environment.

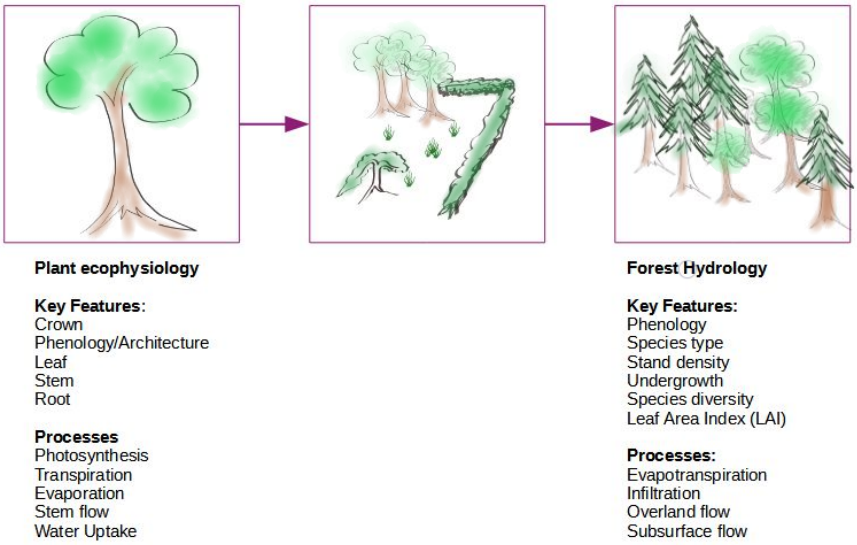


Figure 2.5: Diagram and details adapted from IUFRO 2018, Lambers 2019, Cooper et al 2021

How these different features interact to influence tree-hydrology relations is still a matter of ongoing research. For example, Webb (2021) and Webb et al. (2022) found significant differences in the root structure and water uptake of different hedgerow species, Chandler et al. (2018) found that tree species affected soil hydraulic properties (increase in k_sat), but that land use itself could mask these differences, having a greater overall impact. Murphy et al. (2020) found that recently established woodland increased k_sat but that the percentage of soil organic matter (SOM) influenced how much change took place, with a much greater impact on high SOM sites (less 'degraded' soils). Whilst some critique forests for the negative impacts of greater water use (Buechel et al., 2022), others have discussed its potential for groundwater recharge (Ellison et al., 2017). Debates and explorations around these complex interactions don't just take place under the ground and include atmospheric recycling (Ellison et al., 2017; Springgay, 2019), evaporation during storm events (Page et al., 2020) and the micro-climates created by thinning practices in forestry (Grunicke et al., 2020). On top of all this, these relationships change over time; Dixon et al. (2018) explore the temporality of tree growth, demonstrating variable effects across the lifetime of a woodland itself.

Forest Hydrology

The understanding that forests and their management impact hydrological responses is far from being a new or revelatory topic. Alluded to by Pliny the Elder (Andréassian, 2004), 'forest hydrology' began to emerge as a scientific discipline following the impacts of the French Revolution (ibid, Bren 2016). The large-scale felling of the 'Kings forests' was observed to have significant impacts on the local hydrology and geography, causing erosion, flooding, land slippage etc. The agricultural chemist Boussingault stated that "independently of conserving the running water, the forests safeguard and regulate its flow;" (Andréassian, 2004, quoting Boussingault 1837[5]).

Experiments began including the famous 'Wagon Wheel Gap' paired catchment study (Andréassian, 2004). Paired Catchment studies involve taking two streams of as similar character as possible, and treating one whilst maintaining the other as a control (Leon Bren, 2016). Benefits of this approach have been linked to the 'visual tangible' nature of 'the experiment', and include; the knowledge of the experimenters, usefulness as a teaching tool, inexpensive maintenance once established and importantly that they are considered 'trustworthy' (Bren 2016 p5). This last aspect is of concern when we consider the difficulties of paired catchments. It is unlikely that all the soils, vegetation, topography and ecology will be truly comparable at the beginning of the study (Cooper et al., 2021; Leon Bren, 2016), and further unlikely that they would have remained so over the duration of the study – controls are very hard to maintain. The climate and weather add an additional complexity to this as one must assume that both catchments undergo similar precipitation both in duration, rate and relative location. Birkinshaw et al. (2014) shows that even at small scales, the slope aspect may significantly influence precipitation and evapotranspiration. On a more practical level, paired-catchment studies are expensive to set up and management must be maintained over decades (Leon Bren, 2016).

Alternatives to the paired-catchment approach include plots and before/after comparisons. These are rarely seen in the NFM literature, largely again due to the complexities

[5]Boussingault, J.-B., 1837. Me -moire sur l'influence des de -friche-ments dans la diminution des cours d'eau. Annales de Chimie 64, 113 — 141.

of time scale and maintaining control variables.

2.3.2 Using Trees for Natural Flood Management

In 2011, (the same year that saw a u-turn on a decision to sell the public forest estate, Independent Panel on Forestry, 2012), Forest Research published the Woodlands for Water report, referencing a "need to raise awareness amongst policymakers and planners of the benefits of woodland for water." (Nisbet et al., 2011, pv). The focus is on diffuse pollution, however, the report also includes questions about water resources and flooding. Catchment woodland is only expected to have an effect on small or moderate floods due to infiltration. The authors recognise a significant lack of field studies and evidence reliant on modelling (which had contradictory results depending on the approach used), however, state that "there is probably sufficient evidence to promote floodplain and riparian woodland planting to reduce flood risk in appropriate locations" (ibid, p52).

The report can be held to have reached its audience, though the interest appears to have focused on flooding rather than water quality; with growing policy and public interest for the potential of trees to be a part of NFM interventions (Dadson et al., 2017; Environment Agency, 2021b).

Tree planting for NFM is a subject that has been treated, in the UK, in a very similar manner to that of engineered flood management. Literature focuses on the mechanisms and processes that link trees to water (Cooper et al., 2021). Trees and water are objectified and the situation is simplified to exclude any other actors. Whilst the scaling effect of mechanisms to functioning ecosystems is recognised as a source of uncertainty (Dadson et al., 2017), it has not at the time of writing, been discussed within the literature as the impact of actors with agency, as might be reflected in wider literature (section 2.4.4).

Whilst the science of forest hydrology underpins the subject of woodland for water management, there are key differences in the findings and the practices of the discipline in comparison to the NFM literature.

In particular, the findings that most stormflow in woodlands is underground - within the forest floor (Williams, 2016), is not reflected in the NFM focus of vegetation, surface

or channel roughness as a key parameter. This assumes soils are fully saturated in storm events (Soulsby et al., 2017), however recent work on the importance of soils and saturation suggests this may not be the case, particularly in large catchments (Buechel et al., 2022; Wang et al., 2018).

Forest hydrology has tended to focus on forested catchments, in which the most practical observations to make are at the rate of greatest change, i.e. felling or deforestation. It makes sense that in a UK-centred approach, with our sparsity of tree cover at only 13% (ONS, 2021), we need to understand smaller features and afforestation.

The UK Government NFM evidence base (WWNP Evidence base) identifies four types of woodland: Catchment, Cross-slope, Floodplain and Riparian.

Riparian woodland refers to trees growing directly along the river or stream and influenced by it, i.e. within the 'riparian zone'. This is described as the "transition or ecotone between terrestrial and aquatic ecosystems" (S.S. Panda et al., 2016, p173). Riparian woodland is therefore unique in regard to its functioning ecosystems as well as it's hydrological and geomorphic functions such as filtering runoff, regulating water temperature, maintaining bank structure etc. The main mechanism so far studied in regard to Riparian woodland for NFM is the effect of increased roughness above ground (Cooper et al., 2021; Nicholson et al., 2020). Whilst this appears to contradict (or ignore) the findings from forest hydrology that stormflow runoff is within soil surface and subsurface, most forest studies are on sloped ground, whereas riparian woodlands are more likely to be on flatter ground and more easily saturated.

Floodplain woodland is again defined by its geographical location. The floodplain of a watercourse is the area into which the river will break and is characterized by flat ground and rich soils. Most of UK floodplain woodland has been lost (G Kerr and T Nisbet, 1996), as the rich soils make for excellent agricultural land. Cooper et al. (2021) suggest that 90% of floodplains are 'functionally extinct'. Whilst primarily studies have considered floodplain woodlands for 'slowing the flow' through increased vegetative roughness, the

usefulness of evapotranspiration has also been suggested in relation to Willow coppice, which would grow quickly and provide strong root structures (Cooper et al., 2021).

Cross-slope woodland is a commonly stated flood management intervention (Peskett et al., 2019), usually as smaller strips of woodland planted across steep slopes. However, the complexity of soil depths and slope angles may limit effectiveness in infiltration (Peskett et al., 2019), with reliance on surface roughness as the primary mechanism dependent on ground vegetation and the density of the woodland itself.

Catchment woodland is a loose definition referring to any woodland within a catchment and usually referring to its cumulative % cover (Cooper et al., 2021). Whilst it has been suggested that extent is more important than type (Buechel et al., 2022), the studies above demonstrate how large catchments with diverse land types will affect the type and therefore the primary mechanism impacting woodland-water interactions.

A key concern of tree cover expansion for NFM is the 'lack' of evidence (Bark et al., 2021; Dadson et al., 2017; Lane, 2017b; Waylen et al., 2018). Long-term (+10yrs) studies have been conducted, although within distinct and limited contexts (For example; the longest term being at Coalburn (Birkinshaw et al., 2014; Robinson' et al., 1998); with shorter term examples such as Pickering (Nisbet, 2017) and Great Triley Wood (Burgess-Gamble et al., 2017)). However, with the complex factors described above, both social, ecological and physical, plus the precarity of the weather and climate, there are few comparable case studies. For example, there appear to be currently only two extant studies on the impact of cross-slope woodland: Pont Bren (Wheater, 2006), which was specifically not for the purposes of NFM (Wynne-Jones, 2016) and Eddlestone Water (Peskett et al., 2019).

Cooper et al. (2021), state that "Trees have distinct characteristics that set them apart from other types of vegetation, especially in terms of water use, owing to their size and longevity." (Cooper et al., 2021, p3). Whilst this may be true in a general sense, the fuzzy definition of 'tree' would suggest that the reality may be more complex. The traditional

comparison between tree cover and crops or 'improved' grassland (in the UK improved usually implies a specially sown, predominantly Ryegrass mix that has had fertilisers and/or soil conditioner applied), has already proved controversial with farmers interested in the differences between 'improved' and permanent pasture. The question of what is woodland and what is 'scrub' may be particularly important as, despite its lack of timber properties, the ecological properties of these long-lived lower-growing woody structures (including hedgerow tree varieties) will have a range of interactions that may be similar to those identified in unmanaged broadleaf woodlands (Rackham, 2015). The posthumously published work by Rackham (2022), Ancient Woodlands of South Wales, identifies 'Fridd' and 'Coed Cae' as woodland types. These types are both hard to define and measure but are of significant ecological and cultural importance. By most definitions, Fridd would be classed as scrub. This poses another difficulty in regard to our empirical measurements, directly impacting decision-making and governance (Turnhout et al., 2014). Not only are these features not measured in England, but there are no 'English' words for them; they are culturally unknown and therefore excluded from measurement. There are no extant studies (as of August 22) on the hydrological impacts of scrub, wood pasture, Fridd or Coed Cae. This lack of evidence does not mean that they have no impact and yet risks a culturally important landscape being neglected or removed in favour of other funded opportunities.

Given the time scales required to run woodland-based experiments (Dixon et al., 2018), developing solutions, and the majority of studies, lean heavily on modelling interactions. Whilst studies have then been able to explore alternatives, they are reliant on parameters set by mechanisms about which we are currently uncertain. In addition, the methods of calibrating a model risk 'over-fitting' or getting the right results for the wrong reasons (the wrong set of parameters) (Beven, 2012; Seibert and Bergström, 2022).

Predictive models are therefore hard to develop, relying on Monte Cristo runs and/or significant observational data to be remotely accurate (Beven, 2012; Beven et al., 2019). Over the timescales at which trees grow, the required parameter set would be vast, and the potential socio-cultural, ecological or climatic variables unpredictable. A predictive

model for a newly planted forest would therefore be unrealistic.

As described (section 2.2.3), models can be used as heuristics, learning tools; "a model can be uncertain and still be useful" (Seibert & Bergstrom 2022, p1383). I will use a hydrological model as a heuristic tool in exploring Trees as an NFM intervention in a case study catchment. There are past examples of this, however, paper titles and conclusions tend to present a fait accompli, that the 'finding' of the model suggests a particular outcome despite it exploring a 'future scape' that is rarely contextually likely to occur. Whilst this may be a matter of language, this presentation may be important in relation to how end users engage with studies. It also impacts current thinking and the likelihood of interventions being planned at the current time.

2.3.3 Barriers to tree planting and NFM - focus on land managers 'social barriers'

Are farmers a barrier to increasing Tree cover

I have discussed the importance of social systems in exploring tree cover expansion for NFM (Trees for NFM) and whether a model supporting this as an intervention is irrelevant if no one will plant any. The barriers associated with tree planting have been more directly addressed in relation to applications other than NFM (Dandy, 2012; Duesberg et al., 2013; Emmett et al., 2015; Fleming, Stitzlein, et al., 2019; Gruère and Wreford, 2017; Rois-Díaz et al., 2018; Tsonkova et al., 2018). Tree planting for NFM is significant as an aspect of landscape change for a number of reasons including:

- The considerable practical and aesthetic landscape change on a large scale in comparison to other NFM features (Burgess-Gamble et al., 2017).
- The longer (generational) timescales relating to woodland and tree planting as a flood management feature compared to features usually implemented, both the short-term fast-acting (like woody dams) and the long-term, but also fast-acting storage ponds or river meander changes.

- The change in paradigm for woodland planting to carbon storage, biodiversity and other social benefits, rather than commercial forestry. (Rackham, 2015)
- The lack of tree planting over the last two decades (ONS, 2021) means the UK timber industry is facing a lack of resource over the next few years.
- The significant shift in the political and public drive to increase tree planting in the UK.

The significance of this change in public and policy perception of trees and woodlands can be demonstrated by considering the uproar directed at parliament when it proposed to "sell off" the public forests (BBC, 2013). The public response achieved a quick about turn, an independent enquiry and a complete restructure of the Forestry Commission (Independent Panel on Forestry, 2012). This is not to suggest that political bodies did not support planting trees prior to this juncture. The primary purpose of the forestry commission was seen as commercial forestry, and the conservative move of commercial interests to private bodies and governance via the market is entirely in line with this.

The 'Woodland for Wales' strategy, initially focused on timber, was developed in 2001. A 2018 update demonstrates a more gradual inclusion of wider social concerns; engaging with climate concerns (Welsh Government, 2006), failures in biodiversity conditions(Welsh Government, 2012), the Well-being of Future Generations (Wales) Act 2015 and the Environment (Wales) Act 2016. The strategy, however, claims to keep "core elements [..] in place. They have been robust and do not need significant change" (Welsh Government, 2018, p3). The strategy focuses on Woodland Expansion and lays out the requirements for "the kind of woodlands that we want" (ibid).

It is perhaps surprising that the then Welsh Manager for CONFOR, Martin Bishop reported in February 2018 (Bishop, 2018) that Welsh forestry was facing a 'catastrophic decline' in timber production over the coming years due to a lack of planting. Bishop gave the Woodland for Wales Indicators 2015-16 as an example, with only 39ha planted in 2016. The 'Woodland for Wales Action Plan' (Welsh Government, 2016) put in place to support delivery of the strategy had expected planting of 2000ha per annum (p25)

carrying out its own reflection when it stated that: "Both the Land Use and Climate Change Group and ADAS recommendations envisage new woodland creation at a level that is much higher than the actual achievement over recent years: between 2010 and 2015, 3,203ha of woodland has been created in Wales." (p23). The Action Plan, however, includes little to tackle the lack of uptake of planting opportunities, expecting the inclusion of woodland management by community groups (p.32). It is unsurprising then that little positive change occurred between 2018 and 2021 when the Welsh Government launched and published the findings of the Trees and Timber Deep Dive (Welsh Government, 2021b) which focused on the barriers to tree planting.

In 2013 the Welsh Rural Observatory reviewed the lack of uptake of funding provided to support the aims of the initial strategy. The review sheds light on the 'social barriers' to uptake, including economic barriers. The findings are supported by literature tackling similar issues in Ireland, Australia and more widely. When faced with a hypothetical economic decision-making process (Convery et al., 2012; Pröbstl-Haider et al., 2016) financial business was put first (although all papers reviewed recognised other factors affecting decision-making, economics was always given as the primary factor). In practice, however, the decisions made by farmers in regard to tree planting have not followed this simple premise. Researchers have found that decision-making drivers include, alongside economics and aesthetics; family well-being, identity, social relationships, legacy, independence and autonomy; complex values that are context and time-specific (Duesberg et al., 2013; Fleming, O'Grady, et al., 2019; Wales Rural Observatory, 2013). These findings support those of Holstead et al. (2017) into factors that may affect farmers' uptake of broader NFM measures, identifying; economics, availability of advice, public perception, joined-up policy, catchment planning and tradition as contributing to the decision to implement changes.

Duesberg et al. (2013, 2014) (with data from a large survey and 62 interviews) finds that the majority of farmers were not farming for financial profit, and less than 10 per cent were looking for additional financial incentives to integrate forestry. Over all the research found that preferences to not forest included food production, land-use flexibil-

ity, 'tradition', incentives and lifestyle. Decisions made to move into forestry included 'bad land', legacy assets, and ecological and social good. (Duesberg et al., 2014 p198). Duesberg found that policies didn't suit the needs or realities of the farming communities. The reason that the majority of farmers were not moving into forestry was "because it was not farming" (Duesberg et al., 2013 p163).

Wynne-Jones (2013) finds that the policies do not support the small-scale style of woodland planting that would appear most suitable to the majority of farmers interviewed. These aspects of tradition, farming identity and values, merit much further exploration if they are to be fully understood. As Fleming, O'Grady, et al. (2019) states when addressing the lack of uptake of tree planting schemes on farms in Australia "adoption is likely to remain slow if recognition of the social, value-based nature of perceptions and their link to behaviour is ignored" (p10). Although there are many supporting findings between trees on farms and the wider agricultural literature, there is a strong argument here for more research particularly, in relation to increasing tree cover for NFM. For example, designs for NFM will change the styles, types and functions of woodlands planted from the 'forestry' that has been the traditional paradigm.

The expected aesthetics of the 'tidy farmer' (Burton, 2012) are important in regard to implementing landscape change; but not necessarily as expected with the 2015 Glastir Evaluation report finding that farmers appreciated the 'messiness' of woodlands, as it was their expected aesthetics of the 'natural' aspects (Emmett et al., 2015). In addition, the differing timescales between forestry and farming have changed (Wynne-Jones et al., 2022), questions of succession and farm futures (Barbara Agstner et al., n.d.) may affect the types of planting farmers would be willing to introduce. Short-rotation coppice may be more amenable to tenant farmers with no generational plan, whilst long-term floodplain woodland may be more suitable to an owner farmer with succession in place. These factors may be context-specific, and the weighting of different values may change depending on the landscape and timescape in which they are addressed. Fleming (Fleming, O'Grady, et al., 2019) notes that farmers have demonstrated that they are able to hold multiple values, this means that the timescape, the way in which they view the history and future

of the landscape, at the moment they make the decision may have significant impact.

2.4 Decision-making and the importance of participation

2.4.1 Drivers that determine uptake of agri-environment schemes

In the UK the Common Agricultural Policy and Basic Payment Schemes for many years required the removal of scrub and Trees from agricultural land (Wynne-Jones, 2016). Increasing woodland cover therefore depended on land managers' uptake of agri-environment schemes. Drivers determining farmers' uptake of these schemes have been well-researched in the last decade.

Forested landscapes and flooding must be considered unique to the broader spectrum of agri-environment schemes for differing reasons. The term 'forest' is socio-politically difficult to define (Ghazoul, 2015; Rackham, 2015). But in the last century has become associated with the forestry commission and still carries connotations of large-scale conifer plantation (Deakin, 2008; Rackham, 2015). This association is particularly strong in Scotland where plantations were linked to the tax relief schemes of rich landowners (Warren, 2000) and the destruction of significant and unique habitats (Rackham, 2015). Although these historical connotations may have less of the colonialist impact in Southern parts of the UK, they are not invisible. In addition, whereas many agri-environment schemes adjust the management of a known landscape, afforestation is a significant land use change which may impact not only the aesthetic character of a landscape, its physical and environmental characteristics, but also the socio-ecological relationship, in particular the way the land is worked.

Flood or water management within a catchment can also be treated as separate from the wider agri-environment schemes. It is the management of a resource which has significant and, occasionally immediate, social impact, whether through drought, pollution or flood (Newson et al., 2021; Pahl-Wostl et al., 2020). There is a wealth of literature relating

to water quality. This is likely due to the implicit understanding that 'flooding' was a societal problem whereas 'pollution' has been directly linked to land owners (Newson et al., 2021). This has not always been the case, and the change in perceptions that occurred around the 1970s has been well examined (Lowe et al., 1997). Whilst in the past flooding has been considered an engineering problem this has now shifted (section 2.2). The discussion of flood management as flood 'risk' reflects a 'societal' focus, a clear suggestion of harm where mismanagement may occur. This responsibility has resided at large with the Environment Agency, however, with the introduction of NFM, the focus of solving this 'problem' has moved towards that of land management. Managers, rather than the government as the embodiment of 'society' become the significant 'other' who can make change. This is not reflected by a shift in empowerment in policymaking literature.

Whilst there is recognition that land management choices significantly impact flooding with negative or beneficial choices, there is significant societal confusion as to where responsibility and empowerment should rest (Bark et al., 2021; Holstead et al., 2017; Howgate and Kenyon, 2008; Posthumus et al., 2008) In much of the NFM literature that reviews decision-making it is the 'relevant experts', defined as those within flood management bodies or policy with an 'ability to make change' (Bark et al., 2021; Dittrich et al., 2019; Waylen et al., 2018), rather than the land managers themselves whose decisions are scrutinised (Emery and Hannah, 2014).

At the time of writing, there is no literature that directly examines the more complex drivers behind land managers' decisions to plant trees for Natural Flood Management. From the wealth of literature on wider agri-environment issues, however, we can draw repeating themes that may inform the research. Two key themes are found; The 'Good Farmer' and the Bordeusian idea of Social Capital. These two are interrelated, but with differences that it is worth explaining here. There is a third theme, that has appeared in agri-environment literature but has not been widely applied in political discussions. The phenomenological exploration of 'Lived Experience' as introduced by Ingold (1993), how it may inform us about the impact of identity and the temporality and emplacement of decision-making.

2.4.2 Can concepts such as Social Capital and the 'Good Farmer' fully explain decision-making and uptake?

Much literature pertaining to farmer decision-making has drawn on a Bourdieusian concept of capital (Bourdieu and J.G. Richardson, 1986). Social capital is key, alongside that of cultural (aspects symbolic of 'cultural competence') and economic capital (material property)(Shortall et al., 2018). In addition the concept of habitus or knowing the 'rules of the game' (Bourdieu 1984 in Riley et al., 2018).

The importance of relations with outsiders can be seen through examinations of the governance of agri-environment schemes. Reports on barriers to schemes that have not demonstrated the expected uptake regularly identify; a lack of trust, poor communication; enforced or prescriptive actions from an outside source and the significant impact on community acceptance (Emmett et al., 2015; Howgate and Kenyon, 2008; Morris, 2006; Riley et al., 2018; Wynne-Jones, 2013.

The first and most significant limitation to an exploration of decision-making through the lens of social capital is that it has been shown that social interactions can cause actors to swing either way. The lens of social capital does not on its own predict or explain these influences. Neither does it account fully for the individual's formation of identity, assuming an entirely externally constructed form.

Building on a Bourdieusian framework is the concept of the 'Good Farmer' (Burton et al., 2008; Saunders, 2016; Shortall et al., 2018; Thomas et al., 2019). The social standing of a farmer is determined by the symbols, or practices which demonstrate 'good' farming. These can be directly impacted by changes in 'the rules of the game', in particular, changes in policy approaches (Shortall et al., 2018; Sutherland and Darnhofer, 2012).

Studies have centred 'Good Farmer' on an assumption of a productivist ideal suggesting that this will "inhibit environmental actions due to productivist goals" (Wheeler et al., 2018, p666). This suggests that the identity of the 'Good Farmer' creates a reluctance to change. However, Wheeler identifies that the 'Good Farmer' identity can and does integrate with environmental management, finding that the construct is contributed to

by “interrelated personal, cultural and economic objectives" (Wheeler et al., 2018, p768) in which the priorities for each individual are different complex and multiple.

Gunhild Setten stated that “we often think in ways too complicated to be rendered neatly as losses and gains" (Setten (2012) in Wynne-Jones, 2017, p73). This reflects moves beyond economic framings (Emery et al., 2017), and findings that framing landscapes or socio-cultural systems in primarily financial terms (something reflected in the economic language of store, exchange and capital), could have negative impacts on the uptake of interventions (Fleming, O'Grady, et al., 2019; Fleming, Stitzlein, et al., 2019).

The Good Farmer concept allows for the understanding of exchange within a community; can be emplaced; demonstrates the importance of local variety (farm size, type, location); and can be more widely applied in rural contacts (Linné and Sellerberg, 2017). In particular, it clearly demonstrates that when considering motivations for land-use change the cultural, social and economic capital must all be considered. However, there are some key limitations to the concept in regard to an exploration of the choices of land managers for environmental interventions that directly impact the material landscape

- the Good Farmer concept assumes a social shaping of identity
- Even where the Good Farmer trope is relevant, it can be shown to be temporal and context relative (Thomas et al., 2019; Wynne-Jones, 2017).
- Within the Bordeusian framework of habitus, the multiplicity of identities held concurrently (rather than absorbed or adapted) cannot be easily accounted for (Naylor et al., 2018)
- The concept of the Good Farmer with or without the concept of capital, does not account for influences of the ‘more-than-human’, the materiality of place or for emplaced affective experience.

2.4.3 Beyond the socio-cultural: How a phenomenological approach can add to understanding

Relating decision-making to the barriers in implementing tree cover expansion for NFM it is clear that socio-cultural complexities are important. However, the scientific literature (sections 2.2 and 2.3) also identifies the uncertainties and complexities that arise with the heterogeneity of space and landscape. I am using landscape here in the sense that (Casey, 2001) describes it, as a 'cusp concept' between space and place. Reflecting Ingold's (2000) use of the term, not just as a visual, but as the space within which we *are*. The economic and relational approaches to understanding the 'social barriers' to landscape change are limited by a lack of engagement with place and the non-human. The emplacement of the social has become central to studies of human understanding and interaction across disciplines. Yet 'social barriers' is still used as a catch-all phrase within policy, and studies on the decision-making processes focus on the relational, human aspects. In the next section I draw on phenomenological literature recognising the materiality of landscapes as 'places' and the implementation of tree cover expansion for NFM must be viewed as a change to these landscapes. There has been a growing body of work incorporating a phenomenological approach, informing us of social relations and understandings of landscapes, however, Emery and Carrithers (2016) critique these approaches, highlighting the missed opportunities for political analysis. This topic overlaps with the neglect of rural, local knowledge in policy making. By making a concrete link between experience of place, knowledge and decision-making we can argue that it is a significant missing factor that may explain barriers and enlighten more effective policy pathways.

Phenomenology - landscape through lived experience

Understanding Landscapes: The impact of place-identity

Lewicka (2008) notes that although in much literature place-identity is used interchangeably with Place Attachment they can be treated as two related, but different phenomena. Place Attachment is described as 'an emotional bond with place'. This discussion focuses

on understanding and exploring the impacts of self-place relations in terms of place-identity, the "self-categorization in terms of place" (Lewicka, 2008, p.212). Place-identity is discussed by Casey as 'the geographical self'. This is the constitutive coingredience" of place and self where the one informs and exists in iterative dependence on the other. Or as he more simply states "there is no place without self and no self without place" (Casey, 2001 p.684). Whilst Casey implies a place identity, he determines that there can be no space identity and the difference between place and space is a 'cusp concept' of landscape. Inherently place is space once you add history, culture, society, and meaning.

Ingold's (1993, 2000) phenomenological work on the dwelling perspective can inform this understanding of place, how lived experience of dwelling in the taskscape leaves traces (Anderson et al., 2013) on the physical environment and the social self. Furthering this by discussing the temporality of the landscape, the permanence of some traces, layering meaning onto the landscape, furthers the meanings which may be read through interaction with it (Ingold, 1993, 2000; Rose, 2002; Vergunst, 2012; Wheeler, 2017). It is the body which Casey determines as being the interacting 'heft' within the physical environment (Casey, 2001) referring to the landscape and the body as the 'epicentres' (Casey, 2001, p.629) of the geographical self. This is expanded upon through later phenomenological (or post-phenomenological work) to include interactions with the non-human; for example the importance of the written word, the photograph.

These place-identities directly impact decision-making and acceptance of change (Devine-Wright, 2009). The implementation of significant landscape changes that do not take into account 'tradition' (Duesberg et al., 2013; Holstead et al., 2017) or allow change at a pace that can be incorporated within these self-place relations, are likely to cause conflict (Wynne-Jones et al., 2022).

Understanding landscapes: Embodied experience inform narratives and place-relations - the phenomenological and cultural are entangled

Bender (1993) proposes the need to 'enmesh' the cultural and phenomenological approaches to understanding landscapes. Recognising an entangled co-production of land-

scape and self, referring to both lived experience and landscape as being 'cumulative and reworked'.

Place relations form not only from 'being there' but also from 'being with' (Ash and Simpson, 2016; Jones and Cloke, 2008; Latour, 2006; Mol, 2002).

Literature exploring how lived experience may inform understandings has often focused on identity or self-place relations. Accounts are descriptive of both the landscape and the self, creating beautiful accounts of self-place, and the importance of the way in which we 'dwell' (For example: Cloke and Jones, 2001; Lewis, 2012; Vergunst, 2012; Whitehouse, 2012). The assumption of the 'geographical self', has developed methodologies designed to illicit these place relations and enlighten understandings (Anderson, 2004; Thomas et al., 2018) in a manner that is informed by academic calls to expand the limited range of voices informing geographical 'knowledge' (Bender, 2010; Rose, 1993). A greater understanding is developed, not only of the perceptions of landscape and self, but the active narratives that are told around these concepts, for example, how students construct their own narrative in choosing walking routes when engaging with researchers (Holton and Riley, 2014).

Tuan (Tuan, 1991) described how place-making, depended on narrative, as well as material actions and socio-cultural behaviours. He states as anecdotal that the way in which we talk about something changes how we perceive it (p688). Turnhout et al. (2014) introduced the term 'measurementality', to conceptualise "governance that emerges from privileging scientific techniques" (p583). The direct implications of this are related to the performativity of science (Law, 2009; Mol, 2002), "as only what is counted counts" (Turnhout et al., 2014, p594). A recent example of this is the identification of two, rather than one, species of African elephant, the 'forest' and 'savanna' elephants. By understanding that there are two species of elephants - the way in which they are counted has changed and so has their status in the threatened species list (ICUN 2021). Names and descriptions 'draw attention' to things (Tuan, 1991). The material and narrative factors of place-making are entangled.

Whilst the experience of landscape and the different narrative frameworks have clear implications for political discussion and decision-making, this discussion has possible reflections for the scientist's perceptual frameworks (section 2.2.3). The system which is identified by a scientist's perceptual model is primarily influenced by the physical interactions in space. However, this is unlikely to reflect the complex space-place experience of the system of farmers and land managers. The implications of these two different ways of knowing the system will be discussed further in section 2.5.

Understanding post-phenomenological or entangled landscapes: inherently political and therefore a key factor in decision-making

A critique of the 'dwelling' concept, particularly in the language of Heidegger, when encountered without cultural or historical context, is its lack of perception of unequal power relations (Bender, 2010). Bender (1993) critiques Heidegger's descriptions of 'dwelling' due to their relation to 'rootedness' "through kin and 'blood' in the German soil" (Heidegger 1972, p358 in Bender, 1993). This type of thinking is reflected in Ingolds referring to landscape as a 'homeland' (p171). Bender reflects, however, that this somehow reduces the 'authenticity' of anyone 'less rooted' in the landscape.

Wylie (Wylie, 2016) expands on a similar idea - the idea of 'ontopological' or 'homeland' thinking, demonstrated in extreme in cases of ethnic nationalism or more generally in the "yoking together of existence and nationalism". Wylie states that landscape is a, but not the foundation of peoples identity and specifically that landscape "cannot be a homeland" in part because "there are no original inhabitants" (p414). Wylie himself ponders whether his statement is not "too severe", however, he challenges the reader to recognise that whilst landscape is a space of 'settlement' and the "deeply felt and time rich connections" (p415) must be discussed, landscape may also be "the space of strangeness and estrangement" and one in which 'dwelling' does not confer 'belonging'. Bender (2010) and Wylie (2016) both reflect that the landscape, the 'familiar setting' can become 'uncanny', unfamiliar (Kastrinou et al., 2020). As such, 'dwelling' in place does not automatically gain knowledge or expertise in a familiar place in all contexts. Whilst

Ingold's earlier works leant heavily on Heidegger's 'dwelling' concept, in later works his perspectives develop and he finds that the 'making' of the unrooted wayfarer as much as 'dwelling', is an active practice of living and 'homemaking' of which landscape is "both the context and the product" (Ingold, 2011)

For example, the Farmers in Cheshire et al's (2013) study on mobile farming practices, associated their identity with having farmed the land, rather than the specific piece of land they were in (Cheshire, Meurk, and Woods 2013, p.71). Their place-identity was informed through 'dwelling'. They took their identity from place to place, linking it to the practice of knowing how to work the land; the act of dwelling defined them, rather than the length of time they were present in place.

The 'phenomenological approach' has been critiqued for its lack of political analysis (Bender, 2010; Setten, 2004). However, Emery and Carrithers (2016) have shown that this is rather through the 'choice' of the researcher than the approach taken. In fact the accounts of Vergunst (2012), Lewis (2012) and Whitehouse (2012) all demonstrate how the lived experience of individuals is used to construct narratives of self and place; these narratives are then used as the basis of analysing information from other sources and determining how choices are made or individuals act. The farmers' response to a 'frozen' idyll being represented by an external tourism industry in 'Thalloo my Vea' (Lewis, 2012) is formed around a fear of the self-place relation being broken by farming being removed from the landscape. Ironically both the dwelt and represented landscapes are not 'frozen' but formed by the farming practices that may be displaced.

Emery and Carrithers (2016) found that the lived experience gave farmers not only the knowledge and interaction with the land but the ability to utilise both understandings, that of a changing lived landscape and a static represented one. Lived experience directly informed the narratives of farmers, enabling strong and informed rhetoric in their political interactions. In 'How the Land Should Be' (Whitehouse, 2012) Farmers respond negatively to imposed, external definitions of 'environment' and 'nature' which do not take into account their own experience. For example, conservationist values were perceived as

having 'colonial trappings' (Whitehouse, 2012, p182), where they supported activities like 'shooting' and 'hunting' at the exclusion of other land uses like farming.

Taking a specifically political approach Wheeler (Wheeler, 2017) explored assumptions of rural place-identity in examining attitudes towards wind farms. Wheeler found that embodied experience was key in forming both individual and collective place relations and that this directly impacted political attitudes. This is therefore a key factor in decision-making, although Wheeler is careful to situate her findings in the temporal context in which they are set. This directly relates to the understanding of lived experience and landscapes as cumulative and reworked and has direct implications for research into environmental challenges where timescales can be long (the lifetime of trees) or immediate (the experience of a flood event).

2.4.4 Landscapes are 'more-than-human' spaces where humans are not the only actor

Having stated that the landscape is not a mere stage (Ingold, 2000), it must also be recognised that the human is not the only actor (Castree, 2014; Lorimer, 2015). Foucault critiques the people-centred approach of phenomenology (Foucault 1977, in John Wylie (2007)) and this literature review has demonstrated a very people-focused way in which decisions about agri-environment initiatives are discussed. Yet landscapes are multi-natural, "more than human" (Lorimer, 2015; Whatmore, 2006), in which agency is held by multiple human and non-human actors and there is a non-hierarchical distribution of power (Bennett, 2006). Whilst I acknowledge these critiques, I also acknowledge the limitations of this thesis, by focusing on knowledge and knowledge making (delved into further in the next section), I am centring the thesis on human actors and the materiality of the landscape.

I have described landscape as something which is socio-cultural, and physical. The phenomenological approaches described have focused on the interaction between actors (mostly human) and the topography and physical processes of a place. Bender (2010)

however, describes landscape as bio-physical, and this 'bio' is far from limited to the human.

Actor Network Theory (described as a methodological 'toolkit' rather than a theoretical approach in itself (Callon, 1984) proposes an ontology of the world that flattens out the approach to the actors within it, referring to human actors and non-human 'actants'. No primary hierarchy is assumed, an approach also present in the concept of Assemblage (Anderson et al., 2012), and the relations and agency acting must be uncovered by 'following-the-actors'. The terminology of 'actant' here is broad, and may include anything from the living to the socio-technical, a map for instance has agency.

I wish to specifically explore the agency of those that would fall into our traditional (highly contested) category of 'natural'. We are, after all, concerned with 'natural' flood management. These actors are not the socio-technical but may be loosely described as the bio-physical that through practice and process make our landscape one that is 'living'. These 'actors' are described in different theoretical streams as non-human or more-than-human, though this is sometimes confused as different authors use more-than-human to refer to 'other than' or 'including' human. The language we use to describe them is important, it changes the framework within which we interpret the world around us (Kimmerer, 2013; Tuan, 1991).

"Geographers should avoid considering the earth or the scene on which the activity of man(sic) unfolds itself without reflecting that this scene is itself living" (Sauer 2915, in Whatmore, 2006, p605); Geography has long recognised the 'other' in the landscape. However, geographical approaches have focused primarily on the human, in such a way that expanding thinking to the 'other' has its own theoretical niche, the 'posthuman'. Critical posthumanism (Castree and Nash, 2006) is described as a political-analytical perspective (as opposed to a 'historical moment') that challenges the "reductive but effective categories of human/animal, nature/culture" (p502). Looking forward, Panelli (2010), describes a posthuman, poststructuralist, hybrid approach to social geography in which the more-than-human is entangled, and recognises the enlivening impact of addressing "the diversity of ways in which social geographies are more or less involved in

more-than-human contexts." (Panelli, 2010, p84)

Whether humans are considered as separate, or 'other', does not untangle the entangled relationships that form landscapes. Policies and scientific disciplines are built on the foundational principles that separate the human from the non-human, and this is inherent in the naming of 'natural flood management', whilst its entanglement is evident in the multiple ways in which it is interpreted (section 2.2.2).

Lorimer (2015) reflects that Latour is accused of anthropocentrism and this is perhaps reflected in the us and them terminology of actor and actant. For simplicity, I will use the term 'actor' to mean any bio-physical entity with active agency in the landscape. I will refer to 'more-than-human' to encompass all actors and actants, as in Whatmore (2006), i.e. both human and non-human, and will refer to 'non-human' and specify the bio-physical non-human when necessary.

Where this is relevant in this thesis, is whether the 'multi-natural' or 'more-than-human' worlds are significant in our areas of concern: knowledge and expertise of land managers, knowledge production and decision-making, and the relationships between trees and catchment hydrology.

The latter may seem more evident, however, the framework of animals/plants/processes as actors with agency is rarely reflected in Natural Flood Management literature. Literature discussing trees for NFM focuses on the interactions and mechanisms that govern the characteristics of catchment hydrology (Cooper 2021). By focusing on simple mechanisms, trees and vegetation are treated as physical objects, in frameworks where they are more easily compared to our engineered approaches to NFM. The complexities that arise at scale, where the land cover is part of a complex bio-physical ecosystem are well recognised (Dadson et al. 2017), though this still takes a reductionist approach, recognising objects, rather than practice or agency.

There has not been much work on the identification of 'whom' the key actors in the wider ecosystem with the agency to impact tree planting for NFM might be under either framework of object or actor.[6]. There is no evidence of research addressing the agency of

[6]An exception may be made for the agency of sheep as the perpetrator of 'grazing', which has been

non-human actors within tree planting for NFM at the time of writing. There are, however, examples of the agency of other plant/animal/process relations that suggest that non-human actors may affect both the knowledge production and decision-making of land managers, as well as the tree-water processes. The agency of water (Laborde and Jackson, 2022; Strang, 2014; Yates et al., 2017) itself in moving through the landscapes and breaking down socio-cultural boundaries may have significant relevance for this project if land managers experience it in this way.

Whilst it will be beyond the scope of my research to significantly identify the full impact of a 'more-than-human' framework, the work will endeavour to take a 'flattened hierarchy' approach enabling me to identify key actors in the wider socio-bio-physical landscape, their impact, and identify if there are research gaps of significant concern. Whilst this may seem to go beyond the subject of 'decision-making' this literature draws attention to the fact that there are other agencies beyond the human-social that may be affecting decisions, and having an impact on both how decisions are made, and ways of knowing the landscape. The further implications of these alternative ways of knowing are discussed in detail in the next section.

2.5 Participation, Decision-Making and Knowledge production at the science-policy interface

The literature discussed in section 2.4.3 suggest that alternative 'ways of knowing' landscape, such as lived experience are inherently important in our understanding of landscapes and environmental change. This knowledge is predominantly held by those who manage the landscapes in which the implementation of change is expected, and the inclusion/exclusion of this knowledge extends beyond that of engagement. In addition the 'scientific' literature on NFM (section 2.2 and Trees for NFM (section 2.3) identified inherent limitations and uncertainties recognising the entangled nature of systems, particularly over long time frames. This suggests that the problem of expanding tree cover for NFM

widely narratively assumed if not directly investigated (Halfacree and Williams, 2021; Monbiot, 2014)

goes significantly beyond 'social barriers' and directly reflects on the wider science-policy interface and the frameworks by which society produces, evaluates and applies knowledge. I will outline some of the key critiques of the way in which environmental knowledge and policy has, and is, being produced. In particular the power-hierarchy and linear approaches of the science-policy interface at the expense of land manager/farmers expertise (or knowledge-cultures) and the implications this has for the successful implementation of effective interventions designed to address environmental challenges.

This final section of the literature review is structured to discuss the following claims:

- that UK environmental governance is overly reliant on 'evidence' and an exclusive 'science-policy' interface
- that environmental challenges can be described as post-normal, or 'wicked' and require extended knowledge(s) and expertise
- that farmers hold knowledge which is directly relevant to and beyond science,
- that farmers can be identified as 'experts in their F/fields' (Riley, 2008) and that this has a direct impact on power relations at the knowledge-policy interface
- That co-production of knowledge and environmental governance has the potential to produce more effective policy but whilst these approaches are recognised and included in rhetoric they are not well evidenced or evident in practice.

I show through current literature why environmental challenges (specifically Tree planting for NFM) are framed as 'wicked' problems, and the theories explaining why these problems require a wider knowledge production than purely 'scientific'. Having identified farmers as holding knowledge relevant to the problem, I then explore how farmer knowledge/expertise has been framed in the past, and how engaging with this knowledge may be not only directly relevant to the 'science' but the wider, entangled 'wicked' problems. I also explore the attribution of 'expert' and how this has been used/critiqued in previous literature.

I will finish this section by identifying frameworks of knowledge-making and governance that have been critiqued against this new way of knowing environmental challenges through the co-production of knowledge and distributed expertise. This critique enables us to reflect on the wider challenges that shape the socio-ecological landscape system through which expanding tree cover for NFM is being enacted.

2.5.1 Postnormal science and wicked problems - re-framing environmental challenges and 'knowing' the problem we're trying to solve

Lane (2017b) identified NFM as 'wicked'. The term 'Wicked problem' following Rittel and Webber (1973) is often used in the context of environmental challenges. However, it's use is often undefined in studies which is understandable when the problems described as wicked have been attributed the property of 'indefinable' in such a way that this first statement 'undermines' any further attributions (Duckett et al., 2016). One cannot produce a 'realistic picture' of a wicked problem but rather must identify perspectives (Andersson and Törnberg, 2018), which will depend on framings and are "rarely subject to universal agreement" (p127). Wicked problems are identified by the authors as both complex and complicated. Not all complex problems are wicked; in complex systems, large numbers of 'relatively simple' yet 'irreducibly entwined' entities are organised "without the benefit of a central controller into a collective whole that creates patterns, uses information and, in some cases, evolves and learns" (Mitchell, 2009, p4); examples included colonies of Ants and the Brain. This entanglement is part of the nature of complex systems and we cannot define them using reductionist logic. Complicated systems are far more predictable, for example, technology and organisms (Andersson and Törnberg, 2018)[7], yet contain many different hierarchical levels.

Wicked systems have many heterogeneous parts with individual agendas, strongly connected interactions ("seamless webs") and have no 'general avenue for simplification'

[7]STS and ANT scholars will debate this, recognising the entanglement with social systems in technology (Agar, 2012)

(Andersson and Törnberg, 2018). This lack of simplicity links to another of Duckett's (2016) qualities of wickedness: 'boundary ambiguity'. Our scientific and policy practice has been shaped by the desire to reduce things into simple parts, this practice may link to our brains' need to classify the world by 'chunking' data to help us learn (Tett, 2015 p28). This approach has developed and defined our institutions, disciplines and practices. 'Wicked' problems are such because they do not sit neatly in the arena of one discipline or another, they are defined by their entanglement across multiple complex systems (Andersson and Törnberg, 2018; Duckett et al., 2016). Wicked environmental problems are ones in which bio-physical and social systems are entangled.

"Every wicked problem, however, is critically unique in its details. Interventions to address wicked problems must therefore be designed in the form of meta-solutions that scaffold the generation of actual solutions" (p127).

Tree planting for Natural Flood Management is a challenge that sits at the intersection of multiple complex, overlapping systems (Figure 2.6). As discussed in section 2.2.4 hydrological science has been going through a period of reflexivity recognising hydrology not as a 'natural' physical system but one that is entangled with human agency and social systems (Rusca and Di Baldassarre, 2019).

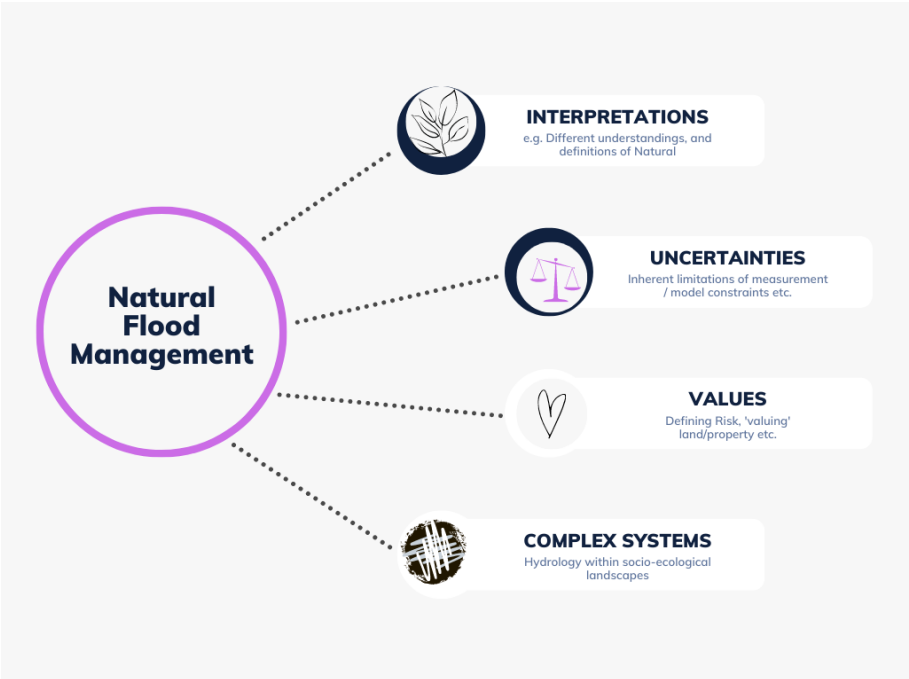


Figure 2.6: NFM wicked features

Increasing Tree cover is another 'wicked' area, where 'science' is inherently entangled with 'society' with uncertainties and value-based judgements being applied across varying spatial and temporal frames (Figure 2.7).

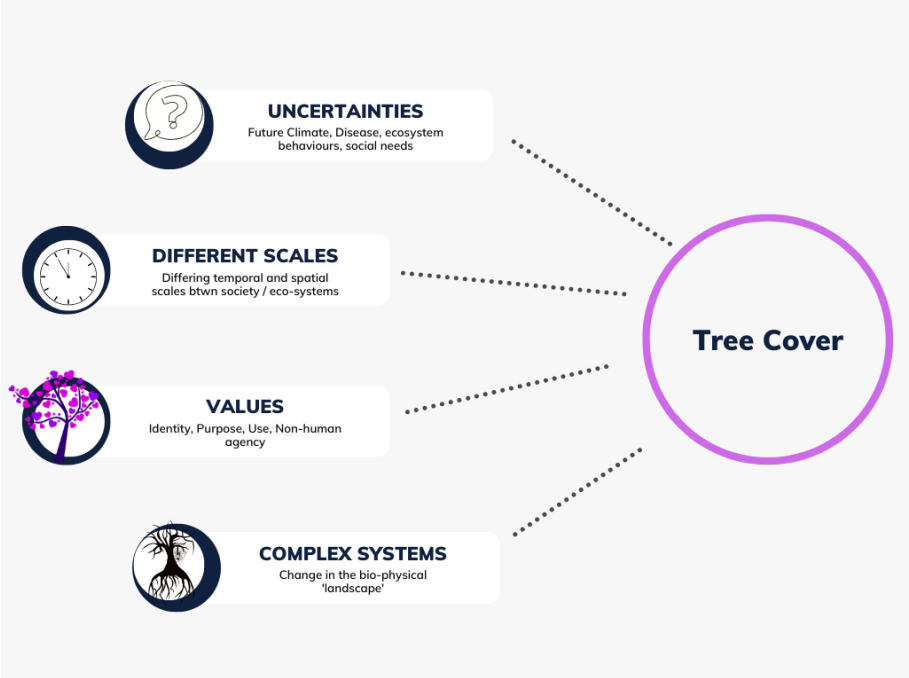


Figure 2.7: Wicked features of Trees

Both Andersson and Törnberg (2018) and Duckett et al. (2016) acknowledge the desire to 'reduce' wicked problems to something which appears more manageable. However, this returns to the reductionist logic and 'generalisable' solutions identified as ineffective and place irrelevant. Expanding tree cover for NFM is a wicked problem that itself is seen as a solution to a wicked problem. However, the implementation of tree planting can be identified as a wicked problem itself. This starts to fall into the trap of the in-definability of wicked problems. However, an exploration of Trees for NFM could be described as a 'meta-solution' one which can "scaffold the generation of actual solutions" (Andersson and Törnberg, 2018, p127)

Funtowicz and Ravetz (1993) recognised 'inadequacies' in a linear science-policy interface, proposing a second order or 'post-normal science' (PNS) to meet policy issues of 'risk and the environment'. They critique a dominant teaching of science which presumes 'a universe of unquestionable facts, presented dogmatically for assimilation by uncritical

students' (p741). By extending science into the real world it had not 'merely lost control' but was faced with uncertainty, ignorance and ethical uncertainties 'lying at the heart of scientific policy issues'. They did not devalue science but wished to situate it within what had been shown to be a complex and entangled system. Proposing that challenges be assessed based on an evaluation of systems uncertainties and decision stakes; if both were low then the problem fell in the realm of applied science, but if both were high, the problem was situated in that of post-normal science.

Funtowitz and Ravetz's 'dynamic resolution' of issues of post-normal science requires the identification of a set of 'legitimate participants' of 'extended peer communities' (p753). Whilst diverse fields have engaged with the principles of PNS (Dankel et al., 2017; Turnpenny et al., 2010), the identification of these 'extended peer communities' has caused extended debate (Carolan, 2006). Only a few examples of the practice at a policy level exist; one often quoted is the Danish governance model including Consensus conferences (Andersen and Jæger, 1999; Ara-jo, 2017). Governance approaches that attempt to organise 'sleek' single methods of identifying or imposing an organised structure to developing these communities risk losing the 'messy' or clumsy nature that is likely to make them effective (Ney and Verweij, 2015). In an analysis of attempts to 'open up' UK water governance (Mehring et al. (2018) find that prescriptive 'one-size-fits all' approaches which stem from the technocratic roots of FRM 'pervade' and negatively impact participatory approaches, conflicting with the heterogeneity of communities. This is also reflected in the NFM literature with the identification of stakeholders being primarily those already situated in institutions rather than wider land management communities (section 2.2.4.)

Both the frameworks of wicked problems and post-normal science have led to calls for policy to engage with a wider range of knowledges. Exactly 'how' to do this is a matter of critical debate but that it involves participatory and interdisciplinary approaches is evident: boundary crossing both across disciplines and engaging with knowledge holders outside of certified disciplines (Krueger et al., 2016; Nesshöver et al., 2017).

Situating 'Trees for NFM' as a wicked problem (or potentially wicked solution) suggests

the need for an extended peer community. This adds complexity to the 'doing' of participatory approaches which requires further exploration within the literature. Critiques are concerned with the identification of 'who' potential 'peer communities' are, emphasising the difficulty of reliably attributing expertise (Carolan, 2006) and how 'experts' should be engaged. The following sections will engage with the challenge of identifying the 'who', the 'why' and the implications of including/excluding participatory work in tackling this wicked challenge.

2.5.2 Environmental science, policy and expertise: participation and the problem with who is excluded

Much literature referencing Brian Wynne's seminal work 'May Sheep Safely Graze' focuses on the relationship between the scientists and the farmers (Wynne, 1996). Authors, however, have critiqued this perspective of science-making as distinct from policy-making and the linear understandings from which this is derived (Maas et al., 2022; Turnhout et al., 2020). I will return to this critique in section 2.5.4, but I introduce it here as it is the knowledge–policy interface/relationship that will shape the actions and regulations put in place for tree planting for NFM. I therefore briefly introduce the topic of Wynne's work by situating the story of the radioactive sheep through the way in which 'science' was used in the House of Lords and House of Commons debates that were directly relevant to the case.

May Sheep Safely Graze

In 1986 one aspect of the Chernobyl nuclear reactor disaster was a radioactive plume that extended north, then west reaching the United Kingdom. Rainfall interacted with the plume bringing the nuclear contamination into the water and soils with Cumbria, Scotland and Wales being particularly affected by Caesium-137 (Agar, 2012; Wynne, 1996). Mr Michael Jopling, Minister for Agriculture announced the restrictions which would prohibit the movement or slaughter of sheep in the House of Commons Arts debate

on a Friday[8]. When challenged about public reaction to the announcement the Minister retorted that remarks assuming the public would be concerned were 'foolish' and that there was "no reason for anyone to be concerned about the safety of food in shops" (col 1335). This is whilst recognising that no contact had yet been made with those who would be impacted by the action.

In the House of Lords debate[9] the following week Lord John-Mackie points out that his own wife would now only buy New Zealand Lamb. Lord Ross of Marnock points out that even if there is no concern to the consumer, there was "considerable cause for concern to the farmer" (col 182)). They are reassured by Viscount Davidson who states that there are no concerns with any other livestock and "categorically" that they are expecting "the amount of caesium will be reduced over the next 21 days" (col 183).

By 1988 a significant number of farms were still under restrictions, the half-life of Caesium-137 being 30 years, suggesting farms could "remain under Government restrictions for years"[10] (col 1063). Difficulties with the scheme are attributed to 'misunderstandings' in the market and farms, rather than any issues with the scheme itself; mistrust of the Sellafield site as a possible contributor has been identified and denied; and when asking about livestock the Minister Mr Forsyth states that "one would have to eat about 20 grouse per year to reach the levels with which we are concerned" (col 1068). When it was pointed out that few of the questioners constituents would be able to afford grouse and the minister Mr Foulkes MP had specifically asked about Trout and Rabbit, Mr Forsyth responded that he had been giving the "worst case scenario" as the levels of Bq/kg "were very much less" (col 1069).

Not only does Mr Foulkes MP demonstrate a lack of conception of the agri-food realities in the countryside, but the 'facts' later turned out to be entirely incorrect. Values for Trout in Ennerdale Water in some cases exceeded the value at which lamb could not go for slaughter - over 1000Bq/kg (Elliott et al., 1992).

These debates use science as justification, frame the science that will be carried out

[8]HC Deb 20 June 1986 vol 99 cc1333-8
[9]HL Deb 24 June 1986 vol 477 cc179-83
[10]HC Deb 20 January 1988 vol 125 cc1062-70

and attribute political value to what is measured, the results and how that science is done.

In his seminal work, 'May sheep safely graze' Wynne (1996) demonstrated that neglect of lay knowledge of farmers around sheep behaviour and farming practice meant that the advice given by external scientific experts was ineffective and unrealistic. Farmers observed the inherent uncertainties in the field observations and were penalised by regulations based on incorrect predictions for which no 'mistake' or recognition of uncertainty was made. They were ignored when they made attempts to share their local and contextual knowledge of the landscape, environment, farming practice and sheep behaviour. This created a level of distrust between farmers and the scientists that was not based on a lack of scientific knowledge of the farmers themselves. Conflict existed between farmers' and scientists' understandings of certainty and control (Wynne, 1996).

The Chornobyl fallout was a man-made disaster that deeply impacted socio-ecological landscapes, creating a significant environmental challenge. It highlighted how the science-policy interface created policy that impacted the rural environment without consideration or even acknowledgement of the concerns or knowledge of those either living within and dependent upon the landscapes or the general public's attitude to and perception of risk. The impact of this way of policymaking has not been short-lived. The final restrictions and regulations on farms weren't removed until 2012 (BBC, 2012). It also demonstrates the value-based and a-political way (Jasanoff, 2005; Maas et al., 2022; Sarewitz, 2004) in which politicians use, make and direct science on both sides of political arguments. I will return to this point in section 2.5.4 but for now will continue to focus on the science-policy-society relationships.

When Bovine Spongiform Encephalopathy (BSE) devastated the agricultural community and caused another national panic (Lord Phillips et al., 2000) it was also a turning point in the relationship between science, policy-making and 'society'.

In her analysis of environmental governance Jasanoff (2007) found that the UK had demonstrated a 'unique' reliance on scientists by policymakers. Science and policy believed that 'public understanding' was the cause of the conflicts

In 1985 the eponymous Bodmer report (Bodmer, 1985) began a series of studies ex-

ploring an assumed 'deficit' model of the 'public'; 'publics' distrusted science because they didn't understand it (G. Thomas and J. R. Durant, 1987). This was inherently untrue, with the 'public' demonstrated to have exceptional scientific knowledge within diverse contexts that were relevant to themselves (Bauer et al., 2007). The subsequent 2000 House of Lords report (Hansard, 2000) and 2001 debate[11] directly recognised the damage caused by a didactic approach and a perception of a deficit of public understanding. A move from deficit to dialogue was promoted and the time of the 'public consultation' began.

It appears, however, that the importance of public opinion and support has been integral in shaping the attitude towards public engagement, rather than impacting a change in knowledge development.

The foot and mouth disease which 'wreaked havoc' in 2001, revealed the lack of understanding of the 'out-of-date' conceptions of the rural landscape (Ward and Donaldson, 2004). Two policy u-turns based on public opinion (re-opening footpaths and showing compassion to certain (highly specified) 'at risk' animals), did not reflect any consideration of real changes in rural policy-making (Wilkinson et al., 2010). The introduction of a scientific group of experts selectively chosen, supported a policy approach of a mass cull, framing environmental and animal welfare groups as 'irrational' and 'irresponsible'. The discussion of a vaccination program amongst the scientists themselves was considered not to be worth the time "as farming unions were known to be hostile" (p341). 'Public opinion' and the 'industry' were publicly offset against each other, despite the views of the unions being at odds with significant numbers of their members. Ward and Donaldson (2004) identify the potential of this rural crisis as a 'learning opportunity', but that the three government-established enquiries were "distinct, separate, and reductive" losing site of framings such as the rural economy in their approach (p305).

The technocratic and teleological approach of policy to environmental challenges in the rural environment appears to have undergone a thorough critique and reassessment (Stilgoe et al., 2014). With a recognition that limiting policy to 'evidence-based' insti-

[11] HL Deb 16 February 2001 vol 622 cc405-59

tutionalised science limits the effectiveness of policies in action (Maderson and Wynne-Jones, 2016) A development and adaptability of the scientific knowledge culture has been demonstrated (Morris, 2006), with impacts on social learning (Reed et al., 2010), and the accountability of science and scientific processes (Stirling, 2008). Of particular interest to this study are studies incorporating public participation into Flood Management modelling (Krueger et al., 2016; Landström et al., 2011; Pasquier et al., 2020; Tsouvalis and Waterton, 2012).

Yet Lave (2015a) states "Today, it is broadly assumed that legitimate knowledge claims about the environment can be produced only by professional scientists who have undergone lengthy academic training and work with expensive equipment in specially designed settings. People who do not have or do those things yet claim to produce environmental knowledge are commonly viewed as dabblers, or even crackpots" (p245)

After foot and mouth, MAFF became DEFRA, who actively encourage consultation (Defra, n.d.-a). Yet when Cassidy (2015) reviewed the BTB bovine tuberculosis crisis and the process by which 'expertise' impacted policy-making. She identified the evidence-based approach to policy and reflects that despite the expert scientists' methodologies centralising farmer participation reports refer to their input as challenging or an interference rather than reflecting a 'truly' participatory relationship.

Despite the potential and prospects for a 'learning' in policy knowledge culture, the practice of policy in the UK appears to have moved towards rather than away from a desire for an "evidence-based approach" (Defra, 2018; NRW, 2020c; Smallman, 2018).

Since Wynne (2006) argued that the change in policy approach to public participation was "hitting the notes but missing the music" the democratisation of science and society, particularly in the rural environment, appears to have faltered (Chilvers and Kearnes, 2020). Public participation as public engagement with policy aimed to increase trust yet failed to engage with the multiplicity of "diverse and emergent publics" (p349) or problematize the primacy of science as the sole maker of knowledge or provider of expertise (Turnhout and Neves, 2019; Wynne, 2007).

In critiquing the 'science to the rescue' sociotechnical imaginary, Smallman (2020)

identifies how this 'elite' perspective is reinforced by institutional structures and held by those shaping the policy-making structures and processes. In particular, it reinforces ideas that uncertainties were manageable and social and ethical issues were separable from science and technology.

This reinforces a residual realist perspective of public participation (Chilvers and Kearnes, 2020) one in which a public contributes to decisions made around knowledge but are external to both science and democracy, the making of knowledge and its application. The WFD led to advances in flood resilience and planning, engaging communities at risk. Stakeholders or 'experts' have been identified as those with codified knowledge (Bark et al., 2021). Farmers and land managers are those expected to implement interventions whilst still being excluded from the production of knowledge. This is despite significant literature suggesting the direct relevance of land manager knowledge. The following section expands on this and explores why farmers and land managers can be identified not just as relevant knowledge holders, but as relevant experts.

2.5.3 Farmers are relevant experts

What is an expert

Carolan (2008) suggests that anyone with relevant expertise should be involved in the decision-making/problem-solving process, yet the attribution of expertise is complex (Jasanoff, 1990, 2003b)

Collins and Evans (2002) recognise that science alone 'cannot solve technical problems in the public domain (p269) and identify two problems of participatory decision-making, the problem of legitimacy and the problem of extension; decisions will not be legitimate if they do not extend beyond the 'core of certified experts' but that how far participation should extend has not been identified. They propose a 'third wave' approach to expertise which recognises technical expertise in non-certified individuals.

Jasanoff (2003a) argued that the concept of expertise needed to be "diversified and opened up to a wider range of views" (p161). Collins and Evans (2002) however, contrast

'expertise' to 'lay knowledges' declaring the definition of layman as 'one who has no expertise'. Whilst recognising that members of the public may hold expertise that has not been certified, they declare this as 'technical', referring only to knowledge which may be directly codified into 'scientific' technical knowledges. In this way, they identify three types of expertise 1 - non, 2 - interactional and 3 – contributory, all of which revolve around the non-certified individuals' ability to engage with 'science'. Jasanoff (2003b) directly critiques this science central approach to expertise. She recognises the problems identified by Collins & Evans but declares them reluctant to "take on board the dynamic, politically constituted nature of expertise" and that they demonstrate "a reductionist conception of the role of ordinary citizens in even the most esoteric domains of public decision-making" (p398)

Jasanoff supports a need to analyse expertise, how it is demonstrated and how it comes into being (Jasanoff, 2003a, 2003b) but critiques the attempt to demarcate and give defined boundaries. Jasanoff recognises that this will occur throughout science and policy and instead challenges the focus of analysis to identify 'the experts' political power to define the issues and select the very terms of deliberation" (p162).

Carolan (2006) attempts to integrate ideas of values, by extending Collins & Evans 3 types of expertise to include a 4th 'public expertise'. This expansion begins to incorporate and legitimise wider ideas of values whilst also explicitly treating them as separate from science. This separation leads Carolan to directly limit the involvement of the 'public expert' unless they can also demonstrate 'contributory expertise' (p665).

In responding to the question of 'expertise', and identifying it in 'lay' communities Wynne (2008), focuses on the problematization of science itself,

"In most public conflicts involving science, these are the substantive epistemic—and tacitly ontological (and hermeneutic)—differences, about what questions knowledge should be addressing, and thus, what (combinations of) knowledge should be in play." (p24)

Wynne's argument highlights that the attribution of 'public' or 'scientific' expertise ignores the literature challenging whether science itself can be isolated in this way. 'Scientists' are also members of the public, and members of the public can hold highly relevant

'scientific' knowledge. This knowledge is not exclusively held by institutions and, as the next section explores, neither is it the only form of knowledge production.

Land Manager Knowledges

In a systematic review of literature on Practitioner (specifically Farmer/Agricultural) knowledge, Girard (2015) identified four main strands of literature or 'strategies': Deficit (Land manager knowledge as a barrier or limitation), Heritage (As something to be preserved), Use (as a source of innovation) and Co-production (as part of knowledge exchange). Of 197 empirical studies, over a third sat in the first category, where 'science' would provide innovation where LM knowledge was limited. This draws on studies which occurred over many years, but research in recent years only saw a small decline in this category. This suggests that the social science findings we have previously discussed are still to be accepted into the mainstream where a positivist view reasons that "knowledge is only legitimate once it has been scientifically validated" p960.

Collins and Evans (2002) were concerned that 'the public gets things wrong' however it is recognised that 'science' from its political-cultural framings (Jasanoff, 1990; Latour, 1999; Sarewitz, 2004) is "neither apolitical nor value-free" (Douglas, 2015, p296) and whilst often reliable, also gets things 'wrong' (Douglas, 2015; Irwin, 2001; Jasanoff and Simmet, 2017; Wynne, 1996). In fact, being open to challenge, and therefore implicitly allowing the possibility of being 'wrong' is one of the strengths of the scientific process (Douglas, 2015). Rejecting strategies one and two (though preserving Girard's reflection that understandings of 'power' needed more careful research and consideration in regard to farmer knowledge) we are interested then in the 'use' LM knowledge may provide to innovation (in this case the direction of environmental management policy and practice), and the knowledge that may be co-produced or shared to enhance this innovation[12].

Whilst Raymond et al. (2010) explore the challenge of integrating knowledge 'types', their approach relies on categorisation. The authors themselves recognise this as complex

[12]This is not the same as assuming that local knowledge is automatically more 'sustainable' (Castree, 2001; Girard, 2015)

and that how knowledge is produced (epistemological challenge) may be as informative as trying to classify what that knowledge is (ontological challenge). Girard (2015) finds that further research is required into how knowledge may be combined, particularly when it has been produced within a particular knowledge paradigm.

Turnhout and Neves (2019) demonstrate through four case studies the manner in which practitioner knowledge was directly able to inform and improve scientific practices. Brockett et al. (2019) demonstrate how engaging with farmers "provided us with unexpected information and data sources for the natural science study, which led to subsequent changes in our study design and research parameters" (p196). Farmers' scientific knowledge could be directly utilised, and wider knowledges could be codified to be directly relevant to scientific practice, in particular, the authors found that seemingly homogenous survey units were heterogeneous when historic farm management was considered. Turnhout and Neves (2019) caution us however not to rely on only that knowledge which is, or translates directly into the scientific as this 'risks the neglect of wider knowledges'.

There is a tendency in the literature to split or compartmentalise knowledges, for example, Siebert et al. (2008) recognises scientific knowledge as 'decontextualised, standardised and specialised' and contrasts this with lay or local knowledge as 'highly variable and non-universal' (p225). This, however, neither recognises the variability and contextuality of science nor the legitimacy of lay or local knowledge. However, the author's study goes on to show that local actors do not only apply one knowledge 'type' but that it "in most cases is a mixture of scientific knowledge and local knowledge based on practical experiences" (p235)

This reflects an important concept that I draw on throughout the thesis: 'knowledge cultures'. Tsouvalis et al. (2000) explored knowledge production as one in which "knowledge forms are constantly merged and mingled – their boundaries transgressed – in the relational-responsive way people make sense of their worlds in their everyday lives" (p922). Following Tsouvalis authors have found that farmers know through a complex interweaving of knowledges, experiential, geographic and scientific (Morris, 2006; Riley, 2008).

Riley (2008) demonstrates that farmers lived experience, embodied and often tacit knowledge culture, embedded in a particular temporal understanding, narrative, social history and performance; is not just an 'addition' to scientific knowledge, but provides "insights which are often beyond the reach of techniques and records of elite science" (p1291).

Farmers are able not only to specifically challenge scientific knowledge, but they are also able to use their way of knowing as a political tool, a moral framework from which to 'refute and undermine' scientists who "do not share this context-specific social history" (p1291). This leads back to the political potential of a phenomenological approach. It also reflects on the question of whether, with a complex way of knowing a challenge already identified as wicked (i.e. both complex and complicated), land managers could bring relevant 'expertise' to increasing tree cover for NFM.

Farmers and Land Managers, Experts in their F/fields (Riley 2008)

Expertise is different to 'being knowledgeable', it can be attributed by institution or by social accountability (Jasanoff 2003, 2005). In Designs on Nature (2005) Jasanoff states that "Experts are indispensable to the politics of knowledge societies" (Jasanoff, 2005, p267). Jasanoff identifies that how we define an expert changes depending on our political and cultural structures; that 'expertise' is identified quite differently in her case studies, America, Britain and Germany. This suggests that 'attribution' of expertise is in itself something that may be considered and exploring this may shed more light on the power dimensions of the science-policy interface that have been critiqued for a lack of challenge (Girard 2019, Smallman 2019).

Carolan (2008) recognises the potential of a 'flattened hierarchy' of knowledge, where knowledge is shared and co-produced between experts. Reflecting on whether we identify land managers as experts is therefore important as it changes the power and political strength of voice (as Jasanoff recognised – 'experts' have a direct ability to shape problems themselves (2003)). It also changes the hierarchy of who is engaged in interrogating a challenge, with institutional recognition 'strengthening the voice' of those with formal

training (Maderson & Wynne-Jones, 2016).

In previous studies, identification of 'experts' has been limited to those with technical/scientific expertise (e.g. Siebert et al., 2008) or expanded to include a lay or non-expert but relevant stakeholder participant voice, there to judge the values but not necessarily the 'science' (Wynne, 2006, Stilgoe, 2009).

It appears that to be involved in the conversation, a level of expertise must still be demonstrated or acknowledged. Despite the lack of identification of farmer/land managers as 'experts' in association with Trees for NFM to date, there is significant literature supporting the claim that not only do farmer/land managers hold relevant knowledge to critique the problem and inform solutions, but they are expert within the 'places' in which policy implementation is focused.

Lowe et al. (2019), describe expertise as "the skilful development and deployment of knowledge and other technical abilities" arguing that "everybody has some sort of expertise [...] in so far as one's expertise is drawn from experience and embodied in skills" (Lowe et al. 2019, p29). The attribution of expertise can then be through either certification or institutional recognition or socially constructed, 'contingent and negotiated' (ibid). They describe two methods of assessment of expertise, the hierarchical or 'as instruction' and the non-hierarchical or inverted 'in service', with examples such as the medical professional and patient in a 'co-production' of expertise. Rust et al demonstrate this in the farming community with more trust placed with peers than with institutionally attributed 'experts' (Rust et al. 2022). Lowe et al argue that this non-hierarchical peer-to-peer understanding of knowledge co-production and expertise counters "the ideological assumption that science [..] is the only sure source of reliable information, evidence and discovery on which sound policy making and related decisions should be based" (Lowe et al, 2019, p29). Interestingly they reference both Collins & Evans (2007) and Wynne (1996) in this statement, despite Wynne's later critique of the overtly scientific assumptions of Collins & Evans (Wynne 2007). In Lowe et al. (2019), it is the expertise of the rural advisor being critiqued, an individual who could loosely be described as falling already into the traditional technocratic role of 'expert'. However, it is the co-production of expertise

between the farmers and the rural advisors that the empirical evidence enlightens, with Lowe et al. specifically attributing farmers own 'vernacular expertise'.

Lowe et al. (2019) use the term 'vernacular' expertise, specifically to avoid the power dynamics of lay – science knowledges, however, this itself has been critiqued (Turnhout & Neves 2019), as it implies 'ordinary' and therefore sits alongside 'lay' as a term that denotes a 'lesser' knowledge than that of 'elite' science (Smallman, 2018). I have already, through the literature, problematised and identified the imaginary of the elite scientist. This raises a difficulty in what terminology to use to refer to land manager expertise. Lowe et al. do not use the term 'place-based' as this, to them implies that knowledge is restricted to the local. Lowe et al. (2019) refer to vernacular expertise as a 'hybrid' comprised of 'local and extra-local experience, skills and knowledges' (p36). Eversole (2021) expands on this referring to an extra-local, externally networked expertise. By framing the 'expert' as institutional/traditional, Rust et al. (2022), highlight the negative connotations the term itself has come to be associated with, though implicitly querying the suitability of the attribution by keeping the term in quotation marks throughout the paper. The literature has shown that the compartmentalisation of knowledge into different 'types' (Morris, 2006; Raymond et al., 2010; Riley, 2010) can be inappropriate and is largely unsuitable for a discussion of farmer/land manager knowledges. This suggests that this question is unresolved and this research may reflect upon it.

The literature does, however, identify that the question of expertise is an open one. Farmers/land managers may be reliably identified as relevant experts, although knowledge that is considered relevant, and how it may inform the challenge of Trees for NFM will be a significant contribution of this thesis. Collins & Evans's (2007) concerns that the 'public' get things wrong are unlikely to have been dispelled by the acknowledgement that scientists are both members of 'the public' and also 'get things wrong' (section 2.5.2, Douglas, 2015; Jasanoff and Simmet, 2017; Wynne, 2007). However, literature suggests that farmers/land managers have ways of knowing that are both convergent with and different from scientific ways of knowing. This suggests that including farmers/land managers in the sphere of experts may co-produce a richer knowledge culture which may have

the potential to develop alternative approaches to understanding knowledge gaps or incorporating uncertainties. For example, peer-to-peer co-production by experts may have the potential to develop say a hydrologist's perceptual model of the system, supporting the scaffolding which could enable more suitable solutions.

If this is the case, then it will reflect on the whole system of knowledge production and governance for environmental decision-making.

2.5.4 Reframing governance, knowledge and participation to scaffold the solution

Framing the knowledge-policy interface

Participatory approaches extend from citizen science, through to the democratisation of environmental governance, yet have been critiqued for being either a perfunctory exercise in engagement or a method of drawing additional data into 'science' (Chilvers and Kearnes, 2020; Turnhout and Neves, 2019; Wynne, 2006, 2007).

As mentioned at the beginning of section 2.5.2, Maas et al. (2022) critique the linear understanding of science-policy development. This can be visualised (figure 2.8) with the predominant (highly critiqued) imaginary of an externalised publics (Chilvers and Kearnes, 2020; Smallman, 2020; Wynne, 2007) the framework of science policy generation currently appears as a linear process, with clear jobs and definitions easily defined. The public are neither considered part of knowledge production, nor of the governance process, but external to and reflecting upon each stage. This then frames the types of 'engagement' at each stage and by its nature frames the ownership of the problem as within the science-policy interface, and the 'public' as an external party who must be included.

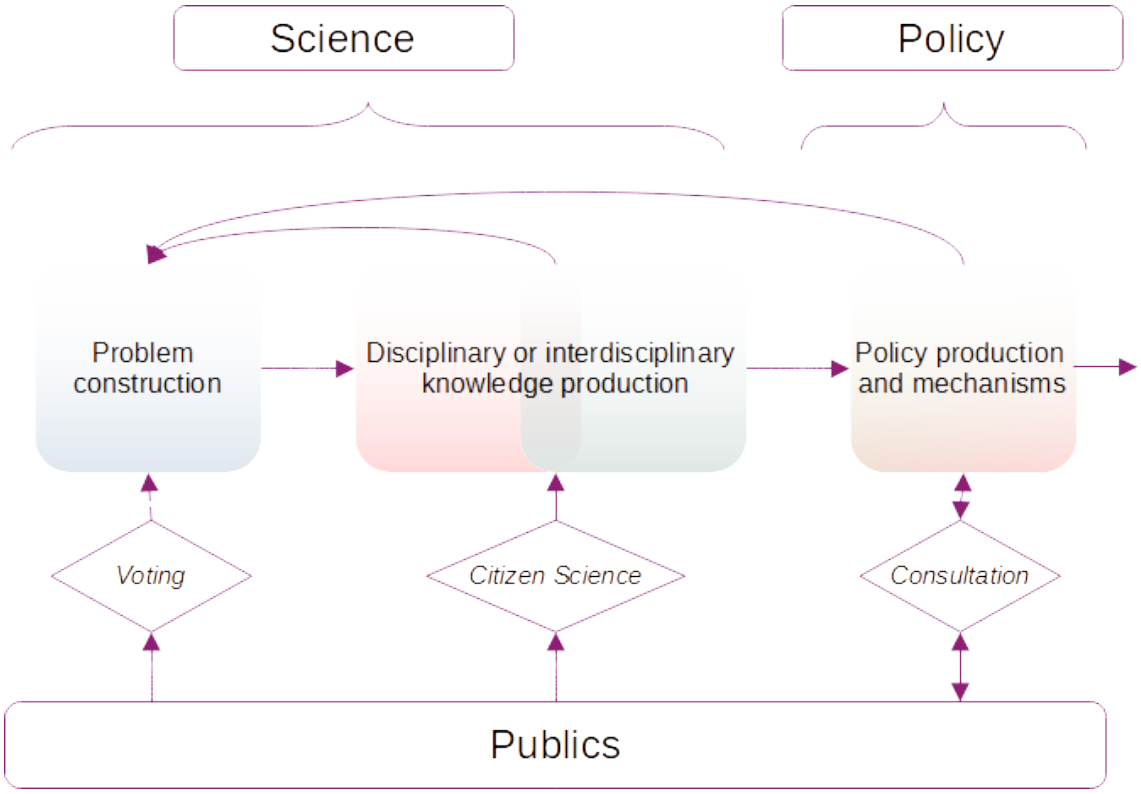


Figure 2.8: A visualisation of the extant linear conception of the science-policy framework

The extant literature described clearly denounces this perspective, yet recognises that it is the current one evidenced in our science-policy institutions and held in place by our institutional frameworks, governance structures and social acceptability.

The relevance here is how the science-policy interface might be reframed when the literature(s) of knowledge, expertise and landscape are all drawn upon, to use Bender's (1993, 2010) approach, enmeshing the perspectives and taking a more holistic view to see what arises.

- First, engaging with the co-production of science; policy is not the recipient but is directly engaged in the production of knowledge (Jasanoff, 2005; Maas et al., 2022; Turnhout et al., 2020).
- Secondly, the problematisation of the 'public' as external; recognising 'society' as the overarching frame in which knowledge-policy is situated (Wynne, 2006, 2007)
- Third, the problematisation of science (I have shifted already in the language of this section from 'science' to a more general 'knowledge'), and acknowledge that

science is not the only way of knowing (Kimmerer, 2013; Latour, 1999; Morris, 2006; Turnhout and Neves, 2019; Turnhout et al., 2020; Wynne, 1996)

- Finally, incorporating phenomenological understanding and recognising landscape, the materiality of place in space as in co-production with the socio-ecological system with which we are concerned (Bender, 2010; Ingold, 2000; John Wylie, 2007).

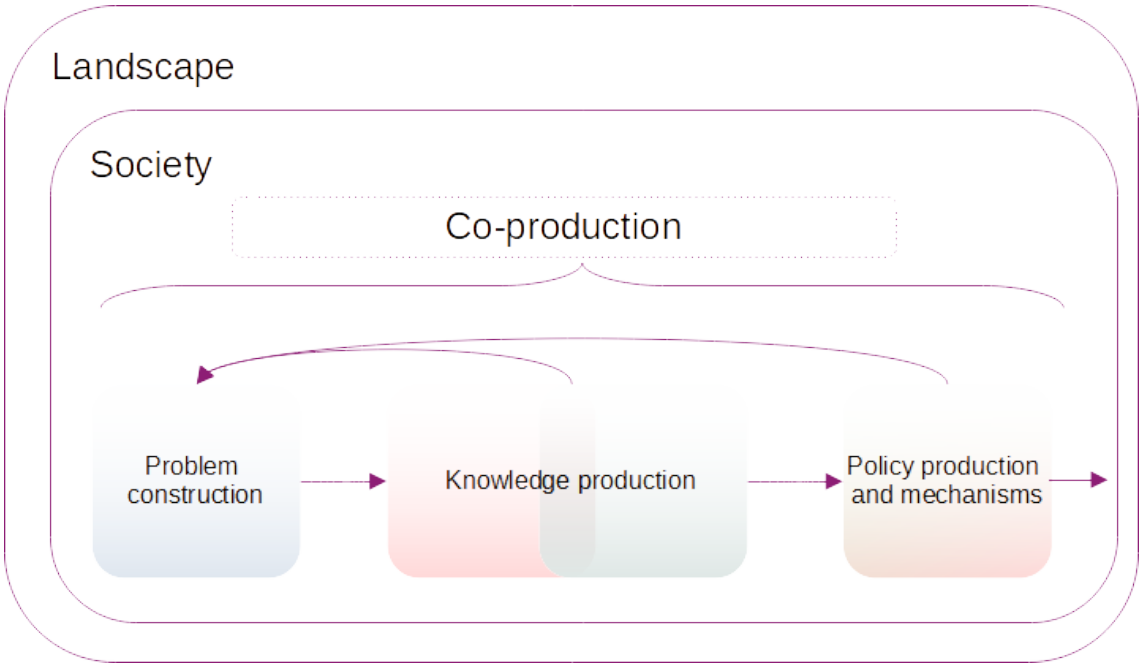


Figure 2.9: Re-conceptualising a knowledge-policy framework shaped by society and the landscape

When these factors are considered the re-framed knowledge-policy interface in figure 2.9 is co-produced, shaped by the frameworks of both society and landscape. This suggests that interventions tackling environmental challenges and landscape change such as Trees for NFM, need to be understood within this framework, which is both interdisciplinary and participatory. It responds to challenges of interdisciplinary and mixed methods approaches (Dwyer et al., 2020; Nesshöver et al., 2017; Oughton and Bracken, 2009; Raymond et al., 2010) whilst extending those to step cautiously out of the traditional scientific frameworks of knowledge creation and may require new frameworks of analysing and synthesising data, as well as how and what that data inevitably informs (Girard, 2015; Krueger et al., 2016; Turnhout and Lahsen, 2022; Wesselink, 2009).

Implications for current governance approaches

Concepts in STS literature that explore entangled systems such as socio-ecological landscapes in this way include Actor Network Theory and Assemblage. ANT has been critiqued for focusing too strongly on the relations at the expense of the components of a network (Müller, 2015). Assemblage is perhaps a more suitable concept and has been used for political discussion despite critiques, its focus on the 'makeup', the component parts of the socio-ecological landscape and how they come together is a useful way of envisioning and exploring the socio-ecological (e.g. Bear (2013) and Jones et al. (2019)). However, assemblage has also been critiqued for the risk of staying at a descriptive level, being a "philosophical perspective, not an empirical toolbox" (Müller and Schurr, 2016, p220).

A more analytical approach is the socio-ecological systems frameworks (SESF) developed by Ostrom (2009). This approach rooted in the management of the commons has been critiqued for its treatment of the 'social' both for (Stojanovic et al., 2016) and against (Partelow, 2018) its ability to incorporate the fluid, heterogeneous and interpretive nature of the social sciences. For example, the manner in which agency (particularly the impacts of non-human agency) and co-production can be incorporated into the SESF is limited. Systems approaches are, however, useful for the purpose of analysis, particularly in terms of knowledge-policy where 'learning from and learning for' policy are the objectives (Dwyer 2021). This indicates that the whole system of governance will impact the thesis objectives, rather than falling into the linear reductionist model of assuming an exploration of land manager knowledges will automatically fall into a 'bottom-up' approach led by an externalised 'public'.

A further reflection on figure 2.9 is that the reductionist terms 'bottom-up' and 'top-down' may no longer apply. Significant analysis has used these terms in the analysis of the effectiveness of co-production or locally-led projects. Whilst these analyses and practices can draw interesting and relevant conclusions, they also risk reinforcing established and unequal power relations (Turnhout et al., 2020)

For example, Newson et al. (2021) recognise the importance of co-production at the science-policy interface yet situate 'science' as external to a localised public, and whilst recognising the importance of 'localism', associate this with 'experience and opinion' as opposed to a 'science-led' top-down policy for which they appear to advocate.

Even within a more linear model, the bottom-up/top-down (BU/TD) framework is recognised as a simplistic and potentially false dichotomy. Short (2015) presents a more nuanced approach identifying micro, meso and macro level organisations and the concept of 'crafting' (following Thiel et al. (2015) in Short (2015)), in which institutional frameworks are 'shaped' to enable delivery within local contexts. At the micro level, key factors include 'trust, power and legitimacy' and the question of agency - with Short finding that the most relevant knowledge and the greatest agency may not be held by the most committed actors. Breaking the BU/TD dichotomy further, analysis within water governance (Pahl-Wostl et al., 2020, and NFM in particular: Garvey and Paavola, 2022) building on Ostrom's work, explore the concept of polycentric governance which presents a more fluid understanding of the way in which policy is actually done.

Where community-led, cooperative approaches may once have been a key aspect of rural land management, this has shifted in the UK, with land management being framed as a purely individual issue (Riley et al., 2018). This is recognised in Short et al. (2018) and Black et al. (2021) where an experienced facilitator was essential in developing networks and translating between institutional groups (a key critique of 'local' delivery groups in Newson et al. (2021) being a lack of translation between CaBA and Flood Action Groups). Garvey and Paavola (2022) note (following Ostrom (2009)) that an 'external party' is not needed to 'impose' action. Yet communities and networks benefited from the functional facilitation of their involvement. This however, requires humility (Jasanoff, 2007; Sarewitz and Pielke, 2007) and reflexivity (Lane, 2017a; Tadaki et al., 2015) on the part of the 'facilitator' to not fall into the unequal power trap (Jasanoff, 2003a; Turnhout and Lahsen, 2022).

The frameworks of governance outlined above, however, reflect figure2.8 and still, to an extent, treat the landscape as something to be measured and integrated with the

socio-cultural. Spatiality is considered in terms of place and localism and it is hard to see how these might 'enmesh' with the experiential approaches of phenomenology or the bio-physical agency in the co-production of landscapes.

Krueger et al. (2016) reminds researchers to 'remain attentive to closing down moments in research' (p368) which these frameworks of analysis may engender if the analysis were to insist on fitting the findings into the frameworks through a desire to target the approaches before engaging with those who hold the 'wider knowledges' that may yet be more relevant.

2.6 Summarising the challenge so far: entangled systems and the importance of participation and co-production of knowledge

Increasing tree cover for NFM is a wicked challenge where the socio-cultural, bio-physical systems are inherently entwined. With the exception of a limited number of significant projects, analysis of community or non-institutional stakeholders has focused on those impacted by the flooding, with limited inclusion of land managers targeted for implementation of change. The current frameworks of analysis have been situated strongly in either the bio-physical / natural sciences or within the socio-cultural / policy and governance frameworks. Frameworks of integrated analysis focusing on the scientisation of socio-cultural aspects have met disciplinary or methodological challenges. Yet, paradigms of post-normal and wicked sciences and the significant extant literature on the co-production of knowledge suggest that both the decision-making and knowledge production by, and with the community directly expected to make change will be necessary in scaffolding solutions. In addition literature supports the importance of understanding the whole system, yet demonstrates the significant challenges in integrating knowledges. Part of these challenges may be being cemented by institutionalised disciplinary structures within interdisciplinary approaches, where studies recognise the importance of two distinct aspects of a system, and cannot force one within the other. Re-framing these interdisciplinary

approaches is inherently entwined with a re-framing of the whole knowledge-policy system. If society is recognised as a fundamental shaping feature of science and policy, and inherently part of both our social and physical sciences (as recognised in CPG and Socio-Hydrology) then these disciplinary approaches and scientisation of data may not be suitable. It follows that the governance of the system is a significant factor in both the decision-making and knowledge production that frames the uptake and efficacy of increasing tree cover for NFM. As stated, the current governance structures are ill-defined and institutionalised into silos, linear structures which do not reflect the whole system. Adaptive governance measures have been suggested that may be more suitable, but may need to work alongside a more significant shift in the way in which knowledge is deemed relevant and levels of expertise are attributed. Whilst Geography literature delves into the understanding and co-production of landscapes, the enmeshing of the physical and cultural, this is not reflected in policy and governance analysis. Where place is identified as inherently important, spatiality, the materiality of space and the complex heterogeneity of landscapes are not.

Recognising the co-production of knowledge, I take on board the reflection that the framing of the problem must be situated outside the institutional disciplinary structures. This suggests an inductive approach (which will be addressed further in the methodology) to the exploration of the problem. However, within the context of increasing tree cover for natural flood management, we can identify from the literature three challenges with which the research must engage:

- Interdisciplinarity and the problem of 'disciplines': Trees for NFM is a wicked problem, which extends beyond the bio-physical. Therefore there is the challenge of boundary translation between social and physical sciences, both in terms of knowledge production and attribution of 'relevant' knowledge. Geography has been situated as a resource capable of addressing reflexively the co-production of knowledge across the social and physical sciences and the 'landscape' that is both place and space, can be considered as shaping or framing the challenge

- The science-society problem: translation between knowledge holders with and without the traditional accreditation of institutional expertise and how expertise is attributed

- The knowledge-policy problem: problematization of the system in which decision-making and governance are framed and within which knowledge is, and isn't translated.

In synthesising literature across disciplines I have identified that in relation to increasing tree cover for NFM, there are evidence gaps and uncertainties on one hand and excluded knowledges on the other. The extant frameworks that situate these knowledges as separate have been critiqued. The complex concepts of knowledge cultures and co-production suggest these knowledges may be directly relevant to both scaffolding solutions and understanding decision-making; and that a more entangled approach than 'integration' is required. This has not been widely explored and not within a specific practical application such as Trees for NFM. This challenge frames the overarching objectives and significant contribution of this thesis.

Chapter 3

Interdisciplinary methods

Contents

3.1 Theoretical frameworks **76**

3.1.1 'Doing' interdisciplinary, participatory research 76

3.2 Methods for an iterative boundary-crossing case study **79**

3.2.1 Participation and Ethics 79

3.2.2 A single case study catchment 80

3.2.3 Methodological overview: Stages and process 82

3.2.4 Co-production: Mapping participation throughout the study . 84

This chapter first identifies the conceptual frameworks on which the methodology is based (3.1) before outlining an overview of the thesis methodology (3.2). The interdisciplinary and participatory approach has been built on the methodological rigour of disciplinary foundations and this includes significant detail. These details are included before each relevant chapter: Methods I (p 89), Methods II (p 89) and Methods III (p 89).

3.1 Theoretical frameworks for interdisciplinary research and the co-production of knowledge

3.1.1 'Doing' interdisciplinary, participatory research

Wesselink and Warner (2010) demonstrate in a flood management study, the importance of co-production producing knowledge which reflects the entangled understandings identified in the literature review. She describes a transdisciplinary (which she defines as new knowledge production beyond interdisciplinary boundaries) concept of 'Landscape quality' which she contrasts to an 'integrated assessment' (with politicians and practitioners finding this approach insufficient). Landscape quality is explored as a unifying or 'boundary' object. If there are boundary objects, this suggests that the boundaries between 'disciplinary' structures are fuzzy, and less well defined than our institutional situations would appear, directly reflecting 'wicked' literature.

This research will explore knowledge and its production that is normally strongly situated within disciplinary frameworks (phenomenology, computational hydrological modelling) at these boundaries through the exploration of both the socio-cultural and biophysical implications of expanding tree cover for NFM.

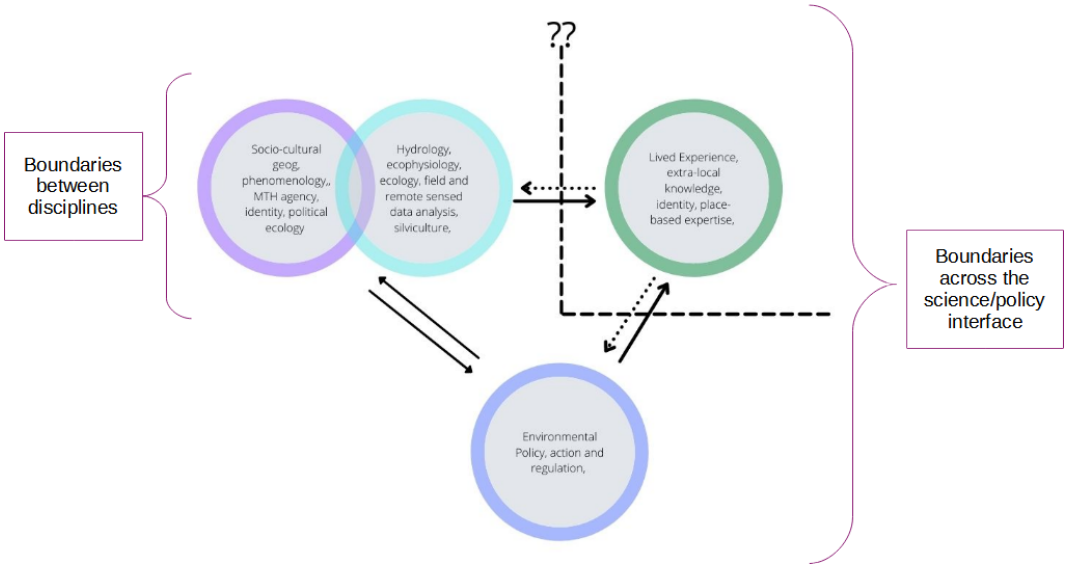


Figure 3.1: identifies the boundaries between physical and human geography; the boundaries between scientific, policy and local/place-based expertise

As figure 3.1 shows, there are two boundary groups identified in the literature: boundaries between disciplines and boundaries across the knowledge-policy interface. Working across these boundaries is described by a wide range of terminologies. I do not (following Wesselink (2009)) engage in the highly debated differences between multi-, inter- and trans-disciplinary terminologies. This is for the simple reason that, for me, the term revolves around 'discipline' and therefore immediately frames this as disciplinary, therefore institutionally led and reinforcing extant and unbalanced power relations. I will refer to 'interdisciplinary' practices and participatory practices or practices of co-production.

Co-productionist literature reinforces the importance of participation and wider knowledge(s) beyond the institutional (section 2.5). This has been formalised within the EU Water Framework Directive[1] and the later Flood Directive[2], with examples of 'water resources' literature being referenced as at the forefront of participatory practice (Colven et al., 2018).

Some key examples include: Wesselink and Warner (2010), Landström et al. (2011), Lane et al. (2011), Tsouvalis and Waterton (2012), Whitman et al. (2015), Rangecroft et al. (2018), Landström et al. (2019).

One of the clear differences between these approaches and the study I am undertaking is the identification of a stakeholder group. With a focus on the flood event, the stakeholders are either identified as the community at risk (Landström et al., 2019; Lane et al., 2011; Whitman et al., 2015) or administrative bodies either political or practitioner-based (Bark et al., 2021; Waylen et al., 2018; Wesselink and Hoppe, 2010). The exceptions are Tsouvalis and Waterton (2012) and Rangecroft et al. (2018), neither of whom were tackling floods. In the Loweswater care project (Tsouvalis and Waterton, 2012) the focus was water quality, an area in which local land managers had already become holders of responsibility (Lowe et al., 1997) and it was a farmer who initiated the project. In Rangecroft et al., 2018 the focus is drought, and whilst it is still a local community being engaged

[1]Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy; http://data.europa.eu/eli/dir/2000/60/oj

[2]Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks; http://data.europa.eu/eli/dir/2007/60/oj

with, it is more integrated with the land management community. This may be due to the nature of this community, but it is also likely that the FRM frameworks in the UK and EU, driven by the Floods Directive, have created this focus on flood resilience and therefore the primary stakeholder becomes the community at risk.

This choice of stakeholder group has direct methodological implications. In their 'guiding principles for hydrologists' Rangecroft et al., 2020 identify a list of methodological best practices which should be utilised by the researcher. As a trained social scientist this is an interesting read, as it lists the basic principles of social research, ethics, positionality etc. that would be considered in any project. In an extended discussion Rangecroft et al., 2022 explain the resource challenge in engaging with the social sciences more deeply, critiquing time frames and funding. However, they go on to claim that lived experience risks creating case studies which are too 'context specific' and therefore creating knowledge which is neither transferable nor widely applicable. Whether this claim is justified will be a key consideration of this research.

Working with communities can be an efficient practice of social research utilising methods such as focus groups or Q methodology (e.g. Forrester et al., 2015) can reduce the time and funding requirements of the social science aspect. There are two difficulties with these approaches. Q-methodology involves the sorting of questions by groups, however, the questions are created by the researchers, seating the original frameworks within those of the researcher rather than participatory group and reinforcing extant power hierarchies. The problem with focus groups or working parties is the time commitment, and the fact that, even when invited (and where the data is available), the number of land managers/farmers engaging with these groups appears always in the minority (e.g. Posthumus et al. (2008) compare interviewees to workshop attendees). Whilst they may have active roles in the community, living at a distance and having lifestyles that do not fit the 9-5, restricts farmers' access to these sorts of groups.

In addition, developing a phenomenological understanding of the landscape would require an emplaced, on-site engagement with land managers (Thomas et al., 2018), in a way that has not been demonstrated in NFM studies to date.

3.2 Methods for an iterative boundary-crossing case study

3.2.1 Participation and Ethics

Before any research involving human participants a full ethical review must be conducted. The accepted application and supporting documents relating to this are included in Appendix Appendix V (p 396).

Ethical considerations are complex in an interdisciplinary study, where location is key to physical principles and yet also an identifying feature of participating individuals. Implications of this are discussed throughout the thesis but in particular in the method chapters 4 & 9. An ethics chapter was not considered for this thesis as not being directly related to the main aim. However, significant ethical considerations of interest in the area of interdisciplinary research have been raised and are a key area of future research consideration (see Chapter 12).

The iterative process of this study required a review of the ethical process at regular stages, and the impact of COVID-19 required a significant review and amendments (also detailed in Appendix V).

A note on positionality: Whilst I engaged significantly with literature on co-production, I refer throughout to everyone I have engaged with as 'participants' in the research, rather than using terms such as co-researcher. This partly acknowledges that I (and my supervisors) have devised and driven this 'research' as a project. This did not preclude me from engaging with other parties as 'co-researchers'. However, I was aware from the start of the project that the group I was hoping to engage (farmers and other land managers (LMs)) have complex, demanding and full-time jobs. Their timescales are subject to the weather, harvests, and the whimsy of livestock and machinery. The previous text has identified the difficulties of using 'efficient' social science methods with farmers, for several reasons, but simply getting them in the same room at the same time is a challenge (Bella Bathurst,

2021). Despite positioning myself as the project 'lead', I refer to the co-production of knowledge throughout, and I found that in practice, this is as true as in theory. It is formalised and codified in the legal requirements and ethics review. LMs have ownership of their data and have signed it over to me as part of the consent process (Appendix V).

Also relevant is my position as an institutional researcher who is independently funded (I will already have expressed my thanks to the Leverhulme Trust but reiterate here the quality of the position in which I am placed due to their style of funding). I have access to resources and am situated in a position which enables me to cross the multiple boundaries necessary to conduct this project. It is a privileged position that is not widely available, both valuable and fragile. To me that confers a responsibility to do with it the best work I can.

3.2.2 A single case study catchment

With few practical methodologies to follow, and repeated calls in the literature for exploratory, reflective practices, (e.g. Emery and Hannah, 2014) the most suitable approach is that of an iterative, inductive case study (Bryman, 2016; Yin, 2018). The case study approach is detailed further in Methods I. A constructivist grounded theory (inductive) approach (Bryman, 2016; Charmaz, 2014; Charmaz and Thornberg, 2021) would require the evidence collected to be reflected upon and would guide the application of methodologies and frame the analysis. Exploring the fuzzy boundaries between disciplines whilst still applying disciplinary rigour to each stage of the project. The following criteria were then used to select the most suitable disciplinary methods: I wished to explore the lived experience, as well as wider knowledges of LMs alongside the heuristic computational hydrological modelling most practical for investigating tree cover expansion for NFM.

The gold standard of hydrological studies is the paired catchment (Leon Bren, 2016). A hydrologist identifies sites where the geomorphology, soils, vegetation, and other physical characteristics are as similar as possible; ideally, identify one variable to change, and analyse the different responses in these 'as close as possible to each other' sites. Over larger spatial and temporal scales, however, characteristics become harder to control. As

soon as the catchments become large enough to be entangled with social systems (there is an argument that this includes all sites) the ability to isolate individual characteristics becomes impossible (Beven, 2012; Leon Bren, 2016; Rangecroft et al., 2022). This is one of the reasons that activity such as natural flood management over a very large catchment is less often studied, it is hard for the hydrologist to identify and control their single variable of change. The empirical difficulties in carrying out this paired catchment research when significant periods of time must be considered to further limit the ability to control and maintain the rigorous scientific method.

The impact of different management choices could perhaps be studied in small catchments where one could guarantee the geomorphology soils and initial vegetation were identical on two different sites, and the managers prioritised well-controlled different choices. It could be argued however that this single behaviour study is unlikely to shed light on the impact of a network of behaviour responses and actions that develop at a community level.

As in Rangecroft et al. (2022) it is rare that two catchments will be alike. Studying two catchments to explore these differences would be a possible method of tackling this project. However, this is a very small sample size, how many catchments should one compare before one can say that all catchments are different? There is also the practical consideration of time, the greater the number of catchments studied, the smaller those catchments must be to engage with an appropriate diverse sample of the community in each catchment. These approaches warrant further study, however, they need a stronger foundation, a greater understanding of the impact of lived experience and expertise on the landscape is required before analysing the effects across many different sample catchments. Engaging in the study of a 140km^2 catchment in which lived experience and expertise are hypothesised to have a significant impact on the hydrological behaviour of the catchment, dictates that a paired catchment study is no longer an appropriate method. This is therefore a 'critical' and 'revelatory' single case study (Yin, 2018). The mixed methods approaches of many case studies also provide suitable methodological and analytical techniques such as triangulation which may be comparable with the findings of this study. The case study

approach is discussed further in Chapter 4

3.2.3 Methodological overview: Stages and process

Before each chapter, I explain in detail the methods applicable to that section. Here I outline the overview of the mixed methods case.

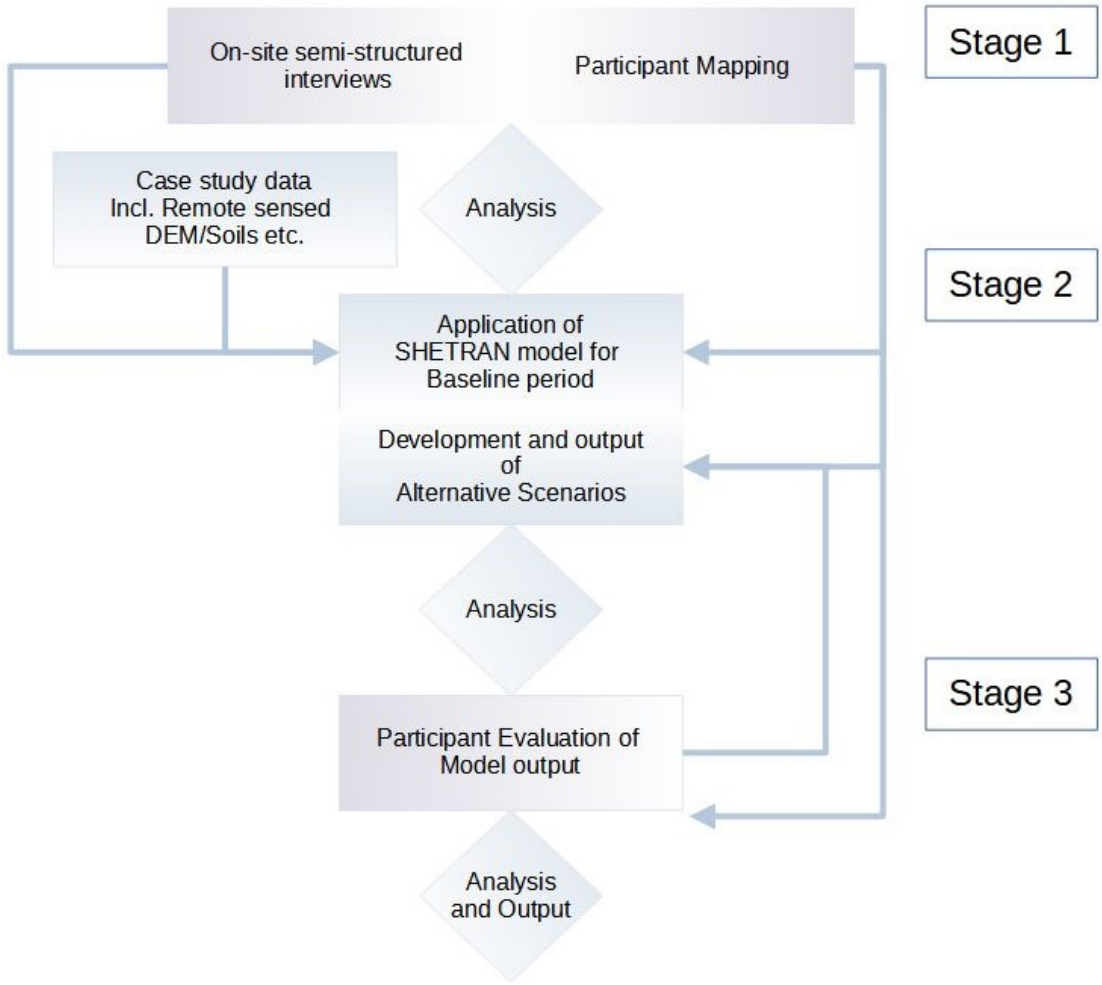


Figure 3.2: Overall project flow chart showing iterative stages and feedback loops

Stage one: The Fieldwork

During the fieldwork I gathered preliminary landscape data, before any hydrological modelling. To explore phenomenological and wider knowledges of LM knowledge culture and expertise a mixed methods approach was taken, including semi-structured, emplaced in-

terviews and participant mapping. This would also incorporate the gathering of case study data and ground truth relevant physical data required for the model. The fieldwork came to an abrupt end in February 2020 due to the COVID-19 pandemic. This work is detailed in Chapter 4

Stage two: The Model

I applied the SHETRAN hydrological model to develop and evaluate a baseline model of the catchment. The model choice was confirmed only after sufficient fieldwork had been completed to ensure that the choice of model (see further detail in section:7.2) was suitable within the catchment context. I used a preliminary analysis of the full catchment data, including the semi-structured interviews and participant mapping, to inform the development of 'Alternative Scenarios'. Changing the land cover vegetation input for the model to reflect different extents and spatial locations of tree cover. The model output was then evaluated to identify changes to the catchment hydrology under different scenarios. This work is detailed in Chapter 7

Stage three Evaluation and Synthesis

This stage drew the model output back into the catchment context within the wider landscapes of interdisciplinary, participatory approaches to wicked challenges. I draw strongly on the geographical literature of landscape here, returning the theory to its place, situating the approaches guided by the STS literature and attempting to practice what is preached with a flattened hierarchy of expertise. This itself was complex and is discussed in section 10.3. This stage underwent the greatest change during the research process, in part due to the COVID-19 pandemic which began part way through Stage 1. However, the inductive, reflexive approach of the research always intended to ensure that this stage would be shaped as informed by the analysis of the previous two stages of work. The details and changes can be seen by reviewing the Ethics reviews (Appendix V) and Chapter 9

3.2.4 Co-production: Mapping participation throughout the study

The participatory nature of the study, and the fact that participation developed throughout makes for a complex set of numbers of participants and sites, where involvement took place over different timescales and across multiple research stages. To ensure the reader can track who is involved and where a table of participant data has been included in Appendix IV. This data is summarised in the diagram below.

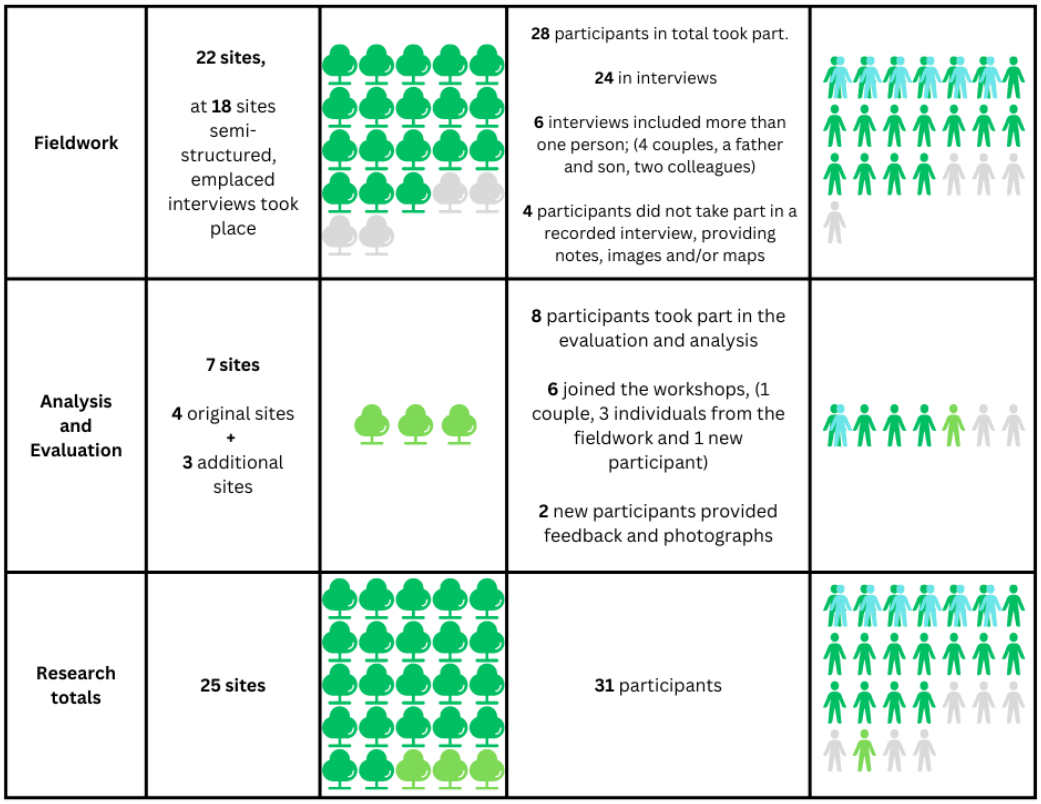


Figure 3.3: Diagrammatic illustration of the number of sites and participants that were engaged with the full study

Preserving participant confidentiality is a key aspect of the ethical considerations of the project, and this includes the locations of the sites at which fieldwork took place. The details and considerations are included in the ethical review (Included in full in Appendix V). To indicate the coverage of the sites, Figure 3.4 shows the distribution of the 25 sites across the catchment as divided by its main tributaries.

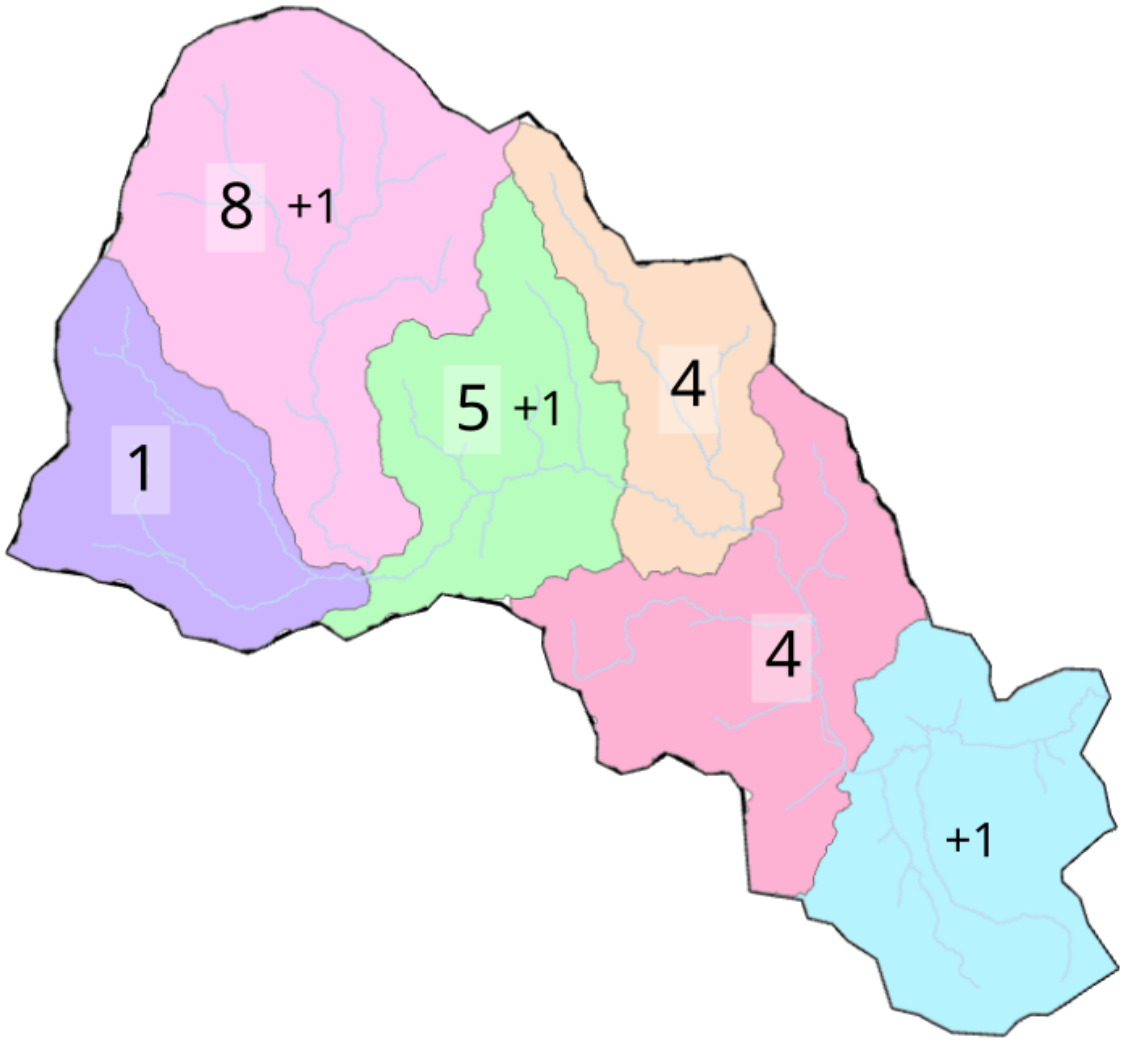


Figure 3.4: Distribution of study sites across the catchment, grouped into areas relating to the main tributaries. The 3 sites engaged later in the study are identified as +1

Part II

The Fieldwork

Chapter 4

Methods I

Contents

4.1 Conducting the Fieldwork **89**

4.1.1 Case study selection and data collection 91

4.1.2 Positionality and ethics 93

4.1.3 Semi-structured interviews 94

4.1.4 Participant Mapping 97

4.1.5 Participatory observation 98

4.2 Analytical approach **99**

4.1 Conducting the Fieldwork

The literature suggests that Land managers (LMs) lived experience and expertise would have relevance for the application and implications of tree cover expansion for NFM (Trees for NFM)(section 2.5. In addition, that lived experience had direct political implications (section 2.4.3). I expected that LMs would have contextual or place-based expertise, which may draw on multiple different knowledge(s), both local/place-based and extra-local/scientific. In addition, STS studies have long shown that local knowledges and place-based expertise have been missing from the research/policy interface, creating bar-

riers to implementation (section 2.5.4). Engagement at this early stage could test whether LMs demonstrated place-based expertise, the knowledges that they used to inform this, and whether the place-based expertise directly impacted the science/problem being addressed by the researcher. Whilst I theorised that this knowledge was important, I didn't know what it was or what it would tell us. A grounded theory approach (Bryman, 2016, Charmaz, 2014) was therefore taken, for which semi-structured interviews were deemed suitable (McCracken, 1988). This differs from common NFM or flood management qualitative approaches, which have often used methods such as Q-methodology (see Chapter 3). Q-methodology involves the creation and ranking of statements. Whilst this is an efficient technique, the 'statements' are often created or refined by the researchers. This assumes that the institution holds the primary expertise rather than the participants.

The interdisciplinary approach meant that I was interested in a broad possible range of knowledges/expertise that could inform the problem of trees for Natural Flood Management. I needed methodologies that were open to exploring knowledge held by the participants and also able to apply it to rigorous scientific methods of analysis, including hydrological modelling.

A case study approach: enables the investigation of phenomena within a real-world context when "the boundaries between phenomena and context may not be clearly evident" (Yin, 2018, p15). This was the most suitable method for what is, at this stage, quite a novel field. Here, the phenomena (the impact of lived experience and expertise on landscape change), in the context of the history, culture, hydrology, geomorphology and ecology of a large complex river catchment on the Welsh-English borders were unlikely to be separable. If culture and history played an integral part in management choices, future plans and current behaviours, as the literature suggested, then the context is inherently part of the phenomena. In addition, it is the context of the physical characteristics of the landscape that determines the starting behaviour in the process of landscape change; a case study approach best enables exploration of this.

A mixed methods case study (Yin, 2018) allowed for the collection of in-depth socio-

cultural data, which could then be 'mapped' (both physically and theoretically) to the socio-ecological, physical landscape.

The 'Fieldwork' would therefore include:

- Semi-structured, emplaced interviews
- Participant mapping
- Participatory observation
- Physical on-site data collection
- GPS photography
- Secondary and remote sensed data collection

4.1.1 Case study selection and data collection

The interdisciplinary nature of this study should make it evident from the offset that this work needed to take a mixed methods approach. Therefore, the first challenge of the study was to identify a suitable case. There were several key criteria the case needed to meet:

- Large - approx 100km2: most studies for Natural Flood Management engage with very small catchments or plots (Ellis et al., 2021). The sparsity of evidence, modelled or otherwise, for large catchments, let alone studies that integrated the social as an inherent part of the work, are lacking and given as one of the key barriers to implementation by stakeholders active in Flood management (Waylen et al., 2018, Bark et al., 2021)
- Feasible - There were three key criteria for feasibility; I needed a large catchment, but one that was not so large that I would be unable to get a representative sample, either socially or physically.

- Accessible - I was going to have to make multiple site visits, so I either needed to be able to stay locally or to be able to travel to the site from home. As a lone worker, the site also needed to be one in which I could put in place appropriate safeguarding.

- Politically sensible - The devolution of Wales and England has complicated landscape management to an incredible degree. It probably doesn't need to; however, simple things, like the fact that the EA maps no longer show anything over the Welsh border, and NRW maps likewise to the English, meant that to review rivers without downloading huge datasets, I had to line up two screens next to each other, and try to get scales to fit. Even with downloaded data - it is necessary to download both the English and Welsh data and try and compare it on the same map. Different and often incompatible datasets are now being collected and uploaded by each devolved party, this added an unnecessary complication to the process. The long-term implications of this on managing cross-border landscape change is an area that needs immediate focus and pertinent solutions presented to both parties.

It is recommended that complex data collection for a single case would involve a team of researchers (Yin, 2018) working from a clear protocol. However, as a single researcher, multiple methods must be engaged on individual field visits, a clear protocol to follow, and ensuring that the correct data is collected becomes perhaps even more important when you are trying to juggle all the jobs!

Afon Trothy | The River Trothy was one of a small number of rivers that fit initial criteria and were local enough to support multiple site visits; this included the Rivers Arrow, Lodon, Frome and Garren. The River Trothy directly fit the above criteria whilst also being a clear example of a river likely to be targeted for Natural Flood Management. The reasons for this relate to the local authorities' flood management planning and the site's socio-cultural and physical characteristics, detailed in Chapter 5. In addition, the case provided a site that engaged with a wide range of land managers without being too large or diverse to achieve a representative selection.

To make the most efficient use of my time, I ensured that both social and physical data collection could occur on each visit. So, a trip to a local church was combined with taking GPS data, GIS-located photographs and on-site observations of soils, geomorphology and measurements of the riverbed, etc.

A full description of the physical data collection that took place over the visits to the site and the remote and observed secondary data is listed in Appendix II.

4.1.2 Positionality and ethics

As an interdisciplinary study, this research underwent a full ethical review before data collection. Key considerations included maintaining the confidentiality of participants taking part. This includes identifying site locations, as this data would identify participants. All interview participants received an information and consent form which was completed and signed before interviews and participatory mapping commenced. Further details of the ethical considerations are detailed in the full review which is included in Appendix (V, page 396).

These formal processes can have implications for the relationship between the participant, the research and the researcher, therefore impacting the potential depth of data (McCracken, 1988). I situated the landowners/farmers as 'expert', whilst I, the university-educated researcher, was positioned as 'geographically ignorant' (Thomas et al., 2018). This put the farmer in a position of power, and I, as the researcher, could listen and record the data/knowledge they held. My catchment choice made me both an insider and outsider (Thomas et al., 2018). Whilst being an external university-educated researcher, I grew up in South Wales, in a rural setting not far from the catchment. I did not know any of my participants; however, I knew their community had shared landmarks and histories. This insider/outsider positionality and the balance of power (McCracken, 1988) impacted both the recruitment of participants and the narrative conversations that I could hold.

My fieldwork approach was pre-emptively ended by two crises: the floods in the winter of 2019/2020 and the COVID-19 pandemic. Both of which had ethical and contextual implications for the fieldwork.

During the COVID crisis, the farming community gained no respite, and the older rural community predominating the catchment were both at high risk and would suddenly have found their lines of contact severed. Given the risk to both myself and the catchment participants, the best thing I could do was to stay away. To remain in touch, I sent a message to the WI chair and newsletter, which they circulated. In addition, participants remained in touch, sending videos and pictures during flood events throughout the period. Given the catchment location, over the Welsh border, the overlapping timetables of lockdowns and regulations, as well as changes to University regulations and uncertainties of risk, it was over a year before I could return.

4.1.3 Semi-structured interviews

By using semi-structured 'long' interviews (McCracken, 1988) I was able to provide an interview 'guide' that kept interviews focused, yet enabled a 'depth' of discussion that would be otherwise unachievable. Within that, the LM was positioned to discuss topics they felt comfortable with provide information related to the subject in question.

For purposes of recruitment, I did not consider asking participants to take time out or travel for interviews. Neither did I consider an online interview as suitable for this project – at the time of planning in 2019 (pre-COVID), it was not a reasonable ask of farmers based in a rural area with poor internet signal. Travelling to the catchment to conduct the interviews had several merits. By being 'on-the-farm', I was in the place of the farmers' expertise rather than my own and this helped sway the power relationship in the farmers' favour ((McCracken, 1988), Thomas et al., 2018). In addition, it demonstrated my willingness to 'get to know' the landscape. The importance of this became evident during conversations and supported my position as insider/outsider.

Conversations needed to relate to place and space, knitting together, enmeshing the phenomenological and socio-cultural (Bender, 1993, Bender, 2010), and I used two key methods to enable this: participant mapping and the emplaced semi-structured interviews. Participant mapping as part of the interview will be discussed in greater detail below (section 4.1.4.

Most semi-structured interviews took place at the farm table, with walking interviews of smaller sites and specific features discussed in the interviews. Walking interviews have been shown to support a more even power balance in interviews, and to identify knowledge and values that are specifically linked with place (Holton and Riley, 2014). In addition, they can support the researcher/participant relationship by creating an affinity between the two (Macpherson, 2016). This walking interview relationship had to be quickly adapted on-site. I am tall and a hiker familiar with rough terrain, which had an impact on developing this 'affinity' with my participants, as did simple things like knowing how to cross a permanently closed gate (at the hinges – its strongest point!). Whilst we took maps with us, they were rarely used and referred to later, bringing both the researcher and participant 'back into' the place. This worked more practically than trying to view them whilst walking (often in the wind and rain), and in addition, it enabled not only the 're-placement' of the team but also the continuation of the 'walk' or tour in an 'imaginary' sense. Walking interviews were recorded, and a GPS route tracker used, meaning that the interview could then be 'mapped' to its location and directly associated with photographs and physical data collected en route. The emplacement, however, getting on to the farm was critical (Thomas et al., 2018), particularly in engaging with the phenomenological knowledges of land managers. At the farm table, farmers were emplaced in their farms and spoke of the land as if we were walking it. They used the map, views and body language indicating directions to emplace both of us within the landscape.

Recruitment – farmers were recruited through the identification of publicly available details on Google Maps, 'at the farm gate' (by visiting catchment and visiting farms), via gatekeepers (primarily the local parish community and Womens Institute) and via 'snowball' methods (Bryman, 2016).

Identifying farms and businesses on Google had two advantages. A wide geographic area could be covered easily from home by calling potential recruits before travelling. In addition, the distribution of potential participants could be easily seen. This method did not tell me in advance the size of each holding or the primary business of participants.

In addition, despite having business contacts publicly available, this did not guarantee that individuals wanted the number being called or gave any indication of whether they would be able to answer it. By starting with short introductions and asking for an email address or number and their permission for further contact, I could make contact with individuals without taking too much of their time.

The reliability of the 'farm-gate' technique was limited, with one excellent interview gained this way and several very quiet days travelling around seemingly empty farms leaving leaflets. I gained no interviews from the 'leaflet drop' (information leaflets are included in Appendix V.)

One of the most fruitful approaches was through the 'gatekeepers'; by including a short piece in the local parish newsletter, I gained both direct contact for future participants and a wider general awareness and knowledge of the project. The Women's Institute (WI) were also particularly supportive and I was invited to speak at an event, which also led to future participation.

Only a few participants were recruited via the 'snowball' method, as we had reached our 'saturation' point with the prior three methods.

This brought the number of sites at the fieldwork stage to 22 with 28 participants (see Figure 3.3, p 84); of these, 18 long interviews with participant mapping were conducted, and data gained for a further 4 sites.[1]

The distribution of the sites across the catchment is shown in Figure 4.1

[1]By the end of the study a further 3 sites and individuals had engaged, bringing the site total to 25 and the participant total to 31.

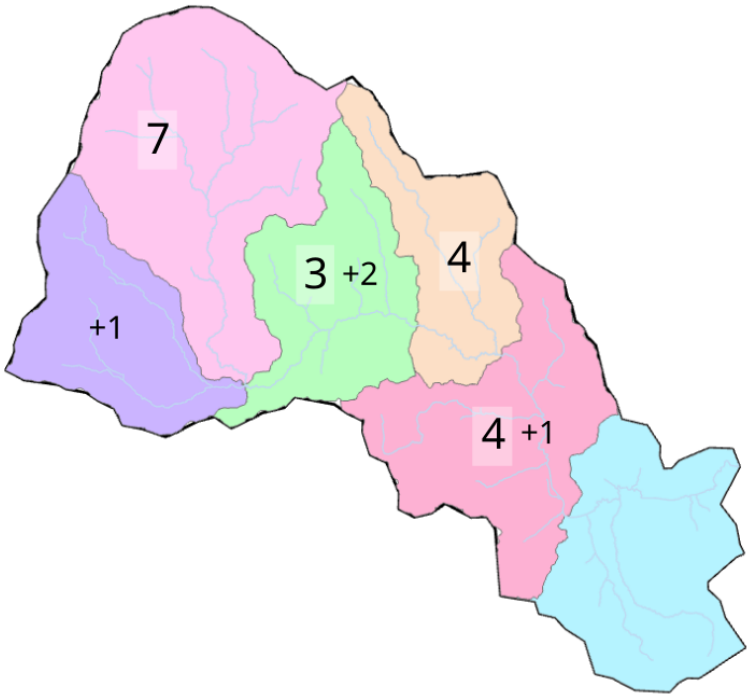


Figure 4.1: Illustration of the locations of fieldwork and interview sites. The distribution of the 22 fieldwork sites across the catchment. The smaller +1 indicates the 4 sites where interviews did not take place

In late 2019, a significant record-breaking flood event occurred (see Chapter 5. This itself would have impacted my decision to recruit further. The final group of interviews in a 'post-flood' space was planned for spring 2020. These, however, were obviously unable to take place. The reassessment of methods in light of COVID-19 and the move to online methods for the final part of the research was impractical for immediate implementation as an application for an amendment for ethical review had to take place before online interviews could be conducted. This was partly due to this methodology's access implications in a catchment with inconsistent internet access.

4.1.4 Participant Mapping

Participatory mapping and GIS (PGIS) are well established (Chambers, 2006,Pánek, 2016) with a range of methodologies being used to tackle subjects in both physical and social geographic disciplines, with examples of boundary work across both disciplines and

knowledges (e.g. McBride et al., 2017). I created simple maps showing only field boundaries (using OS vector data - see Appendix II for citations and Appendix III for an example map). During interviews, participants were encouraged to annotate maps, a method which served multiple purposes, including recording place location of physical features, routes, future or past tree cover plans, locations of experiences etc. This mapping activity was not practical in all circumstances, and whilst I carried maps with me, we only used them twice in the field. This was largely due to the practicalities of meandering around farmland. It was much more practical to complete the maps either before or after the interview while sitting at a table. The participant maps were then digitised; digitising the maps was slightly more complicated as it took place whilst in COVID-19 isolation. Not having access to an appropriately sized scanner, I had to create a camera rig that would ensure a photo was taken perpendicular to the map. This was then imported to ArcGIS and geo-located back onto the original map. By using field boundaries in the maps, this could be completed visually for each map by identifying known locations on the photographs and maps which could be digitally geo-located and locked in place. Digitising the maps gave me a geolocated dataset, which could then be combined with physical and remote sensed data as well as region-coded alongside the interviews in Nvivo. The coded maps and interviews formed a combined dataset, which was used to explore impacts, including that of place-based expertise. Physical features and preferences identified in the mapping dataset were used to inform and develop the SHETRAN hydrological model (Chapter 7). Alternative land-use scenarios directly informed by the participant maps were modelled to explore changes to the catchment hydrology (table 8.2 and Appendix X).

4.1.5 Participatory observation

During the fieldwork, I undertook 'participatory observation' or "Participant-as-Observer" (Gold, 1958 in Babchuk, 1962, p225). This is not a full ethnographic study and is more closely related to 'participant observation; the researcher is not an external observer but actively engages in activities and conversations. Dissemination/information meetings with the community and local organisations occurred between July 2019 and February

2020, including meetings with the local WI group, the Natural Resources Wales team in Monmouth and the Wye Valley AONB. In a meeting with Wye Valley AONB, I became a little more entangled in the floods I was studying than I had intended. An emergency evacuation of the premises was conducted because the River Wye, which had already broken its banks (we were a few km upstream of the Trothy confluence), was rising rapidly and at risk of flooding and cutting off my way home.

I attended regular community coffee mornings in Llanvapley and began to be recognised on my walks around the catchment, visiting not only farms and hydrological sites but also the local churches, the cafe in Dingestow, and working on the benches at White Castle. My last few visits to the catchment included presenting at a Wye AONB conference on Natural Flood Management. Face-to-face engagement with the catchment in this way came to an end in February 2020

4.2 Analytical approach

As I've described, this research took a constructivist grounded theory (inductive) approach. The benefits of grounded theory as an analytical approach to understanding processes, voices and implications for professional practice have been well evidenced (Charmaz, 2014, Charmaz and Thornberg, 2021). Data has been coded, and analytical memos recorded (reflecting on both themes and researcher reflexivity) at multiple stages throughout the project, including;

- identification of provisional themes during collection and transcription,
- during analysis for the development of the hydrological model,
- and in specific preparation for this chapter on knowledge and choices.

This last focused practice used thematic analysis across two stages. In the initial stage of the focused analysis, mind maps of the most important, or focused codes (Charmaz, 2014) were identified for each interview transcription (utilising methods reflecting those of Fearnley, 2022). See Appendix VI for examples.

These maps were used to identify themes/categories (Denscombe, 2007, McCracken, 1988) which related codes and were evident across the interviews (see thematic coding structure – Appendix VII). Transcriptions, maps and photographs were then uploaded into Nvivo and coded in detail against this thematic coding structure.

Whilst provisional theories were identified whilst developing the thesis research questions, this grounded theory approach raised thematic considerations and theories that may have otherwise been assumed irrelevant to the subject matter and have not yet been identified in related literature. It demonstrated the different priorities of knowledge production. Had I followed the substantive literature and theories of 'socially constructed' knowledges on farmer decision-making (section 2.4), the importance of shape and landscape may not have been recognised. Considering the importance of these under-researched themes, this may answer some of the critiques of grounded theory, particularly the practical difficulties and time demands (Bryman, 2016).

Chapter 5

Case Study: Dalgylch Afon Trothy | The Trothy river catchment

Contents

5.1 Catchment Characteristics - Physical 101

5.2 Catchment Characteristics - Trees 110

5.3 Catchment Characteristics - Floods 112

5.4 Catchment Characteristics - Policy and Governance 115

5.1 Catchment Characteristics - Physical

This subsection describes the catchment's physical characteristics, including the soils, geology and climate.

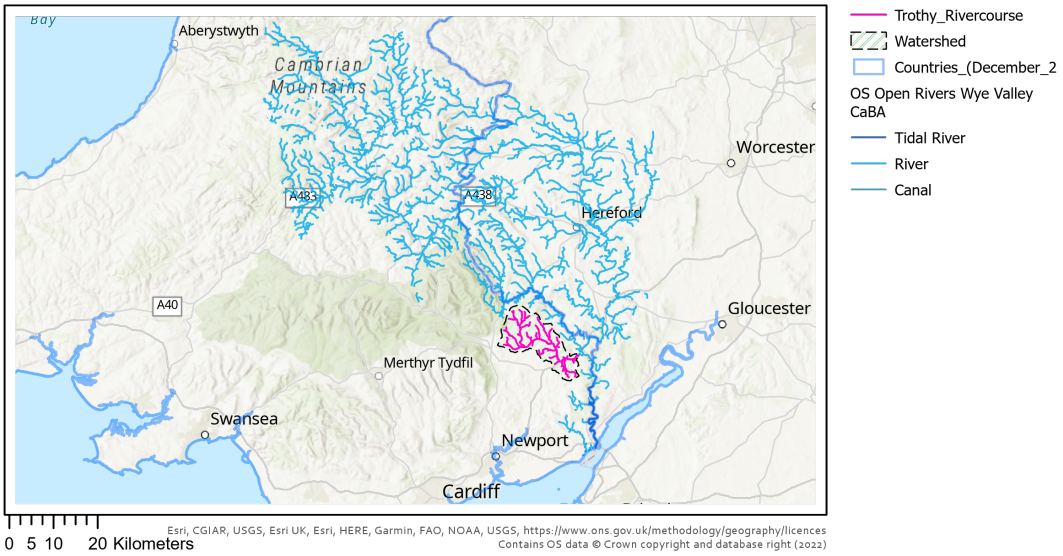


Figure 5.1: Location and area of the Trothy River Catchment/Watershed

Afon Trothy | The River Trothy is a tributary of the River Wye, joining it just below the confluence of the River Monnow and just after the Wye has flowed South Monmouth town. It is over 40km long from the confluence with the Wye to its estimated source at Blaen Trothy, but this frames the river as a single stretch, whilst, like most rivers, it is the sum of multiple branches.



Figure 5.2: The river Trothy during high flows, showing two very different bank profiles; photos taken within a 1km stretch *Participant photographs, consent to use granted*

The vegetation of the riverbank and riverbed profile change along its length. Characteristically the riverbed is deep, partly due to small-scale dredging and 'maintenance' but also to the sandy soil structure of the superficial deposits.

Catchment climate: The catchment has an average annual rainfall in the standard time (1961 - 1990) of 887mm. However, this is significantly spatially variable across the catchment, being wetter in the North West and drier in the South East (NRFA, n.d.). There is a seasonal precipitation pattern with the highest precipitation occurring between October and February and lowest between March and September[1]. The catchment wetness (proportion of time the soils are wet) is 36% (NRFA, n.d.).

Soils and Geology: Whilst near the limestone outcrops of the Wye Valley, the underlying bedrock of the Trothy catchment is predominantly Raglan mudstone (RG) formation in the South, St Maughans Formation (SMG - sedimentary sandstone) in the North and an area of Brownstones in the centre of the catchment - all three types are fluvial in origin and local to South Wales and the Welsh Borderlands.

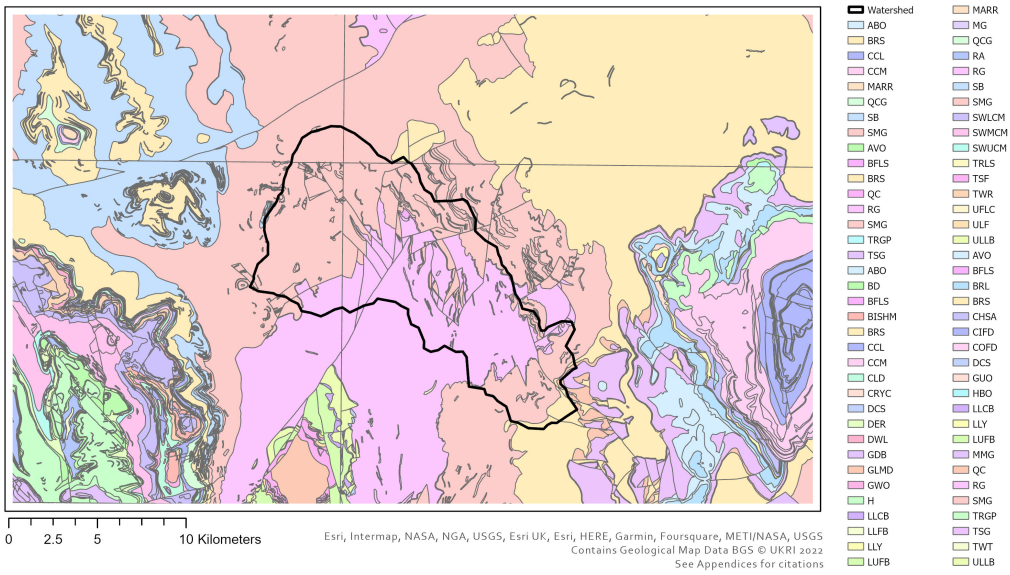


Figure 5.3: Bedrock of the Trothy River Catchment

The catchment soils are characterised by two key areas, in the North East and South

[1] Average monthly precipitation calculated using Catchment Daily Rainfall (CDR) data between 1969 - 2017, downloaded from NRFA, n.d.

West, and the fluvial deposits along the riverbed and floodplains. The soils are of a deep rich loam (cambisols), with more clay content and shallower soils in the north-east (luvisols). The river bed is characterised by sandy, freely draining floodplain soil, and there are small areas of silty clay loam floodplain soil. Four primary soil types were identified in the Cranfield viewer [2] numbers 18:ClayLoam, 6:SiltyClayLoam, 8:ClayLoam, 12:SandySiltLoam (Cranfield University, 2021).

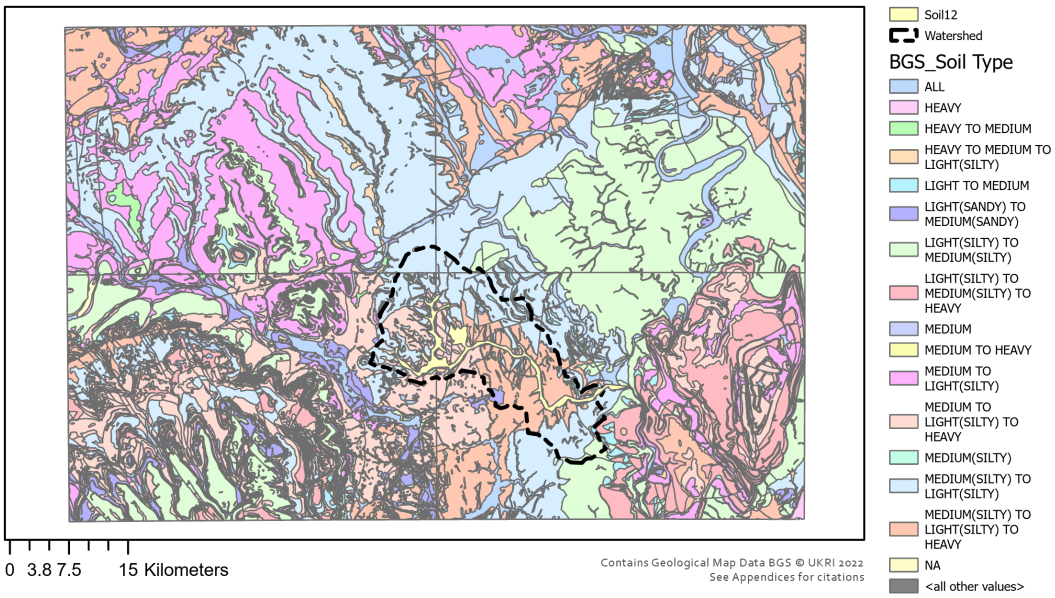


Figure 5.4: Geological structure and parent soil types of the Trothy River Catchment

The catchment soils are deep - despite the classified soil type identifying an 'intermediary' depth. Information from farmers was supported by the SoilsGrid dataset (see Appendix II), which indicated a significant deep loam layer. I have talked in the literature review (Section 2.2.3) and Chapter 8 about the importance and uncertainty of quantifying soil type and depth - particularly in a catchment of this size.

After I had completed the initial data collection and modelling, the Welsh Government published the results of an extensive project improving and updating the soils dataset (Welsh Government, 2022). This dataset should support future modelling within Wales and contributes considerably to the ability to investigate landscapes over large scales where individual measurements are unachievable.

[2] http://www.landis.org.uk/soilscapes/

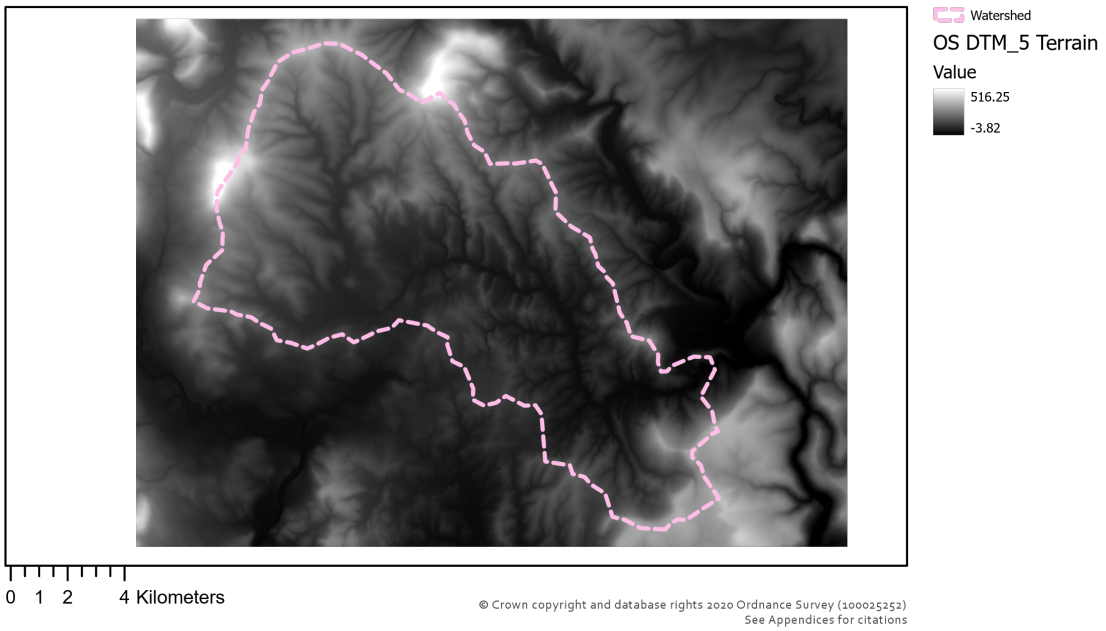


Figure 5.5: Topography from Lidar data of the Trothy River Catchment

The catchment is approximately 140km^2; its highest point at 484m is the peak of Skirrid Fawr, the last reminder of the mountainous Bannau Brycheiniog (Brecon Beacons). The ridge line between Skirrid and The Graig rises and falls between 200m-400m. From here, the landscape becomes more gentle, though its rolling nature hides multiple complex features, with some river valleys wide, smooth, and well-maintained and others more like ravines with ancient Alders clinging to rich soils in unmanageable gullies (Quote 12, p 127.

The catchment has a rich and fascinating history, a true border between Wales and England. The remains of Penrhos Motte and Bailey, Grace Dieu Abbey and White Castle (fortified against Llwyelyn ap Gruffydd, Prince of Gwynedd(CADW, n.d.-a)) mark an unsettled history. Whilst battles receded, the landscape has still changed in ownership and us. For example, Hen Gwrt moated manor house was owned in the 13th Century by the Bishops of Llandaff, in the 15th Century unoccupied for agricultural use and in the 16th Century, probably as a hunting lodge within the deer park of the Herberts of Raglan Castle(CADW, n.d.-b).



Figure 5.6: White Castle, one of three castles built to defend the southern Welsh / English border; *image authors own*

In 1862, George Borrow states that the county of Monmouthshire is English but that "many thousands of its population still speak the Welsh language" (George Borrow, 2011, p.601); something reflected by field names but not by my participants. This suggests that many who worked in the catchment likely identified as Welsh despite predominantly English ownership. The Wales vs. England dynamic has continued to shape the area, with the local town of Monmouth only finally falling on one side of the border in 1974 ("The Monmouthshire myth", 2016). This division is still perceived today, with a participant describing themselves as probably classed as one of the 'rich English' despite perceiving themselves as comparatively not having much capital. The proportion of ownership changed significantly following the introduction of death duties (in particular estate duties) and the world wars (Fletcher, 2021, Hoskins, 2014), enabling many properties to be bought by those working the sites[3]. Many sales have occurred since land registration became compulsory, and the oldest of the large estates can be identified by their absence from the holdings map (Figure 5.7). The 1970s saw landscape change in regard to catchment diversity, however, the field expansion seen across the UK (Rackham, 2015) is here only seen on a small scale, with one or two fields being combined, rather than vast struc-

[3]including women, one of my participants shared the land sale details and stories of how his Great Grandmother worked to raise the capital to buy the house his family now lives in

tural change. The catchment is now made up of multiple small farms, small holdings and rural dwellings.

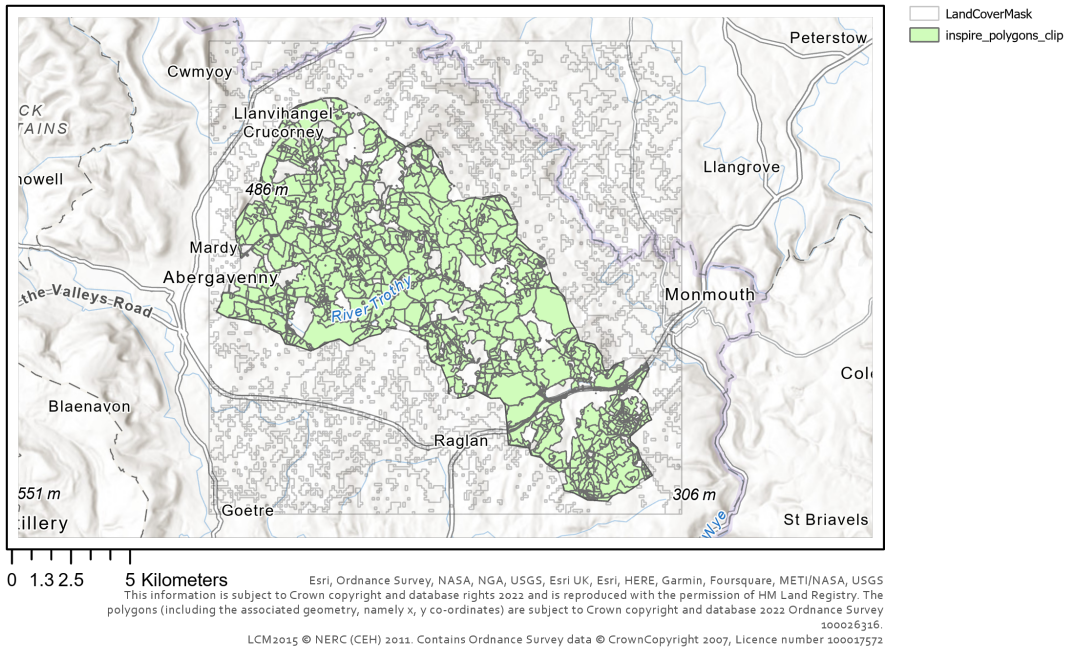


Figure 5.7: Registered Land Holdings demonstrating the complex ownership within the Trothy River Catchment

Table 5.1: The land holdings data from the INSPIRE polygons

Land Holding in Hectares	n	sum (Hectares)	Percent total recorded land (%)
(1-10]	614	2638	23.421824
(10-20]	137	1994	17.703986
(20-30]	46	1152	10.228181
(30-40]	36	1283	11.391281
(40-50]	15	680	6.037468
(50-60]	18	996	8.843115
(60-70]	7	462	4.101927
(70-80]	5	374	3.320607
(80-90]	3	258	2.290686
(110-120]	3	345	3.063127
(140-150]	1	146	1.296280
(190-200]	2	385	3.418272
(200-210]	1	208	1.846755

A ‘rural’ catchment, characterised by mixed farming, there are multiple dispersed dwellings and small conurbations. Whilst satellite imagery and land cover data often

presents a fairly 'people-free' perspective of the landscapes, Figure 5.8 gives a better indication of how distributed and integrated dwellings and habitats really are[4].

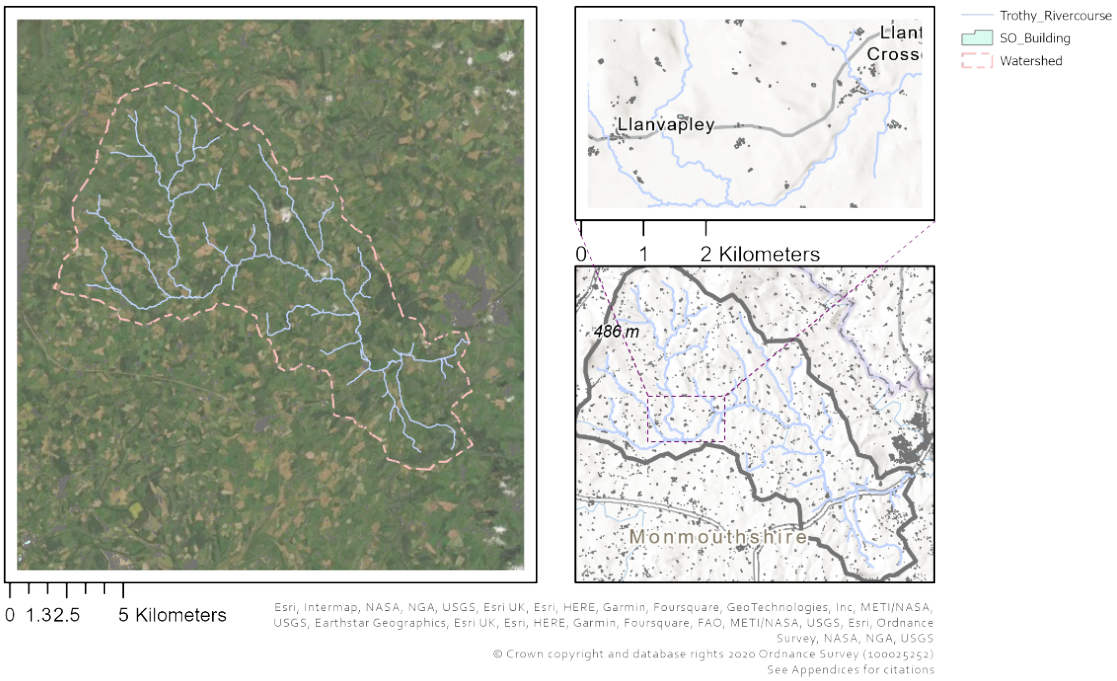


Figure 5.8: Catchment watershed and River Trothy overlaid with the OS vector data for buildings (see credits and Appendix II)

Table 5.1 shows the distribution of holdings above 1 hectare (2.5 acres) a size significant enough to implement changes in land-use. Nearly a quarter of the catchment is held as Small Holdings at less that 10 hectares / 25 acres. The majority of holdings, over 77% of the catchment, would be considered small farms at less than 60 hectares / 150 acres. Whilst one land manager may own more than one holding, they were largely considered and managed as individual farms.

[4]Where necessary larger figures and graphs have been included in Appendix I

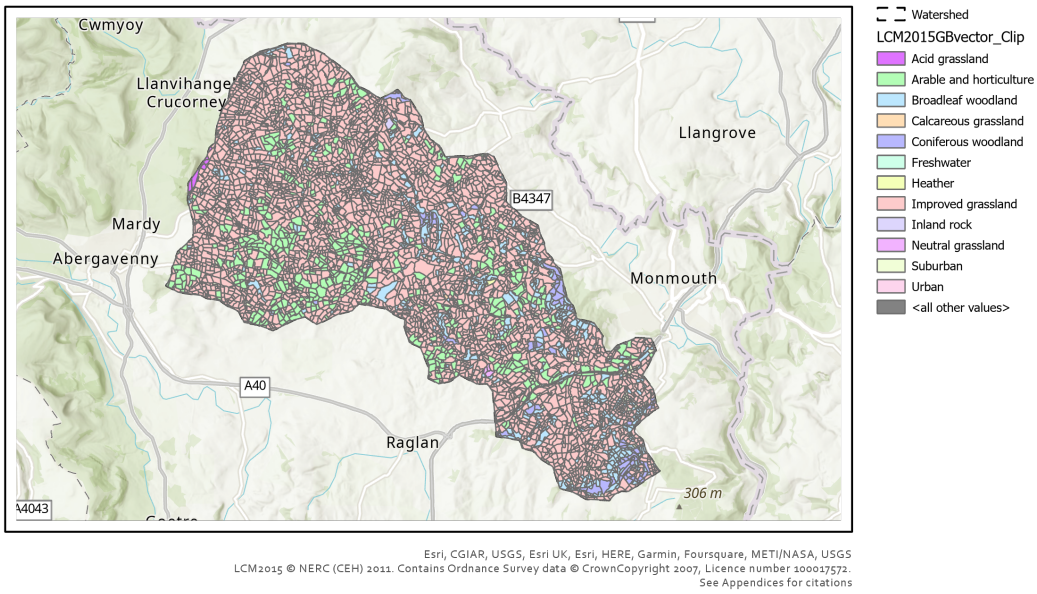


Figure 5.9: Categorized Land Cover data from the CEH 2015 dataset (see credits and Appendix II) of the Trothy River Catchment

The landscape is dominated by permanent pasture or 'improved' grassland. Whilst catchment land use was classified as predominantly dairy in the 90s (e.g. Hooda et al., 2000), most farms maintained a diverse approach. This is reflected in the diverse range of rural enterprises and farm trajectories amongst the interviewees, which will not be reflected in the farm data recorded and analysed for agricultural surveys[5].

[5]Agricultural surveys collect and aggregate stock and volume data enabling a broad overview of change (Welsh Government, 2021a)

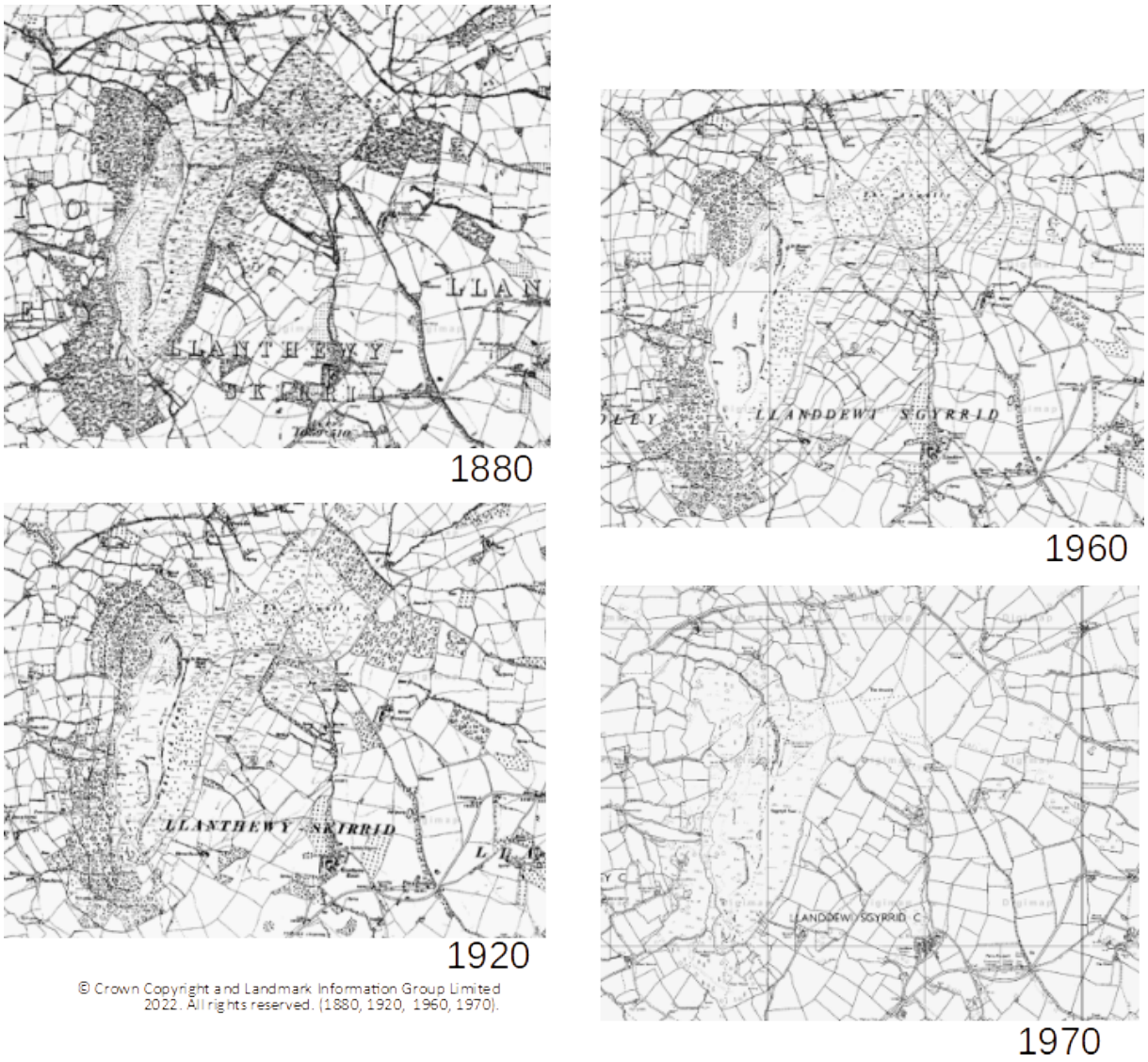


Figure 5.10: The historical maps of Skirrid Fawr at the North end of the Trothy Catchment; 1880, 1920, 1960 and 1970 respectively

5.2 Catchment Characteristics - Trees

This section describes the nature of tree cover historically and contemporaneously within the catchment.

In Rackhams (2022) posthumously published 'The Woods of South East Wales', there is a significant (frustrating) gap between Skirrid Fawr and the English border, where Rackham did not wish to replicate work conducted by George Peterkin around the River Wye. This leaves the Trothy catchment as an under-researched area in regard to its tree cover. However, certain inferences can be made.

Being a predominantly agricultural catchment, the proportional mix of biodiverse woods, plantation crops, wood pasture, parkland and Hedgerows may be representative of the Trothy catchment for significant time. Unlike much of South Wales (Rackham, 2022), there was only gradual change between 1880 and 1960, shown in Figure 5.10. Between the 1960s and 1970s, there was a significant loss of the smaller woods although this is likely to amount to only a few percent of total land cover.

There is significant uncertainty, however, in the maps themselves. Two wooded landscape types are identified by Rackham existing in South Wales that have no extant 'type' in England: Fridd and Coed Cae (Rackham, 2022). Fridd is akin to scrub but would include standard trees, smaller shrubs and diverse grasses. Coed Cae is more complex; Rackham describes it as difficult to tell whether woodland is becoming field or field becoming woodland. This type of landscape, being unrecognised in England, is therefore not included as an identified feature in the maps (only what is counted counts (Turnhout et al., 2014). Landscapes are roughly defined based on the assumptions of the cartographer, with no record of the reasoning behind decisions. This makes tracking woodland change in the catchment difficult, and the loss is possibly underestimated.



Figure 5.11: Photos showing representative 'wooded' features, riparian, small woodland and hedge in the South of the Catchment. Images authors own

Most of the small woods are plantations of one sort or another. Oak woods only really appear in the older parkland sites, with the mixed woodlands being expanded hedgerows or Riparian woods, including much Willow and Alder. Plantation woods outside the NRW-managed site at the South end of the catchment are either Ash or, in a few cases, Larch. There has been a fluctuating number of Orchards in the catchment, with a large

site owned by a major cider manufacturer. The number of active orchards has probably been the greatest change in tree cover and has increased then decreased along with the cider market during the PhD.

5.3 Catchment Characteristics - Floods

This section describes the flooding within the Trothy catchment, exploring the aspects that make it a likely candidate for Natural Flood Management approaches.

The Trothy flooding will go unnoticed by most outside of the catchment. Much of the flooded land is agricultural, although areas impacting the public – roads, the caravan park, do flood – the river doesn't have the tenacity to enter people's homes – keeping its emotional impact at bay. The costs of the floods are then somewhat hidden. The risk people put themselves in protecting livestock and the (animal) lives lost when that doesn't happen will not be 'reported' outside the community. The gates, fences, hay bales, roads and bridges damaged or lost are on private land. One farmer has a public right of way across the bridge that ensures access to their farm. If the bridge collapses, then funds are available to rebuild it – but only if appropriate for the size of a footpath, not the access needed for the farm. When I asked another landowner how they evaluated the state of the bridges, he told me that he didn't look, it was going to be so difficult to replace he just didn't want to know. These hidden costs are not brought to the attention of the wider public or public institutions as they are an accepted part of the behaviour of the river.



Figure 5.12: (LH) Trothy in Flood, 12th Feb 2014 at 17:10; (RH) The same view standing 6ft further back across the bridge *LH Photo contributed by catchment resident permissions for use granted; RH photo authors own*



Figure 5.13: The bridge in figure 5.12 showing the extent of the flood waters. *Photo contributed by catchment resident permissions for use granted*

The Trothy breaks its banks, particularly along the mid to lower lengths, where the larger tributaries have joined it, bringing the water from all three sides of the large 'bowl' into the channel. A funnel near the middle of the catchment sees particularly spectacular flooding here, and the river's path has moved across the valley bottom – which can be seen from the older maps and the positioning of bridges for the roads and paths that cut across the floodplain. The roads are well above the river wherever possible and along the ridgeline of the catchment around the hills. No straight Roman roads here. The floods are also characterised by their speed; the Trothy can break its banks and retreat in under 12 hours. One participant only realised an overnight flood had occurred when they found the contents of their garden two fields further down.

Despite the size and speed of the floods, the Trothy has only claimed one death over recent history; most participants loosely recalled the story, but only one told me in detail. A car being driven across the Trothy during a flood was swept away; the driver escaped, but her mother unfortunately did not. To children, disconnected from death and with no relation to the individual loss, this unpleasant end became "one of our favourite tales". This sounds a bit grim, but it isn't; the telling of these tales is part of the storymaking that enables communities to share the knowledge of the river and ensure that the next

generation are safe (Maitland, 2013). They are disconnected from all the characters in the story except the river. However, these tales only work when community knowledge is intact, and the river behaves as expected. No one who worked on, knew or observed the river expected the floods to stop.

When I started this project, there was little concern about the river; serious floods felt few and far between, with some older members remembering that they used to be more frequent. The highest recorded flood event occurred on Monday, 30th Oct 2000 and reached 3.82m at 6:15am. The most recent high had been Wednesday 1st January 2014 at 7:45pm reaching 3.79m, and December 2013 to March 2014 was chosen as the study period. (riverlevels.uk, 2019)

Since the identification of the study site in May 2019 the behaviour of the river has significantly changed.

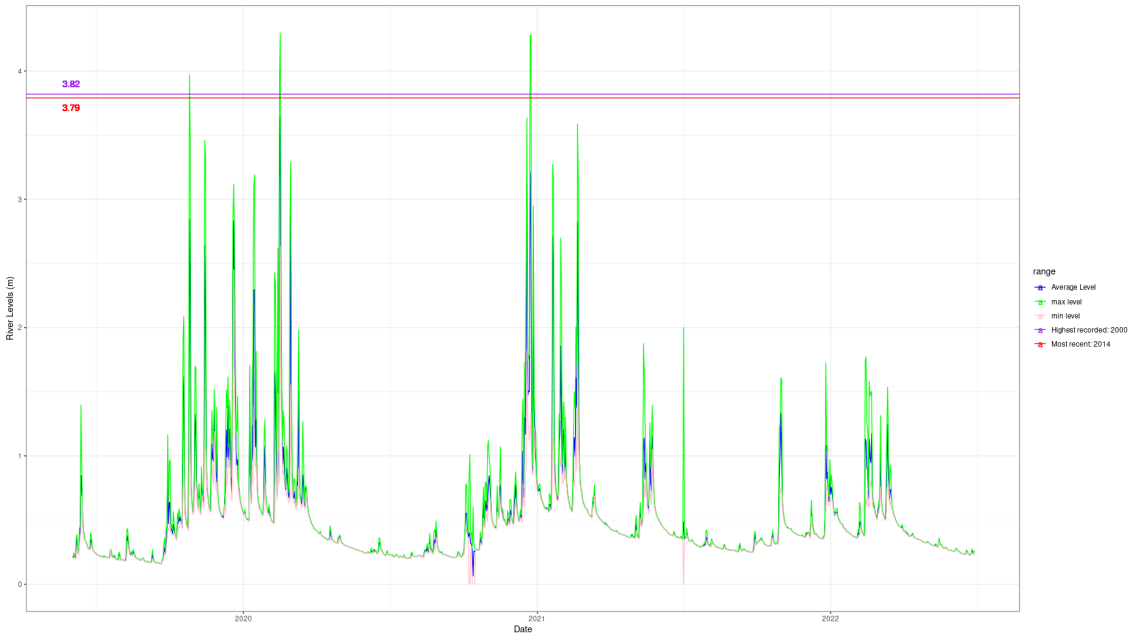


Figure 5.14: Trothy River levels between 1st June 2019 and 30th June 2022, whilst the Trothy flooded on multiple occasions, it broke its highest ever recorded levels on three separate dates, October 2019, February 2020 and December 2020

A series of record-breaking floods have been followed by a year of significant drought. This timeline has formed the backdrop of the research and is explored further in the final Chapter 11 (see Figure 11.2).

5.4 Catchment Characteristics - Policy and Governance

The policies and agencies shaping land use, the river and flood management within the Trothy catchment are complex. Relatively recent devolution, combined with the complex cross-border approaches have largely created confusion even greater than that of the average riparian landowner (Thomas et al., 2019). Figure 5.15 lays out the key actors and agencies currently impacting the landscape where 'Trees for NFM' is likely to be implemented.

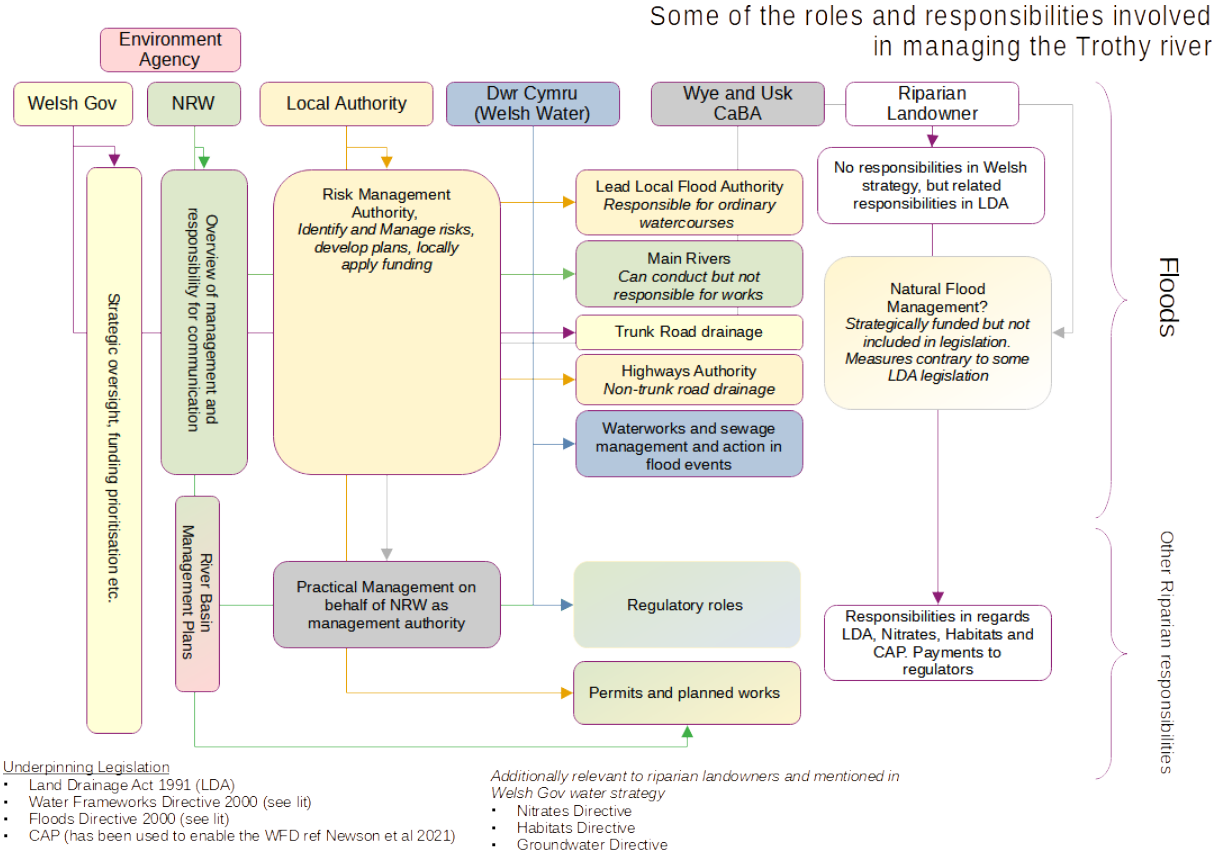


Figure 5.15: This figure maps some (but not all) of the relevant roles and responsibilities in decision-making and management of the river.

An example of the impact of this complex network of responsibility demonstrates a direct impact on Trees: There are misconceptions around whether trees should or shouldn't be removed, with one participant claiming their neighbour had been told by the 'water-board' to remove all the trees due to impacts on water quality. As there are no conifer blocks near the river, one can only assume this is a severe misunderstanding of recommen-

dations from the advisor, or a misinterpretation by the neighbour. However, it prompted the removal of many trees which my participant was helping clear.

The Natural Flood Risk Management Fund (NRW, 2020a) has granted Risk Management Authorities (RMAs) significant funding for the implementation of NFM and this would apply to the catchment. The Trothy is categorised as a 'low level risk' river in the RMA Flood Management Plan (Monmouthshire County Council, 2016), however, this is related primarily to an economic assessment rather than any reflection on the behaviour of the river. Continued building in the floodplain is likely to raise the risk level of the river, and in a very unusual action, the Welsh Government stepped in to withdraw an already granted large planning application in the catchment based on flooding from both the Trothy and River Wye (Julie James M.P., 2019). Whilst the Trothy maintains its current risk level, the only 'cost efficient' flood management interventions that could be funded in the catchment would be catchment-based NFM. In its draft climate strategy discussed at the County Council meeting on the 24th October, Monmouthshire was considering both NFM interventions and a commitment to planting 10,000 trees by 2022 (Monmouthshire County Council, 2019).

The Trothy catchment was chosen as a case study as, when considering river catchments of around 100km^2 in the UK, it was considered to be one of the less complicated systems. It did not cross devolved borders, was not part of a national park, and with a few exceptions, land management was classified as largely private and agricultural. Despite this, the case presented so far is a complex puzzle of physical, social and ecological interactions. It is already becoming clear that the socio-cultural and bio-physical characteristics of the catchment are hard to untangle, and I have therefore not tried to force them apart in the manner that might normally be considered suitable for this sort of case study presentation. Chapter 6 delves further into the catchment, and draws out characteristics which explore this entanglement and how it impacts Trees for Natural Flood Management.

Chapter 6

Fieldwork in the F/field

Contents

6.1 Introduction **117**

6.2 The importance of lived experience **118**

6.2.1 Lived Experience: Encounters, Topography and multi-natural landscapes 118

6.2.2 Understanding landscapes: Policy interactions and political rhetoric 141

6.3 Complex knowledges and relevant experts **148**

6.3.1 Decision-making 148

6.3.2 Experts in their F/fields 155

6.4 Summary and impacts **164**

6.1 Introduction

Since Brian Wynne's seminal work 'May sheep safely graze' (Wynne, 1996), literature across disciplines has identified the importance of place-based knowledge(s) and local experts (section 2.5). I proposed that farmers/land managers may have relevant knowledge and expertise that could inform and shape the project and, therefore, should start my

data collection 'in the field'. I actually started 'at the farm table' with a cup of tea, but the principle is the same.

This chapter draws on the fieldwork detailed in Chapter 4. Through the analysis of this data, I explore the relevant knowledge and expertise of farmers and land managers regarding increasing tree cover for natural flood management within the Trothy catchment and how this impacts decision-making and political behaviours.

After this introduction, section 6.2 explores farmers lived experience as a 'way of knowing' the landscape. I show how this experience is an entangled part of LM knowledge culture: reflects a complex co-produced landscape: and directly informs strong 'evidence-based' policy critiques. Section 6.3 delves further into this knowledge culture and the concept of 'relevant' expertise. I find that LM's ways of knowing (including lived experience and narratives) reflect a complex set of drivers that inform decision-making; that LMs hold directly relevant knowledge regarding Trees for NFM, both for 'science' and 'non-scientisable'; and I reflect on the attribution of 'expertise' and its implications.

After summarising the findings, I finish this chapter by reflecting briefly on aspects of the field study that could not be explored, expanded or included in the thesis: missing voices.

6.2 The importance of lived experience

6.2.1 Lived Experience: Encounters, Topography and multi-natural landscapes

Understanding Landscapes: entangled lived experience

In Chapter 2, I introduced the concept of lived experience as a way of knowing the landscape (section 2.4.3) and as part of land managers (LMs) knowledge culture (section 2.5.3). I found in the field that lived experience played a significant part in participants' knowledge and ways of knowing the Trothy River catchment, specifically in relation to the portion of landscape over which LMs had agency to enact change. It directly informed

knowledges that are normally attributed to science (such as the ground hydrology and soil structure), was rarely utilised in isolation and had complex spatial and temporal limitations and implications.

Language that describes embodied experience, words like squishy and boggy, were used to describe wetter areas of the farm. These words are physical ones, LMs know how the water moves around the landscape because they have walked through it, they have physically experienced it's changes in texture, as directly as the support it provided to the feet doing the walking.

> "Ah, we didn't look at the squishy edge of the field. So the stream comes in right down that edge between us and let's have a little wander and I can show you."
>
> *F19.1*

> "P: this ends up being very wet and swampy for want of a better phrase, because where the rivers flooded, and dropped silt across the top it runs to the river"
>
> *F2.1*

> "A: This is red clay and it sets like concrete in the summer and then you get rain on it and rain on it this, this is like a skating rink and you can't drive along here."
>
> *F2.2*

Embodied experience sometimes extended beyond the individual physical body to the use of machinery, described in such a way that the machinery is an extension of the physicality of the farmer, referring to 'you' meaning the farmer and the machine.

> "If you go across there you'll be sunk creating ruts, deep ruts."
>
> *F5.1*

An embodied experience could be directly related to memory, sometimes a particular event. Brigit was terrified of flood water, and in discussing this related it to the memory

of walking through the waters with her father, showing with her hands how he would test the depth as they went through.

> "And when we were kids there were a really scruffy bridge, in those days, they didn't build them like they do now. Dad always had a rake and as we walked along he'd go like that you know, to make sure the road, the road was actually there."
>
> *F18.1*

This embodied experience is part of several forms of lived experience that contributed LMs understanding of the landscape. These include event-based observation, observation of changes to the landscape over time, experiences of the cultural behaviours of friends, neighbours, policy representatives within the landscape, observations of non-human agency or how the shape of the landscape affected management choices and, therefore, social interactions.

In critiquing phenomenological approaches literatures argue that practitioners needed to avoid making an ahistorical attempt to understand people's activities within the landscape (2.4.3). This assumes an approach in which lived experience is treated in isolation from all other factors. In fact, LMs rarely spoke of embodied experience, memory or lived observation in isolation. Experience was directly linked to scientific and/or cultural-historic knowledge of the landscape, explaining the characteristic within context or for purpose.

When describing how the Trothy flooded, Matthew linked the behaviour of the river to a story he had been told as a child.

> "When we were going to school in Monmouth as children, [...] one of the standard stories that we always loved to hear on our way into school was Mrs Prestatyn-Jones being swept away and drowned by the river Trothy at, just next to the recycling centre. Mrs Jones was one of our teachers there, [...] and she and her mum came across the Trothy bridge in a spate, I'm guessing in

> the 70s and I think their car got swept away and her mum got swept off and drowned.... so that was one of the local pieces of folklore showing the danger of the Trothy."
>
> *F19.2*

These interviews made an important reflection on a further critique of 'dwelling' perspectives (40) apparent. Whilst time theoretically provides opportunities for greater experience, it did not guarantee it and neither did a lack of time 'in place' necessarily relate directly to the depth of knowledge held. Whether younger, newer or just outsider, LMs did not arrive in the place as empty vessels starting from scratch, they were able to use their wider knowledge, their knowledge of other places and communities to shape and develop their knowledge of this new place either through active dwelling, or making the effort to draw more readily on local sources.

Jack described himself as an outsider, referring to his family heritage in Wales whilst acknowledging his need to rapidly increase his knowledge.

> "We're in the observation stage, got to work out the landscape before we make changes. I walk around looking for this kind of thing whereas other farmers might not."
>
> *F9.1*

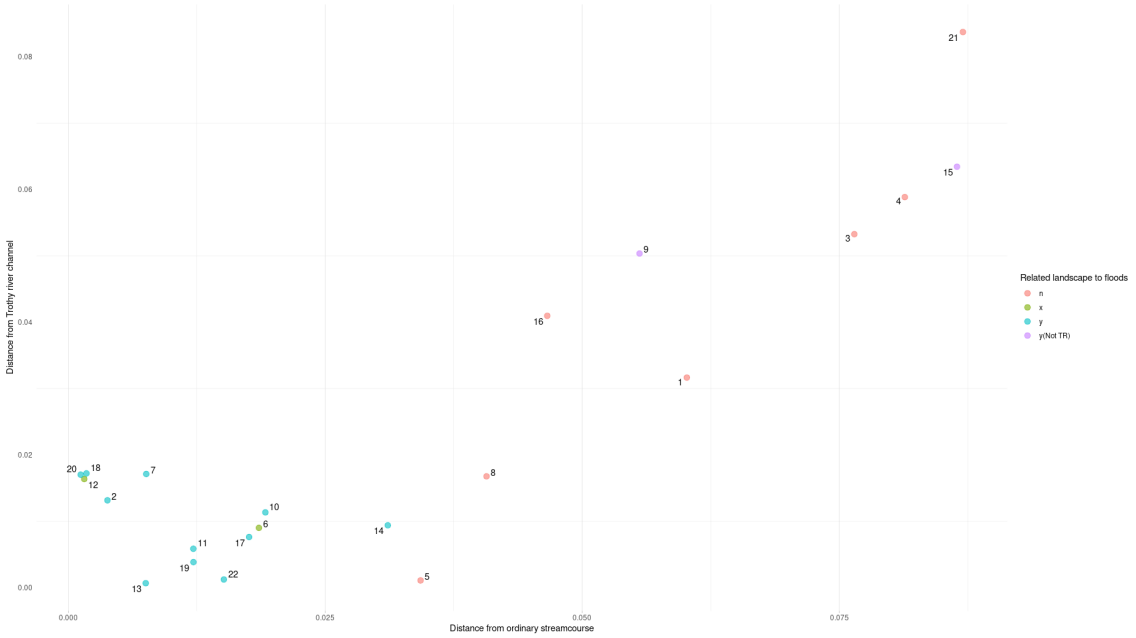
Frank and his son, being newly arrived, were rapidly expanding their knowledge of the 'farm' to encompass knowledge of the 'place'. Historical knowledge of previous practice was directly related to physical features of the site, some of which were uncovered by the family; read from the landscape they arrived at. Where knowledge couldn't be gleaned, it was informed by neighbours and community networks.

> "The locals are telling me, there's no springs the other side[...], all the strata in the hill bring the water out this side."
>
> *F1.1*

There was a value to the place-based knowledge that the community held and they had set to learn.

The extent of LMs lived experience also had a spatial element; the extent to which they had access and the characteristics of that extent.

Furthest from river



Closest to river

Figure 6.1: Abstract showing the relationship between participants' perception/narrative of the relationship between landscape and river, to the distance from and thus experience of the river itself.

Figure 6.1 indicates the relationship between participants' distance from the river (y-axis / height increases with distance from the main river, x-axis increases with distance from ordinary watercourse). The colour indicates whether they shared knowledge of the river floods within the interview and, importantly, regarded it relevant to their landscape. The closer LMs land was to the main river the more likely it was to flood. This was reflected in LMs interviews by clearer recognition of a relationship between the landscape and the floods. Where LMs a long distance from the river demonstrated a similar under-

standing of the behaviour of the landscape and flooding this was related to extra-local knowledge (education) or lived experience elsewhere (working a farm close to a different river.)

The temporal and spatial extent of lived experience can be framed as limitation and uncertainty, which I will discuss later in this thesis. However, as discussed, lived experience was rarely discussed in isolation and in subsection 6.3 (p 148) I will expand on what this means for decision-making and attribution of expertise.

Fundamentally lived experience informs LMs' knowledge of landscape and place. It is a way of knowing that is part of a rich, entangled knowledge. There is a spatial element to this. Where somebody is in the landscape affects their knowledge and understanding of the landscape itself. In the next two subsections, I want to draw attention to two specific 'encounters' with landscape: Topography and more-than-human agency. These examples of lived experience have specific relevance to the project in regard to both LMs decision-making and the current scientific practice of exploring the impacts of increasing tree cover for NFM.

Encountering catchment topography and watershed

A phenomenological approach engages with the materiality of landscapes and sits, therefore, at the boundary between social and physical sciences. In this section I explore how LMs embodied experience of the catchment's physical characteristics (topography, soil behaviours) is part of the socio-cultural and bio-physical co-production of landscapes and directly relevant to the challenge of Trees for NFM.

Part of the process of modelling hydrological behaviour depends on validation that relies on the knowledge of the modeller and their perceptual model of the catchment 2.2.3. I should be able to assess the topography of the landscape (supported by additional information of soil structure, moisture and vegetation) and assess whether the model is 'behaving' appropriately (Beven, 2012). For example, if the river is at any point flowing uphill - I know a fundamental law of physics has been broken and I (or the model) have got

something drastically wrong. Analysing the output of the baseline model, with catchment boundaries, DEM and mapped records of the river's route enable me to analyse whether the paths and flows shown on the model are representative. As well as furthering an understanding of knowledge of place, a question for this section is what or in fact whether, knowledge is held by participants that may inform, impact or influence this process (and by association the researcher (Beven and Chappell, 2021).

Knowledge of the shape, the topography of the catchment and the subsequent path of the water throughout (in particular catchment boundaries) is not endemic or complete across all participants, though a clear understanding of my meaning when I talk about the river catchment is demonstrated. Participants know the river and its tributaries within their own land and familiar surroundings, and most know where it has come from. As previously described (Fig 6.1), spatial limitations impacted the participants' experience of, and their understanding of the relationship between their landscape and floods. The upstream origins of the river were better expressed than where it goes on to, with locals who have lived in the area their whole lives being unsure as to whether it joins the Monnow or the Wye as "I've never really walked down to that" *F18.2.* Knowledge is demonstrated at different resolutions and lived experience of the space is one of the strongest factors in developing the fine resolution.

Frank's farm crosses the catchment boundary, and he has made it his business to know where all the water on his farm goes.

> "You want to know where the line is for the watershed [marks on map]..... it nearly follows the road, there's a couple of fields there that just tip a little bit and it would go from 40m inside there. So all of that lot goes to the Trothy and all of that lot goes to Grosmont. And this up the road is the watershed there, that would go to the Trothy, most of this comes this way, off the edge, off the edge, some of that comes down the road yeah and there's a fair bit off that when it rains a lot, just going out of the gate and down the road."

F1.2

The relationship that Frank describes between roads and the river comes up again in conversations and when I'm travelling around the catchment.

Given its deep channel and relatively small width the Trothy is rarely visible from the road (6.2). However, after a while you learn to recognise the type of vegetation and riparian tree growth, hinting at the river they shadow. Whether you know the river is there or not your direction of travel is determined by its course, and its floods.



Figure 6.2: The closest line of trees, which could easily be mistaken for an overgrown hedge in this catchment, hides the Trothy.

The road follows a route determined by physical attributes and social needs. Whilst it appears to be a material embodiment of culture, (it maintains a route between two settlements), its path follows the smoothest 'material' line, the ridge or the river valley, it is the topography and the behaviour of the river that determine its route. The Trothy's destructive flash flooding means the road cannot sit on the valley floor but has to edge around slightly higher, taking otherwise unnecessary corners. The landscape is co-produced, the topography determined by culture and physical environment. The river places the road, the road places the site of new houses, new houses require works to the river, adding bridges, and changing its floodplain.

This impact of shape, slope and hydrological behaviour is obvious in roads. Participants working and living in the landscape demonstrated that this socio-physical relation-

ship between the land and society weaves throughout. Society shapes the landscapes and the shape and type of our landscape has direct agency in decision-making, it shapes society. This relationship is one of co-production (Bender, 2002 Ashmore, 2015, Lave, 2016). Of particular interest to this study is how this relationship reflects directly on 'science' as both a 'knowledge' and a practice. In Quote F2.3 p 126 Anne recognises how the shape of the landscape has affected its historical management, which in turn impacted the ecology and soil quality.

> "It's the shape of the land, it's such an awkward shape it's steep I think it's all the bits that nobody wants to farm properly because it's so steep and undulating and because it's so wet."
>
> *F2.3*

Slope is a quantifiable value, even though the methods of measurement (degrees, percentage, 1 in 10) can be complex. Gravitational force provides a reliable 'down' against which we can measure what is and is not perpendicular to it.

'Steep' however, is a value that combines both the quantifiable slope, the quality of the ground and the socio-cultural qualities of the situation. For example, the economic capital available to a landowner impacts the type of equipment they can afford and, therefore, how well that machinery can 'handle' the slope. In addition, it is affected by the skill (developed through explicit extra-local, local or tacit embodied learning (Collins, 2010, Lowe et al., 2019) and the judgement and level of risk aversion of the driver (a highly variable concept (Gigerenzer, 2014))

The Trothy catchment can be described as rolling, certainly in contrast to the limestone outcrops of Symonds Yat or the mountainous Brecon Beacons it feels gentle, though it is never flat.

The median slope angle in the Trothy is 3.9 degrees and the mean 4.5 degrees. These are gentle, but this average hides a more intricate landscape. 20% of the catchment is above a 6 degree or 1 in 10: 10% slope, 6.3% of the catchment is over 10 degree or a 1 in 6 : 18% slope.

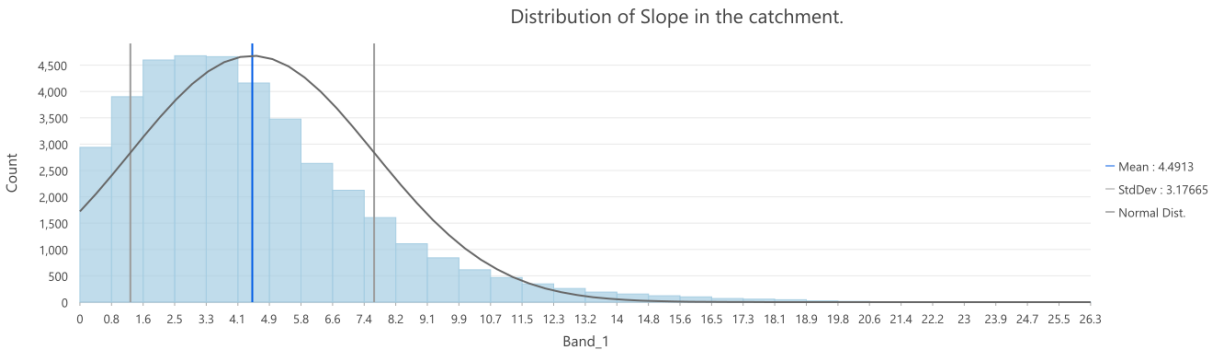


Figure 6.3: Histogram showing range and regularity of different angles of slope within the Trothy catchment

These values, from remote sensed, spatially aggregated data, don't really convey a sense of the shape of the land, this data must be interpreted into a visualisation. A description can enable 'knowledge transfer' between individuals much more clearly.

> "The first year we came here we made a lot of hay, and we've got a round bailer. And the problem with round bails they do roll a bit, and when you put them on slopes .... the man who had [the farm] before me, see where the sheep are, he had it bailed with the square bailer and there were square bails that rolled down and rolled over the road up there. it's a bit different"
>
> *F1.3*

The description is limited to a known, local, small-scale area, whereas the data values can convey information across the whole catchment. However, this generalisation has its downsides, even visualised, the remote sensed dataset of slope, based on DEM data at 25m resolution, is unable to capture the 'gullies' and 'ravines' described by land managers, through which the Trothy gently trundles.

> "this bit is 50ft deep here[....] a little stream that comes down this, from up there and it's fenced off presumably to stop the to stop the cattle falling down into the ravine."
>
> *F3.1*

Increasing the resolution of the remote sensed data is a problem of data collection, storage and capacity, but only to an extent (for further complications section2.2.2 and

Chapter 10). One purpose for which I need this data is for hydrological modelling. Beven (2007) notes that increased resolution does not guarantee better models, for example, where higher resolution data will create greater uncertainty in parameter sets (Beven, 2012). Beven (2007) relates this to 'Type III errors' where we are limited by the understanding of the whole system.

Whilst Beven is referring to the strength of the model, this problematizing can be expanded to the richer dataset I am starting to pull together. It is the combination of the datasets, the qualitative and quantitative descriptions of slope that give us the richest dataset to understand slope, and the implications of slope within the catchment (this will be explored in more detail in Chapter 11). I must challenge the application of model data and its 'usefulness' within the context of decision-making. Decisions must relate back to the lived experience of the LMs as 'slope' may be less important than the qualitative concept of 'steep'.

Hydrological modelling is also inherently limited by an empirical ability to collect quantitative data in opaque environments - i.e. soil. Slope may be quantifiable, but the hidden underground processes of soils and water are much harder to measure (Davie, 2008, Beven, 2018). Yet knowledge gained through practical activity may, for example, impact a decision on whether the steepness of a slope would make it more suitable for an alternative purpose, such as under tree cover; lived experience is more likely to inform decision-making than remote sensed data. Lived experience and behaviours are directly informed by the shape and quality of the land, and these experiences form a place-based knowledge that affects how LMs live and work in that landscape.

> "this field here, there's a little break there, big tree there, and there's some slips in it, if you know what I mean by a slip, where the soil just moves down, and you'll get a bank up like this you know, and at the top end of it you'll get a hole, a furrow, you know yeah quite dangerous it can be, This field here is the same, there's this, there's quite a high bank there, coming out of this field here, and then it goes down in quite a hollow and the bloody soil will keep coming down there, running across there, you can't drive across there

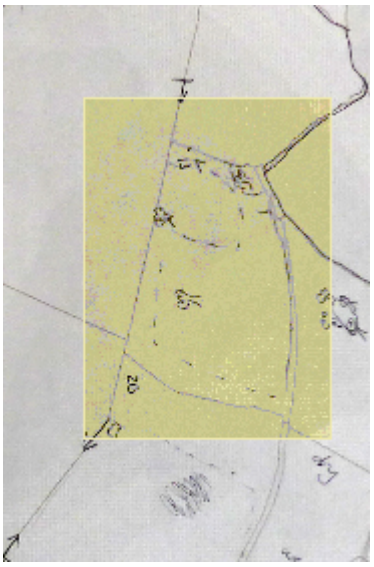


Figure 6.4: Tractor routes drawn by Roger on the maps as he talked

> now, and it's not, oh 20 years ago, we took all them banks off, and levelled it out. And that's been done 3 or 4 times as I can remember, and they come in the same places. And do you know why? Impervious rock, rain comes down, gets as far as the rock and sits there, and then, gradually, the soil just creeps down, almost like a glacier, just creeps down. You can't see it happening, but you go there in two years time and you go oh bloody hell"
>
> *F5.2*

The low centre of gravity on Roger's tractor (old, maintained by Roger with local help, broken when I arrived but fixed by the time I left) may have made it suitable for trundling across the steep hills, but Roger's knowledge of the landscape and how it moved were absolutely necessary to do so safely.

> "Yes, where you can drive the tractor in the winter and not get it bogged in because there's one part is dry. Now, if I wanted to go into this field here, by the gate by there, this is an old lane up there, you just go up through there, go up here, then across there, before you get over there, there's a tree by there, there's one here as well, I wouldn't go from there to there, I'd go up here, cross see here, and then back to there it's almost like a little, er real square detour [all marked on map] You can drive there without much trouble,

but if you go across there you'll be sunk, creating ruts, deep ruts."

F5.3

The more I moved around the landscape, the more I saw and heard how the shape and physicality of the landscape shaped the culture, history and behaviours. What can grow depends on where the plough can get; fields that get wet in the winter can't take livestock - so stocking density choices are determined not just by economics or quality of grass, but where the rivers and streams run. Farmers' choices are determined by the shape of the landscape they live in. Work they did changed the qualities and shapes of the landscape, which in turn went on to amend the behaviour of future farmers.

"You can see how the farm has evolved, and how that has happened"

F1.4

Frank was describing to me here how previous farmers had changed how you could move around the farm.

"It has been ploughed in the past and it has been levelled because, not the man that I bought the farm off, two men before him, they did a lot of drop work, levelled a lot of the ground it, did lots of cunning things with drops."

F1.5

The landscape I heard about was not 'merely' a historical record, it was a lived one, history, ecology, shape and physical process all interacted with what was wanted and needed, the complex socio-cultural. Frank's experience of the landscape gave him a historical record and a working landscape in which past decisions impacted his future choices. This meant not only did the landscape give him a framework within which his decisions might be made, but also a position from which to make value-based judgements of past choices as they compared now to his own frame of reference.

"Some of the people round here say, ah they didn't do it properly and they just bladed it in, and they didn't make sure that they'd got the right level of topsoil on the top, but, in my eyes, they did a pretty good job. [...] The man

> that I bought it off, he put another track in just straight down the steepest bit and piped the ditch and that's alright because that's more direct. But, it does include a big steep bit as you go down out of the buildings. And that, if you've got 200 horsepower tractors it doesn't matter but if you've got little tiddlers, that is of concern."
>
> *F1.6*

This relates directly to Bender's reflection that landscapes are 'cumulative and reworked' (1993, p81), but I would argue that this does not (as she went on to state) reflect a difficulty with a phenomenological approach. Rather that following Bender's own later argument (Bender, 2010) and that of Emery and Carrithers (Emery and Carrithers, 2016), the separation of conceptions of the landscape into embodied and represented are rather 'artificial', how we understand landscape can not be easily untangled. Therefore, the phenomenological approach, understood alongside our representative and empirical understandings of landscape, gives us a fuller, richer depth of knowledge.

> "P: I used to come down here as a, a few years ago [as a child] ..... There's a very wet patch somewhere that comes out of one pipe and into A: It was connected down there and it wasn't so wet here, but because the pipes now failed, it's created this boggy bit in the bottom P: this is fed, I believe from a well. My dad told me that there's a well up there, in one of those big bushes up there. and there is a galvanised pipe, so we've either got to get friends with a metal detector, or I've got to get a digger and follow the pipe A: it's up there somewhere, we know it's down there because we've got water mint down there and this plant as well, meadowsweet, that likes wet places, you can see there because it's all wet"
>
> *F2.4*

Peter's hill leaks everywhere. There are no maps or indications to mark whether this is from springs or the old pipes; galvanised ones might be found, but many are ceramic and are half returned to the earth they came from. Peter points out a few features on our map, but the knowledge he demonstrates walking around the catchment is barely

captured on any official work. If Peter hadn't grown up here, there would be no easy way of knowing which wet places here were 'natural' or 'man-made'.

This is the myth of the nature-culture division (Castree, 2014, Latour, 1993). The distinction breaks down, as pipes are put in place to direct underwater flow or drain an already wet area. The physical process was already there, the wet areas already existed, human intervention changed their locations, physical processes broke down those pipes and changed the texture of the landscape again and the meadowsweet doesn't care who created the wet ground – just that it's there.

The distinction, however, is important when so much of physical geography (including geomorphology and hydrology), rely on the 'expertise' of the practitioner in interpreting their observations. A lack of knowledge of local and historical management and how human practices have integrated into the physical environment limits the quality and validity of the conclusions that the scientific practice alone can produce. By including Peter's lived experience (as Brockett et al. (2019) found with their participants), a richer and more accurate picture of the landscape that informs (and goes beyond) the science is developed.

A picture is being created of a landscape in which, reflecting literature describing 'wicked problems', the socio-cultural and bio-physical systems are entangled (section 2.5.1). Land managers clearly hold relevant knowledges regarding tree cover expansion for NFM (Trees for NFM). This knowledge is not only being excluded (section 2.5.2) it does not fit neatly into the silos that are so well maintained in our institutional approaches (Tett, 2015 and section 2.5.1). I am gathering pieces of a puzzle; each is important, but how they fit together will be the key task of Chapters 10 and 11. Before that is addressed, there was a further finding from the catchment that is significant in regards it's absence from the current literature on land management and farmer decision-making; the agency of non-human actors in the landscape (sections 2.4 and 2.4.4).

Understanding landscapes: More-than-human worlds

I have identified the importance of farmers' lived experience in knowledge production, in particular, how this is shaped and given a framework by the physical shape, the landscape's topography. These findings support the postphenomenological perspective of the landscape (section 2.4.3) not as a stage on which the human/socio-cultural act is played, but part of the character of the play both shaped by and shaping the socio-cultural . Further literatures (section 2.4.4) suggested that humans may not be the only actor, that complex Socio-ecological systems mean more-than-human landscapes with multiple agencies of change. This has direct implications for the outcomes of landscape change and potentially LMs' decision-making.

In this section, I show how the agency of non-human actors within more-than-human landscapes directly impacts policies, management interventions and decision-making (supporting literature discussed in section 6.2.1).

Farmer/practitioner knowledge cultures engage with this additional agency as an entangled part of the landscape that cannot be discounted or simplified out of management interventions. This gives them lived experience, enabling them to develop strong critiques of current policy and directly impacting their decision-making choices and trust in future policy implementation.

Himalayan Balsam Along the river, Himalayan Balsam grows tall, fast and in densely packed stands, quickly shading out and killing lower vegetation that has covered, and supported, the riverbanks. Then, in the winter, it is gone, an annual invasive that kills the perennial vegetation whose roots have been holding the bank structure together, something that has been recognised in the catchment and is of increasing concern

> "We've not seen much change to the flow of the river since we've been here, we do get some bank erosion but we think some of that is due to we've got Himalayan Balsam, so I think that's not.. we're losing the plants holding the banks together."
>
> *F20.1*

When approached by a national group to fence off the riverbank, David initially agreed. The work would be done for free, and this project aimed to help regenerate the Trothy (with a focus on increasing trout stocks), reduce livestock poaching and help address long-term concerns with water quality measurements (Houston and Brooker, 1981, Jarvie et al., 2003). At the last minute, David and Jane changed their minds. The fields weren't stocked during the winter due to their propensity to flood, and they liked having access to the river, not just for the animals but for themselves.

> "*JSK(researcher): do you like being able to see the river and to see further down* D: I do, I do yes, I wouldn't like the thought of it being fenced off to be quite honest, no it's better as it is"
>
> *F14.1*

Fencing the riverbanks prevented cows from keeping the Balsam down and has enabled its advance up the river. This has the opposite effect of the intended impact, leaving bare banks in the winter with no supporting root structures. The limited access of David and Jane's cattle has kept the Balsam off their banks. David and Jane were able to critique the intervention based on their own experience.

> "you can't see the river; it's completely briars rubbish, and this Balsam will grow because it, we haven't been able to put stock on it as much as we'd like this last couple of years because [another farmer] was doing the other side and he had the bank all open. And this Balsam and all this other stuff comes where the stock haven't been. If you've got stock there, they control things like that. [...] So, I don't know, my theory is they should leave it alone, let the stock in there."
>
> *F14.2*

Other participants have also noticed the changes created by fencing off the river and reducing access for livestock.

> "Yes, so that would be alongside rivers, and that also stops then, stops livestock from going down to the river, stops open ground and a lot of mosses and other small plants, that you would naturally get alongside a more dynamic riverbank disappear. So, fenced-off margins are it's more complex than it initially seems Yes, it seems like a nice, easy solution but I'm not sure"
>
> *F2.4*

LMs' experience of the Balsam-Cow-River relationship situates the river as part of a complex system. Policies have a shaping effect on that system, directly impacting decision-making. Lived experience has affected perceptions of interventions and, by association, opinions of external policy-makers and policies of exclusion. The evidence of experience supports LMs' more complex and integrated understandings of management; of landscape, plant, livestock and people being a working system.

Hymenoscyphus fraxinea: Ash Dieback and other diseases

> "L: a major significant problem that we've got is Ash dieback right, and you do have? we think, I need a tree surgeon, or somebody, to come and have a look, but you can see how the ends of the twigs and branches have died back A: we don't know yet but we've got to have someone come and have a look"
>
> *F2.4*

Across the UK, around 15% of broadleaf woodlands are Ash(Forest Research, 2022a), and this traditional tree makes up many of the small woodlands planted in the last 50 years in this catchment. Farmers point them out to me with pride and a sense of concern. They were meant to be a good investment.

Ash dieback emerged in Poland in the 1990s (Mitchell et al., 2014), the fungus was identified in 2006 (Kowalski, 2006) and by the time the Pest Risk Analysis report was published by the Forestry Commission in 2013 the disease had already been identified, not only in nurseries but in the wider GB countryside (Forestry Commission, 2013).

Peter and I discuss the signs of ash dieback. It's hard to see if the distinctive purple, diamond-shaped scar is present from down where we are or whether the dead leaves on

the branch could have been dieback caused by earlier drought; if the dead leaves don't fall, it's not a good sign.

Ash dieback hasn't taken over here yet. It's here; I can see evidence in the woodlands. Most people are uncertain, hopeful, planning proactively.

John is understory planting his Ash woodland as he's worried he'll lose much of it, and this move away from Ash is echoed throughout the participant interviews.

> "there's some old ash trees but they're dying off. I had planted some new ones but, we've cut off the dead parts of the new ones but they're still dying"
>
> *F16.1*

> "in a perfect world I'd put Ash in, because Ash is a really brilliant tree for lichens and mosses, but because of the Ash disease we can't. .....So, this time round I think we'll put some Sycamore in, and then hope that in ten years time somebodies, Ash dieback has worked it's way through, enough resistant strains of Ash have been found and we'll be able to put some Ash in as well."
>
> *F19.4*

> "Ours are 20 to 25 years old now and, they desperately want thinning out, and we've got a lot of Ash dieback, so, er I'm going to thin them out and they're all going into the biomass boiler."
>
> *F11.1*

Ash forms part of the conversation in over half of my interviews across all sizes and types of holding. Everyone is trying their best, but most aren't sure where to access guidance, I'm surprised by how few know where to find this information and provide relevant links.

Ash dieback has a direct and significant impact on tree planting for natural flood management in regard to catchment hydrology and LM decision-making. Webb (2021,2022) shows the potential importance of Ash root structure on hydrology. Webb has found a six-fold greater fine root structure in Ash than in other species studied; the fine root structure

correlated to greater hydraulic conductivity. There is a potential relationship between tree species and hydraulic regulation, as well as ecosystem resilience (Webb, 2021), although significant further work is required to understand the implications of these findings at a landscape scale.

Significant Ash is being removed from the countryside despite advice supporting not felling. This 'do nothing' stance was supported by Rackham (2015), though in a reflection that directly acknowledges a lack of appreciation of non-human agency he remarks that the advice for washing one's boots and all the dogs is only really useful, if you also wash the Deer (Rackham, 2015, p163). There are no available collated figures on the felling of Ash Trees at this time (Apr 2022), however, the following data in media reports gained through FOI requests indicates the behaviours;

- Newport city estimates £8.4M to remove 8600 trees from the city (Cooke-Black, 2021),
- Merthyr Tydfil county over £2M on 3700 trees (Anthony Lewis, 2021);
- Powys has estimated a minimum fell of 23,000 across the county (Powys County Council, n.d.).

Local policy has become entangled with the disease and is changing the landscape at speed, particularly around sensitive built-up areas. It is likely that the hydrological response will be experienced before it is 'measured', and this is one area where modelling future scenarios could help target remediation (I tackle a scenario that reflects a loss of Ash in Chapter 8).

Ash dieback followed shortly after the Larch disease, Phytophera Ramorum (Forest Research, 2022b), which had a serious impact on forestry in Wales (Research Service, 2015). The experience of this new disease directly impacts managers' confidence in species choice, their own and that of external advisors. This impacts their confidence in the trees long-term value, both economic and practical.

> "D: They planted a variety and they got a disease and they can't use them for the original purpose because something happened to them um, so I think you're safer if you plant, and I mean a mixed woodland looks nicer, and it's nice to see all the [] and things J:: natural woodland D: natural woodland yes"
>
> *F11.1*

However, the loss of the Ash tree itself has a greater impact than a practical or economic one. Matthew hints at the cultural impacts of the loss of Ash.

> "Ash dieback is a really really significant country trauma, I think, very comparable to the Elm disease... which I guess we've bounced back from that. My parents remember Elm as a landscape tree here, and I don't."
>
> *F19.5*

Penn (2015) and Rackham (2015) describe a tree which has complex and significant socio-cultural and ecological roots in connecting the landscape. Hymenoscyphus fraxinea, entangled with local policy, is acting to remove that tree and impacting each of its complex connections. Penn's (2015) post-script warns not only of the impacts of Ash dieback but also of the Emerald Ash borer. This beautiful bug / second and greater potential threat (Forest Research, 2022a, Rackham, 2015) would devastate the last of our Ash, removing much hope of the tree developing any resilience to dieback, further changing the landscape.

Water Water and its movement through the landscape ties together every one of my participants with all the surrounding farms. Water arrives through the landscape quickly, slowly, clean or laden – dependent on the shape and quality of the land and the behaviour of all of its past and present occupants. Water's direction is shaped by the landscape, and the movement of the water shapes the land in return.

Gareth was kind, but the idea of trees having an impact on the flooding made him laugh

> "but even so Jenny, you can see the pictures, that is a huge volume, that is a huge area of water, because it's not just, that's going all the way up,

> and, that's going all the way down and it's not something that is little. If you go down to the Onen bridge, where you come across the Trothy going to Llanvihangel, get out and walk across the field next to it. Underneath the road, there are brick culverts to let the water flow through it, so it's nothing new, it's always been going on, it's always been like this, this is a flood plain [laughing] if you can control that, good luck"
>
> *F20.2*

Water has agency (Strang, 2014, Laborde and Jackson, 2022). We work under an illusion of control, an ontology of water as an asocial, physical substance (Laborde and Jackson, 2022). Yet we are utterly dependent on it and devastated when we find we were wrong (Krueger et al., 2016).

While researching the Trothy, it aptly demonstrated its ability to be underestimated. There is a mile-long section on which a wall of large stone blocks has been created. The work is extensive and can be seen in satellite images (Figure 6.5) as it was taking place. Obviously requiring significant planning, I had heard comments about this work in meetings I'd attended, where it was hoped it might improve water quality. When I asked locals about it their views were mixed; they expected the 'experts' to have made the right decision, but in their, view the sandy nature of the soils risked the river causing significant damage.

> "J: We've had a couple of places when it's washed, and you'd be surprised how fast, once it starts right okay like the soils quite sandy or loose you know D: it's very sandy soil J: if it starts to swirl, it'll wash a chunk of soil out, a chunk of land out in no time"
>
> *F14.4*

Despite not being able to travel to catchment throughout much of my later research period, I have been able to watch the river from the sky. The satellite images have been updated, and since the last floods – blocks of stone, which I estimated at 2 square meters, have been swept away from sections along the whole length of the river and now sit in loose piles along its length.

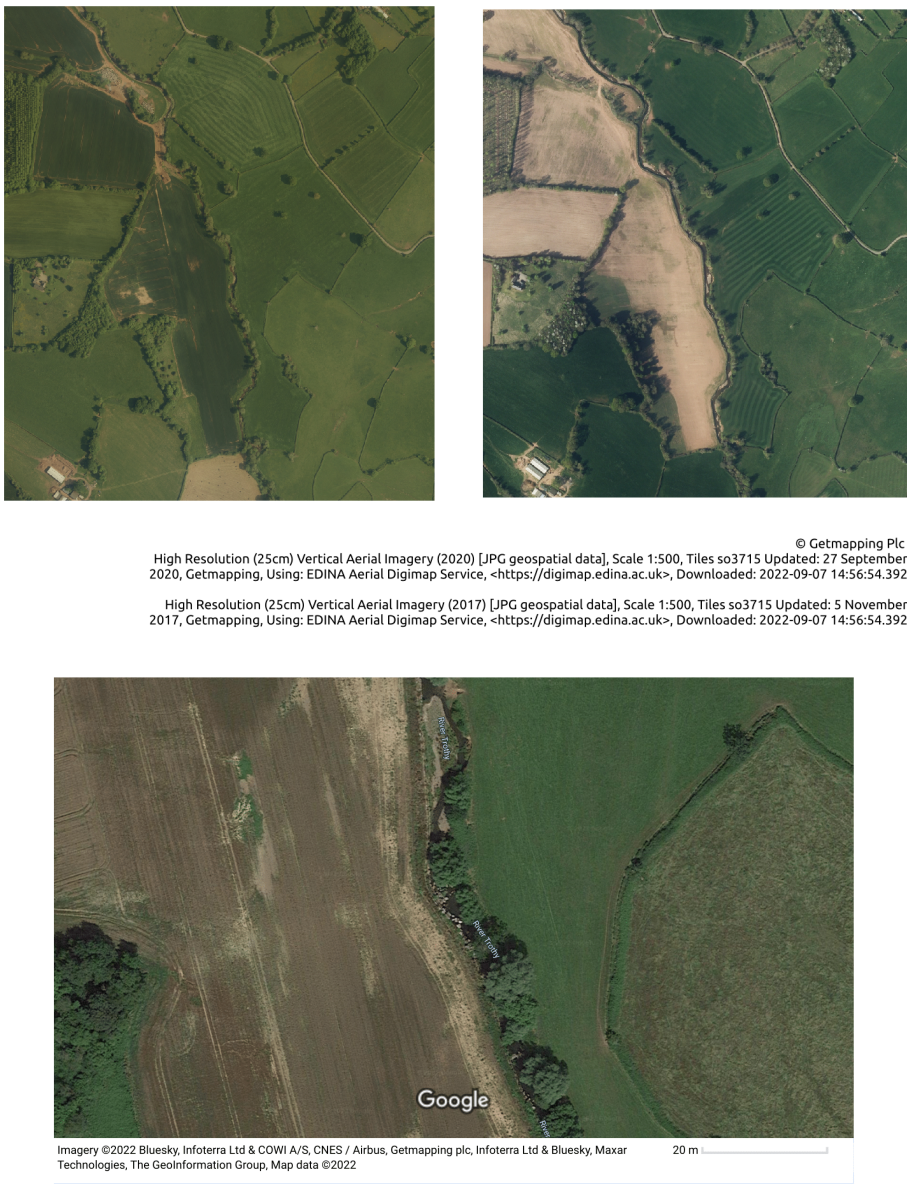


Figure 6.5: A section of the Trothy from satellite imagery (accreditation in photo and Appendix II) in 2017 as the wall was being built; 2020 after the first storm, and zooming in to an example of storm damage using Google Earth images retrieved 6th September 2022

Water connects in ways that break down socially constructed walls of ownership (Kortelainen, 1999, Strang, 2014), and ranges of responsibility (Krueger et al., 2016).

> "Religiously, we've cleared the banks of Himalayan Balsam, of Giant Hogweed, horrible stuff, we did that for about five years running, two years later it's all back because it comes down, it's in the seed beds further up so as soon as we have a flood it all comes back again."

F20.3

Water moves, and it carries, the choices of somebody 'upstream' directly impact the landscape, ecology and management choices downstream.

The strength of water is absolute. Science and policy have not adapted to it's uncertainty, and measurementality keeps the focus on trying to control it by force or by knowledge (Laborde and Jackson, 2022). Knowledge and expertise informed by lived experience of the agency of water is by nature cumulative and often reactive. It can learn and adapt faster than the learning of academic institutions. But a lack of the abstract limits knowledge formed by lived experience, it is responding to complex, interacting systems in which causality can be lost. Here, science may fill in the gaps, adding reason to rhyme. These interactions, the impact of a non-human agency is barely considered in policy (Yates et al., 2017, Halfacree and Williams, 2021) but for participants it is every day, recognised and valued. A system in which scientific expertise and place-based expertise were able to co-create, inform and apply knowledge, may be better placed to engage with, adapt to and manage the agency of the 'other'. Through the discussion in Chapter 11 I will explore whether this system is possible.

6.2.2 Understanding landscapes: Policy interactions and political rhetoric

Section 6.2 has described a landscape that is co-produced, cumulative and reworked through interactions with the materiality of space and by the agency of more-than-human (human and non-human) actors. The 'ways of knowing' this landscape are complex, not limited to but directly informed by lived experience. This phenomenological reflection is not merely descriptive but has direct political implications for the efficacy of interventions and land manager decision-making. In addition, I found that policy itself played a significant part in shaping the landscape, making material changes that LMs were experiencing and with which un-integrated thinking or new policy development could materially conflict.

Shaping the landscape: lived experience and political rhetoric

Responses in the catchment shed some light on the complexities of political rhetoric and how lived experience is drawn into supporting the frameworks often already held by individuals. Whilst this doesn't immediately appear to relate to increased tree cover for NFM, one of the key terms that is used in political discussion to identify suitable planting sites for trees is 'good land'(Welsh Government, n.d.). This discussion is presented here to demonstrate how complex a simple term is, and how a wealth of scientific evidence will not necessarily eliminate conflict of political interpretation (Sarewitz, 2004).

Harry pulled a fistfull of thick, wet silage from a giant heap and thrust it at my face.

> "that's grass that's come off the field at the bottom and this, if I can get to it, is the red clover, smell the difference"
>
> *F15.1*

Harry was well educated in the relevant scientific knowledge to understand and interpret his experience that the grass silage 'smelt better' than the flower-rich haylage. This experience justified his perception that his improved grassland was 'better land' than wildflower meadows, which produced (to Harry) a 'dead' and dusty hay.

I discussed the same fields with Michael, whose lived experience involving his change in perception of the landscape's biodiversity (he had developed an appreciation for the sound of bumblebees) gave a very different experience of the grass.

Looking at different fields, I discussed something similar with Jack, who used exactly the same scientific knowledge as Harry (the nutritional quality of a Ryegrass lay), and his experience to justify a different preference.

> "if you want your child to get really big really fast, you feed it krispy kremes all the time. Is your child a healthy child? are you going to feed your sheep only rye grass all the time?"
>
> *F9.5*

His views appeared contradictory; his opinion of 'good' land certainly was, but there was no actual disagreement in the evidence presented. Jack compared the rye grass lays

to a sugar-rich diet in humans and the rather poor-smelling haylage to a rich nutrient base – somewhat like taking your vitamins. This led him to a different interpretation to Harry as to which grassland was 'good'. This evidence, both scientific and experiential, was part of both farmers' arguments used to justify their management practices and uptake of interventions.

Both farmers used scientific knowledge and their lived experience to directly inform strong, well-balanced political arguments.

The lived experience presented has been developed through event, embodied experience, experiential observation. It is currently under, or un-valued in the way in which we make science and policy. This individualised expertise may be hard to measure, but if you tell the farmer that the hay is 'better' than the silage, and his nose tells him otherwise, he is not going to believe you, and importantly, he is also not 'wrong'.

This phenomenological understanding of landscape is also relevant when LMs' experiences are shaped by or conflict with policy through grants and regulations or translated into practice.

Shaping the landscape: policy narratives

Farmers and land managers actively engage with policy, whether through grant or regulation. This means that policy narratives and frameworks directly influence on the landscape despite farmers' narrative of policy as an 'external'. Participants explicitly recognised the past and potential impacts of policy shaping on the landscape.

> "Most of the woodland creation done here was the previous owner, we've only been here two years and he, wasn't a farmer, he was a stockbroker who really liked shooting and played environmental subsidies. So loads of quite good things have been done, like this whole edge up here has been planted with trees, created a new woods at the top, woods across there, he's got woods running up the side to link to existing patches of woodland there [*pointing at map...*] all of that.. all of that... he's even done all of that, that is woods, woods"

F9.2

"So we want, we very much want to increase tree cover, but, I'm, I'm deeply worried that the way we're going with, with climate change mitigation tree planting. Is that any little pieces of 'unimproved' land 'unproductive' land, are the places where trees are going to be planted. So we are going towards, ever more towards simplification of the countryside. So instead of having, um, variation, small fields, flower rich areas, wildlife. We will end up with just planted trees, intensive crops and areas where people live. And that's what we're, we're trying to show that you can still farm a landscape like this, you can have a mixed landscape whilst also having whilst also having diversity whilst also having wildlife here."

F19.6

The previous quote identifies that the policy consequences in the landscape can be both intended and unintended. This is exacerbated by uncertainties or prescriptive policies which don't 'fit' the landscape for which they're intended.

"Yeah in Tir-Gobal which was the scheme before Glastir, there was a thing for parkland trees but when they changed to Glastir it had to be registered with a big house or something so there wasn't a category for it, so it's just scattered trees in a field, through the BPS we're not allowed to claim under the trees, so you have to circle all the trees and take that out of the area of the field for your basic payment scheme payment, so it's not really incentive to keep the trees."

F16.2

F16

"We, since coming here, one of the first things we did was to fence off the stream, because er, that's one pond, then another pond, then another pond there. The stream connects the three of them then it comes out there and runs along the hedgerow and um. so this bit of stream, fenced off just because

> everything I've learnt about streams it was the obvious thing to do, you've just got NRW to pay for it, but lost it over subsidies. [..] we've taken land out of agricultural production. It's benefit to society but it's not good for me because I lost a load of money"
>
> *F9.3*

> " I need to know about that, the subsidies. There is agroforestry subsidies but, I imagine they are going to be so particular about your tree planting that you can't be creative. I mean you might do but I can't be bothered to wait a year to find out whether or not I'm allowed to plant a tree"
>
> *F9.4*

Supporting the findings of Emery and Carrithers (2016), LMs lived experience of the shaping created by policy and their wider lived experience enabled them to develop, and recognise, strong and informed critique of policy measures.

Shaping the landscape: practical impacts of policy

Policies aren't just translated by land managers, but by 'external' practitioners, boundary and government organisations who must translate narrative into action. How policy is then translated both shapes the landscape LMs experience and creates interactions with LMs that influence LMs' future decision-making.

Arthur has walked me down to the river to show me a tree that has fallen in the river, debris has begun to pile up, and he is worried about localised flooding (there are gaps here where Arthur is moving around and repeating himself)

> "a lot of trees that should have been taken down really, some of the willows have gone past their best so it's age, it wants fencing, it wants a lot of new trees going along, [...] that's because one has fallen and they've left them down like that [...] so they don't clear them now they allow them to sit they don't clear them now, they do nothing, we had the man come and look at that tree and he said well, I'm sorry but we ain't got the money to send people to do

> it, [...] we haven't had any bad floods for a couple of years have we. The next weir down was blocked just like that, completely blocked and then we were getting the floods, it was backing up."
>
> *F9.4*



Figure 6.6: Willows that used to be coppiced have been left to grow. Now the large trees are coming down, blocking the river and causing localised upstream flooding. Whilst strategies may lean towards leaving wood in place this is contradictory to land manager responsibilities as outlined in the Land Drainage Act (see 5.15, *photograph authors own.*)

The river used to be cleared but hasn't been for years. This falls under a situation where economic and environmental considerations would be unlikely to justify intervention (NRW, 2020b). Arthur has the right to protect his land from flooding but has to submit a plan if he wishes to do so (see Figure 5.15, Chapter 5). He tells me he knows someone who will probably just climb down there and 'haul it out'. It is around 10ft to the riverbed from the bank, and the tree is well over 1m in diameter. Arthur confesses he used to do it himself, laughing as he tells me how he once fell over in the river whilst working the chainsaw, and his glasses fell off.

This 'policy interaction' not only affects the future behaviour of the river but it directly

impacts Arthur's evaluation of the current and, importantly, future policy and policy representatives.

In this section, I have presented data which directly evidences the impact of policy interactions. However, this relationship can be traced throughout the findings, for example;

- Section 6.2.1, p133 described LMs experience of fencing off the river landscapes and Himalayan Balsam, which interacted to put river vegetation at risk – with direct impacts on both water quality and flood management. This work was done by an NGO supported by a scientific evidence base suggesting the over-poaching of riverbanks was responsible for pollution levels in the river (Wye and Usk Foundation, 2014). However, it is used to critique environmental policy (LMs recall NRWs responsibility for the river, rather than remembering the NGO that completed the work) rather than the 'science' or evidence base for it. Farmers are objecting to the imposition and translation of 'science' rather than the evidence base itself.

- In section 6.2.1, p138 I discussed the riverbank blockwork that has subsequently collapsed. LMs evaluated the wall by referencing their lived experience but weighed this directly against expertise and approval from regulatory bodies. I have not been able to evaluate the impact of this collapse on either the behaviour of the river or the opinions of the LMs who have observed it's creation and collapse, but it is unlikely to reflect well.

A phenomenological understanding of landscapes is intensely political. It helps us identify policy as a material agency in shaping the landscape. The cumulative and reworked nature of the landscape means that the material impact of policy is part of LMs' embodied experiences. This directly impacts decision-making, which I will delve into more deeply in section 6.3.1. It also reflects on the suitability of different policy and governance approaches where integrated policy may need to act not just across contemporary silos but also with the past.

6.3 Complex knowledges and relevant experts

The second half of this chapter moves beyond the phenomenological to explore LMs' complex knowledge cultures (including lived experience) in relation to decision-making and attribution of expertise. Complex narratives shared by LMs shed light on the complex and interrelated drivers that impact LM decision-making, which I explore in direct relation to Trees for NFM. In the final section (6.3.2, p 155) of this chapter, I reflect more broadly on the relevance of LMs knowledge and how this supports an attribution of them as 'Experts in their F/fields'.

6.3.1 Decision-making

The narratives used in the interviews demonstrated how complex and related all the different aspects of place and the act of dwelling/living in place is.

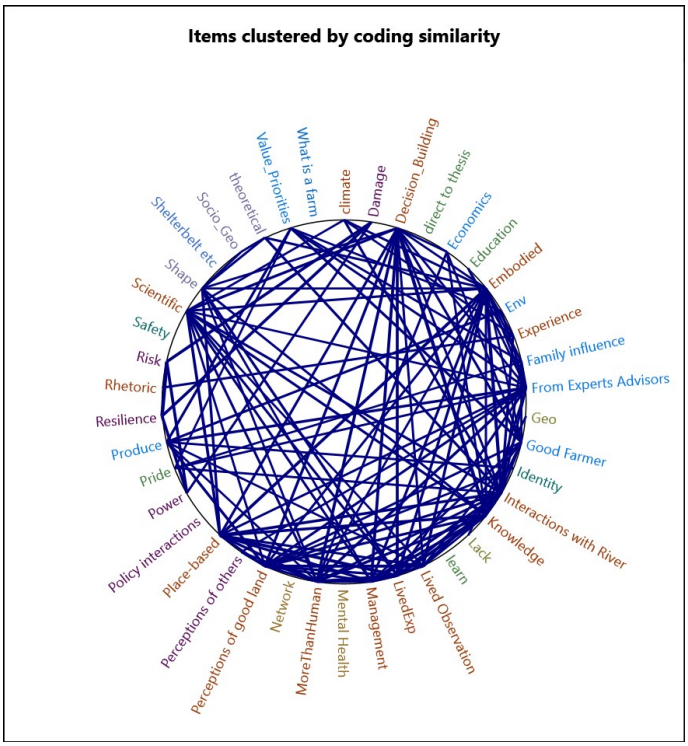


Figure 6.7: Network of intersecting codes
NVivo cluster analysis of codes for Harry's interview to demonstrate the complex web of narrative and decision-making *(Jacquards coefficient at a lower limit of 0.6 for similarity)*

Figure 6.7 on page 148 shows the relationship between codes in Harry's interview and

the different threads he weaves together. If you dig down into the data, there are patterns, but this picture helps demonstrate the complexity and diversity of strands drawn in. This pattern is demonstrated throughout the interviews, and in most cases, the interview length correlates to the cluster's complexity.

Decisions then are shaped within the landscape formed by all of these factors. Decisions are made in a particular place at a particular time. I could have used many different examples to illustrate these points, but to focus on the problem I share decisions that directly relate to either tree planting or water management in the catchment.

When I'd spoken to John, our conversation kept returning to his identity and the identity of the farm. The two were hard to separate; food production was "in his DNA", and the farm was "the gem", the best land in the area for food production. He didn't want to move away from that, and he didn't want the farm to move away from that. He wasn't against tree planting, but he considered it in much the same perspective as solar farms – it was a tool that required land, and his land was too good for that.

However, this perspective did not seem to apply to the woodland already on his farm. Whilst its size had been reduced over the years, it played an essential function in the farm as he perceived it. We talked about it acting as a shelter against some of the worst of the wind, but he also expressed a broader potential for it as a missed desire in that he wished he'd "had time to manage it properly".

A predominantly Ash woodland, rather than removing it now the risks of Ash dieback had arisen, he was under-planting it to ensure its survival. The woodland is in a prime position on smooth land across two fields directly adjacent to the house and close to a large continuing strip running up the following field. Its removal would increase the area of three fields by a third. For John, this was no contradiction to his expressed views that land for tree planting should only be unproductive, steep and hard-to-access areas.

John was one of the people who suggested I talk to David and Jane. David, he said,

was like him

> "he's equally dedicated to food production and, that's his life. Even more than me I think."
>
> *F13.1*

David would have agreed with John. Jane has been working towards the idea of retirement for a while. However, David grins and says he's "too young yet". Both David and John passed retirement age some time ago. David's farm was mostly dairy, though they have a beef herd now as well. It makes a difference to how the land is used, Dairy animals "you want round the house" whereas beef cattle can go down by the river in the summer. There are still sheep on the farm "habit, a bad habit", but "they're good in the winter" as the sheep will top off the grass and make the most of what the cows have left. They can go to different fields in the winter as they do less damage to the wet ground.

Thirty minutes into our conversation about the farm, and recalling John's comments, I asked David whether he would consider planting trees anywhere on the farm. I carefully frame the question. I don't want to suggest that I haven't been listening, but at the same time, I don't want to make any assumptions. I have been making assumptions, as I'm genuinely surprised when David says yes.

We spend some time unpicking this, and I have to relate it to a lot of different information David and Jane provide over the time I spend with them and the places they choose to show me. They say their son is particularly keen on tree planting, and David identifies two fields they are "seriously considering" planting up. The land is steep, up to a 24 degree slope and covers 3.1ha.

They state it's an economic choice, and they may look for a grant but then explain:

> "this ground is to steep to do much with, this one here we've worked it, I've worked it a bit in the past but it slips in places. And I'd rather see trees planted on it than one of these boys working on it."
>
> *F14.5*

Safety and risk are more relevant in this statement than economics. A grant will only cover the costs of initial implementation; it won't provide an income. There are ways of

making an income, but as discussed later, these are not of direct concern; the economic aspect of the decision is regarding not making a loss.

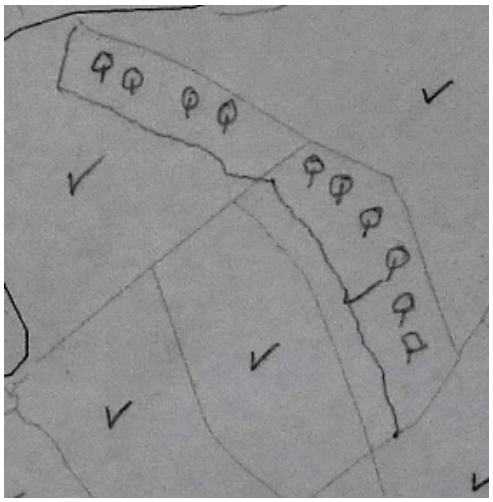


Figure 6.8: David's map of potential tree planting

The woodland is adjacent to a road, which would be of interest for woodland management and access. This links to another key factor in their decision: a neighbour has recently planted mixed broadleaf woodland in a field adjacent to theirs, which Jane takes me to see. It is beautiful and appears laid out for access, amenity and potentially woodland management. Jane particularly likes the idea of access for her grandchildren, and her neighbour's wood is young; the trees are slender at only around 12years. It isn't useful as hardwood timber yet, but it's a beautiful place to be, and that's what is of interest to Jane. It has shown her that something they planted would be of interest within time for both her and David to appreciate. This is different from the perspective often portrayed that a broadleaf wood is of no interest for 40-50years. Their lived experience of the wood has significantly impacted their choices and decisions. As has their experience of another woodland nearby.

The farming literature would suggest that a crop woodland may be suitable economically for farms, and that might be the case, but David and Jane have no interest in trees as a crop; they want a mixed woodland (See quote F14.3 in section 27, p 138). They relate this directly to a woodland visible from their farm. Jane thinks it might be Willow, but from our viewpoint, I'm fairly certain it's Larch. I'm pointing this out because their response isn't based on a rhetoric or narrative aversion to non-natives or conifers. What is most visible is that it was a plantation stand that had suffered a disease, and most of the crop was dead.

Whilst still in the planning stages (they are thinking about getting advice but haven't decided where from, mentioning the Forestry Commission or Farming Connect), their

decision-making is informed by:

- Family, their son's preferences and ideas
- legacy, creating something for future generations
- Socio-geomorphology: the physical shape of the land
- Economics: it's economic viability to farm and
- Social Capital, Risk and Care: The safety and security of members of their family/team who might be working it
- Good Farmer/networks: Their neighbours' choices have directly influenced what they are thinking about in both positive and negative ways, including the social capital they attribute to the new woodlands and this is informed directly by their
- Lived experience: Of the land and the two grown woodlands, both the visible impact and the embodied experience of being in the woodland. These things are shaped into their narrative, explaining their decision (a narrative which will have physical and long-lasting impact) that a 'natural' woodland would be best.

Interestingly, a positive capital is attributed to the 'successful' neighbour who has created something of benefit, but no negative associations are laid against the farmer whose crop has been unsuccessful. Two factors may impact this: the diseased woodland is on land owned by a farmer who has other reasons for diversification. I know these reasons from other sources, and David and Jane do not share them. The farmer who did share them considered them unusual but appropriate enough that the farmer was 'justified' in his choice of changing land use.

In addition, throughout this interview, the language that David and Jane use reflects a relationship with the wider inhabitants of the more-than-human landscape that is a flatter hierarchy than reflected in literature (section 6.2.1). A greater agency is attributed to the animals in their care; they do not manage sheep to be useful and eat the grass that cows have left – that is just what sheep do. David and Jane work with this sheep-led

behaviour. Their tacit awareness of non-human agency in the situation may also affect their decision-making. The owner of the diseased woodland wasn't considered to have done anything wrong. The issue was the plantation; disease can easily run through a single species crop, and therefore, 'mixed' was considered better.

Decision-making is complex, drawing in multiple knowledges and being spatially and temporarily contextual. The complex factors which inform decision-making reflect Morris's (2006) reflections on farmer knowledge culture. The factors that inform decisions and do not always break down into simple, easily identifiable drivers. Whilst some decisions will be weighted more strongly by one variable over another, it is not always possible to identify at any given time which the 'driving' variable can be, and even if there is a driving variable, this does not mean that other considerations combined will not outweigh it. This complexity was reflected in nearly all participants' thinking around tree planting, for example:

- Jack's reasoning for tree planting encompassed his education, environmental values, his interactions with neighbouring farms, his repeated walking and his understanding of the site; he was influenced directly by his education, his environmental values, the shape and ecology of the site itself, his interactions with policy and grant structures, his family and friends.

- Morgan was another who said trees were not an option. However, he went on to identify several possible options/locations he would consider planting, which were unsuitable for expanding his crop, could create a wind-break, was a species choice which would not transmit disease to the crop and was evidenced as suitable for use elsewhere

- Matthew and his family were actively planting with additional plans; reasons were related to the quality of biodiversity (of the ecosystems and the trees themselves), to reflect the cultural heritage, to improve amenity value and within the bounds of the purpose of the different sites, for direct community benefit,

- Peter and Anne were looking to use a steep field more appropriately, to reduce runoff and protect the river banks, to maintain meadow biodiversity in one area whilst reducing bracken in another, their choices directly reflecting, amongst other factors, their experience of the landscape, their interactions with a local community, with local expertise and their observations of runoff on two neighbours fields that were under different management.

There is an important reflection on the research methodology and the wider context of public body or political surveying. The 'long' conversations that I held with participants and the knowledge-sharing nature of these conversations enabled a more detailed exploration and understanding of the decision-making process (as would be expected (McCracken, 1988), section 4.1.3). This could be argued not just to provide a 'richer' dataset but also a more accurate one, reflecting the complex process by which decisions are made daily.

Table 6.1: LMs expressed decisions regarding tree planting in their landscape

	Yes	No
Initially against increased treescapes	12	10
Would/Planning to or Actively planting	19	3
Plant for NFM	8	10
Plant for other	18	2

Decisions expressed in one context may not reflect actions and decisions in another. For example, 22 participants gave a clear view of increased tree planting in the catchment. Table 6.1 shows that 12 out of 22 participants declared a negative view of increased tree planting at the beginning of the interviews; it was unnecessary, or they would not consider it. However, later in the same interviews, 19 of 22 participants would consider increasing tree cover, were already planning this or were actively planting trees on their land. The average amount of land identified amounted to around 7% of the landscape managed by

participants. This increase would bring the total tree cover of the catchment managed by participants from 11% to 18%.

This complexity of knowledge and decision-making is not reflected in the way 'social barriers' to tree planting or Natural Flood Management have been identified (see section 2.3.3). In the final discussion (Chapter 11, section 11.2.1, p 285), I will address this in more detail, why this might be and how it may be resolved.

6.3.2 Experts in their F/fields

For this chapter, I have chosen the term 'place-based' expertise. To summarise my reasons for this, for this thesis (and as the researcher attributing 'expertise' to the LMs), the term 'place-based' linked together the spatial and contextual knowledges of place and landscape whilst also recognising the range of institutionalised or vernacular/local knowledges (including Lived Experience) that informed land managers expertise. I note here that in Chapter 10 section 10.3, I discuss my findings regarding the fluctuating nature of expertise. This calls into question the categorisation of expertise reflecting Raymond et al. (2010) difficulties in categorising knowledges. However, the term 'place-based' is useful within the context of this chapter. I outline below the evidence on which I justify and explore the attribution of LMs as 'Experts in their F/fields'.

Land managers demonstrated high levels of 'place-based expertise' informed by a complex layering of knowledges (reflecting the concept of knowledge cultures (Morris, 2006)) both local and extra-local (Lowe et al., 2019) including 'field science', lived experience, 'scientific' and applied regulatory knowledges, all of which were informed by the vernacular socio-cultural knowledges of their landscapes, their multi-natural worlds and social communities.

The complexity of this and how knowledge is shared and built upon raises a problem for the attribution of expertise - how to judge the reliability and validity of information, particularly if presented out of context.

For example, Jane shared (Quote 42) a snippet of information about tree use of water that, within this context, doesn't appear correct.

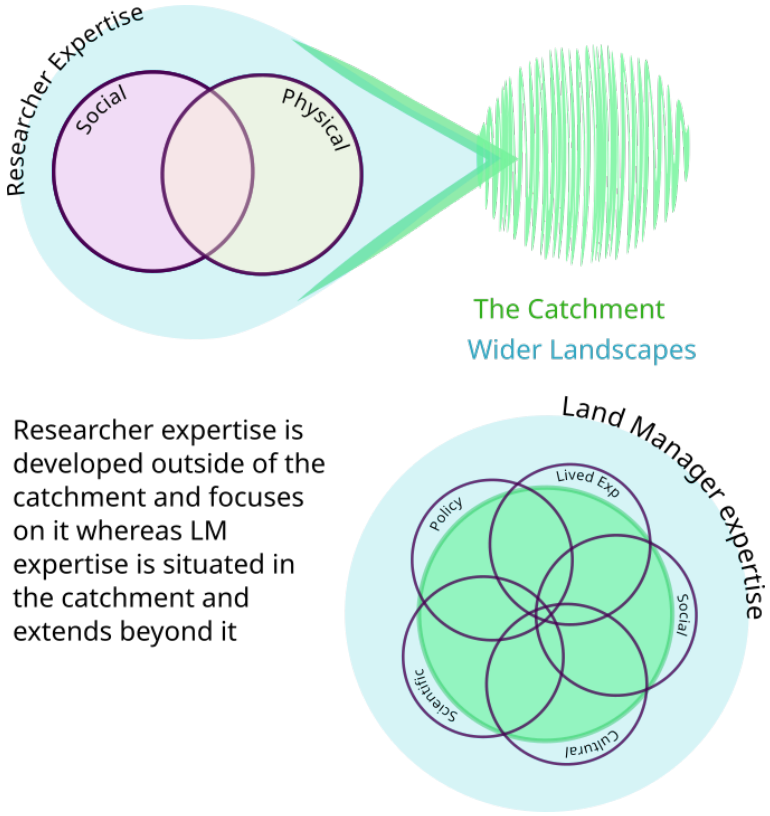


Figure 6.9: A visualisation of researcher and land manager expertise; how they are integrated and framed.

> "J: also, there's not much water in there, is there D: no, no J: Not like when the children were little, and we used to go and bullheads in the wood, but there's not that water, it's not there now whether its that the trees are using it or we haven't had the rain"
>
> *F14.6*

An important piece of additional context is that she told me earlier that many trees have been removed from the riverbank recently, which contradicts her statement that the water might be low because the trees are using it. It is important not to assume that Jane is confused or necessarily 'wrong'. Jane demonstrates 'active' thinking and shaping of her ideas throughout the afternoon; she is willing to test new information against her knowledge and see how it fits, explains or contradicts. The 'facts' she uses to situate this narrative may not seem quite right. However, it is also important that there may be other reasons for this, such as significant planting upstream or a greater expectation of water use in the summer. Whether or not she is 'correct' does not detract from her other

experiences of the river.

Participants were not always drawing from many sources in well-organised paragraphs but related different threads, weaving them together in the narrative. The ability to judge the accuracy or completeness of a narrative is limited by how and when information is shared. However, participants did not (often) handily point this out; an interview is a bank of narratives, which the participants expected me to store and accumulate. Knowledge shared becomes assumed and does not need referring to throughout.

How this 'issue' acts as an identifiable limitation has been one reason why lived experience and vernacular knowledge described as 'anecdotal' is not used or weighted in relation to 'scientific' knowledge (Turnhout and Neves, 2019). As social sciences have well-developed methodologies to deal with this complexity, it suggests that the problem is the need for problematization of scientific methods and the subjective and value-based nature of data analysis and translation (Heather Douglas, 2009). This is explored further in the summary of Chapter 8 (p 220).

Science and other knowledges (and their place in place-based expertise)

> "We're men of science"
>
> *F1.7*

Four of my participants (none of whom gave the above quote) were trained in a scientific expertise, three having worked in that capacity at some point. Their ability to utilise that scientific knowledge within their landscapes and apply it directly and heterogeneously to place, complemented by their lived experience within those landscapes, did not diminish their scientific knowledge or practices. Instead, their scientific knowledge was more applicable to each unique place - their knowledge was more 'true' for any given place than the generalised 'science' applied in policy.

The concept of knowledge cultures allows for integrating scientific knowledges (held by all participants, not just the institutionally recognised 'scientific' experts) into 'place-based' expertise and the potential for exchange with 'scientific' expertise.

As found by Turnhout and Neves, 2019 and Brockett et al. (2019), land managers' lived

experience and field science can directly inform scientific practices with little translation and can be 'scientised' to inform scientific practice.

Natural Science and ecology, for example, have a long history of amateur experts (Dorinda Outram, 1996) and land managers evidenced these practices in discussing their landscapes:

> " I suppose this area, this is a kind of hotspot for the SSSI, probably around, where, well the spring line. You know because it's, it, you get, you notice it's a bit wetter in this area, so you get a concentration of the sort of wildflowers or whatever, in the Spring, sadly you've missed it, but we have been monitoring the orchids which have been extending their range."
>
> *F3.2*

> " there's a nice bit of fleabane, we've got orchids in this field, this is the old lands, butterflies, there's a fritillary there, spotted? welsh fritillary."
>
> *F2.6*

Identification of relevant situated knowledge with the application of codified/formal science was also demonstrated in fields of soil science, hydrology, genetics etc.

> these fields have quite a lot of compaction, the field we've planted up over there didn't have compaction because it didn't really see that much sheep. whereas cos a lot of the land was rented out previously it'd have a lot of sheep on it and it was kind of not looked after, classic kind of you know you don't look after you extract from it um, also this half of the farm got limed with a magnesium based lime. So the magnesium- calcium ratios a bit off it doesn't really work right. It's just like, the pore spaces are smaller."
>
> *F9.6*

> "We are on the soft boring Raglan Marls, so that is the same stuff as the Usk valley is on, just south of here we've got the St Maughans group, which is a harder sandstone, cut with these bars of impure limestone the sonostious limestone. We don't have any of that here, we're just kind of, lower lime, very

very soft and soggy mudstone. So that's why the road comes through here because it's easier.

F19.8

"

"We're on hard clay up here, but if you drop down we're on silt. But that's one of the problems."

F20.4

Land managers also demonstrated high levels of scientised knowledge, where they could translate lived experience, which ranged from embodied observation to experimental 'field science' directly to the codified/formal scientific knowledge.

"we'll show you later, but this ends up being very wet and swampy for want of a better phrase, because where the rivers flooded, and dropped silt across the top it runs to the river"

F2.7

"and my wheat over there, that's not as ripe as some of the peoples wheat down at Llanover and Llantillio down there, cos I've been down their towards raglan today and been driving round to get a hydraulic pipe repaired and there's wheat down there that'll be a fortnight before my wheat, but that's because it's wetter here than it is down there. Because the soil is different here than it is to there. Because it's more clay, and there's more water comes out of the soil, especially this side"

F1.8

"we're putting in like a cover crop for the winter trying to stop the soil erosion and that sort of thing, so we did some strip tillage after we harvested the maize save ploughing the soil again and that's just to improve we've been looking, we don't want to lose our top soil into the water and it helps improve the water quality as well"

F16.3

This was particularly helpful in gathering data which would inform the hydrological modelling processes.

> "And I guess that the lake itself slightly reduces the runoff, in, in high rainfall conditions, 2 or 3 days ago when we had proper downpours, the lake goes completely brown, there is a lot of soil that is still washed off into the lake, it is gradually silting up. But that then doesn't carry on downstream of the dam."
>
> *F19.9*

> Then probably from a flooding point of view the most interesting thing is, there's a stream that comes down here, through a culvert, down a ditch, into a pond just here, that only fills up in storm conditions oh right, okay once it's full it flows through the woods and then down across the valley and then down into the, it goes that way right okay that's really interesting cos there's a band of different bedrock running through the farm there."
>
> *F9.7*

I had an interesting conversation back in 'academia' about the hydrological and physical knowledge provided by land managers. There was an assumption that this was useful in relation to un-gauged catchments or to reduce the work of empirical measurement. This assumption presumes that a scientist, given the right resources, access and time, would be able to gather and interpret the same data as the land manager. This perspective is science-centric and intrinsically devalues LM knowledges, ignoring some of the inherent limitations of empirical measurements.

For example, there is a limit to the number and location of soil samples you can take (without digging up a field and changing its soil structure). Field hydrology is affected by historical land management in ways that may not be observable with even multiple core samples taken - two seemingly identical fields may actually be hydrologically heterogeneous. This directly reflects Brockett et al. (2019) experience of the ecological attribution of fields

Lived experience and experiential knowledge gather information over time and space,

where the experience is an inherent part of that knowledge rather than separate from it[1]. Focusing on science risks devaluing other forms of knowledge and losing those which cannot be 'scientised'. This institutional practice does not reflect how place-based expertise is formed and not acknowledging these fuller frameworks risks both alienation and also being factually incorrect (homogenization vs place-specific).

Value and Extent

Whilst I have stated that knowledge is not silo'd and is entangled with other ways of making knowledge, our society does create silos. This is recognised in literature exploring how expertise is allocated (section 2.5.3). LMs value their lived experience, but they also value it in relation to other institutionalised knowledges or rather, the experts who have provided this knowledge.

In relation to policy expertise a lack of lived experience was used to directly justify critique of those external to the landscape

> "It doesn't fit in with so much of the legislation, there's just like, gaps that we sit in, and it's just like, it's out of date stuff with how people think about the world and how business is run and how everything fits together."
>
> *F16.4*

However, the accreditation of expertise and the 'value' of lived experience was weighted quite differently when compared with local or scientific 'experts'.

In section 6.2.1, I discussed the wall that the Trothy brought down. Jane has lived by the river her whole life, and I asked her, as someone who knows the river, what she thought about the wall. She is uncertain in her response; when she first saw it, the loss of the trees upset her, but she also felt the wall looked strong, neat and tidy. She believed land managers conducting the work would have had to have it approved, and are well known for engineering ground works. But she knows the river, and importantly the soil,

[1] a gauge also changes the landscape it is in: there is a further reflection here in recognising that research, its instruments and actors ARE part of the landscape. A perspective which I draw into Chapters 10 and 11 but is somewhat off-topic for this section

she had talked about it earlier with her husband David and she repeats what she had said before, now, standing here and watching the river.

> "we have very sandy soil here, there's a big depth of soil. Its a lot of soil here, good soil and it's sandy and if the water starts to come in it will wash it"
>
> *F14.7*

Jane knows how she expects the river to behave and that the river will wash behind the blocks, she points out where parts of the field that belong to another farmer and are on the other side of the river to the wall already appear to be being washed away, but she won't place her lived experience of how the river and soil behave above that of those who have put the wall in place and approved of it.

> "That's what shocked me about it, but if he's done it to protect the lands it'll probably do that but is it going to have a benefit for others?"
>
> *F14.8*

The blocks' positioning will now exacerbate the loss of soil from both sides of the river as the water is funnelled around them.



Figure 6.10: In 2019, evidence of the looser blocks being worn away on the left bank was clear, however, the right bank looked solid. This wasn't, unfortunately the case as shown in Figure 6.5, 140. *photograph authors own*

The place-based expertise of land managers enables them to develop strong and informed frameworks which directly reflect on their decisions and choices.

I have shown where land managers lived experience enabled them to directly critique, either positively or negatively, interventions based on generic environmental policy (6.2.2). Lived experience can change, affect, or be used to evidence and support decision-making. Land managers, however, do not rely on these lived experiences, and where this is their only source of knowledge will devalue their experience against the 'expertise' of others. Knowing the context of my PhD, managers often started conversations or introduced themselves by stressing that they didn't think they would be able to help much. They checked a lot of their language or assumptions, acknowledging uncertainties readily.

In some situations, the value of lived experience and how it informed place-based knowledge was highly regarded. It was valued highly in comparison to 'external' policy knowledge,

> "Yeah the danger is that someone in cardiff dreams up a scheme that they think will suit all farmers which is going to be quite difficult"
>
> *F16.5*

.

Yet an attribution of expertise, particularly scientific could, in some cases, overrule and undermine the knowledge of LMs. For example, Jane judged her place-based expertise (historical knowledge of the river's behaviour and observations of soil structure both visual and embodied) as inferior when positioned against that of the institutionally approved 'experts'.

6.4 Summary and impacts

A synthesis and discussion take place in Chapters 10 and 11. This summary;

- reflects on the methodological approach,
- identifies the key findings and discusses their implications, including the impact on the next stage of the research,
- finishes with a brief reflection on findings and implications from this field study that could not be explored, expanded or included in this thesis: missing voices.

Methodology The methodological approach of long-form interviews and emplaced participant mapping combined with the positionality of both researcher and participant significantly impacted the findings. Long-form interviews use significantly greater resources, potentially limiting sample number. However, this may be countered by the richness and relevance of detail (McCracken, 1988). This is demonstrated in the key finding that whilst initially participants presented a negative view of increased tree cover or 'no need for more trees' early in interviews. This was contradicted by the number of participants either identifying potential planting locations, actively planning or in the process of planting trees. (see p 154 for details). This demonstrates that the early presentation or rhetoric did not necessarily reflect a final decision or actual practice. Whilst there is a potential here for response bias, it is more likely that the initial response presents a defensive attitude which softens to a more pragmatic approach during the course of the interview. This directly reflects on the reliability of the short-form interview or survey over the long form interview.

Chapter aims and findings This chapter aimed to identify farmers' and land managers' relevant knowledge and expertise regarding increasing tree cover for natural flood management within the Trothy catchment and how this impacts decision-making and political behaviours. Key findings included:

- Lived experience had significant importance as a way of 'knowing' landscape, and whilst the temporal and spatial resolution and limits of lived experience were evident, they did not always directly correlate and could be affected by multiple factors.
- Lived experience of LMs directly reflected the importance of the co-production of landscape by multiple bio-physical actors. This impacted LM decision-making, for example:
  - Encounters with slope were directly related to the practice of hydrological modelling
  - Encounters with Himalayan Balsam, Ash dieback, and the river itself informed LMs' decision-making and critique of policy whilst also speaking to the neglected agency of these non-human actors on the challenge of Trees for NFM
- Lived experience was rarely treated in isolation and informed (and was informed by) multiple local and extra-local knowledges (as suggested by Lowe et al., 2019) reflecting the concept of 'knowledge cultures' (Tsouvalis et al., 2000, Morris, 2006). The complexity of LMs 'knowledge cultures' was directly reflected in their decision-making. This complex knowledge culture, of which lived experience was a fundamental aspect, enabled LMs to evaluate and develop strong critiques of both policy and science, often concerning previously held political frameworks (supporting work of Emery and Carrithers, 2016).
- The identification of LMs as Experts in their F/fields could be directly justified in relation to the relevant knowledge and agency of decision-making (see Wynne, 1996). However, this attribution was not reflected in LMs' own conversations and the 'value' of different types of expertise is complex, relating to multiple political and social frameworks.

The wider implications of these findings will be discussed further in Chapters 10 and 11. However, reflecting the literature of critical physical geography and the STS approach

of democratisation and co-production of science, the fieldwork also provided knowledge directly relevant to the project's next stage. I will identify throughout Methods II:Chapter 7 where participant involvement impacted practice. However, to briefly summarise here the implications:

- Lived experience of landscape behaviour (participant and researcher) and participant interest directly impacted model choice
- Knowledge of factors such as soil structure and hydrological behaviours drew out limitations to the model as well as constraints to parameter choices
- Alternative scenarios could be developed to directly investigate types of planting of interest to the community.
- Participant mapping enabled a spatial investigation of complex factors such as 'slope' in alternative scenarios
- The limitations of the 'usefulness' of the model output could be identified by relating participant interest to available data; this directly impacted model constraints and, therefore, parameter choices.

This chapter builds on decades of literature that support the identification of LMs as 'Experts in their F/fields'; relevant knowledge holders whose direct involvement enables engagement in the co-production of our landscapes within the context of wicked challenges. The research indicates not only LMs importance in the efficacy of scientific practice but that the lack of LM expertise currently impacts both the efficacy of design and the likelihood of 'successful' implementation. A level playing field is needed for an exchange of expertise to become possible, meaning we are not only 'getting it right' but 'doing it right'.

Missing voices During this research, I have reflected on the critique of phenomenology for its past relations with the concept of 'rootedness' leading to the exclusion of those who 'do not dwell'. Whilst showing that this perspective is not a reliable one (section 2.4.3), it

is a perspective that is and is reflected in participants critique of policymakers as "someone in Cardiff"(Quote 57 p 163). Reflecting on this and the implications of exclusion, there are three largely unmentioned groups within this study who are yet directly relevant to the environmental challenges addressed.

In most cases, my discussions have taken place with the 'representative' of a farm. Whilst, through interviews and in the information related, I have tried to reflect the importance of the family and business network behind that representative, there is further research to do to look at how the decision-making capacity is held by this figurehead. There also needs to be a development of understanding of the importance of traditionally gender-based roles. All bar four of my interviewees were men, and two women were interviewed in partnership with a husband. This does not, however, mean that all other women weren't important (at least one interview contact started with 'I'm calling because my wife told me too'). Neither should it detract from the importance of the roles held by those not in a figurehead position (e.g. the son who was lead stocksman, three wives who ran all the accounting and held most of the economic knowledge of the farm). There is a deal of work to be completed here which is beyond the scope of this study but does directly reflect on farmer decision-making.

I have included little reflection in this research on the voice of the community who live within or are impacted by the landscape, where they have not had 'direct' access to enabling landscape change. This is partly out of choice and reflects a response to flood management literature where the stakeholder community are regularly identified as those with regulatory responsibilities or those at the impact of the floods (section 2.2.4), and rarely those working the land which is being discussed. Our laws of ownership and responsibility of landscape make this a very tricky area to navigate – who has the rights to determine how our landscape is managed is a field of research in itself (outlined briefly in Chapter 5, Figure 5.15). Whilst it is far beyond the scope of this PhD to investigate this, it cannot be ignored. Someone who walks a landscape may have valuable place-based lived experience of it, in addition to place-identity developed through interaction with a landscape. This includes those policy-practitioners who can also have experiential

knowledge of place (if, as shown by Shortland (2021), to be of a different quality to farmers.)

This leads, however, to a third group: those largely excluded from the landscape and those who do not dwell. The background of my participants is British and white, as this group is directly representative of those who are in a position to enact change within this landscape at this moment in time. Phenomenological approaches and the dwelling perspective have been critiqued for implying that if you do not 'dwell' in that landscape you cannot know it as well as someone who does (section 2.4.3). This risks a belief that historical ownership gives knowledge a greater value, whereas someone from a different place or culture will not hold knowledge of the same value or relationship with the landscape. I would suggest that this is due to our insistence on weighting or valuing different types of knowledge above each other instead of understanding that there are multiple understandings of landscape each with its own 'value'[2]. This concern is beyond the scope of this research yet directly relevant to it. Prior to the tragedies that led to the Black Lives Matter campaigns in 2020, after my fieldwork, the unequal voice and unjust implications of my research were already evident and alarming. I felt I was lending further weight to anyone other than the voices most desperately needing to be heard. However, those dwelling and working in landscapes are not heard in a way that respects how they are engaging with, and part of, the landscape, and this lack of voice means that, in a climate and nature emergency, our actions and intentions are caught in quagmire. Acknowledging these voices is necessary, it does not preclude us from acknowledging the voices of others as well. It is a multiple understanding of the value of different knowledges, including those that have not been voiced in this research, that will lead us to properly engage with this wicked problem of changing landscapes.

[2]This is something an inherently economic approach to landscape in our language and policy risks continued consolidation of see Chapter 12)

Part III

The Model

Chapter 7

Methods II

Contents

7.1 Hydrological models for NFM 171

7.2 Model choice 172

7.3 SHETRAN; description, setup and application 174

7.4 Model calibration 181

7.1 Hydrological models for NFM

In section 2.3, I describe the tree-water interactions and the disciplinary and historical frameworks that form the perceptual model on which Trees for NFM is based. I critique the technocratic frameworks and this critique is supported by the findings in Chapter 6, which identifies a more complex 'way of knowing' the landscape and relevance of lived experience to scientisable knowledge(s).

For example, in section 6.2.1, I showed how Peter's knowledge of the drainage in his fields created a 'richer' picture. It is immediately apparent that this knowledge must inform the perceptual model of the catchment. The inclusion and impact of field drains identifies, for example, a difficulty in identifying suitable hydrological response units (HRUs). This has direct implications for the choice of model.

In addition, considering the literature review, case study and chapter 6 findings, it

should be clear that attempting to model future planting plans is unrealistic given the temporal and spatial scales of tree growth combined with the socio-cultural (and bio-physical) complexities of a large catchment.

Section 2.2.3 introduced the concept of hydrological modelling as a heuristic to explore scenarios where empirical evidence was impractical or unattainable. LMs were supportive in principle of the idea of increasing tree cover for NFM; however, queried its effectiveness and had other priorities for tree planting. Given the impossibility of empirical evidence (someone has to plant more trees before the effect of planting more trees can be measured), a model has a useful part to play in providing information regarding some of their questions, including: Does increasing tree cover within the catchment reduce flood peaks? Do different interventions that are suitable within farm systems have similar impacts? Are there negative consequences associated with floods?[1]

7.2 Model choice

To explore scenarios that may inform the efficacy of tree cover expansion for NFM (Trees for NFM), I needed a model which could spatially represent the catchment and alternative land cover scenarios. In addition, the land managers were interested in sheet flow across fields, subsurface hydrology and the links between water quantity and water quality.

Table 7.1 outlines two examples of hydrological models previously used for flood management, which were well evidenced in the UK when I conducted the initial review.

For this study, I required a model that was suitable at large spatial scales whilst able to incorporate small-scale land cover changes, could model sheetflow and other observations of land managers, incorporate both overland and subsurface flow and support several different vegetation types.

I chose the SHETRAN model for this study as it met the criteria and needs for modelling the behaviour under landscape change at a spatial scale suitable on farms. The second key consideration was the ease with which it could be explained to participants.

[1] A question I am not tackling is that of drought, and this is an omission that I reflect on in Chapters 10 and 11

Table 7.1: comparison of Hydrological models for NFM

Model	Type	Supporting	Challenges	Example case studies	References
Dynamic TopModel (and Jflow)	Lumped plus 2D	Hillslope processes using hydrological response units (HRU) in DT, channel and flood plain hydrodynamics in Jflow (also possible to use non-proprietory HecMas 2D)	Lack of case studies for non-proprietory HecRAS; requires identification of HRUs in catchment with complex topography and unknown drainage systems	Eden catchment (2,300km2); Swindale beck (15km2); Trout beck (11.4km2), Wye basin (10.6km2), East Dart (21.5km2)	Beven and Freer, 2001, Hankin et al., 2019, Hankin, Metcalfe, et al., 2017, Hankin, Lamb, et al., 2017, Gao et al., 2016
SHETRAN	PBSD	Uses a grid system to represent catchment, visually representative of catchment layout, can model sheet flow across catchment, windows version potentially accessible to participants	Requires multiple parameter sets across complex and large catchment	Blackwater (18 km2), Kit Brook (22km2), Guabalcon basin (Ecuador) 65.8km2, Halfwhistle Burn (42km2), Coalburn catchment (1.5km2), Flothers (1.4km2)	Ewen et al., 2000, Lewis et al., 2018, Bathurst et al., 2010, Escobar-Ruiz et al., 2022, Rangecroft et al., 2018, Bathurst et al., 2018

SHETRAN provides the ability to 'map' the catchment changes to a farm-relevant scale with a grid structure that was easy to explain. The fact that SHETRAN is freely available in a desktop format that participants themselves could potentially access was also part of the decision. I decided to use SHETRAN as a heuristic model to inform and improve the perceptual understanding of the catchment under alternative scenarios.

A further decision was whether to use SHETRAN as a stochastic or deterministic model. Given the gaps in the perceptual model of the catchment, a stochastic model would be useful where the range in uncertainty of parameters could be used to inform the perceptual model of the catchment. Unfortunately, at this catchment size, the ability to identify why or where uncertainties were relevant was prohibitive. I would have followed this method for a smaller catchment, where additional engagement with a higher proportion of managers was possible and may have provided greater coverage overall. In this scenario, I would also have been interested in running both my primary model choices to see what additional information could be learnt. This is an area of future research worth exploring.

7.3 SHETRAN; description, setup and application

SHETRAN is a physically based spatially distributed model (PBSD) (Ewen et al., 2000, https://research.ncl.ac.uk/shetran/). PBSDs are used to explore the impacts of land use change and climate, where management choices and interventions create complex landscapes. (section 2.2.3). SHETRAN (as visualised in Figure 7.1) represents the catchment using a grid; bank elements and the river channels run alongside grid cells. Each cell, bank component and river/stream channel has an allocated number, and the cells have a 'face' (North 1, East 2....). This numerical code is how the model identifies each position and to which each parameter set by the modeller is attributed. Each cell in the Trothy model represents 100mx100m; this meant that the maximum openly available model could incorporate the 140km^2 catchment and was at a fine enough resolution to model small woodlands and shelterbelts. It could not account for hedgerows and the implications of this are discussed in later chapters. The boundary of the catchment is defined in the frd file FR34, with the grid allocating a 1 to cells within the catchment and a 0 to the rest. A catchment mask defining the boundary of the Trothy catchment was created using ArcGIS and the methods described in Birkinshaw, 2013.

Each cell also has a 'depth'; different soil types and levels can be associated with this and impacted by factors such as vegetation rooting depth.

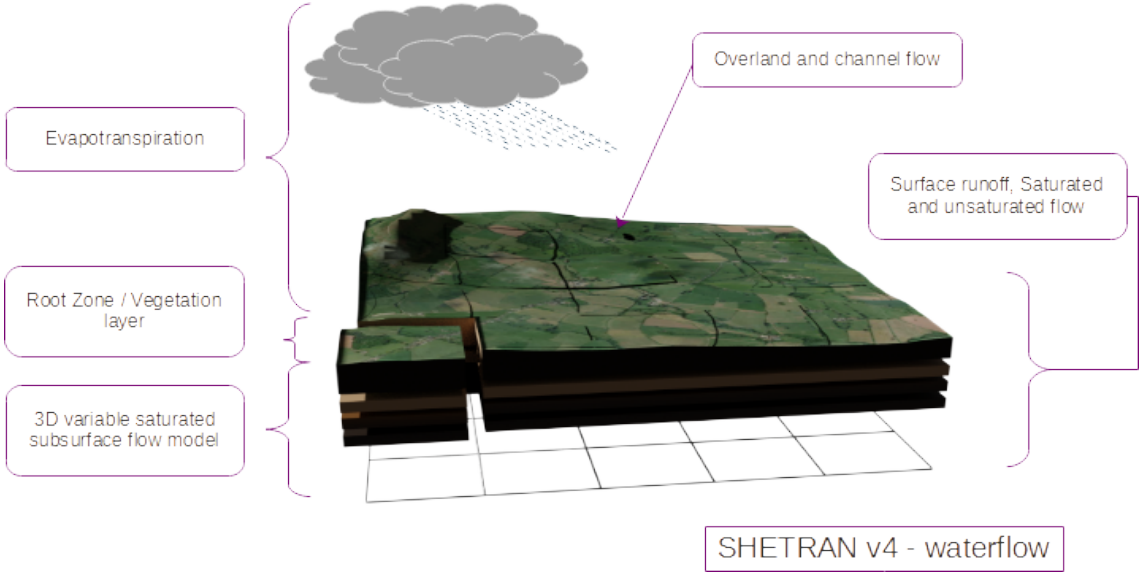


Figure 7.1: SHETRAN v4 processes

Soil depths were obtained from the International Soil Reference and Information Centre SoilGrids and checked against the Cranfield soil descriptions (see Appendix II). In addition, a deeper soil layer representing the subsoil to bedrock baselayer was included as advised in Birkinshaw, 2016.

The hydrological behaviour at any given time can be deduced by using physical equations to evaluate each cell's attributed properties (parameters). Each cell relates to multiple parameters; thus,the complexity of resultant calculations increases exponentially as the cell number increases.

The SHETRAN model uses a modular approach to tackling this. It has 'Components' which can be included in addition to the standard Water flow component, including Sediment Transport and Contaminant Transport. Each component is broken down into 'modules', responsible for certain physical mechanisms, and each module interacts with the others in a specific order. The interactions within the water flow component are shown in Figure 7.2.

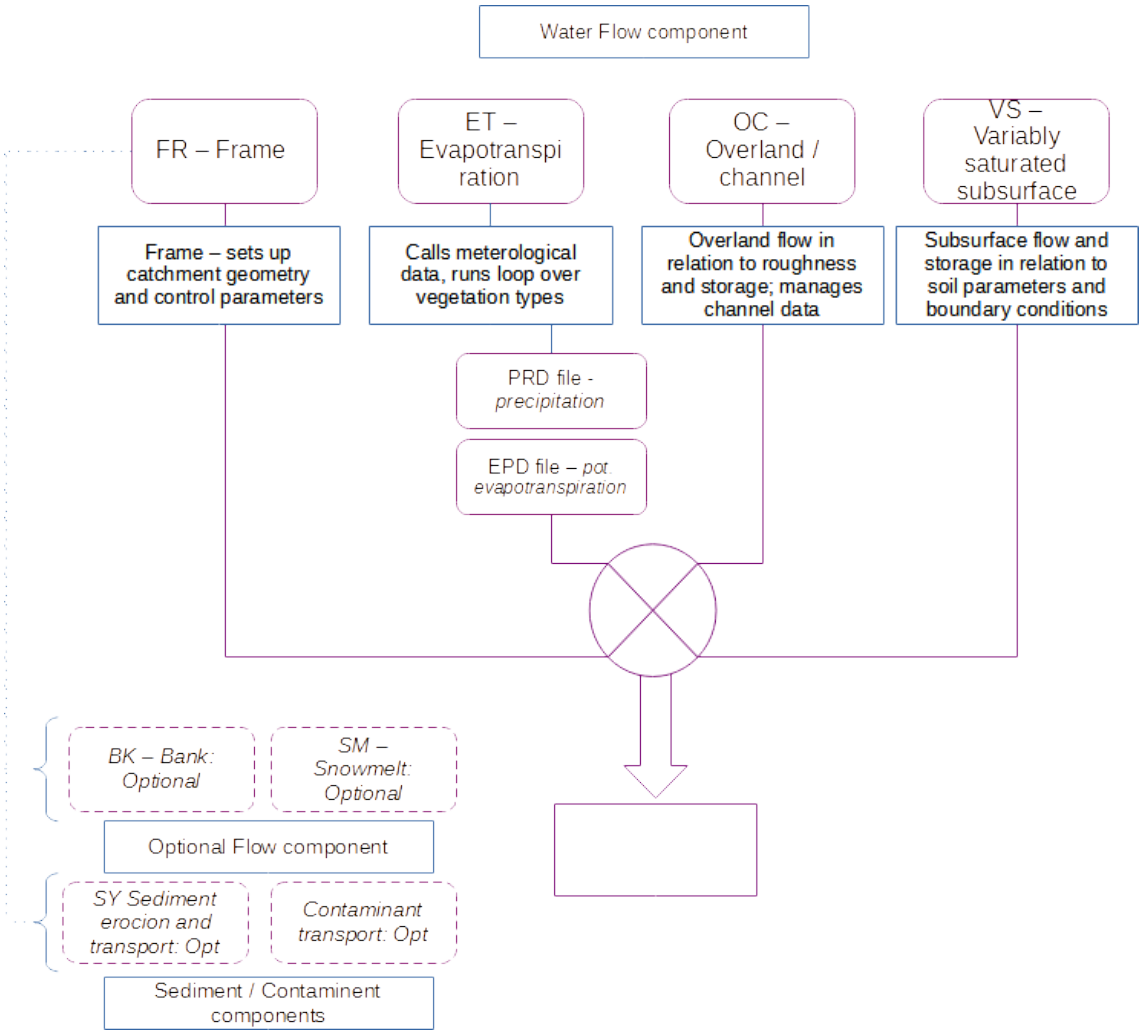


Figure 7.2: SHETRAN v4 modules

Whilst the focus of this thesis is water flow, an advantage of SHETRAN was its capacity to interrogate sediment and water quality in the future, as these factors were of particular interest to the catchment community.

The Linux version of the model can only be used for examining water flow as only the summary ASCII files and discharge are output. However, having set up the input files, these can easily be run on Windows to gain HDF5 files, which collate additional variables such as overflow and phreatic surface levels. This was completed for the baseline run to examine Phreatic surface levels at different simulation stages (useful for both evaluation and development of alternative scenarios).

The Water flow component[2] includes three modules that are 'called' at each timestep:

[2]The detail and equations are given in the SHETRAN documentation, which is freely available here:

Evapotranspiration/interception (ETD), Variable saturated subsurface (VSS), Overland/channel flow (OC). These three modules are included as standard; a snowmelt module can also be programmed but wasn't needed for this catchment. The modules calculate and pass data at each timestep (see figure 2.4, p45 "SHETRAN Water Flow Component, Equations and Algorithms", n.d.).

In the **Evapotranspiration/interception module**, two conceptual models on which the physical equations are being based are used:

- evapotranspiration based on Penman (1948) and Penman-Monteith (Monteith, 1965);
- a relationship between actual and potential and interception based on Rutter et al. (1971, 1975)

Figure 7.3 showing the processes modelled and calculations completed is based on section 3.4 and Figure 3.1 on p14 and p44 of "SHETRAN Water Flow Component, Equations and Algorithms" (n.d.).

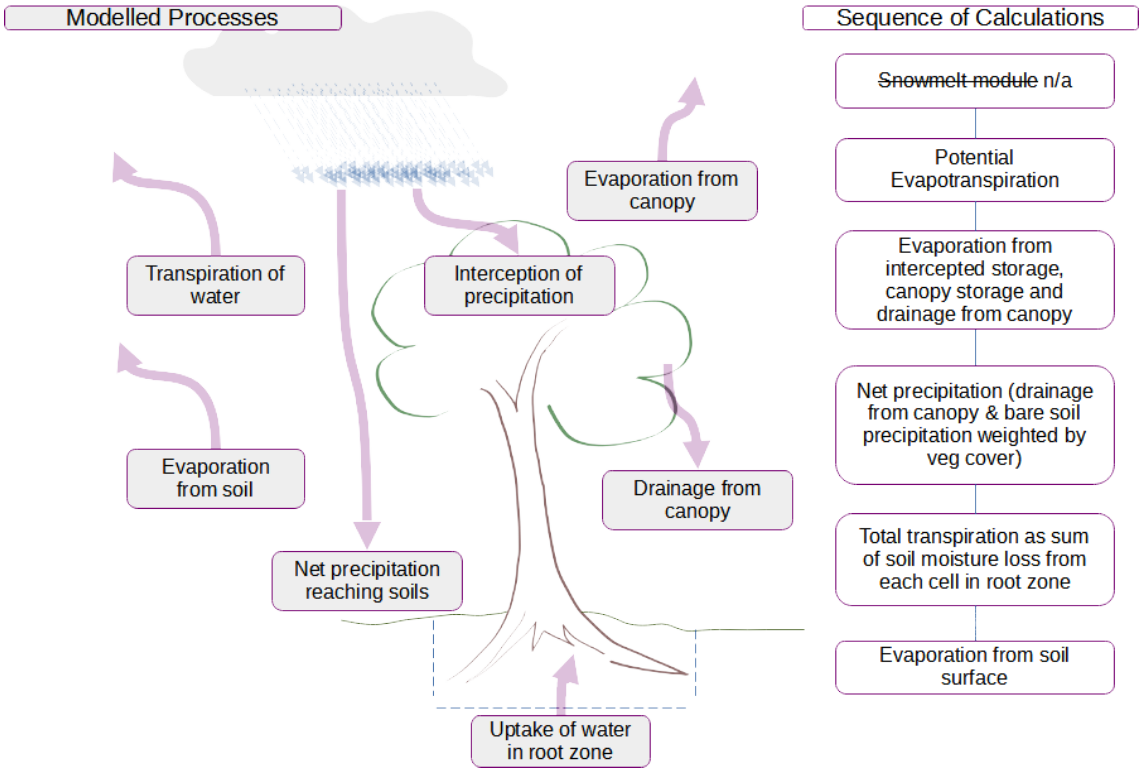


Figure 7.3: ETD module processes and order of calculations

https://research.ncl.ac.uk/shetran/Documentation.htm

As full meteorological data was unavailable for the Trothy catchment, the alternative of using rainfall (PRD file) and potential evapotranspiration (PET)(EPD file) whilst calculating actual evapotranspiration using actual/potential evaporation ratios Erc ("SHETRAN Water Flow Component, Equations and Algorithms", n.d., p25 and p28) was completed (Appendix VIII & IX). The input timesteps were hourly for both Rainfall and PET.

The **Variable Saturated Subsurface Module** allows for a complex three-dimensional flow with variable saturation levels in soils of a single porosity/permeability. Each cell is considered a column (Figure 7.4) and waterflow occurs vertically through each column and horizontally between them. Soil parameters were set using remote sensed data as described in Appendix II.

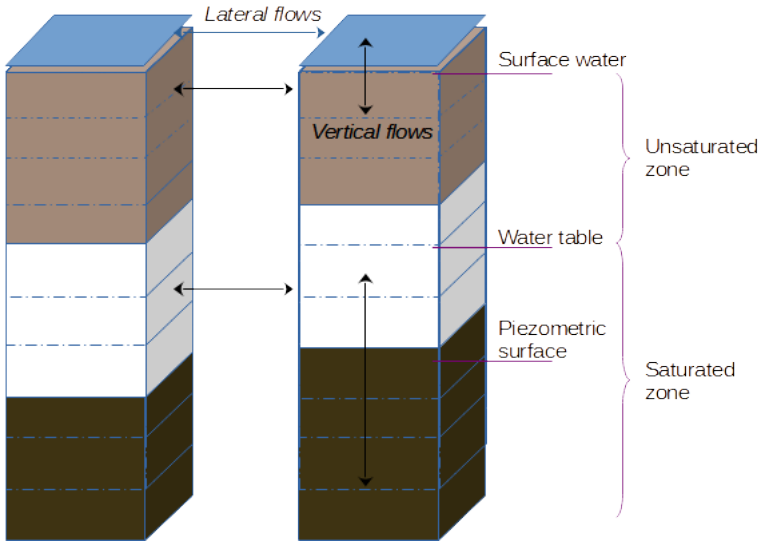


Figure 7.4: VSS module processes based on Figure 5.1, p51 "SHETRAN Water Flow Component, Equations and Algorithms", n.d., data sources in Appendix II and parameters in Appendix XI

The **Overland/channel module** calculates the depth and flow of surface water, both on the ground and in the channel. The flow is also calculated into or out of stream channels, which includes overbank flow. When considering the discussion with land managers, an important attribute of the SHETRAN model is that the model calculates sheet flow (the movement of water across and through each cell) rather than channel flow. A ho-

mogenous river bed is assumed throughout my use of this model for considerations based on the practicality of measurements, the uncertainties produced by estimating difference, and the relative impact of the channel heterogeneity vs. land management changes.

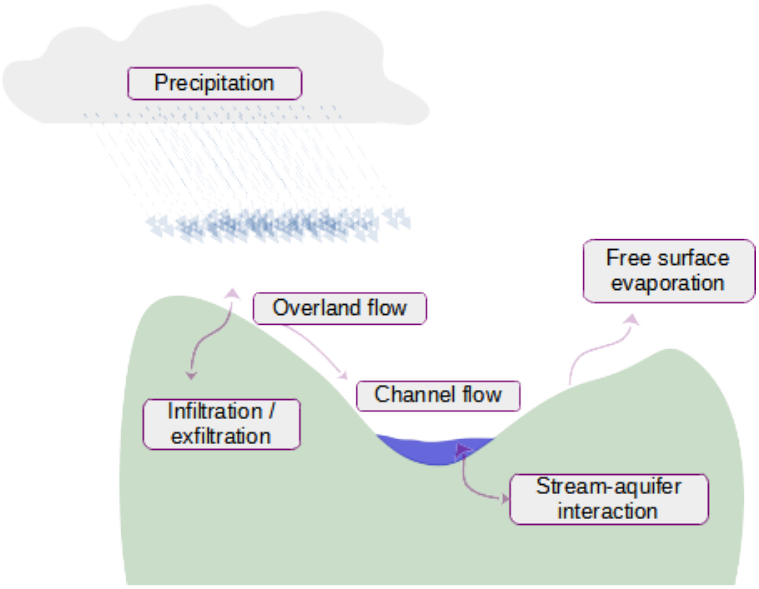


Figure 7.5: OC module processes based on Figure 4.2 p49 SHETRAN waterflow equations

The **order of execution** starts with the net rainfall and evaporation calculations by the ET model, feeding into the VSS groundwater levels and soil moisture calculations. These feed back into the ET model and the surface water river levels module, OC ("SHETRAN Water Flow Component, Equations and Algorithms", n.d.)

Outputs include the following discharge and summary data in ASCII format:

- Discharge is output at 'every' and 'regular' timesteps, which the user may define. The Trothy model timestep was hourly totalling 6576 hours (just over nine months).
- Daily mass balance data - this is the spatially averaged cumulative totals for each day, including: Precipitation, Canopy Evaporation, Soil evaporation, Transport, Aquifer flow, Discharge
- Storage data, including: Snow, subsurface, Land Surface and Channel

- Phreatic surface levels and head data for the end of the simulation (this can be copied to a vsi file to create a 'hot-start' as it reduces the time needed to run in (to get water into the catchment to a point where it is behaving normally). Whilst a hot-start wasn't needed for this model, the output phreatic surface levels were used in creation of certain Alternative Scenarios, see table 8.2)

Appendix II includes the secondary and remote sensed data collated and used in applying the SHETRAN model to the catchment. Appendix VIII and IX include the R code used to generate the PRD (rainfall) and EPD (potential evapotranspiration) files.

Figure 7.6 shows the stages of building the baseline and figure 7.7 alternative scenarios.

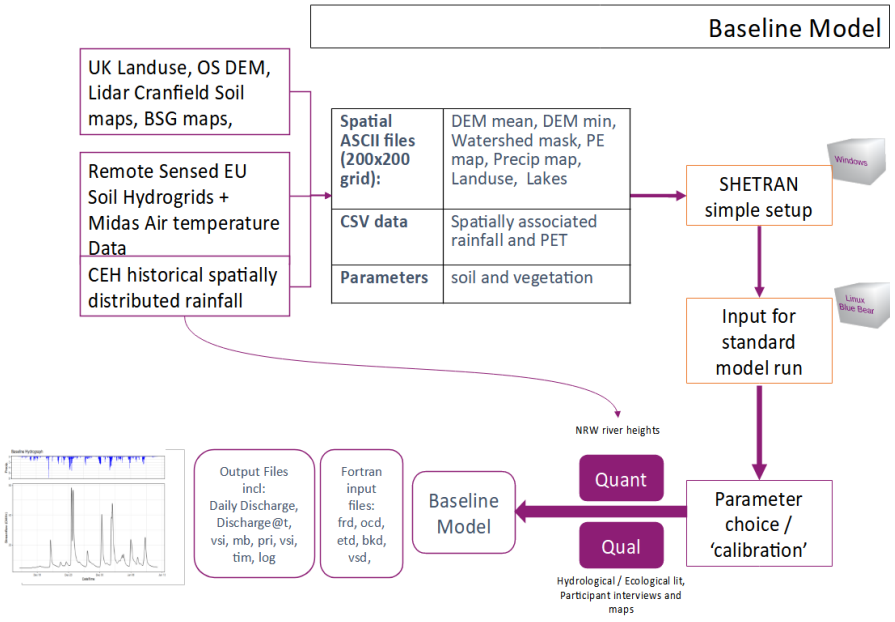


Figure 7.6: Workflow to develop the baseline model of the Trothy catchment 2013-2014

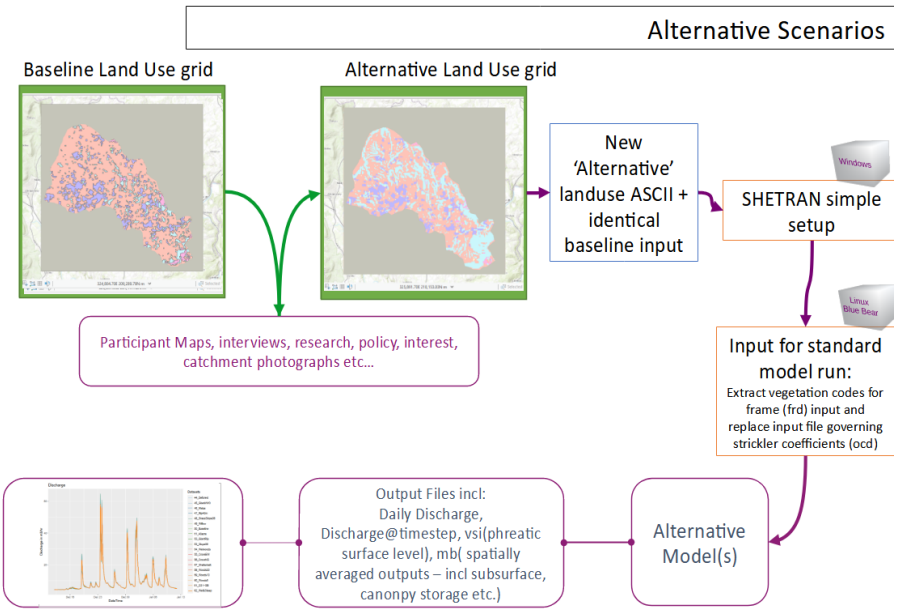


Figure 7.7: Workflow to develop the alternative landcover scenarios of the Trothy catchment

7.4 Model calibration

The standard for model parameter calibration is to compare repeated simulations and model output with available observations (Beven, 2012). This process uses a statistical measure of performance, usually the Nash-Sutcliffe calculation of model efficiency. A value of 1 would indicate a 'perfect fit'; a well-performing model is given as achieving a value above 0.7 (Nash and Sutcliffe, 1970). Whilst this is the standard measurement, its reliability has been questioned, with even poor models being able to reach a high efficiency where they respect the water balance (Seibert et al., 2018).

The Trothy had been monitored for flow measurements; however, since 1982, only level measurements have been recorded. I therefore required a method of calibrating the baseline model using levels data and a limited fieldwork period 2019-2020. One technique uses a gauged period to calibrate an ungauged period (a temporal gauging divergence). However, the time over which I could collect discharge data would be shorter than the time between the records I was using. Seasonal variation would make it unlikely that the results would reasonably reflect catchment behaviour (Seibert and Beven, 2009). Another

strategy is to use observations to relate discharge to levels generating a ratings curve. The recorded levels from the past event could then be read, estimating discharge. This method relies, however, on the riverbed profile being the same between the two events (which could not be guaranteed in the case of the Trothy) and reasonable observations of seasonal variation. Fieldwork examined only one season's data, so if the weather was significantly different, or behaviours had recently changed, the measurements would not reflect the catchment behaviour in 2013/14.

Decision making, time, the reality of flooding and other world events caught up with me. I decided to take regular discharge measurements whenever I was in catchment for conducting interviews. However, working with a river required that I planned trips adequately and could be joined by another person as lone working 'in' a river was not going to pass any risk assessment requirements. I was in Monmouth when the first of the unexpected events occurred - being evacuated due to extreme flooding (see section 5.3). This was the first of the floods that broke the 'previous highest peak' of 2000.

My challenge to collect discharge data was now faced with the fact that it was too dangerous to visit the area. The Trothy rises and falls remarkably quickly, but the River Wye stayed high for a long time. When I visited for an interview in November, it was clear that the impacts of the flood were still affecting the catchment. At this stage, I had missed the October/November period and would not have discharge for the stage I needed to calibrate model parameters for conversion from levels to discharge. This still left the opportunity to collect a smaller number of measurements in order to use the inverse rating curve (IRC) method described by Jian et al. (2017) for developing hydrology of ungauged catchments. The method assumes that the water level h and discharge can be related by a power function. a0, a1 and a2 are parameters, and the method requires between one and three observed discharge measurements to calibrate the parameters.

$$Q = a_o + a_1 h^{a_2} \tag{7.1}$$

I decided to carry out these measurements early in the following year when the river

would still be high, but not dangerously so – it would also be an easier time to arrange a small team to take measurements rather than the busy run-up to December. The risk assessments completed and equipment availability sorted, a second significant flood in January pushed us to mid-February, giving me two months, March and April, to arrange to take a suitable number of readings. Then, in March 2020, we went into COVID lockdown. My catchment was over the border in Wales. Even had I been able to arrange fieldwork support within my 'bubble', I was unable to travel to the river due to overlapping lockdowns, revisiting risk assessments, and a moral duty to create no possibility of harm to myself or others. I could not gather data or even visit the river for the next 12 months.

This left me with no discharge data to calibrate my model. Whilst the riverbed profile could be used to generate a ratings curve and theoretically convert the discharge to height data, this would introduce significant uncertainties (Hulsman, 2018; van Meerveld et al., 2017) even assuming that riverbed profile hadn't changed in the past 6 years.

Calibration using river levels has, fortunately, seen significant development as part of work to develop the ability to monitor catchments, largely due to the ability to gain these measurements through citizen science (van Meerveld et al., 2017). The Spearman Rank Correlation Coefficient (SRC, ρ) can be used to evaluate the correlation between data which have a positive, non-linear relationship. The model could be calibrated by evaluating the relationship between the observed height data and the modelled discharge by maximising ρ (Jian et al., 2017; van Meerveld et al., 2017). $\rho = 1$ when the river levels and modelled discharge are monotonically related (the relationship stays the same; it never increases or decreases). As SRC is evaluating level rather than volume, it is expected that a value of 1 would never be achieved. The canalised nature of the deep channel in the Trothy suggests ρ could be quite close to one, but if the model is reliable, the point at which the river breaks its banks would change the correlation. This means I was not attempting to reach $\rho = 1$, but the model parameters could be used for calibration as the similarity between the dynamics of the discharge and the observed level should be at the highest achievable value of ρ. I could test parameters therefore, to see if a change

increases or decreases ρ.

With any calibration method, it is still important to avoid parameter overfitting or selecting the wrong parameters for the right reasons (Beven, 2012). This can be a danger of using statistical methods of parameter fitting. In addition, the time taken for a model run and the number of parameters in the SHETRAN model meant that a decision had to be made between the time required to run enough models to get a good statistical response or to run fewer models and use expert information: i.e. literature describing parameter suitability for SHETRAN (see table 7.1), remote sensed data and modeller choice. As very few parameters could be accurately measured, the most appropriate method was to manually fit parameters, based on the workflow suggested by SHETRAN developers (Birkinshaw, 2016) and the available literature.

When parameter fitting, I used the Pearson correlation coefficient to compare the difference between model runs and visually examine the output. This way, I could see how much difference each change had, and I could see which mechanisms were being affected, i.e. if changes were affecting the baseflow (the average or low flow behaviour of the hydrograph) or peakflow (the shape of the flood peaks).

The parameters used for the simple model runs are included here. The ETD and VSD (vegetation and variable subsurface/soil) files, which include the final parameters set, can be found in Appendix XI

Veg Type #	Vegetation Type	Canopy storage capacity (mm)	Leaf area index	Maximum rooting depth(m)	AE/PE at field capacity	Strickler overland flow coefficient
1	Arable	1.5	1	0.8	0.6	1.5
2	BareGround	0	0	0.1	0.4	2
3	Grass	1.5	1	1	0.6	1
4	Deciduous	5	1	1.6	1	0.5
5	Evergreen	5	1	2	1	0.5
6	Shrub	1.5	1	1	0.4	1
7	Urban	0.3	0.3	0.5	0.4	5

Table 7.2: Vegetation Parameters for the simple run

Soil#	Soil Type	Saturated Water Content	Residual Water Content	Saturated Conductivity (m/day)	Van Genuchten alpha (cm-1)	Van Genuchten n
1	ClayLoamTop(18)	0.55	0.156	0.008	0.0112	1.229
2	ClayLoamSub(18)	0.489	0.153	0.055	0.00923	1.657
3	SiltyClayLoamTop(6)	0.555	0.151	0.0074	0.012	1.238
4	SiltyClayLoamSub(6)	0.507	0.144	0.0036	0.00724	1.608
5	ClayLoamTop(8)	0.554	0.151	0.008	0.0121	1.238
6	ClayLoamSub(8)	0.489	0.153	0.055	0.00923	1.657
7	SandySiltLoamTop(12)	0.551	0.15	0.009	0.0124	1.239
8	SandySiltLoamSub(12)	0.452	0.093	0.0434	0.00515	1.681
9	SandstoneBaselayer(00)	0.5	0.093	0.5	0.00515	1.681

Table 7.3: Soil Parameters for the simple run

Soil Category	Soil Layer	Soil Type	Depth at base of layer (m)
1	1	1	0.6
1	2	2	8.9
1	3	9	15
2	1	3	0.6
2	2	4	9.4
2	3	9	15
3	1	5	0.6
3	2	6	8.9
3	3	9	15
4	1	7	0.6
4	2	8	10.1
4	3	9	15

Table 7.4: The four catchment soil categories for the simple run - see Figure 5.4 page 104

Chapter 8

Modelling increased tree cover for NFM

Contents

8.1 Evaluating the Baseline Model **188**

8.1.1 1. How well the model represents catchment hydrology 189

8.1.2 2. An evaluation against observed river levels 190

8.1.3 Baseline Evaluation against Archived data 194

8.2 Alternative Scenarios **194**

8.3 Findings **198**

8.3.1 No intervention prevents flooding at the maximum peak . . . 199

8.3.2 Increasing woodland planting decreases floodpeak 201

8.3.3 Time to Peak and peak flood dates 207

8.3.4 The 'type' of landscape that is under tree cover, where it is and what is replaced are important (not just the extent) 213

8.3.5 Loss of trees or other management choices have a greater impact per area of change 217

8.4 Reflections and implications **220**

8.4.1 Methods 220

8.4.2 Interpreting the model output 221

8.4.3 Limitations and implications 227

8.1 Evaluating the Baseline Model

The Baseline model was developed as a representation of the catchment during the flood events of the winter of 2013/2014 (see Chapter 5). A model run generating the full range of output files was performed to examine discharge, cumulative totals, storage and phreatic surface. The standard approach to calibrating and validating the model output is to compare the measured discharge with the modelled discharge during separate calibration and validation periods (section 7.4). Beven (2012) suggests that even for predictive models, validation is not really a suitable term, particularly if the predictions fall outside the validation period, suggesting 'evaluation' as a more suitable term. This model is not meant for predictive purposes; I am interrogating alternative scenarios for a past event. None of the modelled alternative scenarios are intended as a true reflection of the catchment at any past or future time. The model is intended as a heuristic, where we cannot constrain the uncertainties of future events, the model acts as a learning tool to enable us to better understand the mechanisms of the catchment hydrology in different scenarios (Rangecroft et al., 2018; Seibert and Bergström, 2022). This knowledge may be used to inform future management decisions and to evaluate the potential effectiveness of current or future approaches. Whilst 'validating' a heuristic model is not always deemed necessary (Rangecroft et al., 2018), an evaluation of the baseline model run provides data that may be used to determine confidence in the output and enables comparison with any future output.

With this model, there is no available discharge data during the time in which the baseline scenario occurs. This means that evaluation must take a different approach. To ensure rigour, three factors were considered:

1. How well the model represents the catchment hydrology:

- Physical/visual representation of the river channels, phreatic surface levels etc.

- Analysis of the hydrograph including:
  - how does it reflect the behaviour of the river
  - Does the model respond to rainfall in a similar way to the river levels

2. An evaluation of the baseline run against observed river levels:

- Analysing the relationship between the river levels and the modelled output both visually and using the Spearman correlation coefficient for an evaluation period

An evaluation of the baseline against archived data

- Checking that the baseline is within bounds set by historical data (the 2014 flood was the most recent high at the start of the project, but not a record-breaking flood: it is anticipated that the river levels should be within a similar range)

8.1.1 1. How well the model represents catchment hydrology

The river channel links demonstrated the complexity of the catchment tributaries and visually match the known river channel distribution.

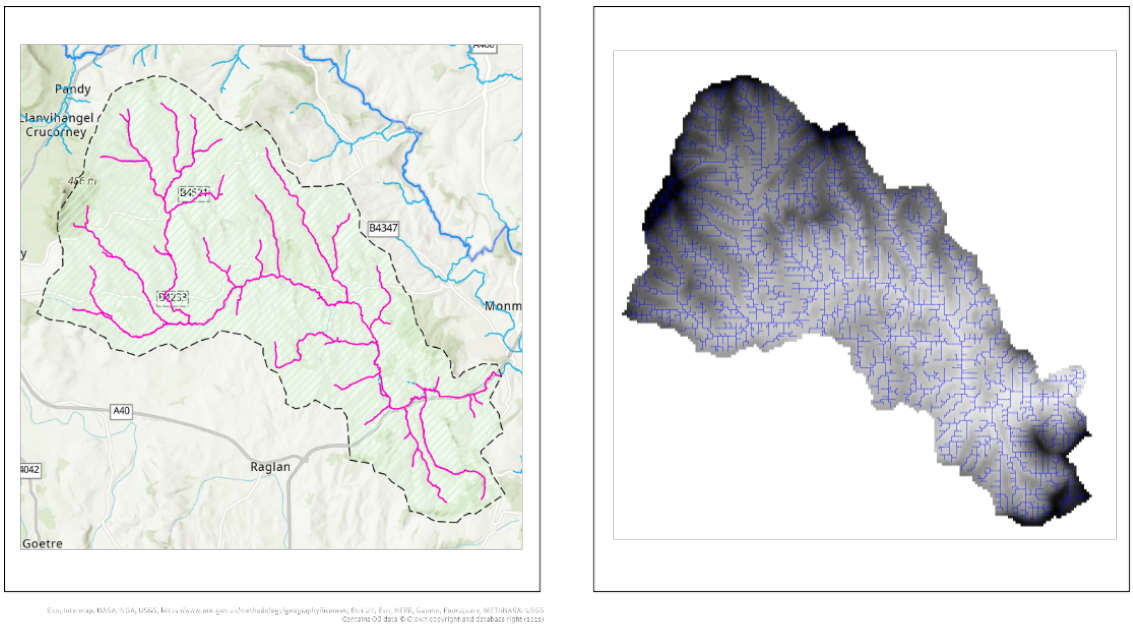


Figure 8.1: The channel network produced by the SHETRAN model against the channel network from the OS maps

The catchment hydrograph shows the variation of discharge over time and is shown alongside the average catchment precipitation.

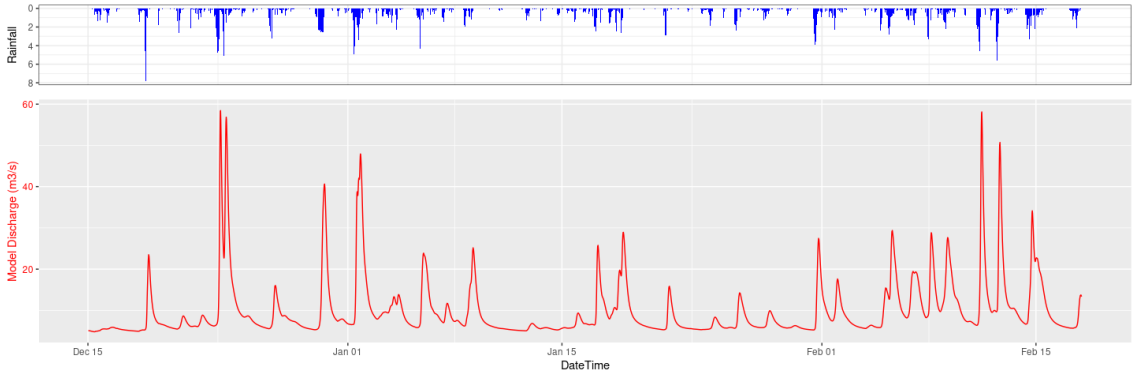


Figure 8.2: The Baseline Hydrograph for the evaluation period Dec 2013 - Feb 2014

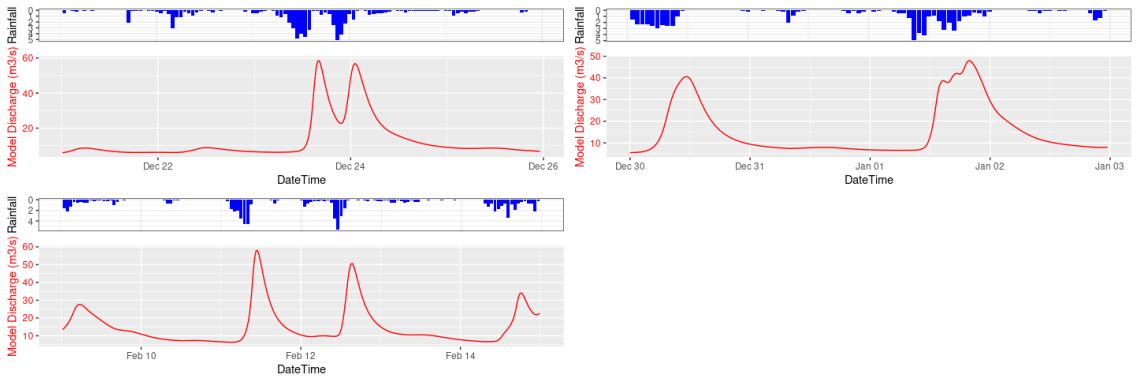


Figure 8.3: Baseline Hydrographs for the 2013-2014 flood events

Figure 8.2 shows a river that responds very quickly to the precipitation across the catchment. The steep slopes of the flow duration curve indicate highly variable flows - this reflects the behaviour observed by catchment participants (Section 5.3). Beven states that "even qualitative or “soft" information of different types that cannot easily be reduced to a statistical likelihood might be useful in model calibration (Beven, 2012, p241) supporting the validity of this qualitative evidence in evaluating the hydrological model.

8.1.2 2. An evaluation against observed river levels

As stated in the methodology (section 7.4, I used the Spearman Correlation coefficient to calibrate the model parameters by ensuring that parameter adjustments maximised

the correlation coefficient between the observed river heights and the modelled discharge (Jian et al., 2017; van Meerveld et al., 2017). The model calibration period ran from Sept - Nov 2013, and evaluation for Dec 2013 - Feb 2014 visually and using the Spearman correlation coefficient.

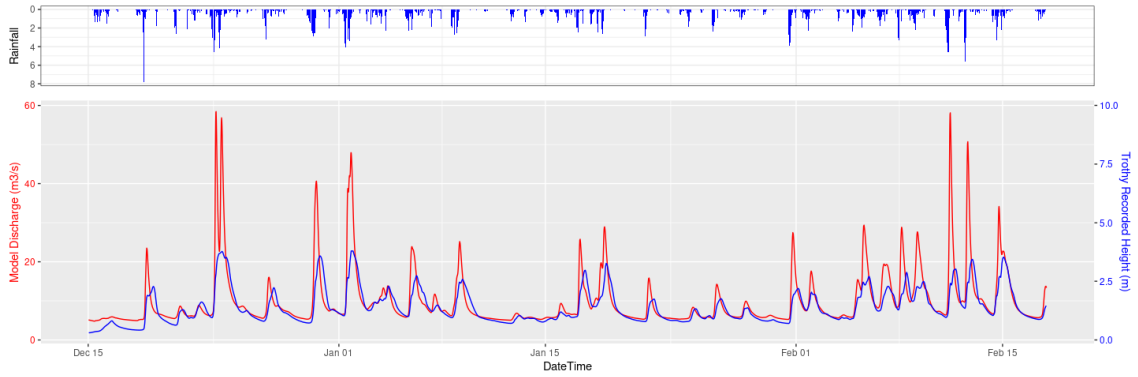


Figure 8.4: The Baseline Hydrograph overlaid with the observed NRW levels data

Spearman correlation $\rho = 0.9779377$ for S = 6353.5, p-value $<$ 2.2e-16

A correlation coefficient of $\rho = 1$ would indicate a perfect fit between the baseline scenario discharge and the observed river levels. This should not be achieved due to the non-linear relationship between levels and discharge.

While flow is within the bank, a reasonable linear relationship exists between increasing discharge and increasing stage. However, as flow exceeds bankfull capacity and spreads onto the floodplain, the river's width increases dramatically, thus a faster rate of increase in discharge to level. As expected, a considerable discharge rate does not produce an equivalent increase in level.

Both periods include peaks above the overbank stage, so we would not expect either to show a direct relationship between the discharge and river levels across the full range of discharges.

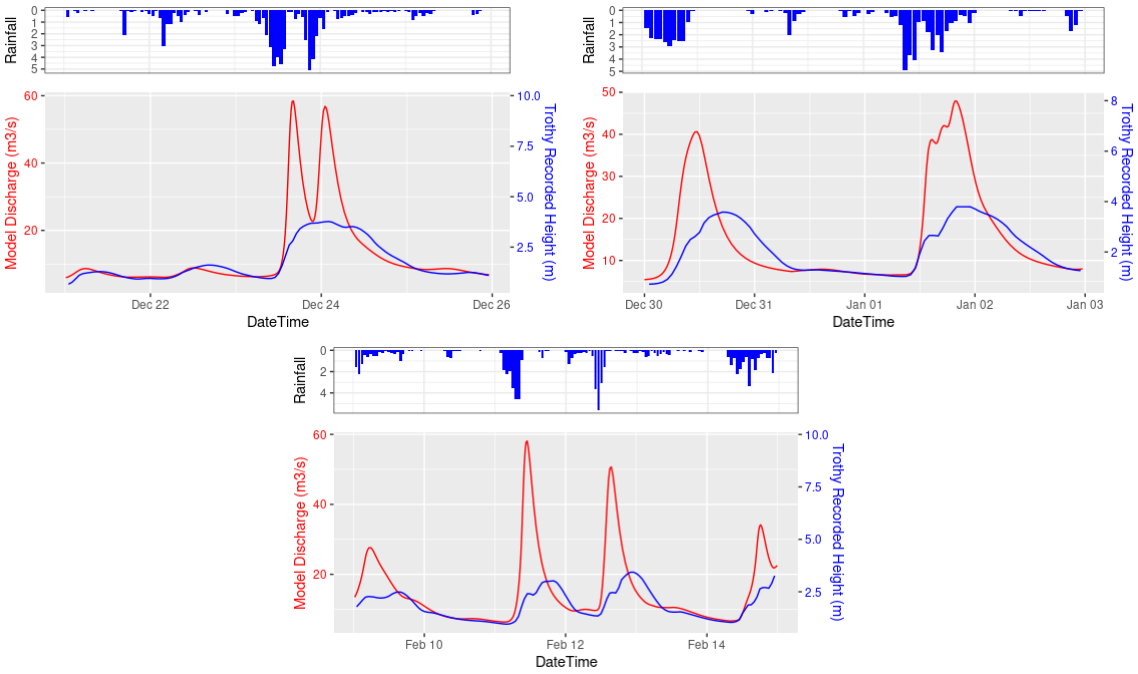


Figure 8.5: The Baseline Hydrograph overlaid with the observed NRW levels data for the flood events

The discharge behaviour can be seen to closely resemble the dynamics of the river levels. We can confirm visually that the differences between modelled and observed data are for expected discharges occurring during the peaks. Two discrepancies, however, can be identified in Figure 8.5, a double peak shown in the modelled output for December and a more significant peak in February 11th discharge rather than the February 12th as would be expected from the observed levels. There are a few possible factors that may explain this:

- measurements of height may be inaccurate depending on the type of equipment used past this point (a change in peak over a very short period will not be recorded)
- bank has overflowed, so the changing volume is reflected in a changing width/volume of flood water rather than the changing height of the river. A rapid change in discharge may not be reflected by a height change during overbank flow.
- By comparing the river levels and discharge to the precipitation, we can see that a different rainfall pattern has created the second peak. 'If' the precipitation is a good reflection of the actual event, the river levels appear to respond to the increased

peak in precipitation on the 12th, whereas the river discharge responds to the greater overall rainfall on the 11th

- However, the 'real' precipitation that impacts the measured river level may not closely match the precipitation data input into the model (see Appendix II), and the values seen here are an average of the spatially distributed model input

Model output is closely related to the interpolation of precipitation input (Bárdossy and Anwar, 2022). Figure 8.6 represents the spatial distribution of the precipitation input (each graph is identified with a 25th of the catchment, Appendix VIII),

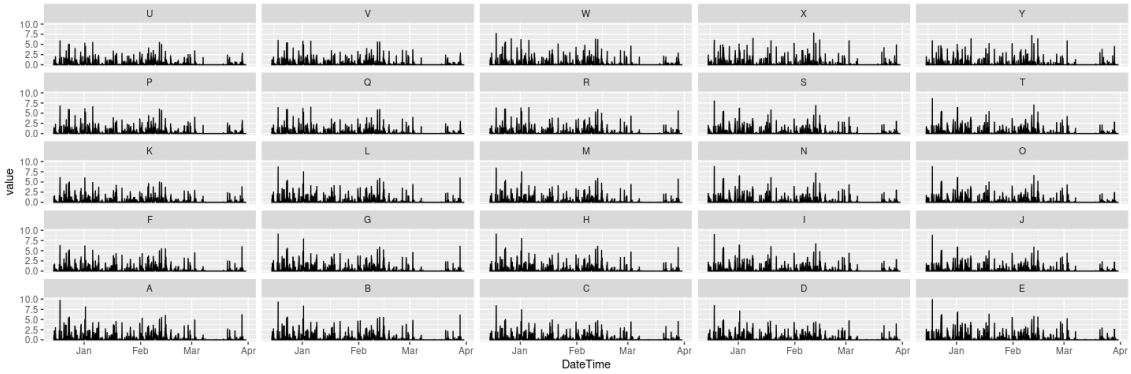


Figure 8.6: The spatially distributed rainfall used for the SHETRAN precipitation input

There is considerable spatial variability to the rainfall. As each alternative scenario uses the same precipitation pattern, we can state that the behaviour reflects this given pattern but that any spatial change in rainfall may have different implications. Further research could address the hydrological response to different rainfall events.

The rainfall pattern that causes the double peak in the modelled discharge in December can be observed in Figure 8.6 and Figure 8.5 but could also be caused by the impacts of overbank flow. Discrepancies between the peaks in February's observed levels and modelled discharge are also reflected in the precipitation data. Therefore, I can state that the modelled output is a reasonable representation of the catchment behaviour for a given precipitation period regarding the discharge at the outlet. Given the purpose of the Baseline, it is acceptable as an event characterisation from which to develop and explore the alternative land cover scenarios.

8.1.3 Baseline Evaluation against Archived data

The NRFA holds current and historical flow data. Although the monitoring equipment at Mitchell Troy now records levels only, the station recorded flow from 1969 to 1982. The daily recorded discharge has been archived and is open access[1]. Whilst this data can't be relied upon to give us a ratings curve, it can be used to confirm whether the baseline flow for 2013/2014 is within the expected bounds for the river.

Table 8.1: Table of archived data against baseline output (the time period for the archive data has been chosen to eliminate impacts of the 1974 drought and 1981 typhoon)

	NRA Archive (1975 - 1980)	Baseline (Oct 2013 - Apr 2014)
max	25.520	22.608
mean	1.428	7.220
min	0.019	4.576

While this data cannot be used to confirm the discharge totals or peak flows, it shows that the baseline is in the correct order of magnitude for the daily averages. The low minimum in the archive data can be attributed to the period of the baseline scenario being from Oct-April, whereas the archive data covers the year to date.

8.2 Alternative Scenarios

Time and computing capacity constraints meant that running the Windows program was not practical for running the alternative scenarios. In the initial stages of the COVID-19 lockdown, I only had access to my laptop, and on a good day, a run took 2.5 days. To run the program on the BlueBEAR HPC, I needed to use Linux limiting output but considerably speeding up the run to 20.5hrs. This enabled me to test and run all 30 alternative scenarios.

The alternative scenarios have been designed to explore the hydrological behaviour of the catchment under different amounts and spatial distributions of tree cover. These

[1] https://nrfa.ceh.ac.uk/data/station/meanflow/55022

distributions have been identified by location, purpose and size and have been informed primarily by the types of tree cover participants were interested in, either favourably or to critique (see Chapter 6, e.g. Table 6.1). In addition, policy approaches and available advice regarding likely planting for NFM (e.g. Glastir woodland mapping, woodland types identified in the WWNP evidence base) were considered.

Types of distribution (roughly related to analysis 'Groups' - fig8.7) include:

- randomly distributed at different spatial scales, enabling exploration of the impact of increasing tree cover extent whilst reducing the impact of other factors (group=random)
- planting only on steep slopes at a slope identified from an analysis of LM descriptions (section 6.2.1) (group=steep)
- planting in wet areas, including riparian and floodplain and in contrast in areas where the phreatic surface is lower during flood events. Some land managers identified 'wet' areas as suitable for planting, and some specifically did not (this is tackled further in Chapter 10) (group=wet)
- planting farm suitable designs such as shelter-belts (group=steep)
- planting on arable ground (group=arable)

In addition, scenarios were run which investigated other effects of concern (group=not_trees)in the catchment:

- a move to maize planting or beet forage, meaning more bare ground in the winter;
- popularity of permanent pasture amongst agricultural communities;
- deforestation due to Ash dieback and the prevalence of small Ash woodlands in the catchment.

Table 8.2 contains further details for each scenario.

The Baseline scenario run and Alternative scenarios are identical except for the vegetation; this affects the codes in the Frame and OCD files (as the Strickler Overland Flow is linked to the vegetation). All other spatial and weather data are identical. I then explored the potential hydrological behaviours of the catchment by evaluating the Alternative scenarios against the Baseline.

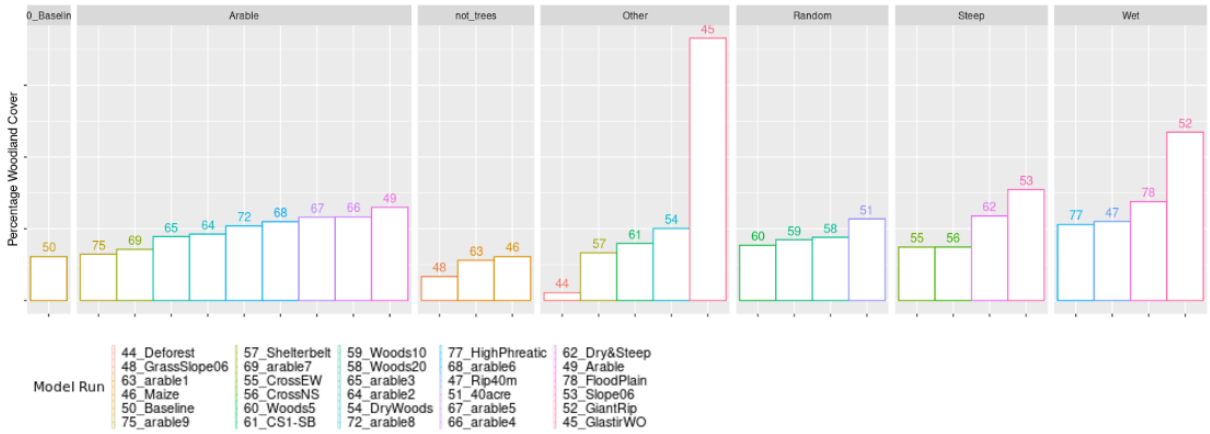


Figure 8.7: The alternative scenarios arranged by group

Table 8.2: In addition to the Baseline run, 29 alternative scenarios were developed, making a total of 30 scenarios used in the analysis.

Scenario ID_Name	Description	% Tree Cover
44_Deforest	Broadleaf woodland cover (4) replaced with grass - to explore effects of Ash Dieback and other deforestation causes in catchment (see section 6.2.1)	2.23
48_GrassSlope06	If steep slopes were pasture rather than mixed pasture/woodland - again exploring loss of tree cover (section 6.2.1 and 6.2.1)	6.69
63_arable1	Replaced arable with grass	11.24
46_Maize	Arable replaced with bare ground - to explore the impact of a move to winter harvested crop (see section 6.3.2) / no cover	12.26
50_Baseline	Baseline Model that demonstrates behaviour of the 2014 flood - all alternatives derived from this one	12.26
75_arable9	Used Erase1 buffer to create small randomly placed woodland in arable areas	12.90
57_Shelterbelt	Small strip woodlands more widely distributed (Farm suitable woodland see section 2.3.3 and 6.3.1)	13.32
69_arable7	reverse 68: status quo as arable, using both buffers to create small tree planted areas	14.30
55_CrossEW	Small strip woodlands placed running East-West on steep slopes (see section 6.3.1 and 6.2.1 plus lack of empirical evidence for cross-slope woodland (Cooper et al., 2021))	14.90
56_CrossNS	Small strip woodlands placed running North-South on steep slopes (as above)	14.91
60_Woods5	Randomly sited 5acre woodlands	15.43
61_CS1-SB	Combined planting of steep slope and shelterbelt alternatives (see justification for no 75 & 55)	15.90
59_Woods10	a randomly sited 10acre woodlands (as no. 60)	16.94
58_Woods20	Randomly sited 20acre woodlands (as no. 60)	17.64
65_arable3	Replaced arable on upper east of catchment with tree cover (exploring implications on lag by focusing interventions on one main tributary (Dixon et al., 2016))	17.82
64_arable2	Replaced arable lower west catchments with tree cover (as no. 65)	18.55
54_DryWoods	Areas with the greatest distance to the phreatic table during flood event	20.09
72_arable8	selected arable areas that had a boundary with the river (model run post workshops section 10.2)	20.80
77_HighPhreatic	- derived from phreatic surface levels and checked against participant provided info (model run post workshops section 10.2)	21.20
68_arable6	Used both random buffers to create a very diverse tree/arable mix (model run post workshops section 10.2)	21.97
47_Rip40m	a 40m boundary on either side of riverbank - extensive riparian planting	22.02
51_40acre	Randomly sited 40acre woodlands	22.77
67_arable5	Replaced arable with tree cover - with randomly interspersed areas of arable2	23.24
66_arable4	Replaced arable with tree cover - with randomly interspersed areas of arable1	23.35
62_Dry&Steep	Steep sites on low phreatic surface levels	23.60
49_Arable	All arable replaced by woody crop - exploring options for coppice or woody crop as income + difference between pasture / arable planting	25.97
78_FloodPlain	Values below 0 in phreatic surface levels indicating floodplain (model run post workshops section 10.2)	27.59
53_Slope06	Farmer identified steep slope, as appropriate for planting	30.91
52_GiantRip	Exploring extensive planting of Riparian area - unrealistic in this catchment, but a common 'buzzword' in NFM suggestions	46.95
45_GlastirWO	Woodland cover mapped against polygon taken from Glastir Woodland Opportunities map (All Ops) 2019 - to model impact of planting majority of catchment	73.13

8.3 Findings

The discharge data from the SHETRAN output ASCII files for the Baseline and each alternative scenario was collated with spatial data about the landscape change of each intervention, generated from the ArcGIS Rasters that were used as the ASCII input for the model maintaining the spatial aggregation as applied to the model.

Through analysis of this data, I have identified five key findings that were of particular relevance regarding the interests of land managers and within the current practice/policy context. I briefly summarise these here before going into greater depth for each individual point.

1. **No extent of tree cover resulting from planting intervention (up to 70% catchment coverage) totally prevented flooding or overbank flow in the catchment.**

   Whilst there is a debate as to whether preventing overbank flow with the catchment is necessary, there is a lack of expectation setting regarding the potential of tree planting in grey NFM literature, whilst at the same time, tree planting is often highly critiqued due to it's perceived lack of impact (section 2.3).

2. **Increased tree cover decreases flood peaks.**

   A clear trend supports the substantial body of work demonstrating that increasing tree cover decreases flood peaks (Cooper et al., 2021). The decrease in peak is also related to the type of flood event and the size of the peak, with a greater reduction the greater the size of peak (in most cases).

3. **Lag or a change of the time to peak was only significant in the scenario with greatest tree cover and loss scenarios.**

   Any synchronisation or desynchronisation of peaks occurs at too short a time to impact overall effect. However, some alternative scenarios did change the overall hydrograph behaviour with the 'maximum' peak occurring at the second flood rather

than the first, when the catchment is more saturated, suggesting an ameliorating effect on the 'flashiness' of the catchment

4. **Whilst random planting followed a general trend, strategic planting (where and on what) had differing impacts that followed identifiable patterns.**
   Different distributions gave different results depending on where tree cover was and what type of land it was on. These results did not agree with commonly used 'opportunity mapping' (part of the original Woodland for Water program (Nisbet et al., 2011)), which relies on generalisations or assumptions about the impact of interventions and also what should or shouldn't be excluded from the mapping.

5. **Loss of trees or other management choices may have a greater negative impact than the positive impact of greater tree cover.**
   This may suggest that priority action should focus on ensuring that flooding doesn't worsen by tackling wider management behaviours

8.3.1 No intervention prevents flooding at the maximum peak

The model shows a significant flood overnight on the 23rd/24th December. Over that winter, there were several large peaks, three of which were identified as flood events by a catchment participant. The top 6 Baseline peaks are shown in table 8.3 and figure 8.8:

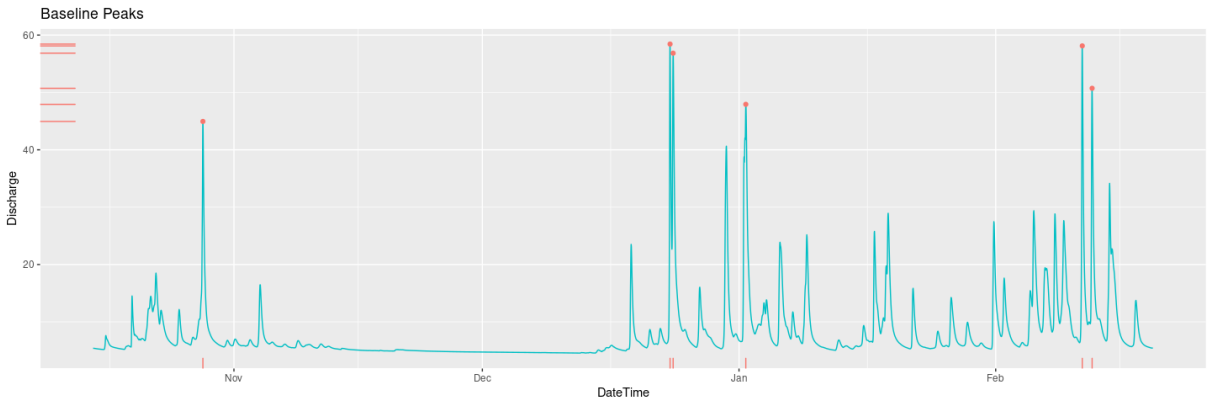


Figure 8.8: Shows the peak events, the flood events relate to the Christmas Eve, New Year and February peaks

This participant data can't be used to identify when overbank flow occurs but does

Table 8.3: Trothy highest peaks flood event period 2013-2014.

Max Peak	DateTime	Scenario
44.94670	2013-10-28 06:02:31	50_Baseline
58.43682	2013-12-23 16:09:37	50_Baseline
56.84687	2013-12-24 01:02:45	50_Baseline
47.92591	2014-01-01 19:40:32	50_Baseline
58.11750	2014-02-11 10:56:39	50_Baseline
50.72472	2014-02-12 15:29:33	50_Baseline

indicate when it becomes a significant flood event. We can see from the data and the dates given by participants that this occurs when the discharge is around 40-47m^3/s.

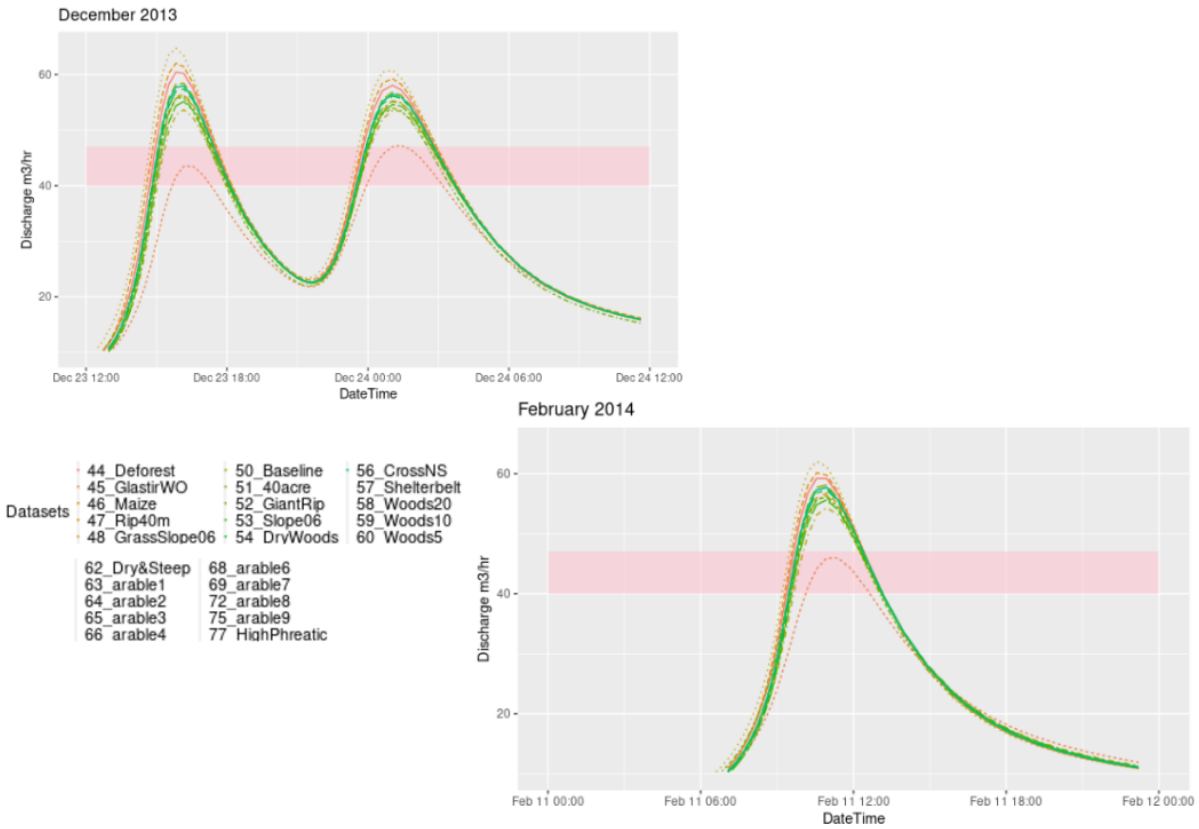


Figure 8.9: Flood event Discharge graphs for all scenarios, with a band the range at which flooding may be expected to occur throughout the catchment

Figure 8.9 shows that, as expected (Dadson et al., 2017; Soulsby et al., 2017), no amount of tree cover reduces the flood peak sufficiently to prevent overbank flow. Only scenario 45, at 73% of the catchment, came close to achieving this with a 27% reduction in the total discharge.

8.3.2 Increasing woodland planting decreases floodpeak

There is a direct relationship between % tree cover and flood peak

Whilst increasing tree cover did not stop flooding, it can be seen to reduce the flood peak and duration.

By plotting the maximum peaks at the December flood against the percentage of tree cover, we can see a clear relationship between an increase in tree cover and a decrease in flood peak.

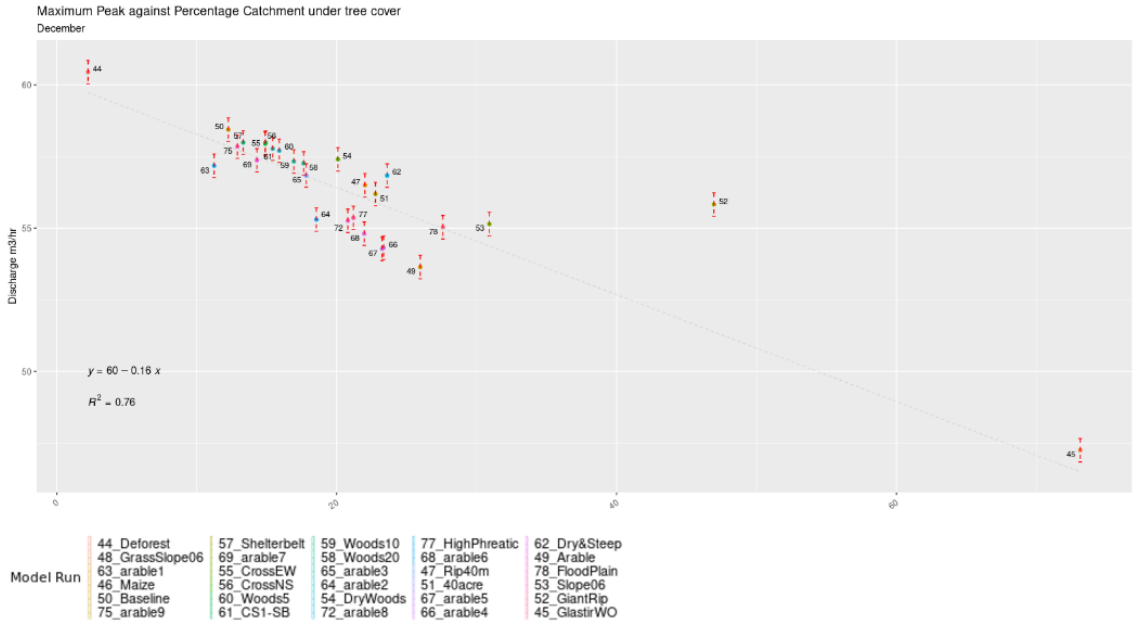


Figure 8.10: Graph showing the maximum discharge of each scenario during the December 2013 flood against the percentage catchment woodland cover of each scenario. This graph does not include scenarios 46, 48 and 63, as they evaluated other impacts to a change in tree cover.

The Change in Peak in Table 8.4 is a change in the stormflow peak rather than the total discharge during this extended period. This shows a 4% decrease in max discharge for increasing tree cover by 10% (to 22% catchment cover in total). This falls easily within the wide range thus far identified in observed and modelled studies (Cooper et al., 2021).

The percentage change in flood peak can be evaluated either by looking at the change relative to the maximum baseline peak (December 23rd) or by considering the largest

Table 8.4: Table detailing the percentage reduction of maximum peak for each alternative scenario where Change in Peak = $(\frac{(D_{max}-D_{baseflow})}{BaselinePeak})x100$

ID	name	Max Discharge (m^3/hr)	Change in Discharge (%)	Change in Peak (%)	Catchment Tree Cover (%)
44	Deforest	60.44	3.32	3.67	2.23
50	Baseline	58.43	0.00	0.00	12.25
56	CrossNS	57.98	-0.77	-0.86	14.91
57	Shelterbelt	57.98	-0.77	-0.86	13.32
55	CrossEW	57.94	-0.84	-0.93	14.89
75	arable9	57.84	-1.02	-1.14	12.90
60	Woods5	57.77	-1.15	-1.28	15.43
61	CS1-SB	57.70	-1.27	-1.41	15.90
54	DryWoods	57.40	-1.80	-2.01	20.09
69	arable7	57.36	-1.86	-2.08	14.30
59	Woods10	57.32	-1.93	-2.15	16.94
58	Woods20	57.26	-2.05	-2.29	17.64
65	arable3	56.83	-2.81	-3.14	17.82
62	Dry&Steep	56.83	-2.82	-3.14	23.60
47	Rip40m	56.49	-3.43	-3.82	22.02
51	40acre	56.18	-3.99	-4.46	22.77
52	GiantRip	55.82	-4.67	-5.22	46.95
77	HighPhreatic	55.35	-5.56	-6.21	21.20
64	arable2	55.29	-5.67	-6.34	18.55
72	arable8	55.25	-5.76	-6.43	20.80
53	Slope06	55.13	-5.98	-6.68	30.91
78	FloodPlain	55.03	-6.19	-6.92	27.59
68	arable6	54.80	-6.63	-7.41	21.97
66	arable4	54.31	-7.59	-8.50	23.35
67	arable5	54.27	-7.66	-8.58	23.24
49	Arable	53.64	-8.94	-10.02	25.97
45	GlastirWO	47.24	-23.68	-26.99	73.12

flood peak per alternative scenario for the whole of the winter period, as the maximum events for different scenarios do not occur on the same date.

Figure 8.11 shows only a slight difference (from gradient = 0.37 to 0.36), demonstrating that the increase in tree cover still decreases the highest maximum peak whenever that occurs. Timings of peaks are covered in section 8.3.3 and the scatter evident in the graphs in the next section 8.3.4

The relationship between increase in tree cover and decrease in peak depends on the size (and type) of the flood event

Each flood demonstrated slightly different behaviour, and by visualising the data in different ways, we can start to identify some of the differences in the change in peak for each flood event.

Figure 8.12 shows a relationship between the size of intervention and the variance in peak reduction; there is greater variance in impact for the larger interventions.

Figure 8.13 shows that different flood events demonstrate different responses to interventions. Figure 8.14 shows a direct relationship between the Percentage Tree Cover against the Percentage Change in Flood peak for each each flood event. However, the relationship changes for each flood event.

The gradient in Table 8.5 indicates the impact of increasing tree cover. By plotting the Baseline Maximum peaks for each date against these gradients (Figure 8.15), we can see that there may be a relationship here but that it is not linear

In summary, there is a general relationship between the size of the event and the percentage change in the peak. The greater the event, the greater the percentage change in peak. (This is true for the maximum peaks; further interrogation could identify if this occurs more widely but is beyond scope here.)

In addition, there appears to be a relationship between the size of flood event and the variance in impact. The greater the size of the event, the larger the impact of larger interventions. This could explain some of the variance in the reported results of other modelling and empirical investigations (Cooper et al., 2021, Dadson et al., 2017).



Figure 8.11: The top graph shows the percentage change in discharge against woodland cover with the linear regression calculations for the December (largest flood event in Baseline) and the bottom graph for the maximum of each scenario

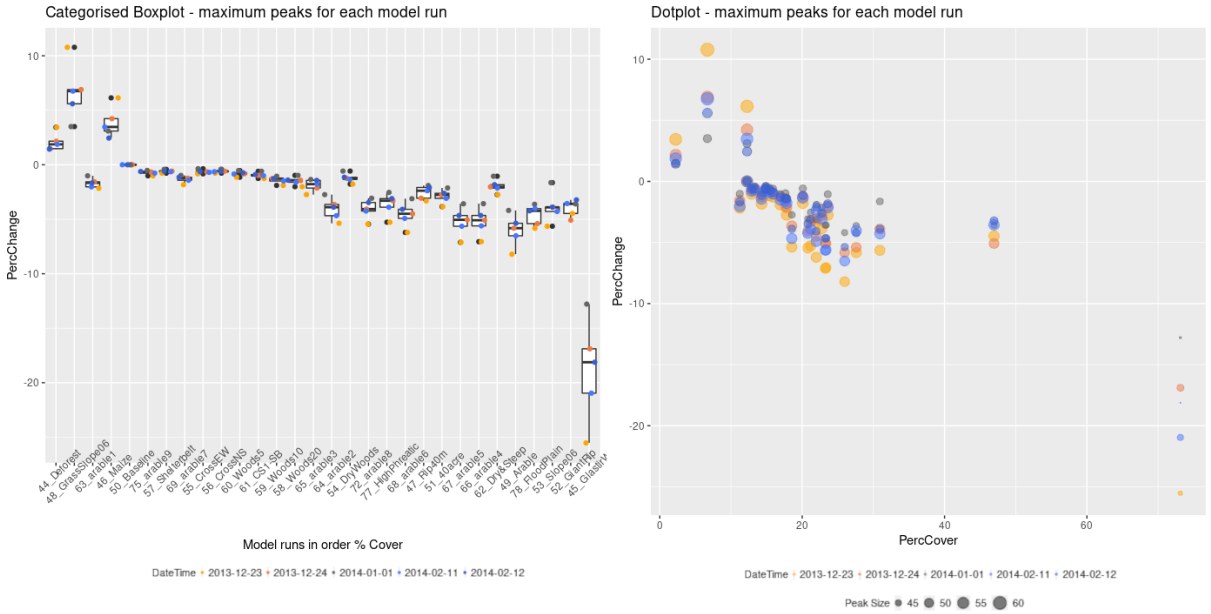


Figure 8.12: The LH graph shows the five maximum peaks for each scenario as a categorical dot/boxplot - showing clearly the variation of each scenario; The RH graph shows the same peak data but plotted against the scenario total tree cover. Note: Scenarios 48 and 46 involved large interventions that were not related to tree cover

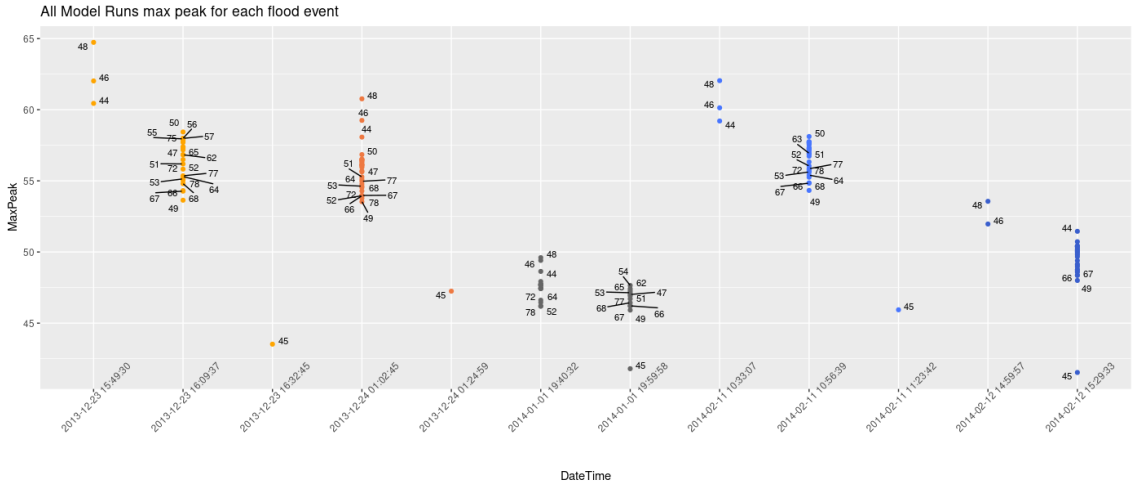


Figure 8.13: Maximum peaks for each scenario in a categoric plot against the flood date.

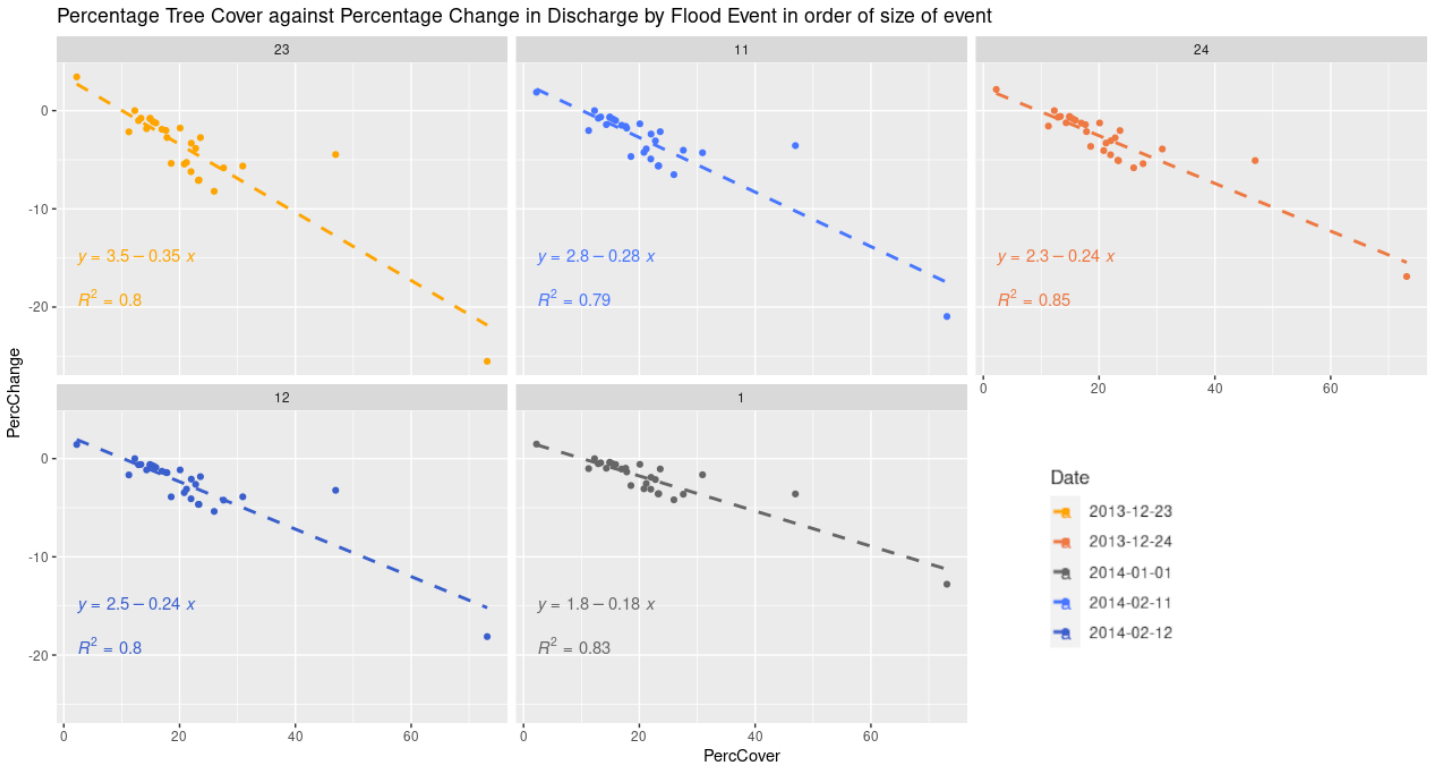


Figure 8.14: Shows the maximum peak for each scenario grouped by the day they occurred

Table 8.5: Shows the Baseline Peak for a given date; the gradient of the regression line for %change in peak against %change in tree cover for each date, the range of those peaks, and the maximum and minimum difference from the baseline

Baseline Peak	Date/Time	Gradient of % δ peak against % Tree Cover	Range of Peak values	max increase	max decrease
47.93	2014-01-01 19:40:32	-0.171	14.27	1.48	-12.79
50.72	2014-02-12 15:29:33	-0.241	19.56	1.44	-18.12
56.85	2013-12-24 01:02:45	-0.243	19.05	2.16	-16.89
58.12	2014-02-11 10:56:39	-0.278	22.83	1.87	-20.96
58.44	2013-12-23 16:09:37	-0.346	28.96	3.44	-25.52

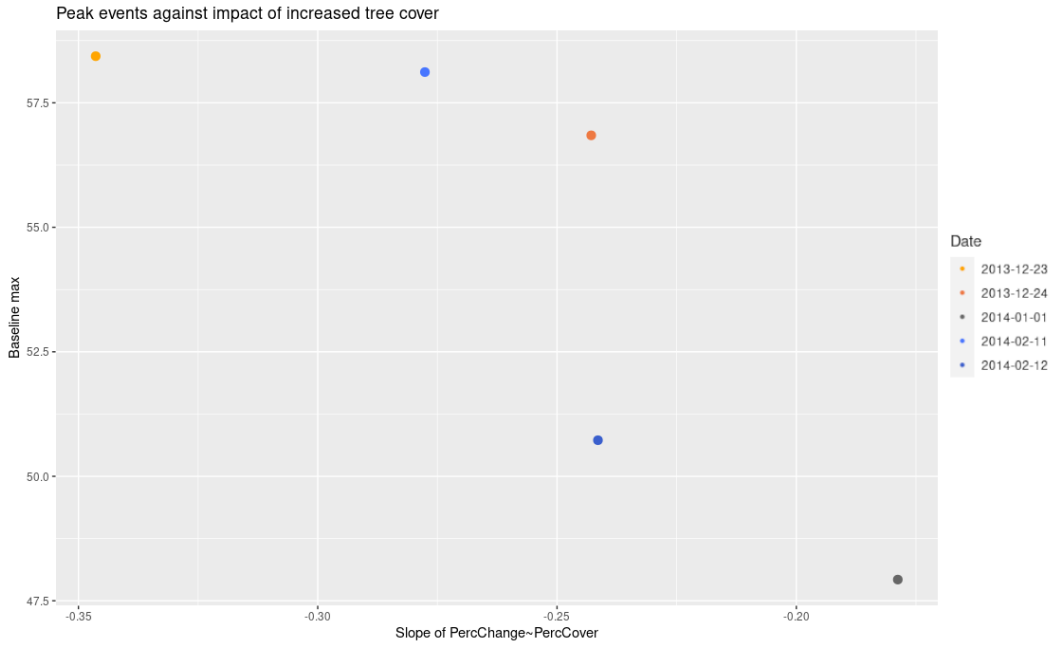


Figure 8.15: Evaluates the variance in impact on each event by looking at the linear relationship of Percentage change in discharge against percentage cover, for each event date by the size of the event

The type and sequence of events will also affect the impact of different interventions as saturation levels will affect the importance of different mechanisms (for example, highly saturated ground will reduce the impact of infiltration).

Neither of the relationships identified here is direct; a much greater investigation of the mechanisms behind these changes and how they interact is needed. Whilst this would be possible from the model output, it extends beyond the overall scope of the research and its focus on the importance of land manager knowledge(s). Knowing when to stop interrogating the model is a key question I will tackle in Chapter 11.

8.3.3 Time to Peak and peak flood dates

The data identifying the flood peaks demonstrated that there was some complexity to the date and time of flood events. By separating out this data, we can identify when each event occurred for each alternative scenario and compare this to the timing of the baseline events.

For all scenarios, the maximum peak was either on the 23rd December or 11th Febru-

Table 8.6: identifies the time and date of the top 10 peaks for each scenario

Scenario	2013-12-23 15:49:30	2014-02-11 10:33:07	2013-12-24 01:02:45	2014-02-12 15:29:33	2014-01-01 19:40:32	2013-10-28 06:02:31	2013-12-24 01:24:59	2014-02-11 11:23:42	2013-12-23 16:32:45	2014-01-01 19:59:58	2014-01-01 17:25:02	2014-02-12 14:59:57	2014-02-11 10:56:39	2013-12-23 16:09:37	2013-10-28 05:47:36
44_Deforest	60.44510	59.20718	58.07592	51.45360	48.63524	46.83222	NA	NA	NA	NA	NA	NA	NA	NA	NA
45_GlastirWO	NA	NA	NA	41.53340	NA	NA	47.24655	45.93735	43.52221	41.79770	37.25091	NA	NA	NA	NA
46_Maize	62.02359	60.13444	59.25057	NA	49.40994	47.95819	NA	NA	NA	NA	NA	51.96665	NA	NA	NA
47_Rip40m	NA	NA	55.10409	49.66552	NA	43.44697	NA	NA	NA	47.01305	NA	NA	56.73261	56.49729	NA
48_GSlope06	64.73537	62.04412	60.76668	NA	49.60371	NA	NA	NA	NA	NA	53.56235	NA	NA	NA	49.62734
49_Arable	NA	NA	53.53918	47.99936	NA	41.56990	NA	NA	NA	45.91729	NA	NA	54.32976	53.64030	NA
50_Baseline	NA	NA	56.84687	50.72472	47.92591	44.94670	NA	NA	NA	NA	NA	NA	58.11750	58.43682	NA
51_40acre	NA	NA	55.27583	49.39650	NA	43.36647	NA	NA	NA	46.90517	NA	NA	56.33011	56.18999	NA
52_GiantRip	NA	NA	53.95651	49.08919	46.20249	43.62003	NA	NA	NA	NA	NA	NA	56.04766	55.82463	NA
53_Slope06	NA	NA	54.62544	48.75386	NA	42.61922	NA	NA	NA	47.13853	NA	NA	55.62611	55.13980	NA
54_DryWoods	NA	NA	56.13369	50.14093	NA	44.17225	NA	NA	NA	47.64767	NA	NA	57.33695	57.40054	NA
55_CrossEW	NA	NA	56.47928	50.40424	47.75039	44.65890	NA	NA	NA	NA	NA	NA	57.71342	57.94955	NA
56_CrossNS	NA	NA	56.51260	50.42262	47.72296	44.65179	NA	NA	NA	NA	NA	NA	57.74438	57.98593	NA
57_Shelterbelt	NA	NA	56.51260	50.42262	47.72296	44.65179	NA	NA	NA	NA	NA	NA	57.74438	57.98593	NA
58_Woods20	NA	NA	56.03773	50.01403	47.45864	44.17100	NA	NA	NA	NA	NA	NA	57.18678	57.26067	NA
59_Woods10	NA	NA	56.12825	50.07546	47.42216	44.20578	NA	NA	NA	NA	NA	NA	57.25233	57.32802	NA
60_Woods5	NA	NA	56.37693	50.35222	47.67019	44.49957	NA	NA	NA	NA	NA	NA	57.62108	57.77116	NA
61_CS1-SB	NA	NA	56.29272	50.27117	47.63863	44.46589	NA	NA	NA	NA	NA	NA	57.53199	57.70154	NA
62_Dry&Steep	NA	NA	55.69291	49.79514	NA	43.76606	NA	NA	NA	47.42091	NA	NA	56.87353	56.83321	NA
63_arable1	NA	NA	55.95259	49.88315	47.43908	44.13124	NA	NA	NA	NA	NA	NA	56.93910	57.17582	NA
64_arable2	NA	NA	54.77673	48.75122	46.61270	43.22091	NA	NA	NA	NA	NA	NA	55.40174	55.29947	NA
65_arable3	NA	NA	55.63212	49.99636	NA	43.30984	NA	NA	NA	47.27761	NA	NA	57.08244	56.83629	NA
66_arable4	NA	NA	53.95166	48.36331	NA	42.02416	NA	NA	NA	46.21372	NA	NA	54.85725	54.31285	NA
67_arable5	NA	NA	53.97487	48.36142	NA	41.99668	NA	NA	NA	46.20944	NA	NA	54.83812	54.27658	NA
68_arable6	NA	NA	54.29082	48.65054	NA	42.34579	NA	NA	NA	46.43300	NA	NA	55.25792	54.80568	NA
69_arable7	NA	NA	56.14364	50.14240	47.45693	44.17207	NA	NA	NA	NA	NA	NA	57.29031	57.36620	NA
72_arable8	NA	NA	54.53481	48.96562	46.45291	42.49929	NA	NA	NA	NA	NA	NA	55.64971	55.25500	NA
75_arable9	NA	NA	56.46797	50.40965	47.67621	44.49473	NA	NA	NA	NA	NA	NA	57.66845	57.84326	NA
77_HighPhreatic	NA	NA	54.97086	49.14759	NA	42.38959	NA	NA	NA	46.70923	NA	NA	55.85486	55.35635	NA
78_FloodPlain	NA	NA	53.77830	48.58079	46.18815	43.05410	NA	NA	NA	NA	NA	NA	55.77511	55.03023	NA

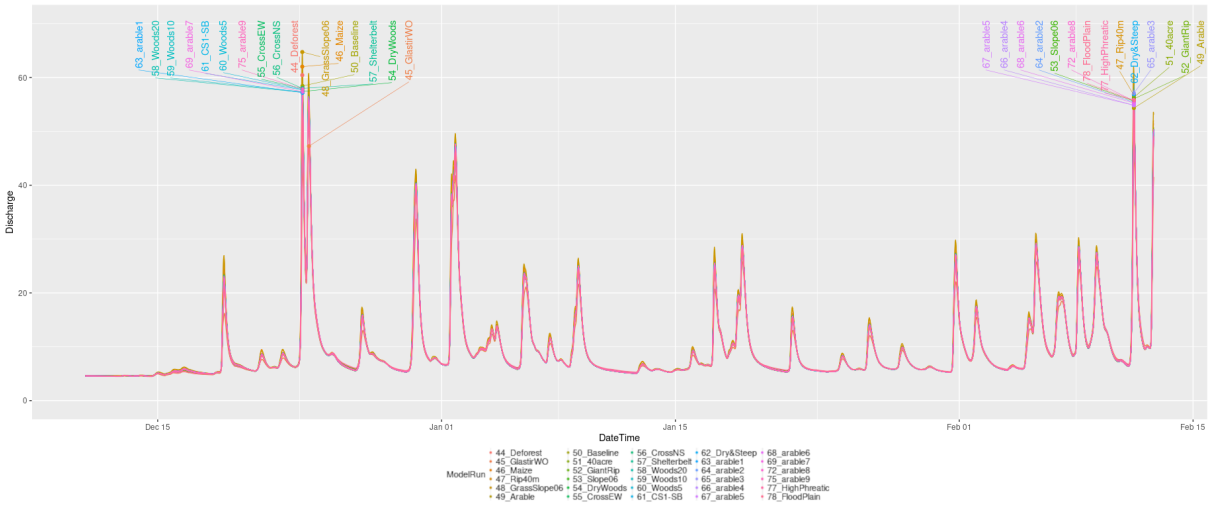


Figure 8.16: Shows that different alternative scenarios changed when the maximum peak occurred, shifting from the relatively dry December to the more saturated event in February

ary,

The flashy nature of the Trothy (section 5.3) (the speed at which water moves through the catchment) means that the desynchronisation of tributaries as an NFM approach will have minimal effect. This also indicates that there is little concern in regards synchronisation of peaks from tree cover interventions in this catchment, demonstrating the importance of heterogeneity of the physical characteristics of catchments (Cooper et al., 2021, Dixon et al., 2016). The data shows that the majority of interventions did not alter the timing/pattern of the hydrograph when peak events occur despite some interventions having more planting on one tributary over another (e.g. Figure 8.17). This suggests that mechanisms reducing peaks are more likely to depend on soil storage, subsoil flow and evapotranspiration than surface roughness (calculated in relation to the Strickler Overland Coefficient - section 7.3).

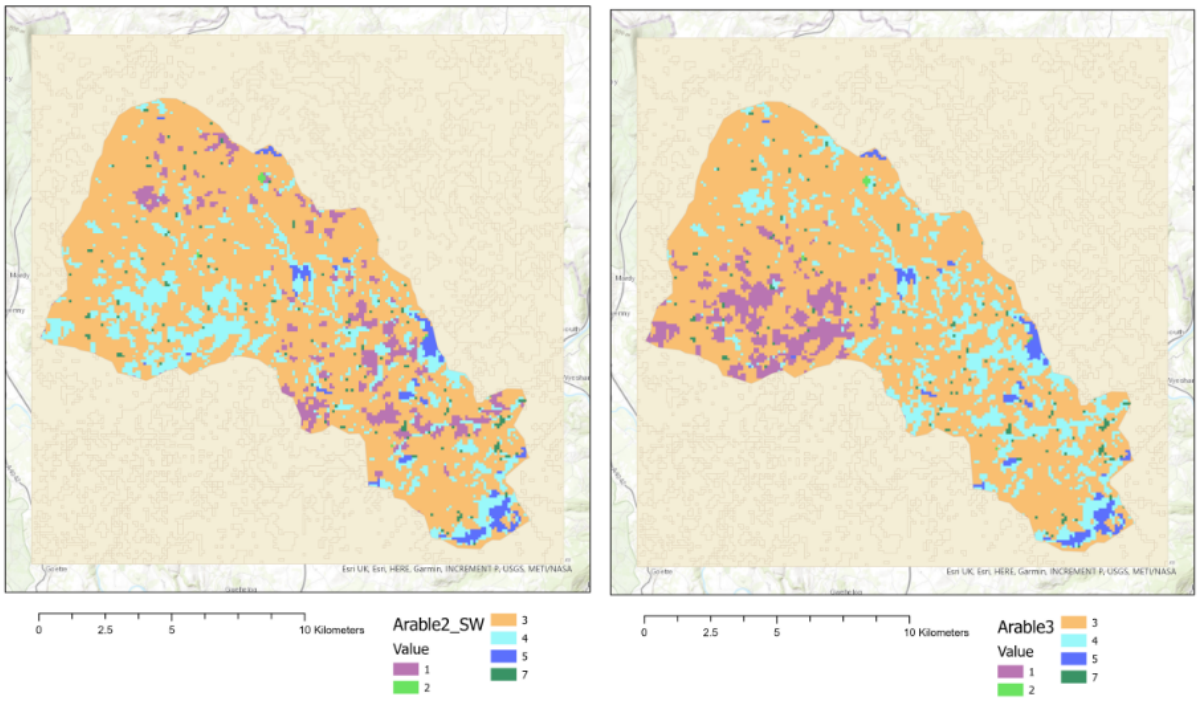


Figure 8.17: The two alternative scenarios, arable 2 and arable 3 are an example of geographical 'weighting' of tree cover. The land cover codes are 1: arable, 2: Bare ground, 3: Grass, 4: DeciduousTrees, 5: Evergreen and 7: Shrub

Figure 8.18 appears to show a relation between the percentage of tree cover and the difference between the December and February Peaks, with greater than 20% tree cover showing the maximum peak occurring in February. This suggests that for a certain increase in tree cover, there is an ameliorating effect on the 'flashy' nature of the flood events.

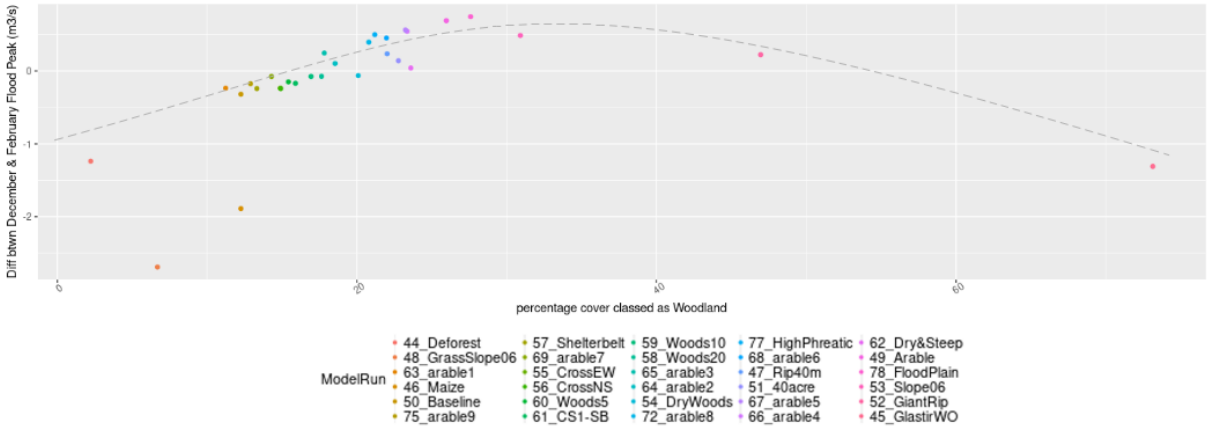


Figure 8.18: Shows the difference between the December and February peaks for each scenario. The highest peak for scenarios with a negative value / less than zero occurred during the December flood. A value above zero indicates that the maximum peak occurred during the February flood event. This difference value is plotted against the percentage woodland cover, appearing to show a shift to a February (saturated ground) maximum flood event at about 18-20% woodland cover, but that this effect is not consistent above 30% woodland cover

There is more complex behaviour shown in the larger and loss interventions. Four runs were particularly complex and had an unpredictable effect on the flood dates. These include the three loss scenarios and the largest tree cover intervention: '44_Deforest', '45_GlastirWO', '46_Maize' and '48_GrassSlope06'. Once these are removed from the analysis (Table 8.7) it is clear that whilst the two maximum peaks were fairly consistent with little change in time (data output is at 15min intervals, so lag time impacts less than this will not be shown), the different interventions do increase the lag time for the peak on New Year's Eve.

The more complex interventions which were removed from Table 8.7 are changing the behaviour of the hydrograph.

Exploring this further, I look at the impacts of different 'types' of planting in the next section.

Table 8.7: Compared to Table 8.6 removing the complex interventions shows that the majority of scenarios occur on the same date/time as the baseline with measurable lag only occurring on the New Year day flood

Scenario	2013-10-28 06:02:31	2013-12-23 16:09:37	2013-12-24 01:02:45	2014-01-01 19:40:32	2014-01-01 19:59:58	2014-02-11 10:56:39	2014-02-12 15:29:33
47_Rip40m	43.44697	56.49729	55.10409	NA	47.01305	56.73261	49.66552
49_Arable	41.56990	53.64030	53.53918	NA	45.91729	54.32976	47.99936
50_Baseline	44.94670	58.43682	56.84687	47.92591	NA	58.11750	50.72472
51_40acre	43.36647	56.18999	55.27583	NA	46.90517	56.33011	49.39650
52_GiantRip	43.62003	55.82463	53.95651	46.20249	NA	56.04766	49.08919
53_Slope06	42.61922	55.13980	54.62544	NA	47.13853	55.62611	48.75386
54_DryWoods	44.17225	57.40054	56.13369	NA	47.64767	57.33695	50.14093
55_CrossEW	44.65890	57.94955	56.47928	47.75039	NA	57.71342	50.40424
56_CrossNS	44.65179	57.98593	56.51260	47.72296	NA	57.74438	50.42262
57_Shelterbelt	44.65179	57.98593	56.51260	47.72296	NA	57.74438	50.42262
58_Woods20	44.17100	57.26067	56.03773	47.45864	NA	57.18678	50.01403
59_Woods10	44.20578	57.32802	56.12825	47.42216	NA	57.25233	50.07546
60_Woods5	44.49957	57.77116	56.37693	47.67019	NA	57.62108	50.35222
61_CS1-SB	44.46589	57.70154	56.29272	47.63863	NA	57.53199	50.27117
62_Dry&Steep	43.76606	56.83321	55.69291	NA	47.42091	56.87353	49.79514
63_arable1	44.13124	57.17582	55.95259	47.43908	NA	56.93910	49.88315
64_arable2	43.22091	55.29947	54.77673	46.61270	NA	55.40174	48.75122
65_arable3	43.30984	56.83629	55.63212	NA	47.27761	57.08244	49.99636
66_arable4	42.02416	54.31285	53.95166	NA	46.21372	54.85725	48.36331
67_arable5	41.99668	54.27658	53.97487	NA	46.20944	54.83812	48.36142
68_arable6	42.34579	54.80568	54.29082	NA	46.43300	55.25792	48.65054
69_arable7	44.17207	57.36620	56.14364	47.45693	NA	57.29031	50.14240
72_arable8	42.49929	55.25500	54.53481	46.45291	NA	55.64971	48.96562
75_arable9	44.49473	57.84326	56.46797	47.67621	NA	57.66845	50.40965
77_HighPhreatic	42.38959	55.35635	54.97086	NA	46.70923	55.85486	49.14759
78_FloodPlain	43.05410	55.03023	53.77830	46.18815	NA	55.77511	48.58079

8.3.4 The 'type' of landscape that is under tree cover, where it is and what is replaced are important (not just the extent)

The lag time data indicates that some groups of scenarios respond in particular ways. For example, the 'loss' scenarios, involving a reduction in tree cover, shift the time of the flood.

These different patterns help us understand which mechanisms have the most influence on peak events.

I will specifically discuss the loss scenarios and 'other land management choices' in section 8.3.5, for now focusing on the tree cover scenarios.

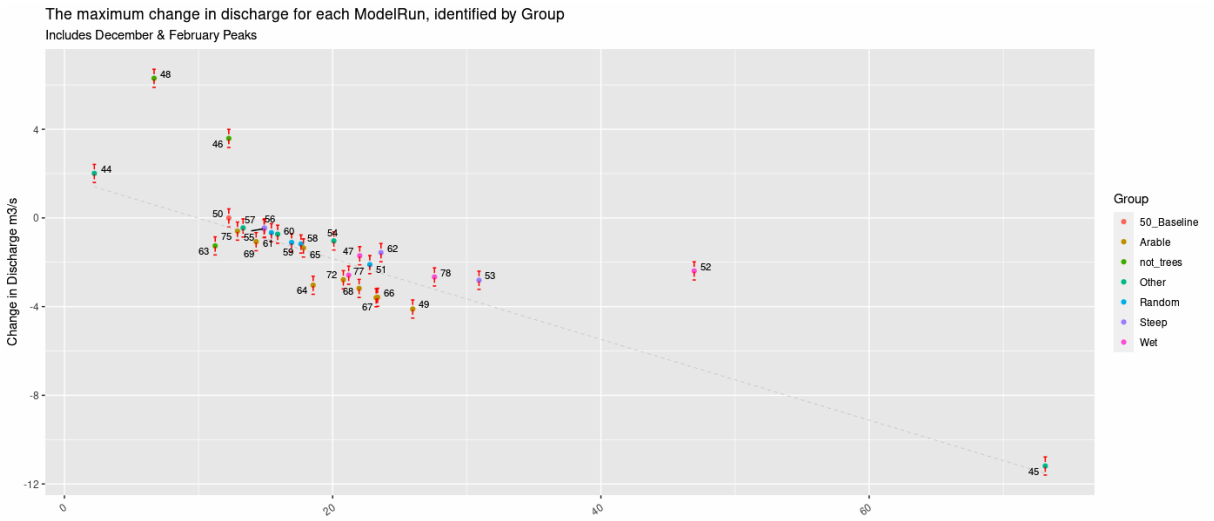


Figure 8.19: Shows the maximum change in discharge for each alternative scenario identified by group

Figure 8.19 suggest certain patterns. For example, interventions on arable land have a greater reduction in peak discharge than those on wet or steep slopes for similar percentages of tree cover, whilst random interventions largely follow a general trend.

Figure 8.20 shows that some groups demonstrate a greater impact per area of planting than others on the 23/24 Dec flood event. However, it is not directly linked to our pre-allocated group types. By looking at all the peak events and sorting by size of planting, it is evident that there is a relationship between the size of planting and the impact per

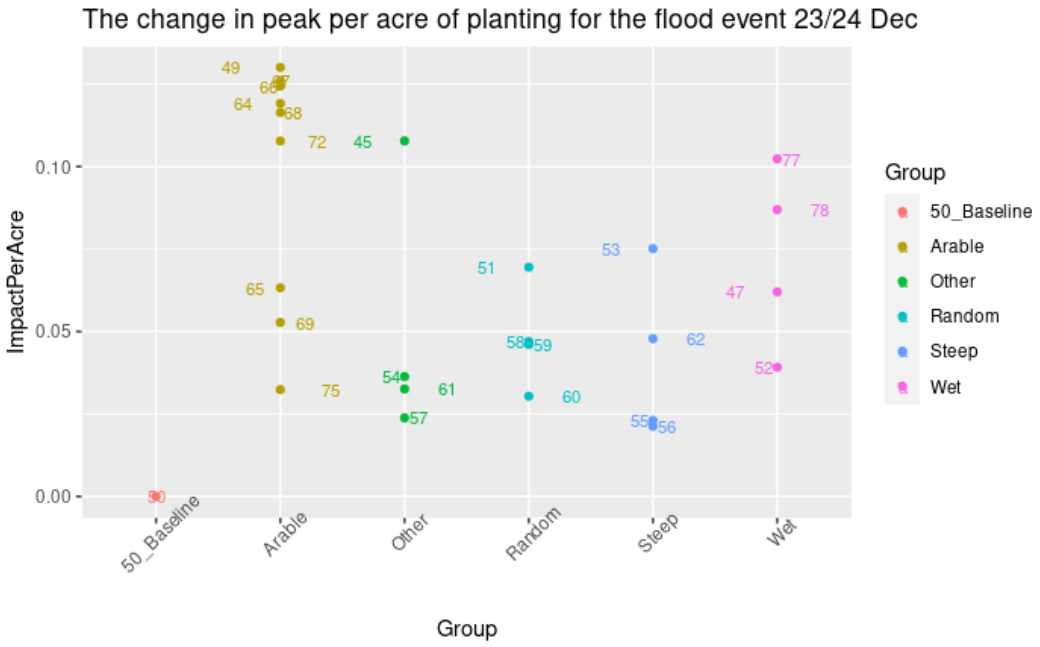


Figure 8.20: Shows the impact per acre of each group of scenarios

acre and that some groups are clustered together.

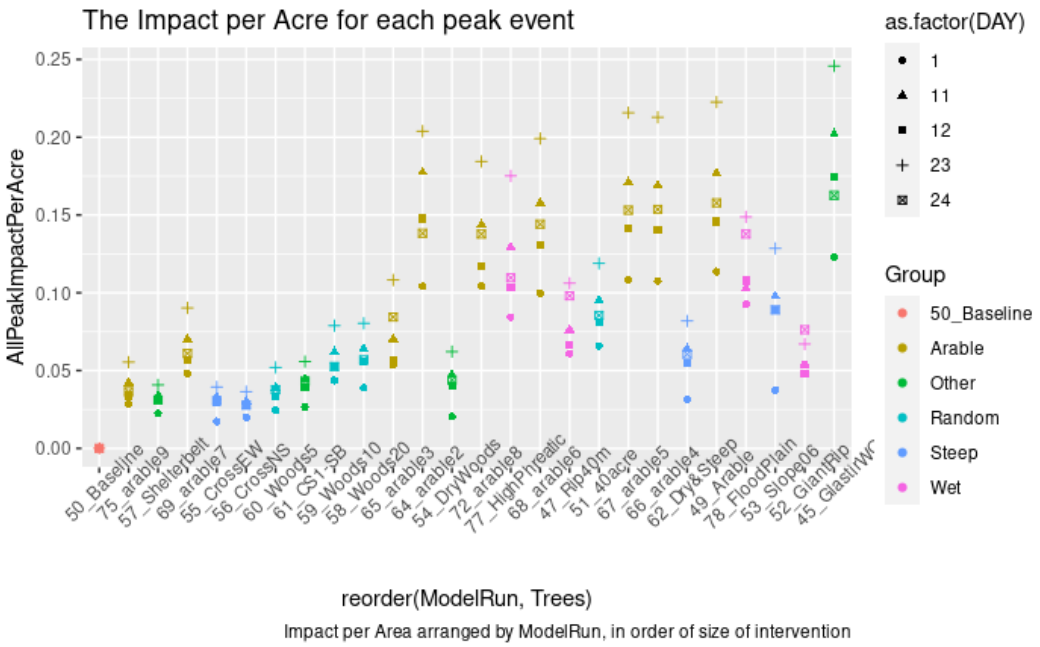


Figure 8.21: Impact per Area arranged by scenario, in order of size of intervention

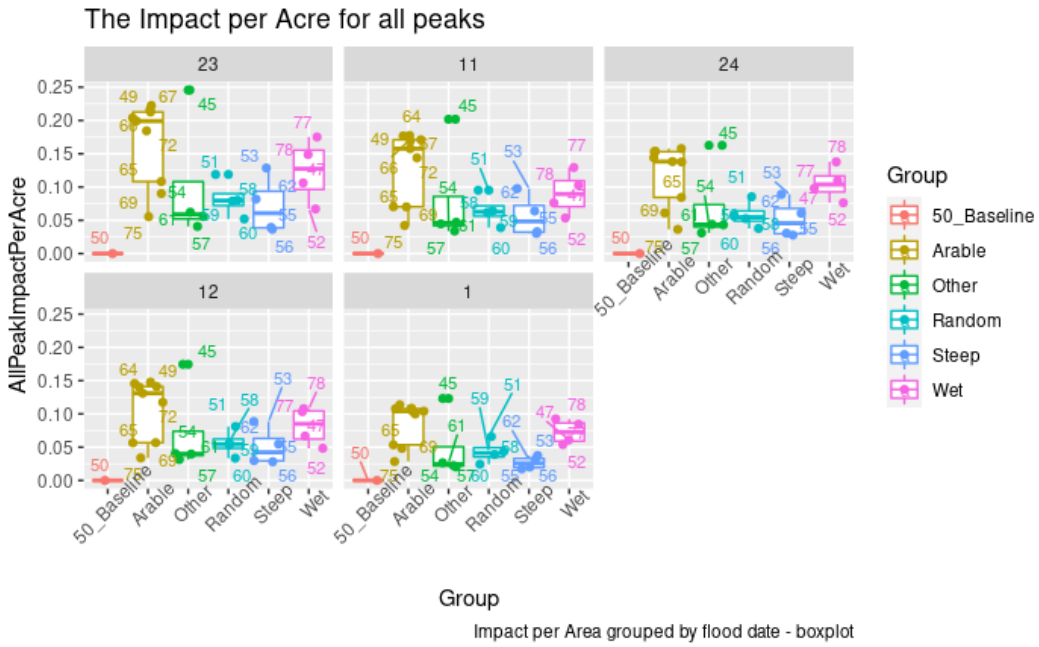


Figure 8.22: Impact per Area boxplot, grouped by scenario groups and by flood date

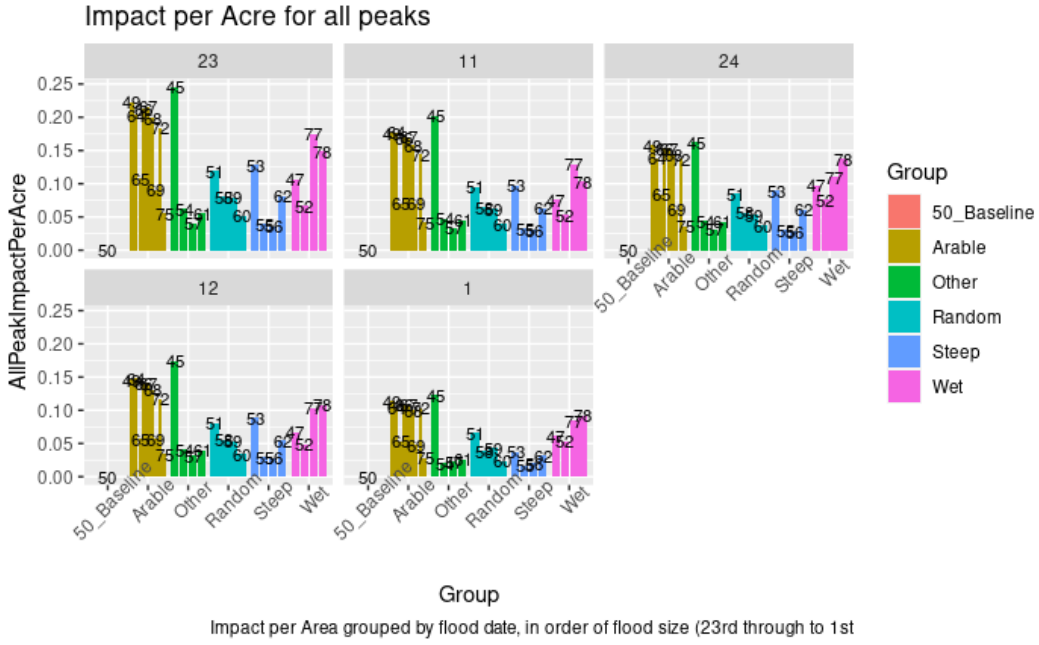


Figure 8.23: Impact per Area grouped by flood date, in order of flood size (23rd through to 1st

Whilst graphs in Figures 8.21 and 8.22 show that both planting on arable land and planting at greater sizes can have a greater impact on the peak for each acre planted, Figure 8.23 shows that this is not a consistent relationship and other factors may be explaining these results.

Removing the group structure from this analysis and viewing the data more simply highlights the importance of not assuming simple relationships. Figure 8.24 creates new groups based on the percentile of impact per acre.

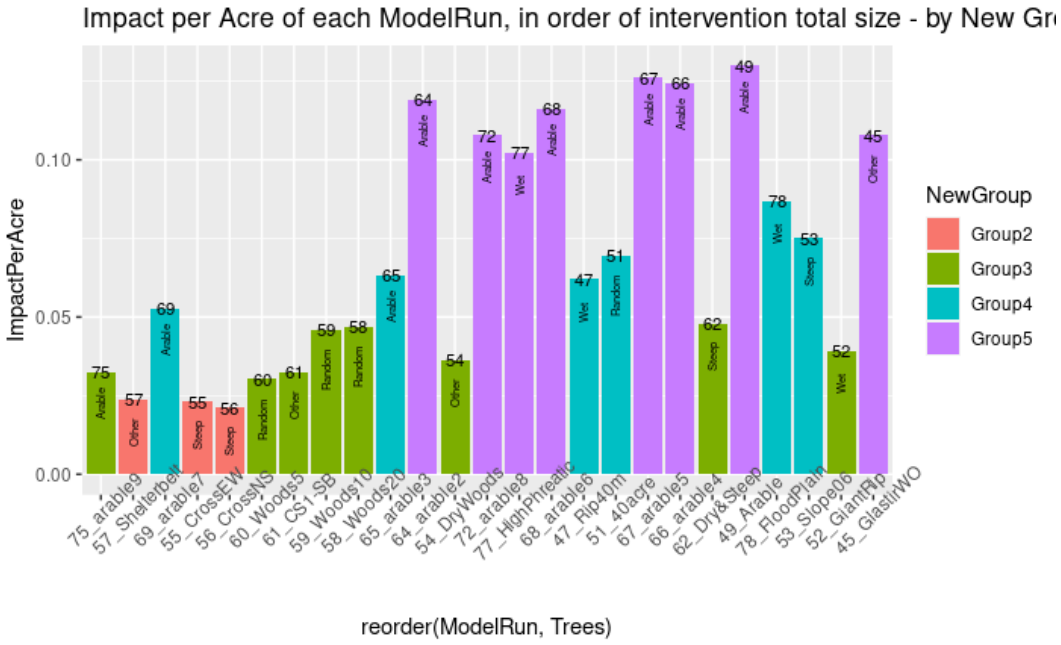


Figure 8.24: regroups alternative scenarios by impact per acre percentile

The scenarios with the highest percentile ImpactPerAcre are either on arable land or contain arable land (77 and 45). The three lowest impact scenarios are all the small rectangular blocks designed as single strips and widely dispersed.

Of the 'wet' scenarios, 52 and 47 are low compared to 77 and 78, and all are spread across 3 percentile groups. The details are important; both 52 and 47 are modelled around extensive Riparian and floodplain planting. 78 is floodplain into areas where the phreatic water-table is high during a flood event. 77 is planting on areas where the phreatic water table is high during a flood event but does not include the floodplain planting. The difference between these four 'wet' areas may be due to the rate of saturation of the ground. The Riparian areas will already be fully saturated during and around any flood event; the only effective mechanism for reducing the flood peak is, therefore the impact of surface roughness on the overland flow. However, the areas of high phreatic surface will benefit from infiltration for longer. This might suggest that planting is more effective in areas of a low phreatic surface to ensure the benefits of infiltration; however, the

lowest phreatic surface levels and steep slopes (54 and 62) also produced a lower impact per area. This suggests that there is a balance between mechanisms and geomorphology. These complex relationships are particularly interesting and will be discussed further both in this chapter section 8.4 and are relevant to discussions of heterogeneity in Chapters 10 and 11. Another outlier might be the difference between arable3 and arable2; this pair are important as they compared the effect of planting across two locations, which loosely tied to the two different soil types. Scenario 64_arable2, planting in the North East of the catchment had a greater impact than planting in the South East.

Whilst these comparisons and groups identify a difference in planting choices, they also highlight the complexity of these. Identifying the cause of difference is very difficult in a large and complex catchment where planting type falls across different elevations, types, hydrological behaviours etc. It highlights that the simplistic 'type' used for describing NFM interventions may be suitable for grey literature but should not be used for creating funding or grant schemes, where mechanisms of change are more important. A knowledge of silviculture [Forester], hydrological response of place [Land Manager + local hydrologist] and key mechanisms affecting both the land type [geomorphologist + farmer] and tree species [forester/arborist] will change the impact per area of planting.

8.3.5 Loss of trees or other management choices have a greater impact per area of change

The change in flood peak for other landuse changes may be greater than that of trees.

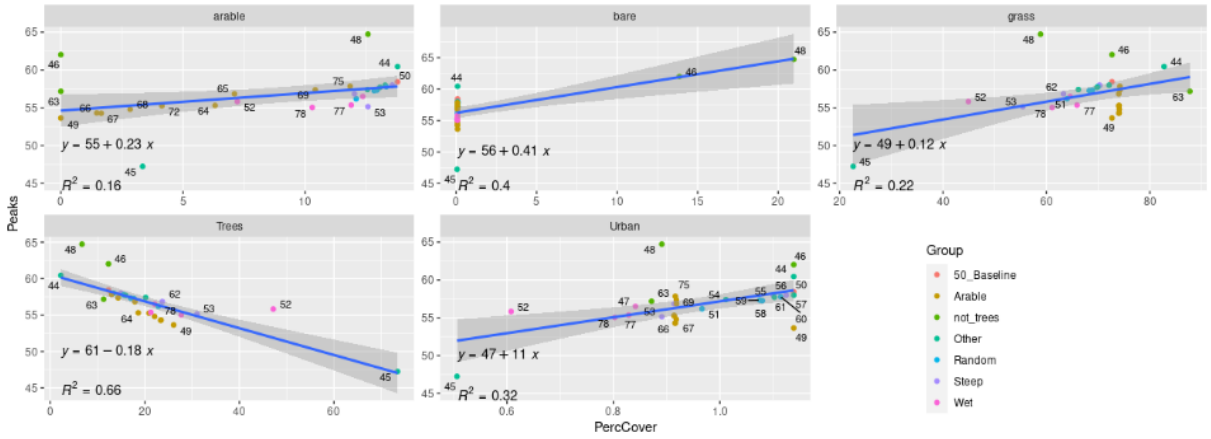


Figure 8.25: Plots discharge against percentage land cover for the largest other landcover codes used in the SHETRAN scenarios

These graphs show the percentage cover of each land type against the maximum peak for each scenario. Note: gridcodes 4 and 5, Deciduous and conifer, have been aggregated as 'Trees' as the proportion of deciduous was very small. Figure8.25 shows the impact on the peak as the percentage of the catchment under that land type changes; the slope of the graph, therefore, gives us the rate of change and whether the change is positive or negative. Overall, only an increase in tree cover decreases the flood peak. Whilst not always the case (for example, bare ground scenarios were related to a loss of arable), primarily, the increase in one landcover is related to a decrease in trees. This means that it is the difference between the graphs that is of interest.

With a gradient of 10, an increase or decrease in urban cover would have the greatest impact on an increase in flood peak. However, this is a very small area, and changes were not intentionally explored, having only occurred due to the aggregation effects of interventions when converting to the 100m x 100m grid. This is still of interest as, due to it being a small area, only a small increase in urban cover would have a significant impact and warrants further exploration. At 0.4, an increase in bare ground has the next greatest impact; however, this was also the least explored option in this scenario, with very few data points to support this. An increase in arable land at 0.21 has a greater impact than an increase in grassland at 0.12 - which is as expected as the grassland is modelled as having a greater rooting depth and Strickler overland flow coefficient. In

the standard values the canopy resistance is greater for grass than arable which should decrease potential evapotranspiration (ra to rc ratio of 0.0125 as opposed to arable 0.025 and trees 0.5), however as the canopy is wet, only the ra would be taken into account, where arable and grass are the same (Appendix XI).

This suggests that the most important mechanisms for the model explaining the difference between arable and grass are the infiltration/subsurface and overland flow.

Given the importance of k_{sat} in calibration (Birkinshaw, 2016), it is likely that subsurface flow is more important to the model than overland flow. The reduced impact of floodplain planting suggests that subsurface flow is the more important mechanism aggregated across catchment for some events (large, flashy, occurring when ground not saturated).

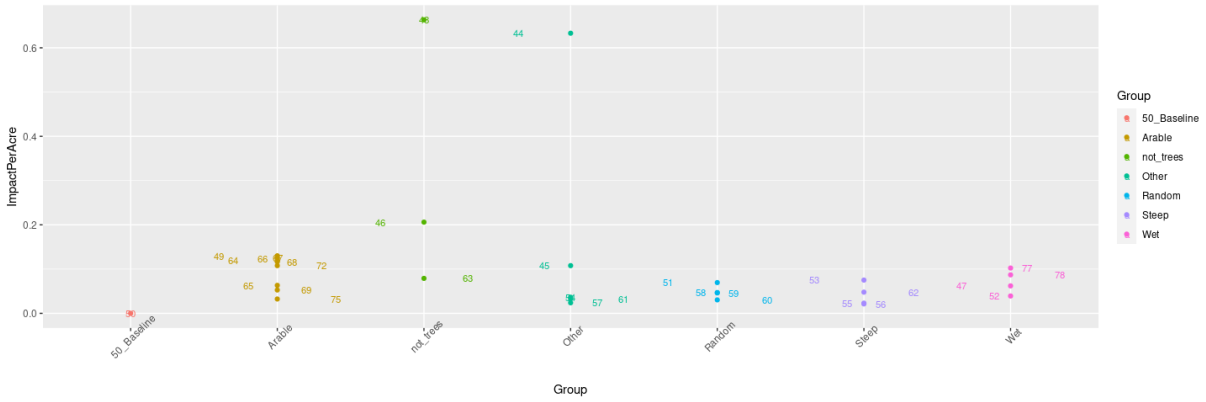


Figure 8.26: Shows the Impact per Acre graph with the loss scenarios added back into the data

Figure 8.26 shows the considerable difference that adding the loss scenarios has on the analysis. Whilst the deforestation, or replacing of all the broadleaf trees with grass falls in our expected pattern, the impact of converting slopes to grass, and arable to a bare-ground crop (such as maize), have a much greater negative impact per acre change, than our increase in tree cover.

8.4 Reflections and implications

8.4.1 Methods

I have, perhaps, applied more rigour (particularly in the calibration and evaluation of the baseline scenario) than would be considered necessary for a heuristic model. (Rangecroft et al., 2018). This reflects on two factors: the future evaluation of the usefulness of the model with LMs and my experience as a hydrologist.

There is a balance between making the model as good as it could be and making it as good as it needs to be. Within this, there are judgements of uncertainties, parameters and analysis.

With decades of experience, I am sure this balance becomes easier to judge. Without those decades, I have erred towards the former, making the baseline as 'good' (representative) as I can make it whilst also being aware of the trap of over-fitting and the illusion of accuracy in precision.

In applying disciplinary rigour, I have done so whilst making evident the importance of the qualitative data and direction of LMs.

I am, in part, responding to the call to hydrologists by Beven and Chappell (2021) to make clear their perceptual models. However, I am expanding this to address not only ontology but epistemology, identifying where 'others' are integral in the production of knowledge.

I have shown that the inclusion of qualitative data (Beven (2012) and a wealth of STS literature section 2.5.2) can inform and improve the methodological processes of calibration and evaluation. The wider knowledge of LMs has helped frame the direction of the research, model choice and ensuring exploration is relevant to the catchment community. Most importantly, it has an impact for the analysis and framing of results.

8.4.2 Interpreting the model output

Increased tree cover reduces overbank flow. Whilst all scenarios reduced the flood peak, no increase modelled guaranteed prevention of overbank flow. In previous literature, this may have been reported as interventions having no significant impact, though a lack of consistency of language in hydrological reporting (Ellis et al., 2021) demonstrates the subjectivity of this statement. More importantly, catchment context and participant interviews demonstrate that (for example, where mitigation and resilience are a greater priority than prevention) the significance of results must relate more to social rather than statistical values. A given percentage appears easily comparable, but a 10% reduction in peak in one location may have significantly different impacts than in another.

A change in focus must arise when we consider these results from the perspective of the catchment land managers rather than scientists.

Most studies report on the flood peak at a given point in the catchment; the CEH 2017 report on trees and floods reflects this with a literature review in which only this impact is comparable. However, no participant within the catchment expected tree planting to prevent flooding within the catchment (e.g. section 6.2.1, Quote 29). Neither did they expect or desire complete control of the river, recognising it as a 'natural' behaviour. It should be remembered that our most fertile land is often that which was once a floodplain. Participants were interested in damage, risk to life and livestock and accessibility; none of these requires a complete cessation of the Trothy flooding, but rather a reduction in the force, speed, duration and regularity of events. In the case of the whole catchment concerned with, for example, the rebuilding of bridges and fences, the smaller, more regular floods may do the greatest long-term damage. It is the flashiness of the river that makes it dangerous to livestock (and the farmers who then put themselves in harm's way).

All the interventions reduced the flood peak in a direct relationship to extent; variation reflects on uncertainties in extant literature .

The reduction of the flood peak and a corresponding reduction in the time over which

that event took place is the most important finding. This supports the extant literature where an increase in tree cover resulted with a decrease in peak flows, with the 5 exceptions being attributed to pre-afforestation drainage (Stratford et al., 2017). The percentage reduction is within the (substantive) range of the wider literature (Cooper et al., 2021; Stratford et al., 2017).

The greater impact on larger flood events is unexpected based on previous literature and could relate to variation in observed data due to other land management factors. Another factor may be the size of catchment and impact of spatially distributed rainfall. It has been assumed in the past that during rainfall events, there is minimal interception, particularly from broadleaves (Nisbet et al., 2011), and whilst this is currently in debate (Page et al., 2020), this is the behaviour that the model would reflect. It has also been assumed that most catchments will be fully saturated (Soulsby et al., 2017). However, due to the size of the catchment, unlike smaller catchments where rainfall can be considered to be less spatially distributed, at no point was the whole catchment fully saturated (as can be seen from the phreatic surface levels), and there were also, therefore, spatially distributed impacts on evapotranspiration. This means that areas of the catchment still benefited from both the interception and infiltration impacts of increased tree cover. The limitations of measuring rainfall mean that often observed studies rely on only a few stations. Using the remote sensed, spatially distributed rainfall with spatial aggregation means that no one individual point may be exactly the 'right' amount. However, the non-stationarity of weather suggests that any modelled event may be potentially possible. Modelling using remote sensed spatially distributed rainfall may then be a better reflection of a 'real' event than taking a single accurate measurement but being unable to account for the impacts of spatial variation.

Minimal lag occurs in all but the most extreme scenarios, however, lag times showed the importance of evaluating multiple events. An evaluation of lag times in section 8.3.3 is important not because of findings related to lag or the synchronisation of tributaries, which is the usual purpose. Rather, it drew attention to the importance

of studying a range of flood events, the heterogeneity of those events and the change in hydrological behaviour only evident over longer periods.

The shift in the maximum peak from the less saturated event to the more saturated event at around 18-20% tree cover is noteworthy. This suggests a situation in which the river is less flashy, flood peaks are more predictable, being caused by excessive overland flow. It is interesting that above 30% tree cover, this behaviour appears to change, and further exploration of a greater range of scenarios would be needed to explore this. In regards to integrating tree cover with other land management interventions, understanding the implications of this may be a key area of further research.

Tree cover and other interventions

For decision-makers interested in trees, the key findings will relate to the location, type and amount of tree cover. A common method of planning interventions for NFM (or other landscape changes) makes use of 'opportunity mapping' where assumptions have been made about the types of land that might be suitable for planting. These maps are largely based on the use of modelled data, which comes with its own difficulties (as described in the literature review section 2.2.3). In addition, assumptions about the type of land that should be included in maps is often a culturally based assumption, for example, excluding any land that is of greater agricultural value than Grade 3. The findings of this model challenge these approaches, suggesting that, whilst opportunity maps and models may be a good way to start a conversation, they are unlikely to be suitable for planning or decision-making on the ground.

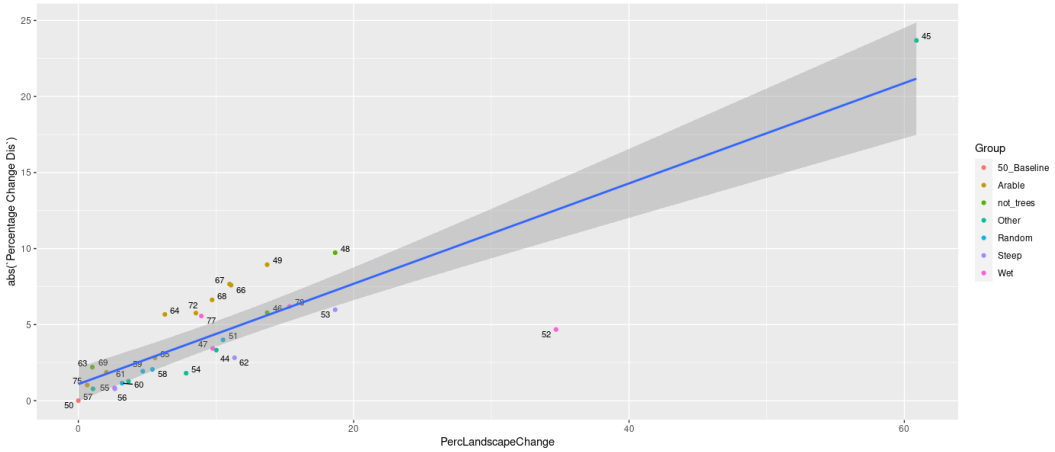


Figure 8.27: Shows the linear regression over the percentage change in discharge against the percentage landscape change against

By reviewing the total percentage landscape change against the absolute change in discharge, we can compare the impact of different types of interventions. We can see that our types fall above and below the regression line, with the following implications:

- Replacing arable land had a greater impact than replacing permanent pasture
- Replacing land on wet steep slopes had a bigger impact than on dry steep slopes
- Replacing dry flat land had a bigger impact than replacing wet flat land (arable planting can be considered the 'flattest' within the catchment due to the nature of its soils.
- Replacing wet areas was effective on slopes but less so in riparian or floodplain planting.

If, however, we consider the standardized residuals we are able to compare the results to each other:

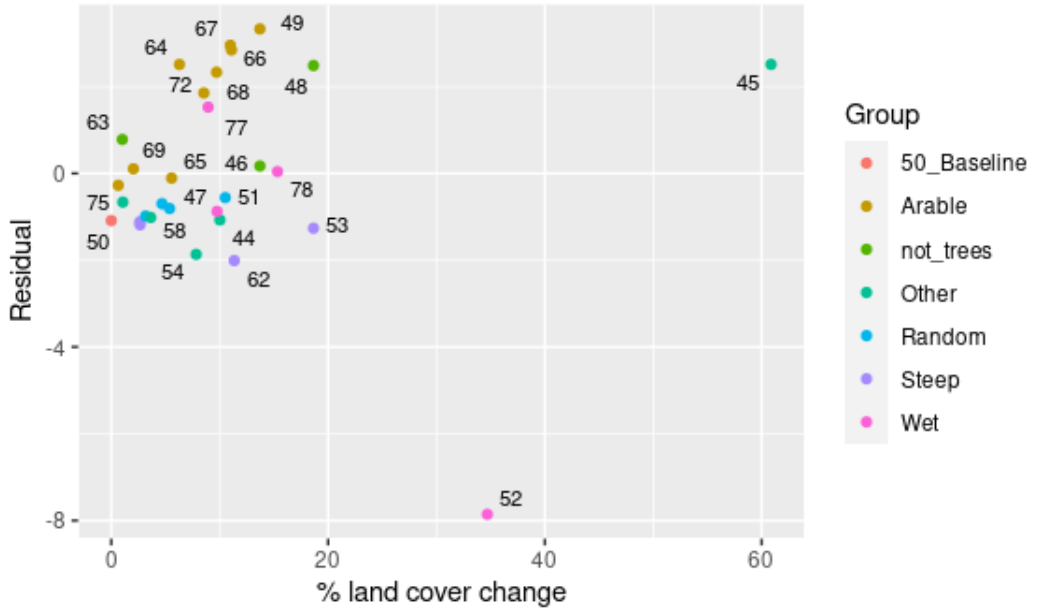


Figure 8.28: Standardized residuals for scenarios against percentage landscape change

We can see that, whilst different 'types' follow a pattern, the only true outlier in the data is alternative 52, the riparian/floodplain planting. This finding is important despite the unlikely event of this extent of tree cover ever occurring in this catchment, as Riparian planting is a key focus in many catchments, and it supports the use of models and monitoring of interventions to identify the changes in hydrological behaviour and mechanisms of interaction within catchments were extensive planting does occur. Increasing tree cover within the catchment in diverse locations and sizes could support the reduction of impacts of floods, alongside other benefits.

I have argued that any model of tree planting interventions cannot reflect a 'real world' as it cannot account for the plethora of socio-cultural changes and non-stationarity of climate over the time of growth of those trees. This model cannot be used to determine exact planting plans for even this catchment. As a heuristic, key findings from this model are useful in identifying, if not exactly where trees should be, how to value the NFM benefits of tree cover created with other primary drivers in mind.

For example: Extensive Riparian planting has the greatest impact on the shape of hydrograph peaks, suggesting shifts in locations and extent of overbank flow. This may directly impact land managers' resilience to flooding and ability to manage change de-

pending on the time over which changes were implemented (Wynne-Jones et al., 2022).

'Wet' area planting may not have the greatest NFM impact, but this is very dependent on soil properties, which will also be linked to surrounding land management choices. This is a key area covered in the workshops (Chapter 10), and itself led to further interrogation of the model - scenarios 77 and 78 were in fact run after the workshops took place.

Tree planting at scale is generally discussed only regarding the (somewhat subjective) 'lower quality' agricultural land. Yet this model demonstrates that arable planting may have the greatest NFM impact. Given the need for arable crops (again, see the workshops Chapter 10), the catchment may be very suitable for agro-forestry type interventions. It is important to note that this wouldn't have been captured in opportunity mapping, where an assumption against planting on good arable land was included. Opportunity maps and modelled data can start a conversation but shouldn't be relied upon to form regulations or incentives.

Whilst further interrogation of diverse catchments and conditions is warranted, it must be connected to the value-based decisions and integrated approaches that inform actual interventions taking place. The importance of wider land management changes and the research required to evaluate these should be a priority for policyholders and land managers for whom flood management is the primary objective.

Reliability and 'value' of findings

The reliability of findings can be related to the number of alternative scenarios interrogated; for example – though the loss scenarios demonstrate an effect of concern, only one scenario of each type was run, and considerable further exploration is needed to quantify any impacts. Only a small number of scenarios, relatively speaking, have been run for each 'type' of land cover, and again this would benefit from further development, as whilst I can state that location and type do have an impact, the mechanisms governing the complexity of this are hard to identify. Studies that could run multiple different landscape changes to differentiate different mechanisms may be of interest where planting plans for the primary purpose of flood management are desired.

For this study, the primary finding that increasing tree cover decreases flood peaks and may reduce the 'flashy' behaviour of the catchment is clearly demonstrated.

The 'value' of these results, however, is harder to identify. Here, the results must be interpreted carefully and depend on the objectives or outcomes that the analyst has identified. The 'value' associated with the model data information on type, or location of tree planting must be considered both on its own merits and in relation to its relative value in regards 'any' tree planting.

When considering the type of planting, the context of the socio-ecological landscape is important, meaning that the results relating to most effective 'type' are directly tied to this particular catchment. Identification of a primary mechanism within any given catchment may help most effectively target planting. However, current literature does not yet agree on how to do this. On the other hand, the potential of interventions over a certain percentage to both reduce the flood peak and potentially reduce the 'flashiness' of the river behaviour suggests a different policy approach. A less prescriptive approach to interventions that are carefully planned and monitored throughout stages of growth could be supported by policymakers. Allowing flexibility for tree planting to meet other priorities will also support hydrological management within the catchment.

8.4.3 Limitations and implications

I have begun to identify the limitations of the model and what the findings can and can't be used for. In addition to these comments, there are specific assumptions and limitations in both the model structure and its analysis that impact what the model can and can't be used for. I shall finish this chapter by outlining these limitations and the implications of this, leading to the final empirical chapter.

Model 'generalisations' of scale Beven (2012) states that all models are 'lumped' to some extent. The nature of the SHETRAN model means that all data is aggregated at both spatial and temporal scales. The smallest spatial resolution is at 100m x 100m, and most data sets were attained at a finer resolution to this, then aggregated on ArcGIS.

Hourly data is input for all temporal variables, which is adequate for the time scale but still an aggregation of data. Three datasets have been aggregated at a coarser scale: Precipitation, Potential Evapotranspiration and Soils, as is explained in the methods section. Whilst the non-stationarity of weather and climate means that the weather data is acceptable as it stands, the soils data will have a significant impact on the reflection of the catchment's 'true' behaviour. There are a few reasons for this and they lie in the scale at which soils data can be attained within the catchment. The ESRC data could have been retained in a larger resolution or field experiments carried out to identify properties for the three main types of soil included in the study. However, small-scale soil changes, e.g. impacts of ploughing, farm woodland management, including the abundance of unmapped drainage systems in the catchment, suggested that any fine resolution data would, at best, give a false impression of accuracy. This heterogeneity of soils also impacts the benefit of taking field measurements over aggregation of remote sensed data, as the ability to take multiple samples and guarantee a representative average is prohibitive when considering the size of the catchment. The likely scale of interventions does not reflect the scale of the model or the catchment; therefore, the choice of analysis framework of the model is a heuristic.

Model data cannot be used to plan or locate suitable tree cover; instead the behaviours and mechanisms suggested by the model can be used to inform decision making.

Model Parameters As with the soil parameters, hydrological parameters have been assumed that have been supported by previous studies but are also generalisations. For example, the model does not differentiate between tree species, whilst this choice was due to the lack of consensus or data on parameters for individual species this knowledge is being developed. However, simplifying the parameters enabled a focus on location and type of planting. Alternative scenarios with multiple species types could be run to interrogate the impacts of mixed species, monoculture or different species planting when this data becomes available. It is likely, however, that the value of this data will not improve the model's ability to predict or plan changes, again this would need to be a

model developed as a heuristic; again due to the time over which trees grow. Changes to the hydrological impacts of different species due to disease, climate and socio-cultural management, may have a greater impact than species type itself. This would be an interesting area of further study. Regarding this study, two areas may have had significant impact – the study of evapotranspiration in storm events, which would mean an increased impact of tree cover than is currently modelled; the different hydrological parameters of long-term permanent pasture over a grass ley, which would differentiate between the older grassland habitat considered more ecologically valuable. In addition, the parameters were attributed to socially determined land 'classes', which are as much culturally determined values as ecological descriptors. The land classification data did not adequately reflect farmers' and land managers' own perception of land types which is a disadvantage of this dataset. In 2021, CEH released a more complex land cover set, but again, this is classified using scientific rather than place-based values (there is for example, no record of Fridd).

Non-stationarity The non-stationarity of climate has been aptly demonstrated during the time of this PhD. When the study began, the 2014 flood was the 'most recent high' event, with the flood in 2000 being the highest recorded. The breaking of this high on three separate occasions since that time demonstrates the inappropriateness of trying to pigeonhole the modelled event as representative of a given type or frequency of flood. It is currently in the top percentile of recorded flood events for the river but may not remain so. The non-stationarity of socio-ecology of the catchment is also important. There has been considerable change to the catchment over the past 6 years. The land use reflected in the baseline scenario is no longer representative of the catchment, and the current year's land use is unlikely to be representative for long either. The model shows that large changes have large hydrological impacts; with changes in crops to maize or potatoes where bare ground may be left, this will have much more impact than tree cover which may take years to develop. In a catchment of this scale, at a time of agricultural change, it is unlikely that any land use mapped would be representative for long. This does not prevent us from trying to understand the catchment, but would seriously limit the ability

of a model to predict future hydrological response; this again leans towards using the model as a heuristic. Learning from the behaviour change demonstrated by the model under certain conditions. Applying that knowledge within a catchment context may be possible, but only when combined with the place-based context provided on the ground.

Part IV

Synthesis

Chapter 9

Methods III

Contents

9.1 Participatory Workshops **233**

9.1.1 Ethics and Methods 233

9.2 Data Analysis **238**

9.3 Participant Observation / Researcher Experience **239**

9.1 Participatory Workshops

9.1.1 Ethics and Methods

Ethical amendments and COVID-19 In the original methodology written for this research project, further interviews and workshops were planned to develop an iterative relationship with participants, bringing them in as active 'co-investigators' in both the analysis and evaluation of the findings.

When COVID-19 prevented all face-to-face research, the shape of participation in this project had to change. However, responding to Chilvers and Kearnes (2020) reflections on responsible democratic innovations, reflexivity, and the findings from the fieldwork, I needed to find a way to return my work to participants. This was not just because it was the right thing to do but because the evidence from the fieldwork demonstrated

the entangled nature of the model and the socio-ecological landscape, the catchment itself. I could reflect on the model output from an informed perspective, but I could not situate the findings within the (now evolved) landscape to which they were relevant. I was able to work and observe within the relevant wider contexts and sectors and conduct dissemination meetings with boundary organisations to whom this work would be relevant. However, I needed to synthesise my researcher experience with reflections from within the catchment to finish the work.

In early summer 2021, the approach to fieldwork in Universities across the UK was uncertain; the possibilities of further lockdowns were evident but unclear. The COVID-19 virus was still present, and levels of precaution in place were high and different across the devolved nations in the UK. On-site discussion with even small groups of participants was precarious and potentially dangerous. I had to assume that emplaced fieldwork would not be possible and look at the options of online methods. The significant change in approach and the circumstances required a review and application for ethical amendments, considering key factors such as access and uptake (Appendix V).

COVID-19 impacts included a greater discussion of online and digital methodologies in academia (Lobe et al., 2020), identifying benefits and limitations of factors such as access. With a poor quality of internet access in the catchment but an increased acceptance of online experiences, I experienced both the limitations and benefits of digital research. Participation was limited, and the demographic was younger than the average demographic of the interview participants. However, those who attended would have been unlikely to be able to attend an in-person event. In an ideal world, this suggests hybrid or mixed approaches have significant merit.

In completing the amended ethical review, the implications of the pandemic made me consider the worst-case scenarios I might face. I was surprised by the lack of conversation around the implications of death. This caused me to reconsider some of the situations I had already faced and my encounters with death throughout this PhD. These encounters had both methodological and ethical implications and also direct implications for research in landscapes and landscape change. My encounters go beyond the main aims of the thesis,

Table 9.1: Workshop participant demographics

Farm size	13 acres to +1000 acres
Holding primary type	Smallholding, events, mixed, dairy
Spatial location	Workshop 1 – mid; Workshop 2 – mid to low reaches; Workshop 3 – upper and lower
Gender	2 women, 4 men
Ages	20 – 50
Education	GCE to MSc

so have not included a discussion of them here. However, I have presented on this topic and written a blog post, which I include as Appendix XII. This is an area of both research and conversation that I consider important and currently lacking.

Recruitment : All bar one participant (Appendix XII) who took part in the study had agreed to continued involvement and had provided email contact details for this purpose. In addition, several further contacts of potential participants had been made during the original fieldwork. All these parties were emailed, inviting them to take part in the workshops. Nine respondents (covering seven sites – six from the original cohort and one new farm) agreed to participate.

All respondents were invited to pick one of three workshop dates when dates were finalised with at least three members to each workshop, a confirmation email with attached consent form and copy of the datasheet were emailed (Appendix XIII), participants were asked to return a signed copy if possible, or to confirm consent verbally at the beginning of the workshop (to ensure that a lack of printing facilities did not prevent attendance).

Workshops : Three workshops were held with attendance, including the researcher, of 2, 5 and 3. These smaller workshops enabled engaged conversation between participant and researcher and (in the second and third workshops) between the participants themselves. In hindsight and after considerable webinar/workshop attendance over the last two years, this group of four created an ideal scenario for discussion, enabling each member to contribute significantly. A group of three also worked well. The individual discussion between participant and researcher was relevant, but the interaction between

participants significantly increased depth.

The workshops were held on Zoom and began with a short presentation by the researcher, including:

- setting the context
- describing the graph and catchment maps included on the datasheet (Figures 9.1, 9.2 and 9.3. The full Datasheet provided to participants can be found in Appendix XIII)
- explaining the details on the datasheet.

All participants were invited to comment and ask questions throughout. The screen was then unshared, with all participants and the researcher on screen. Participants were asked to:

- comment on the model output and if it agreed with what they knew of the catchment
- comment on the research reflections (listed in the datasheet)
- comment on the relevance of the findings to their practice and decision-making

Workshops were recorded, and a VTT transcript file was generated. Transcripts were checked against the audio and edited where the accuracy of the transcription required improvement.

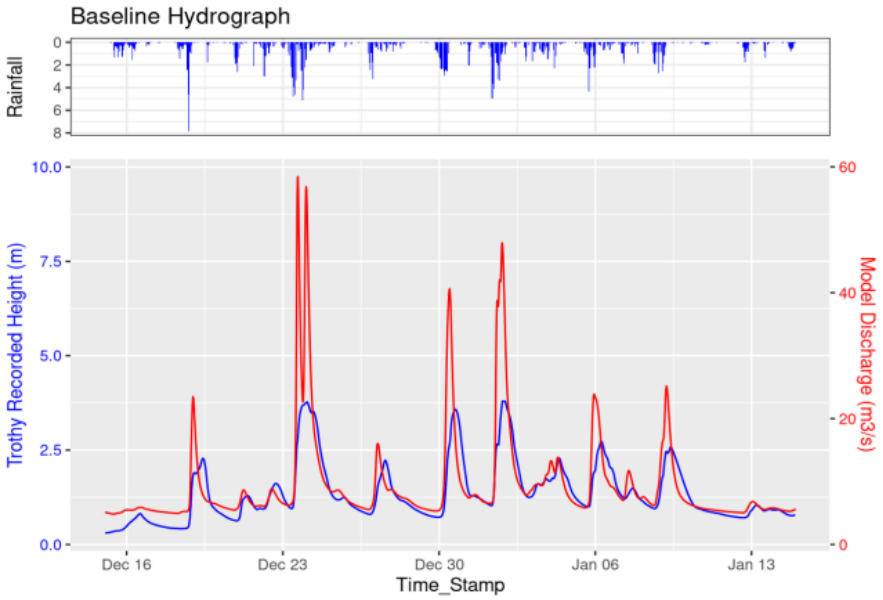


Figure 9.1: Baseline scenario Hydrograph from model output including the observed river height data

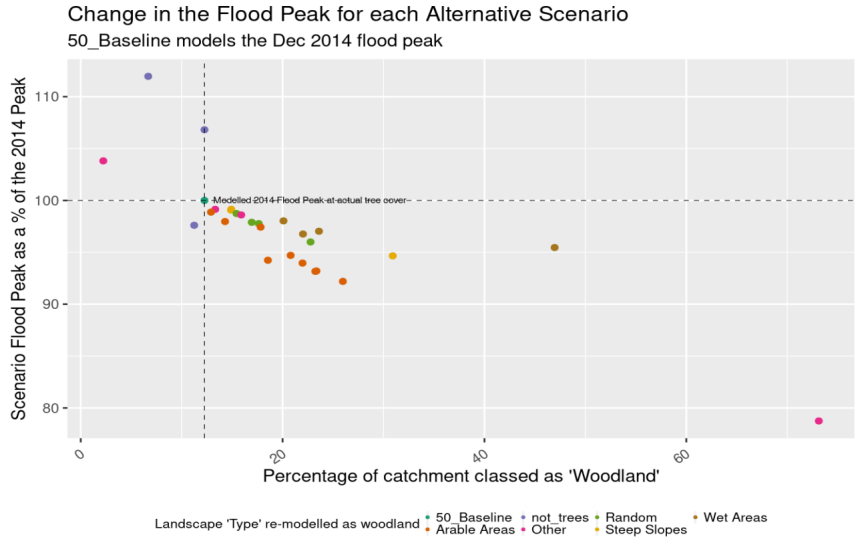
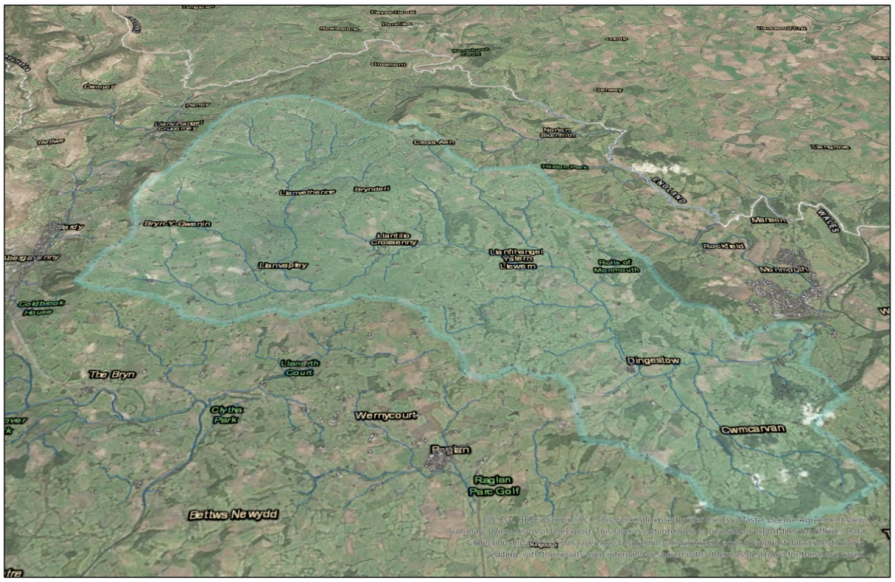


Figure 9.2: Early graph of model output maximum flood peak against the percentage of catchment under tree cover for the baseline and all alternative scenarios. This graph was an early analysis of output and does not include all the data used in the analysis described in PartIII


Llanwnda
Llanllyfni
Dinas
Penygroes
Llandwrog
Caernarfon
Llanrug
Llanddeiniolen
Llanberis
Deiniolen
Bethesda
Llandygai
Menai Bridge
Bangor
Penrhosgarnedd
Llandegai
Llanfairpwll
Llanfair PG
Dwyran
Newborough
Rhosneigr
Aberffraw
Llangefni
Gaerwen
Benllech
Amlwch
Pentraeth
Beaumaris
Llanfaes
Brynsiencyn
Llanfairpwllgwyngyll
Menai Strait
Llanddaniel Fab
Llanfair Pwllgwyngyll
Llanfairpwllgwyngyllgogerychwyrndrobwllllantysiliogogogoch

9.3 Participant Observation / Researcher Experience

Throughout this research, I have included ethnographic elements in my methodology, including: visiting local churches and heritage sites, reading the community newsletter, finding and reading the Millennium journal, walking sections of the catchment with my family and attending community coffee mornings. This engagement, partly supported participant recruitment but also furthered my understanding of the community beyond that of the individual participants. This is particularly important, as whilst participants may have presented themselves as individuals with relation to their farms, they were also part of these communities, and the discussions we had may have been affected by the fact that many knew of my wider engagement.

Through dissemination meetings, placements and volunteering, I also participated in, 'participatory observation' (Shortland, 2021). Within the community, this involved a presentation for the Women's Institute (WI) on the project and writing updates for the parish newsletter. Whilst there was less involvement with the community than initially planned, I have maintained light contact throughout – and some participants have stayed in touch, sending me relevant photos or videos of the river or comments on changes in the catchment.

Additional stakeholders beyond the catchment community include those responsible for its management. I have been in discussion with Natural Resources Wales throughout the project. As well as being provided with the NRW held levels data, I met several times with the local team, responsible for areas of farming practice, water quality, etc., in the Trothy catchment. I was invited to sit in on team meetings (pre-COVID), and the South East team requested a summary of my work to be included in a report on work being undertaken in the South East on Natural Flood Management (Appendix XV). I worked with the Wye Valley AONB team, reviewing some of their interventions and plans early in 2019 and presenting at their Natural Flood Management conference in February 2020. I have presented and prepared a summary for Dwr Cymru at their request, as they were particularly interested in the mixed methods approach that the work took. I have been

in contact with and presented for the team at the Wye and Usk Foundation, who are part of the Wye Catchment Partnership.

For three months in 2020/2021, I undertook a policy placement with the Welsh government forest policy team, where I worked on a strategic and spatial analysis for the National Forest in Wales team. This originally started as a way of developing a discussion tool to understand the spatial potential of the National Forest. I have presented the ArcGIS Storymaps developed to the wider Welsh government departments, the First Minister and the Minster for Climate and the Environment. These maps have subsequently been updated and become publicly available as part of the team's wider Wales-wide engagement process[1] – a step towards the democratisation of environmental policy by involving citizens at the earliest stages of consultation and development. This work has become directly relevant to the thesis giving me an overview of current and potential woodland policy and strategy in Wales.

Following this placement, I became involved again with Welsh policy when I was invited to participate as an expert member on the Government's Tree Planting Deep Dive 'Task Force' (https://www.gov.wales/trees-and-timber-deep-dive). This involved an intensive period of meetings developing the recommendations (Trees and Timber Task Force, 2021). I have remained part of the panel as it has developed to form the Deep Dive delivery panel. I have subsequently participated as an advisor on a panel exploring the future delivery of the National Forest in Wales.

At the other end of the intervention spectrum, I had been aware of Stump Up For Trees since it's very early stages, and once the series of COVID lockdowns finished, I joined them as a tree planting volunteer. SUFT is a charity led by farmers and locals who developed and worked the woodland expansion of Bryn Arw. Since starting with SUFT, I have taken on a much more significant role and have been structuring and coordinating the volunteer data collection of a long-term project to monitor the ecological changes on Bryn Arw. This work has put me at the coal face of landscape change; being led from the ground up, demonstrating the ability of communities to lead and develop their own

[1] https://storymaps.arcgis.com/collections/db09bcb722174bfeab27510b565ed2ba

projects, the passion and dedication of those communities and the support and barriers that entangle their path.

This participatory work sits in the background of all of the analysis and evaluation conducted and detailed in the following two chapters: Chapter 10 tackling the challenge directly with participants and Chapter 11 which draws together and synthesises the whole entangled puzzle.

Chapter 10

Co-production of Knowledge

Contents

10.1 Introduction **243**

10.2 Towards synthesis **244**

10.2.1 Evaluation and analysis of model output 244

10.2.2 Evaluation of researcher reflections 252

10.2.3 Analysis and discussion: wider knowledge and political behaviours 254

10.3 Translating across boundaries **264**

10.3.1 Research as intervention: land manager knowledges and learning through participation 264

10.3.2 Co-production and the fluidity of expertise 266

10.3.3 The unsettling experience of translating across boundaries . . 269

10.1 Introduction

In section 10.2 I explore the workshops and how participants engaged with and situated the model output within the context of their socio-cultural and material landscape. In section 10.3 I reflect on the practice of doing interdisciplinary research, the impact of the

findings both on the researcher and the researched, and the fundamental implications this has for the objectives of the thesis.

10.2 Towards synthesis - working with participants to evaluate and analyse model data

The workshops formed an evaluative discussion which began with a presentation of the provisional data output, findings and reflections (Appendix XIII). Participants were treated as 'experts in their F/fields' (Riley, 2008) enabling a two way sharing of information. Participants were free to bring up factors which they thought were important and relevant throughout the workshop. This led to a number of themes and suggestions that had not been identified by the researcher.

The positionality of the researcher and participants, was not the same as it was during the fieldwork. Whilst I was 'geographically ignorant' (Thomas et al., 2018) during the fieldwork, the online nature of these workshops and the researcher as 'presenter' of the data significantly enhanced my position as that of 'expert'. This impacts the level to which participants may have wished to critique the model output.

I chose the phrasing of questions carefully to try and minimise this impact, rather than asking if the output was right or wrong, I asked if it reflected what they knew, if they saw anything surprising. It may have simply been the character and expertise of my participants and their confidence in discussing their own 'field' which helped. Their clear identification of limitations of the model findings/output indicates that they would have interjected if they believed something was 'wrong'.

10.2.1 Evaluation and analysis of model output

The workshops started informally, with participants introducing themselves, and chatting about current work and events (moving the lambing Ewes to a footpath free field, visiting the Walrus in Swansea). I then introduced the workshops, with a brief review of the

project, and explanation of the datasheet (Appendix XIII) that participants had been sent in advance. Whilst I made it clear that the group could interject whenever they had questions, most listened through each section until I had finished speaking before discussing it. When participants did interject it was either to check that they understood, or to relate what I was talking about to their experience. Through these checks participants were also exploring how the model worked.

> "Matthew: So, can I just check that I'm understanding that the rough way that the model works, you've got your grid squares.
>
> Researcher: yeah .
>
> Matthew: they're classified as woodland wetland grassland various different types of pastoral or arable and then you drop some rainfall on it and the model says okay this land cover takes in X percent of the rainfall and allows Y percent the rainfall to go through to the river is that roughly what we're.
>
> Researcher: it's actually [explaining SHETRAN columns and additional variables]
>
> Matthew: okay. Basically, the basic thing, though, is that you've got you've got all these areas, and you can effectively say okay I'm going to turn that from grassland into woodland and then see what what the water does as a result.
>
> Researcher: Exactly.
>
> Matthew: it's okay. I'm on on the stream with that then."
>
> WQ:10.1

After introducing the information on the datasheet I used guiding questions to elicit the evaluation of the model whilst encouraging participants to extend and direct the discussion.

Participants did not critique or reflect on the output of the baseline model, or talk specifically about the calibration of the model. They related the maps and baseline graph to their own observations:

> "Michael: Because we walk all the way from here, up to Cross ash and all the sudden, it really, it's fascinating walking the land, because that is, the streams look tiny.
>
> They look, when you think where does all the water come from, but then you can see it, when you walk in because they're all sort of the great bowls of grassland feeding into it."
>
> WQ:10.2

Participants identified that the behaviour was reflective of the river they knew, being unsurprised by the speed at which the river levels and volume changed.

Limitations and extent

Participants immediately identified limitations of importance with the model, including spatial scale, soils and vegetation. They identified the limited application of the model, based on the 100m x 100m grid. It would have been useful for participants to have seen a grid at that scale overlaid on a section of the map as it was difficult for some to relate the precise dimensions to their space. But they recognised the fact that even within that grid there would be considerable heterogeneity. The inability to differentiate for features such as hedgerows was significant.

> "Peter: yeah and so [there's] grassland basically on the opposite side of the River where the water can flow absolutely freely straight across. Whereas on my side I've got smaller hedges and smaller areas small fields with cross hedges so knowing there's no way that you're gonna be able to model to that sort of sort of detail to be able to go down to, I don't know perhaps 10 square meters, or even 20 square meters.
>
> You know you're not going to push the model that hard."
>
> WQ:10.3

Participants related the generalisation of soils and land-cover to the spatial scale of the model, however, the lack of variability in the vegetation parameters was also important and compounded by the impact of management choices.

"Anne: The other thing, you talk about about grassland you look at the type of grassland that our neighbours have got and they've just ploughed up and reseeded it.

because their grass is very thin you can see the soil between the grass and either they reseeded it has thickened up a bit, but you still see the soil between the grasses. Whereas our grass is old hay meadow and the thatch on it, it is like a thatch, it's a bit like my hair, it's so thick you can rarely see the soil through it unless you've had a lot of where the sheep have been trampling it down because we don't have as high stocking density. so it's almost like a thatch on the top of our soil so it's slightly different and then on the bottom on the Trothy the things are wild. so we've got lots of vegetation down there, but yet it's not necessarily grass, we've got marigolds and all sorts of other weird and wonderful things, including the lovely Himalayan balsam. So yeah I think it does make a little bit of difference actually what kind of grass have you've got as well.

Jack: Yes, we've noticed that as well and and how fast it drains on the different grasslands yeah so whether it's all meadow like you say or and or new new lay it's very different behaviours isn't it."

WQ:10.4

Differences in management have been shown to have clear impacts on the way in which vegetation behaves (Brockett et al., 2019). However, they are hard to replicate in lab environments and variance, physical characteristics and management choices combine to create an expanding range of possible cases to explore. Within these limitations the key finding of the model of relevance to the participants was that tree cover would help reduce or at least ameliorate the flooding and flashy nature of the Trothy. Anything further was dependent on additional information, whether that was scientific or socio-cultural which I will discuss further in subsection 10.2.3

Analysis and synthesis (how model output was added to knowledge store and informed decision making)

Throughout the discussion participants related their experience and knowledge to the information presented. They took the information and put it within context, both to understand it but also to interrogate it and identify what additional data informed or was needed to inform the situation.

> "Michael: Well they've been felling a lot of trees in Tal Y Coed wood so it'll be interesting to see what happens this winter."
>
> WQ:10.5

> "Lucy: I don't think any of it surprising and from what we've seen, I know, ours is narrow, the narrow path, but obviously we've our land next to it is our silage ground so it's the flat area before a bank, there's a steep bank and the neighbour is potato crop so it's bare soil, so you can see the differences between those two.
>
> But yeah I know ours has got a lot of the willow growth along the edge so like you say you can see the benefits of having trees and the silt reduction of the silt movement, but obviously it doesn't stop any flooding. So no, no surprises, for me, anyway."
>
> WQ:10.6

Two key examples were a discussion of the difference between 'wet' and 'dry' ground, and floodplain planting

The preliminary model results suggested that tree cover in ground that became more easily saturated may have less effect than on drier floodplain ground.

> "Matthew: But yeah so that's. From a nature conservation standpoint that's quite useful because often it's those little patches of wet ground which retain semi natural vegetation because they've just been too too wet to bother ploughing and reseeding. And so often those are the last little focuses of flower diversity and therefore insect diversity, so not planting those is going to be

> highly beneficial from from a conservation standpoint. Dry grasslands I think more often unless they're on very steep slopes most dry grasslands would have been fertilized so much over recent years that they would have lost a lot of their original biodiversity, except on a on a few. A few better farms, but often it's those steep slopes that that have the have the little remnants of species"
>
> WQ:10.7

Matthew draws on ecological expertise and relates it to the model output and the researcher reflection that perhaps wet areas need treating more carefully and the importance of multiple benefits needed prioritising in planting decisions. This relates to the physical characteristics of catchment soil depth, demonstrating the importance of material heterogeneity between and within catchments. [1]

The model also showed a statistically significant increase in the efficacy of planting on land which was currently under arable (section 8.3.4).

> "Lucy: And I just, I suppose, our thing would be that we don't have the space for woodland planting and it wouldn't be you know, for, all of our best silage land is by the river. And, from a farming perspective that's much more value to us than protecting, you know and planting the trees over it, if you see what I mean, so it would be a case of where you have the space to implement tree planting and, for us, I think it would be just on the land that is already you know riverside that that is already given over to the river and we don't, we don't actually farm."
>
> WQ:10.8

Lucy is putting the model output within their own wider knowledge and socio-cultural context, she is evaluating the model and situating it within the decision making process of the farm. Whereas the previous point outlined the importance of the heterogeneity of physical characteristics, here it is the socio-cultural that has the driving influence.

[1] Building on this discussion, additional alternative scenarios for the model were developed and run which demonstrated the output was more complex than stated in the preliminary reflections in the datasheet. See Chapter 8, Table 8.2

Participants considered the model output both relevant, useful and interesting, but that it would not be a driving factor in their decision making implying that it should inform but not 'lead' further interventions.

> "Jack: It wouldn't necessarily impact my design as much as I'd design it and it'd be interesting to see the effect of that. Because it'll be designed around minimizing the cost of fencing and like making easier mechanization of everything going on around it."
>
> WQ:10.9

Whilst this might be because all participants involved were already planting trees where they could,[2] the same would be true for many of the participants in the original study. The interesting group may therefore be those who were undecided, they were interested in planting but didn't have an obvious incentive, this research provides an incentive but is unlikely to determine extent or design.

Participants directly linked this to the importance of additional factors. The output added to the knowledge store, but wasn't (wouldn't be) the primary factor driving their decisions.

> "Researcher: So really [...] of its own it's sort of irrelevant, it's useful when it sits alongside other benefits and other information.
>
> Jack: I don't think it's irrelevant. When people say more trees, you can say yeah more trees, but for people saying 'tree in the right place', you can go into a lot more things about what is the right tree in the right place"
>
> WQ:10.10

A key factor identified by the participants in regards the relevance of the model, or a reflection on how it could/should be utilised was the heterogeneity of land both within and between holdings in the catchment.

[2] it is also worth considering that taking part in the research 'may' have impacted their likelihood to plant trees (SB Emery et al 2014, Whitman et al 2015)

"Peter: What's applicable my side of the River isn't applicable for the other side of the River."

WQ:10.11

"Michael: From our little situation here is, I think we have things exacerbated because we had sort of a narrow window of the floodplain because we've got the slope on our side and the slope on the other and it seems like the water funnels through here. So it's a question of position and as well, in terms of where would you propose to do the plant and would it be more upstream of us because that's where. In our experience, that's where the water is obviously coming in greater volume through us, it's all upstream."

WQ:10.12

Michael identifies here the direct issues faced by a number of farms in the middle of the catchment, prone to flood damage due to the 'funnelling' of the landscape at this area



Figure 10.1: an example of the middle section of the Trothy, where gentle hills constrain and funnel the floodplain. Whilst the Trothy was low at the time this photo was taken (6ft below the treeline to the right) the extent of the floodplain can be seen in the diverse and rough vegetation

The geomorphology causes a narrowing of the floodplain. Whilst in other areas, where the floodplain is wider, there is less damage to infrastructure such as private roads and

bridges. I have included the full quote as it is interesting that Michael identifies 'upstream' as the target for intervention. I will continue the upstream/downstream discussion later (section 10.2.3).

Whilst participants were interested in the range of data the model might provide - for instance if it could be expanded into water quality and sediment. They questioned the effectiveness of increasing the spatial scale of the model, and whether it would be worth the resource required (e.g. WQ 3). Importantly differences and uncertainties weren't just spatial or geomorphic, but social.

> "Peter: So that brings up an interesting contrast. Between the two of us.
>
> Lucy: Yes
>
> Peter: Yes, because, as you know, I'm retired, I've got a pension, I'm not relying on the land as an income, whereas Lucy it's her main source of income. And so, she has to treat the land in one way, whereas our 15 acres you know. We can
>
> Lucy: It's the priorities isn't it yes, yeah."
>
> WQ:10.13

This quote alone indicates the importance of the socio-cultural literatures in agri-environment decision making (Section 6.3.1). I do not have the scope to delve into these here but focus on how these complex relations relate and are entangled directly with not only the material and bio-physical landscape, but the ways in which we chose to study it. Whilst the spatial resolution could be increased on the model, this quote shows that social heterogeneity impacts the relevance or effectiveness of increasing this resolution. Time and resource is required to increase the resolution within holdings when the model cannot account for social heterogeneity between holdings (p 107).

10.2.2 Evaluation of researcher reflections

Included on the data sheet was a list of provisional findings and a list of 'researcher reflections'. These had been prepared by a preliminary analysis of the key findings with relation to the findings from the original fieldwork, interviews and participant mapping.

Whilst all the participants agreed with these reflections, in particular those that related to the heterogeneity of the landscape, they were careful to put them in context of the limitations of the model, the importance of multiple factors and the socio-cultural context

> "Researcher: And then it's sort of this last one [addressing Lucy] I think covers your point: model provide general information within her and uncertainties and local variation monitoring and adaptive approaches required. So I was loath to say kind of in my reflections, you should plan here and there is more important than planting here because of that. It's like you said earlier, you need to be given the information and then be allowed to apply it, as it relates as is appropriate
>
> Peter: To our unique circumstances yeah.
>
> Lucy: I agree with all of that yeah that's good."
>
> WQ:10.14

> "Matthew: it's difficult, I guess, in a way, depending on who takes the information and runs with it. Because tree planting, in particular, is a very political thing and different groups that keen on putting in productive conifer forest versus restoring in inverted commas native woodland. and there are radical differences in conservation terms between a permanent pasture and and a rotated ryegrass and clover lay.
>
> So, I guess, as long as your conclusions caveat it and it's clear that you're only using those those few categories, then people are less likely to take it and say 'Ah well, this shows that all grassland is better than all cropland' or something like that which may well not be the case."
>
> WQ:10.15

Quote 15 shows that participants recognised not just the limitations of the model but also the political implications and how the same output may be situated in different contextual frameworks.

10.2.3 Analysis and discussion: wider knowledge and political behaviours

When discussing the model, participants actively related it to their wider knowledge(s). They discussed the governance and landscapes which shaped the challenge to which the research / model output was responding. They discussed factors that affected not just its relevance, but how multiple factors related or took priority. This evidence directly reflects on the third aim of the thesis and the critique of the science/policy interface and decision making process.

How 'situation' in landscapes affects the agency and desire to act of different actors

Who is acting to manage the behaviour of the water in catchment, and who should be, is a complex and difficult conversation. The scope of the workshops didn't extend to discussions of the rights of responsibility or ownership. However, all the participants engaged in questioning who could and who might implement changes as part of their evaluation of the relevance of the model. I have picked out a few examples that discuss when, or even whether, individuals might engage in implementation of actions.

> "Michael: I think it is. The biggest problem [in the] catchment, [is] it's not as though it's a moorland or a mountain or... it's active, you know actively farmed land isn't it yeah it's a quite intensively farmed. Especially the higher reaches around the sort of Abergavenny any side. And it's going to be difficult to get as you say, getting, getting people to give up land for large scale plans and, but if you can demonstrate small strip planting. I think people, especially if they they have flood problems [might engage]."
>
> WQ:10.16

In quote 16 Michael links a likelihood to act to both the size of intervention and an experience of the problem. They also recognise the implications of the 'working' nature of the landscape, the socio-cultural implications of needing to work the land for other primary

purposes. Michael was interested in interventions happening upstream of their location, however, they believed people are more likely to act if they'd experienced flooding, which largely occurs downstream. This question of experience or awareness of the problem was not always framed in a positive light;

> "Lucy: And I was going to add as well, the other points, maybe is that some people managing the land along the river are not actually living in the area, so have little interest in what happened so maybe just using the land, like you say for monetary gain and getting as much out of it as they can financially from the produce. and not necessarily having any interest in the impact"
>
> WQ:10.17

Quote 17 indicates the entanglement of both phenomenological and socio-cultural factors. There is a difference between not acting because of a lack of experience or awareness of the problem, and knowing that there is a problem but choosing not to act anyway. Perceptions of this were varied across participants. From the view of a recalcitrant farmer to the idea that whilst some minds can be changed, you'll never get everyone on board.

> Michael: farmers will not do anything unless they want or are obliged to, or two will get paid for doing it, that's the way they are you know. You may get one or two like James Herdie Rebanks up in Cumbria, but he's not the run of the mill. Arable farmers, you know. All they're interested in is you know massive production of crop because that's, the only way they make money."
>
> WQ:10.18

> "Peter: I can think of one or two people that might not work on but never mind. We won't go there- personalities [...] And then you've got the other, the other group of people who were out to get money out of the government any way they can and not necessarily spend it on what whatever but yeah I think I've made the point."
>
> WQ:10.19

These attitudes reflect the perception of rural land management as an individual (Riley et al., 2018) rather than collective (Ostrom, 2009) approach. However, they were situated within a discussion of connectivity and community interaction.

How connectivity engenders cooperation

Within the participant group, there was obviously an awareness of the challenge and importance of tackling it (both increasing tree cover and improving water management in the catchment). Some participants still queried whether or not their effort would really be worth it.

> "Michael: Our little individual effort is going to have no effect really because, as I said, you know because of the topography of our land, we seem to have the big volume of water funnel down through this bit of the Trothy."
>
> WQ:10.20

Whereas others saw the cumulative effect of small interventions

> "You know, what can I do to improve that typical coppice, what I'm going to do, to maintain that. but then I've got other little subsidiaries to the Trothy where I can do some water flow management to assist the overall game plan."
>
> WQ:10.21

Neither participants in the workshops or participants in the interviews had a good overall awareness of the connectivity of the catchment. However, all participants recognised the connectivity of the river and the impact of this. For example the importance of communal action when dealing with challenges such as Himalayan Balsam.

> "Michael: You know, unless unless you get a working party to go from the bottom up every catchment stream on the Trothy that you're never going to get rid of it"
>
> WQ:10.22

This was phrased as an unlikely outcome. However, in workshop two the participants began discussing the possibility of community action as a realistic option, turning heterogeneity into a benefit:

> Peter: So that brings up an interesting contrast. Between the two of us.
>
> Lucy: Yes
>
> Peter: Yes, because, as you know, I'm retired, I've got a pension, I'm not relying on the land as an income, whereas Lucy it's her main source of income. And so, she has to treat the land in one way, whereas our 15 acres you know. We can
>
> Lucy: It's the priorities isn't it yeah.
>
> Peter: it's a hobby farm it's, it's you know, I think essentially so whether we could I don't know come to some sort of agreement whereby you've got to be able, for Lucy to make her living, for us well, I don't know is there some sort of offset that they could provide or some sort of offset that you could where you know if we planted all 15 acres to ash trees, you know I wouldn't be adverse to that if if that was the general good, but what could you, could you then, so let's say.
>
> We're a bit far far apart, but if Lucy was, for instance had the land opposite me on the other, on the other side of the River river bank could you offset what i'm doing against the landowner, on the other side of the river is is doing
>
> Lucy: Like like the large companies do isn't it, where they they they buy trees to offset their carbon. Well, at the moment that's what they do isn't it so it'd be like us saying right we're going to we're going to be taking from the land, but where can we buy treat our trees to make to offset our use, in other words isn't it.
>
> WQ:10.23

What is described in Quote 23 isn't 'Bottom-up vs Top-down' (section 2.5.4) but suggests a need for facilitation of integrated catchment management (as in Short et al., 2018) in which LMs are a leading actor. Lessons may be learnt from past practices here,

reflecting Riley (2011) findings that there has been a shift in land management practice to individual responsibility from community based cooperation. One participant related an almost forgotten community management practice:

> "One interesting thing sorry I forgot I should have mentioned this. My neighbour who lives up [...] farm who lived here all his life. When I can get his details for you he's quite interesting to talk to, because well we were talking about the cutting down of Tal Y Coed wood and he said, well, I remember when they planted that which was quite interesting, but he said in the old days on the Trothy and they used to come along and coppice it all. All the way up the Trothy. And they used to use the wood for pit props and whatever. But nobody bothers and all the willows are old and falling down and just people are clearing them. He said it was all managed totally different when he was a young man."
>
> WQ:10.24

Knowledge and cultural practice are still (for a short time) held within catchment on how co-operative management might work. However, the extent of lived experience and the perceived lack of cumulative effect of small practice, an insight that the model and external knowledges can provide, is very likely to be needed to facilitate these practices.

How governance can be a barrier or an enabler

There was a lack of clarity over which regulatory body was responsible for which bits of the river, and no participants seemed aware or clear on the relationship or boundaries between small waterways and the river. Those with land adjacent to the river paid a fee but had no idea what it was for and as reflected in the interviews (section 6.2.2) engagement and management decisions were observed to have reduced considerably.

> "Lucy: We actually pay a levvy I don't know if everyone does along it, but I don't know who and what happens to that, it's the rivers authority, I don't

know why we pay it really it's not a huge amount, but we have to pay every year."

WQ:10.25

"Michael: We had a few trees down and I rang up the Agency. Because they used to, they used to come and help you because I haven't got the big kit you need for removing trees from the river, but you know they said well tough, you know it's the riparian owners responsibility to keep the River clear."

WQ:10.26

Whilst grants were seen as an incentive, prescriptive approaches were seen as barriers to engagement (section 6.2.2). Whether interventions were appropriate was impacted by both the heterogeneity of people and place with interventions that weren't adaptable having negative impacts on landscapes and their environment. For example, excluding stock from woodlands was often a grant requirement (e.g.Welsh Government, 2015).

"Matthew: There has been a bit of a discussion between different bits of NRW in terms of woodland and grazing and there are radically different views in there, as to whether grazing is good or bad and from [a biodiversity perspective] grazing to stop ivy and bramble taking over woodland is absolutely crucial and excluding, the idealistic approach of excluding grazing from all woodland is is really not not good at all."

WQ:10.27

It is still required for new woodland planting at (see Option 420, 421 Glastir 2018 rules - which excludes livestock with no clear time limits), though light grazing has been included in some schemes. The grant structures are prescriptive with administrative and management requirements with little adaptation and no variation for different contexts.

Participants did not have a optimistic view of the move from the CAP / BPS payments to a Sustainable Farming Scheme (SFS), that is expected to be run in a similar manner to Glastir. Participants saw one impact of this as people moving away from grant structures, with government then losing an ability to intervene:

"Lucy: Well it's effectively the single farm payment being transferred over to dictating how you manage your land really. Then what's going to happen if people say, well, we don't actually need the single farm payments so we'll carry on doing as we want to do ourselves really, we know, how are they going to stop. Or how will they manage controlling it in that way.

Peter: One thing about my dad when he lived here, he he never wanted to take the Queens shilling now you never take any sponsorship never take any grants or anything. [...] his theory is once you take the Queens shilling you'll get all and sundry coming in and dictating to me on how I've got to run my land.

Lucy: And yeah yeah. I'd say that's quite a factor isn't that."

WQ:10.28

This supports Fleming et al (2019, 2019) who found that there was no 'one size fits all' solution and that prescriptive grant structures developed through economic frameworks as a sole solution risked conflict with communities wider appreciation of environmental challenges and complex socio-cultural drivers.

Clarity of communication, pathways and timelines were seen as serious barriers to engagement. Not only in terms of accessing suitable support, but also in regards the longer term impact this conflict created.

"Anne: It's like we want to do a little work to on the ground, and stuff that needs [..and they say..] there's a scheme to help you with putting fences in and they'll come in as a team of fencing. Oh sorry that scheme finished, a couple months ago you. When you only just found out about it.

Lucy: yeah yes exactly that

Anne: yeah so well that's been and gone and so we'll plan replanting orchards oh yeah there's a scheme with the orchard trust, whatever it is, Peter: the woodland Trust, Anne: The woodland trust that they'll help you plan and fruit orchards - Oh that was last year, never mind.

> Peter: And the other thing is how do we register for these grants, you know it's the admin of getting involved with these projects as well, so, I'm finding it a little bit challenging"
>
> WQ:10.29

> "Jack: My experience of grants in last couple years is they do everything they can to get out of actually pay you. [...] Like you put out you end up putting out like, I planted a new hedgerow, had to put out like 15 grands worth of cash. I'm still waiting for any money back from that. Even stuff in, specifying longer posts, we're looking at that like we're not putting two inch posts in with the cows will break that, for maintenance we want to put in three inch posts which cost more. But then we're only able to get hold of like a seven inch gate post and they said it's got to be an eight inch gatepost so they might try and not pay for the gate posts.
>
> WQ:10.30

> "Matthew: It does it does sound as though the grant schemes, want to give an impression that they are that funding all this amazing stuff but then they actually aren't doing it. Which seems seems fundamentally wrong if they're giving the impression of being the most well thought out grant schemes, but then basically everything or most things, end up being done at the farmers expense. It just seems fundamentally wrong, but it's hard to know how to change that."
>
> WQ:10.31

Silos within institutions and governance have been shown to be inadequate at dealing with wicked problems (Tett, Anderson & Tornberg), and were strongly critiqued by participants. The contradicting nature of different grant structures were discussed, where actions undertaken to achieve wanted outcomes ended up creating penalties elsewhere:

> "Jack: But that's where [it's] the idea of multiple functions again, it's like getting funding to fence off the stream. People put it like 10 centimetres away from the edge of the stream, and then obviously they can't use the space beside

the stream. Whereas we fenced a stream off and NRW actually paid for it, but then we lost subsidies and the bit that we've fenced off. But we fenced off 5,10 meters away from the stream, so that we can actually fit animals in there yeah actually going graze off the sides. kind of an extra paddock you just go in and graze

Matthew: and presumably some trees are able to grow up in that, not necessarily?

Jack: yeah the shape is changing and there's a lot of natural regeneration yeah yeah."

WQ:10.32

Quote 32 acts to summarise the discussion above. It demonstrates how the participant is taking an action they consider (on scientific and agricultural knowledge developed both through education and experience) of benefit to the river and environment, yet is causing a financial loss. They are undertaking it because it meets multiple other needs of their landscape. They are also in effect, directly ignoring the stated reasons for putting up fences (excluding livestock) and currently would not be eligible for support planting trees in this area.

However, rather than disengaging with the outcomes that current environmental governance appear to be pushing for, all participants were actively engaging themselves in what could loosely be described as landscape regeneration. All participants were planting trees, whether that was as woodland or willow beds along the riverbank. Whilst participants involvement in this study may have increased their understanding of tree planting for Natural Flood Management (Eriksson et al 2019), none of them were planting specifically, or even primarily for this purpose. In addition, despite the critique above, rather than disengage from government approaches, participants made the effort to suggest solutions and adaptations to increase engagement and support the integration of knowledges:

"Lucy: [If you're supplied with information and given choices] you can make your own decisions, then and you're not feeling like you're being told that blanket that, like the NVZ across all of Wales. Then you could apply

your sort of knowledge to to your area in a much better way it's sort of a more you're taking control of it, rather than being dictated I suppose aren't you. Anne: More flexible approach Lucy: Yes"

WQ:10.33

"Peter: It a would be nice to have grants and things, but then you have to supply the knowledge and then have the trust in the landowner, his knowledge, he will apply his because there'll be two parts parts to the knowledge, one is. How his local, how his land performs at the moment. Because he's going to be the best to know that, because he's the one who slipped in the mud and fallen on his ass in the middle of winter several times, because there's is a spring come up where he wasn't expecting it Through to giving the landowner the knowledge on how to manage his land and then having the trust in that in that landowner to then spend money or whatever grants that they supply to be able to do that management more effectively, and I think if you took that kind of strategy, you would have much more."

WQ:10.34

"Matthew: yeah and I think that's the direction that the sustainable farm scheme welsh governments looking at things that that don't just sort out flooding or don't just sort of climate change, they want things that that sort out as many different elements as possible. And yeah some some kind of wood pasture or lines of crop trees, or whatever. I hope, is something that they're thinking about"

WQ:10.35

Participants identify specific needs from governance that lie alongside or are of a greater priority to grant structures:

- adaptive flexible approaches that allow for the heterogeneity of socio-ecological, material landscapes
- knowledge exchange and facilitation

- integrated, joined-up interventions meeting multiple outcomes

By implication these requirements identify a complex role for the LMs themselves, one in which they are taking, at least a part, of the responsibility of integrating knowledge; trialling, monitoring and adapting interventions; and changing practices to meet multiple outcomes. Where this may have been misunderstood in the past is in the rhetorical language that misses the fact that this is what LMs do all the time (Morris 2006, Ensor 2022). But it is widely acknowledged that meeting shared goals requires integration from both the LM and institutional perspectives (Turnhout and Neves, 2019, Ensor and de Bruin, 2022). Participants themselves acknowledge the potential they could have to direct and change their own practice with access to and facilitated support from extra-local experts and governance.

10.3 Translating across boundaries: exploring expertise and research frames

This thesis aimed to explore the importance of relevant knowledge and expertise, how it should be considered alongside traditional scientific knowledges and it's impact on science and policy. This final section of Chapter 10 reflects is a qualitative reflection on the research and evidence of the 'nature' of expertise, shaping how it is considered in the final Chapter. First I explore the 'active learning' that took place in the workshops and as an output of the work. I then reflect on the positionality and nature of expertise of both myself and participants. I conclude this chapter with a note on the importance of an unsettled perspective.

10.3.1 Research as intervention: land manager knowledges and learning through participation

The importance of learning has been studied in a variety of contexts relevant to this thesis, for example; in Farmer led innovation (Ensor and de Bruin, 2022), within collec-

tives managing natural resources (Eriksson et al., 2019), in participatory flood modelling (Landström et al., 2013). These literatures focus on the networks, actors and social groups that shape learning. My research extends this by exploring learning at the knowledge boundaries - learning which is shaped not just by the social but by socio-ecological landscapes including the physical materiality of place; and (building on Landström et al., 2011) by the dialogic, flattened hierarchy of the research.

One participant had 'learnt' from both being part of the research project and their experience of that winters floods. As a result they were planting strips of willow along the bank, but were also discussing further riparian regeneration and willow coppice extending onto the flatter ground; a feature they would not have considered when we first met in 2019. This 'active learning' continued within the workshops. For example, in quote 2 p 246 and quote 6 p 248, workshop participants relate the model output to their own lived experience and extra-local knowledges, drawing both new conclusions and drawing out key points which supported previous understandings. This directly relates to Benders (2010) description of lived experience (and the landscape itself) as cumulative and reworked. The participants demonstrate a reflexive approach (Noy and Jabbour, 2020 taking the research on board as part of their local and extra-local knowledges. They are making changes, with this research as an influencing factor, in ways which are changing the landscape. By the nature of co-production, the way in which each participant incorporates the research will be shaped and adapted by the landscape itself, the wider actors within that landscape (both human and non-human) and other socio-ecological factors heterogeneous to each individual and holding. The research intervenes but not in a way that is controlled in any way by the researcher.

This area of engagement with research as an act of making change (both socially and physically) has been recognised in policy and research practice (see the focus on community engagement in the NERC FDRI). Yet the practices risk falling into the didactic approach that assumes an external 'publics' who may be educated. By recognising the reframing of the knowledge-policy interface as one in which the social is inherently intertwined, suggests that we need to reframe our perception of intervention to extend beyond

the catchment, and to reflect the flattened hierarchy of knowledge exchange. This traditionally would have been considered under research impact; the research increases the store of scientific knowledge, and has direct implications for policy practice. However, this analysis would sit within the previous, linear model of knowledge-policy. If the research has 'intervened' it has intervened everywhere, and theoretically the catchment (and the people within it) have 'intervened' with the science and policy making. I too have demonstrated active learning, with each interaction with the participants and with the catchment itself, acting on my understanding and behaviour within the world.

10.3.2 Co-production and the fluidity of expertise

The previous reflection on active learning is one that is presumably common to all PhDs. The importance of reflexivity arising across the disciplines in which I work. An area in which there is less discussion within the environmental sciences however, is that of researcher expertise. The practice of researching and reflecting on research has highlighted the question of expertise; how my position as expert has fluctuated and how this reflects on the attribution of expertise that I am myself studying. I discuss here my own positionality and expertise and how it fluctuated throughout the PhD. In doing so I am directly reflecting on the nature of expertise and the expertise of my participants, whilst focusing on the one about whom I have the most in depth knowledge.

In the methodology I outlined my positionality as 'geographically ignorant' whilst maintaining an insider / outsider relationship with the catchment due to my background, having grown up in a similar local area. Whilst I did not personally know any of my participants prior to my research, I often knew someone they knew and grew up in the same landscape. This 'locality' may have had a significant impact on the conversations I was able to hold and whilst it did not identify me as a credible 'expert', my locality supported by my institutional accreditation did. Additional factors that impacted my 'credibility' in the catchment included my institutional independence, being unaffiliated with a policy, membership or practitioner bodies either through employment or as a gatekeeper. In all my interviews the only challenges I received were 'do you want to work

for NRW/Welsh government?' and 'you're not vegan are you?'.

Discussions were held on a balanced stage, land managers were clearly the experts in place, however, contributions I made were taken and considered - as those of an equal, of equivalent but different knowledge culture.

This balance however changed over time and context. The first significant factor was that the evaluation workshops and future discussions with participants all had to take place online. This moved the 'stage' of discussion from their field to mine. The second factor was that I was presenting information about the catchment, rather than them presenting their knowledge to me. This changed the balance of power towards myself as researcher, and it took more work than I expected to get participants to challenge and discuss the research. Fortunately the groups worked well, and participants were, by the end of the session, challenging and discussing the research implications in relation to the uncertainties and limitations of the model. I still feel however, that if I had presented the research and asked for 'any questions' without that level of discussion, I would have received very little feedback. When taken into consideration with the impact the long-form interviews had on presenting alternative and more complex participant views (section 6.3), the implications of 'delving' rather than a light touch approach are of considerable importance and have wider methodological implications for the way in which we conduct research dissemination and evaluation. Participants need time, and the appropriate space (McCracken, 1988) in order to actively and actually participate.

My attribution as 'expert' researcher changed with time and context in the same (or similar) group of participants. In addition the context of the 'group' also changed the factors which affected my attribution of 'expert'.

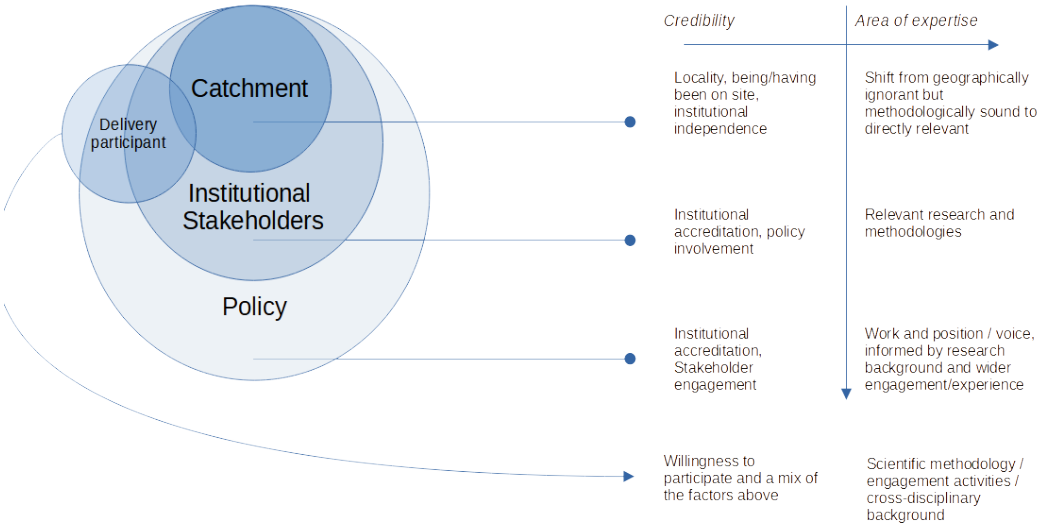


Figure 10.2: Intersecting social groups attribute and identify expertise differently

This analysis visualised in Figure 10.2 identifies the fluid nature of attribution of expertise, which directly reflects on the attribution of expertise and identification of stakeholders in environmental areas such as Natural Flood Management. Jasanoff (2004, 2010) identified the UKs unique over reliance upon 'experts' where expertise was attributed by institutional affiliation or established hierarchical power structures, an imaginary still evident in institutional thinking (Smallman, 2020). However, the shifting attribution of expertise and credibility that I experienced can be viewed as having two significant impacts.

The first is that, whilst I may demonstrate expertise in one area, this does not mean that I am the 'relevant expert' in another, and the knowledges and experience needed to value me as a 'credible expert' need to be reevaluated as new contexts are presented. As someone coming from the established hierarchical structures (white, university educated, scientist), unless I demonstrate humility (Jasanoff, 2007; Turnhout and Lahsen, 2022) this reflexive approach may not be conducted, I could 'pass' for an expert on my institutional/historically situated credentials alone (and I would not be alone, or in any way the

first to do so).

The second, more significant reflection for the purpose of this thesis is that **exactly the same process should apply to everyone else**. Whilst a particular land manager may not be considered an expert in the field of neurology, this does not prevent them from holding the relevant knowledges in their own F/field. This extends beyond their actual fields (and fields of practice) to the communities and socio-ecological landscapes in which they operate. The expertise of a land manager may be local and place-based, but it is also relevant in regards understanding how local and place-based knowledges are integrated into wider extra-local knowledges. Therefore, LMs expertise is relevant significantly beyond 'their own fields' and clearly, given all the evidence of this thesis, an area of significant further policy relevant research. Yet as this conflicts with established hierarchical power structures, the attribution of expertise of the individual or even the credibility of their knowledge will be harder to gain than my institutionally recognised position.

10.3.3 The unsettling experience of translating across boundaries

As the researcher I have been positioned in a unusual frame by the practice of doing interdisciplinary research. Enmeshing the phenomenological and socio-cultural I sit in a space that is linked to different theoretical places, in both digital and material spaces. Whilst being inherently tied to a 'catchment' that itself now exists in a hybrid space/place for me. I have physically walked in the river, over the fields and woods and associate people to specific places within the catchment. The catchment also however exists on my screen, in Fortran code, graphical and quantitative output and satellite view images.

My position crosses social boundaries, between individuals and academic, agricultural and operational bodies; across disciplines of physical and human geography and STS; across sectors of forestry, agriculture, conservation, water resources and flood management.

I am resident in non of these worlds and a translator between them. I am, unlike my participants who draw on all these boundaries but are rooted in place, unsettled.

I have experienced both theoretical and actual unsettling in the practice of 'doing research'. For example in encountering the disciplined structures of the institution which have continually conflicted with the interdisciplinary approach, including but not limited to; the word count of the thesis, who should carry out my annual review; which research groups should I attend; and in which office / floor should I sit (human geography on 2 or physical geography on 3 and 4). The latter problems became tied up in the informal silos where coffee table chats and coding support were less accessible from the discipline I was physically situated outside. The research findings, and the practice of doing the research itself draw attention to the importance in academia of the way in which we are currently practising research despite the weight of literature drawing attention to it. This is not to state that we should disengage with disciplinary practices, we need experts who focus on discrete factors, to ensure that we may draw on a depth of knowledge and can evaluate the suitability of methodological rigour in varying contexts. However, we also need spaces in which we are able to reframe beyond silo'd approaches, wicked challenges need approaches that to go beyond 'interdisciplinary working' to developing different understandings of 'datasets'. This unsettled position is the one from which I tackle the synthesis and discussion of the research. Whilst I draw on interdisciplinary threads I draw them back into the broader picture. This is not really a position of choice but the one which the research, the landscape of both the catchment and the challenge, has made clear. In the next chapter I come full circle to explain how and why this position is necessary, and propose the concept of 'drysi gwir'

Chapter 11

Understanding the whole picture: Y drysi gwir

Contents

11.1 A holistic and inclusive approach **274**

11.1.1 Using temporal extent to build a more comprehensive picture 276

11.1.2 Shedding light on the problem by working with the 'opaqueness' of different data 278

11.1.3 Are we dealing with a false dichotomy when we try to 'integrate' qualitative and quantitative 279

11.2 Entwined systems and entangled data **283**

11.2.1 Making knowledge and policy: Exploring the practice of 'making the best decision' through the practices of data collection, analysis and application 285

11.2.2 Governance and 'solving' the drysi gwir of increased tree cover for NFM 292

The drysi gwir In this chapter, I explore the research as an entangled whole, stepping back from the pieces of the puzzle to explore how they relate, what the shape of the puzzle

can tell us about increasing tree cover for NFM, the implications and, therefore, potential solutions for decision and governance. I refer to this puzzle as the 'drysi gwir'. The drysi gwir roughly translates as a 'real puzzle' in Welsh. Gwir also translates as truth, real or right, and drysi as bramble, tangled, and intricacy, linking to being bewildered, confused, knotted or entangled.

In the literature review, I reflected that the scientific approach, having been framed by positivist roots, often attempts to identify and isolate all the different parts of a system, to untangle it so they can be addressed and evaluated (see Ostrom, 2009; Raymond et al., 2010). However, Raymond et al. (2010) also discuss this 'ontological challenge' regarding the benefits and pitfalls of attempting to 'categorise' knowledge, finding no truly suitable boxes into which knowledge types can be placed. In addition, the STS literature of co-production and geographical literature pointed to a richer, broader understanding of both knowledge and landscapes - for which stepping back and seeing the 'bigger picture' could bring additional understandings.

In section 2.5.4, I discussed concepts such as ANT, Assemblage and the socio-ecological systems framework (SESF), that took whole perspective approaches to analysing systems and networks. Whilst each of these approaches has its merits, I found that they sit firmly in the original disciplinary frameworks and either focus on the analytical roots of that discipline or were philosophical in such a way that describing the system in terms of the approach itself, rather than the analysis of those findings, would have been the primary task of the researcher. Taking a more inductive approach to the research, as framed by the research methodology, I have followed where the research has led. I retain the importance of the heterogeneous component parts, but instead of examining each part or relation, I draw each back to reflect on the whole puzzle.

I do not critique the usefulness of analytical systems thinking (such as SESF) or disciplinary approaches but suggest that broader, more holistic perspectives offer other alternative frames. In this chapter, I call this perspective the 'drysi gwir', the puzzle or web of the fieldwork, models and workshops. I start by poking at the web, exploring the fuzzy boundaries between different datasets (I refrain from stating 'knowledge(s)'

as this re-boxes LM knowledge and researcher knowledge into different categories. This exploration enables me to build a richer picture, which, stepping back, I evaluate against the way in which environmental decision-making, specifically regarding increased tree cover for NFM, is being made.

I draw strongly on Benders (1993, 2002, 2010) work on landscapes, and work on knowledge culture (Morris, 2006; Riley, 2008; Tsouvalis et al., 2000), responding to STS literature (particularly Turnhout and Neves, 2019, Turnhout et al., 2020 and Chilvers and Kearnes, 2020), the knowledge challenges of Raymond et al., 2010, and concerns of Rangecroft et al., 2022 questioning whether qualitative output was only relevant within the context, or whether wider relevant findings could be made.

In the section 11.1 of this chapter, I build on the workshop findings by delving into how the datasets 'enmesh', drawing on the evidence and literature to discuss the potential implications and the methodological considerations this raises, and how it reflects on current practice. I show how two specific examples of limitations or rather 'limits' to the datasets (temporal extent and 'opaqueness') act as areas where differences, rather than making datasets incompatible, provide a richer combined dataset that is potentially 'more true' in relation to the landscape.

In the section 11.2 of this chapter, I situate this discussion within the wider context of the science-policy interface relating to the wider literature, Welsh and UK Governance. I explore how environmental knowledge is produced and decisions are made, looking at data gathering, analysis and application. The findings of the analysis directly reflect on the efficacy and equity of current methods of knowledge production. I take this argument further by critiquing the efficacy of the linear science-policy model through the lens of increased tree cover for NFM. I identify more clearly where different governance structures can support development and intervention, providing solutions to the puzzle presented as drysi gwir. The solutions proposed draw on and bring together interdisciplinary literature addressing the science/society knowledges (p 21, p 28), adaptive management (148)and co-governance (p 69) and include:

- monitoring programs that use integrated approaches (section 11.2.1, p 286)

- frameworks of analysis that utilise local and external expertise (section 11.2.1, p 289)
- governance models that facilitate both connectivity whilst enabling heterogeneous/adaptive approaches suitable for different places and people (section 11.2.2, p 292)

11.1 Towards a richer understanding; how to facilitate a more holistic and inclusive approach to data

The participant workshops add a further dataset, and the whole picture now includes the fieldwork, the model output, archive and remote data, participatory observation and the online workshops. As described in the methods overview (Chapter 3) this richer data is cumulative and not entirely chronological, producing a 'drysi gwir' that enriches our understanding. Literature on 'wickedness' identified some of the difficulties of dealing with interdisciplinary data, including methodological rigour, which often results in reframing complex data back into a disciplinary mould (Andersson and Törnberg, 2018). I have demonstrated this when translating qualitative and mapped data into a 'scientisable' form and therefore directly relevant to the hydrological modelling. This section steps beyond this approach, exploring the possibilities of engaging with the data in a richer way. This analysis explores where strands of the data, pieces of the puzzle, intersect, where they stand apart, and how this can help us build a whole picture.

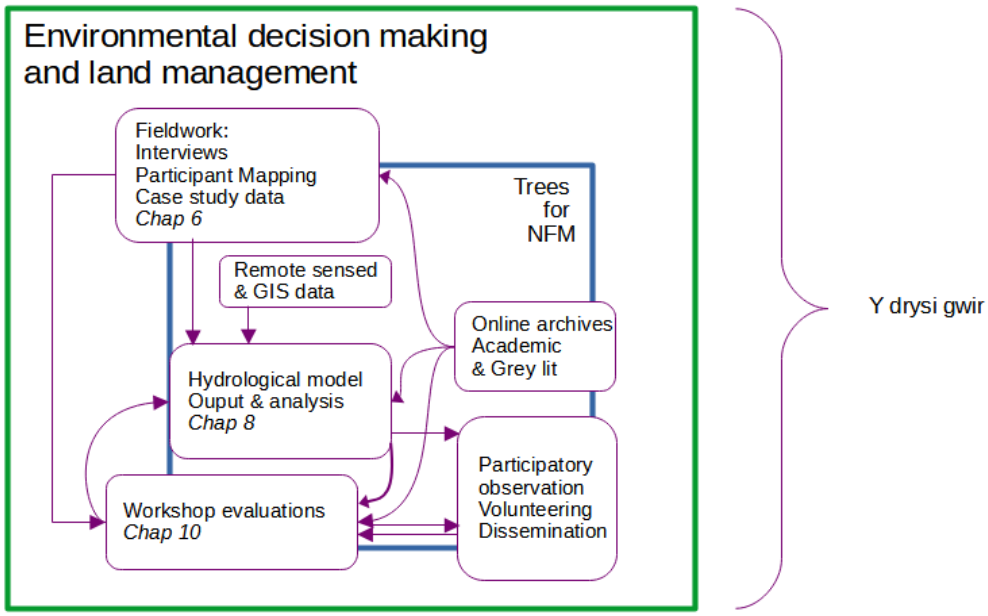


Figure 11.1: Y drysi gwir: data, analysis and the relations between them situated within Trees for NFM and the wider land management context

In section 10.2.1, participants drew out the limits and extents of the model output and situated them within the realities of the catchment context. This discussion identified the model output as one 'piece' of a complex knowledge puzzle (reflecting the concept of knowledge cultures), in which disciplinary or institutional silos were irrelevant and contextual relevance was far more significant than comparability by data 'type' or statistical value. Section 10.2.2 participants reinforced the political nature of the model output and preliminary reflections. These first two parts of the workshop analysis demonstrated how complex knowledges, including lived experience, are drawn into both cultural and 'scientific' discussions in a way that questions disciplinary and institutionally defined boundaries between them.

An interdisciplinary, mixed methods approach can provide a rich analytical picture suitable for tackling 'wicked' challenges. This approach extends those of systems such as SESF (Ostrom, 2009), which focus on the measurement or modelling of a 'resource' questioning whether 'gaps' identified by disciplinary critiques of systems approaches (Partelow, 2018) must be resolved to ensure comparability, or if this is an oversimplification and the findings are richer in their heterogeneity. Data transparency (Partelow, 2018) is signifi-

cant, and the uniqueness of case demonstrates the importance of context in both situating, analysing and applying the findings from the study. To give an example, I focus here on two key 'limitations': the temporal extent or contextual nature of the datasets (a factor often counted against lived experience or lay knowledges being 'reliable' findings (Turnhout and Neves, 2019), and opaqueness - the inherent or material limits to the datasets.

11.1.1 Using temporal extent to build a more comprehensive picture

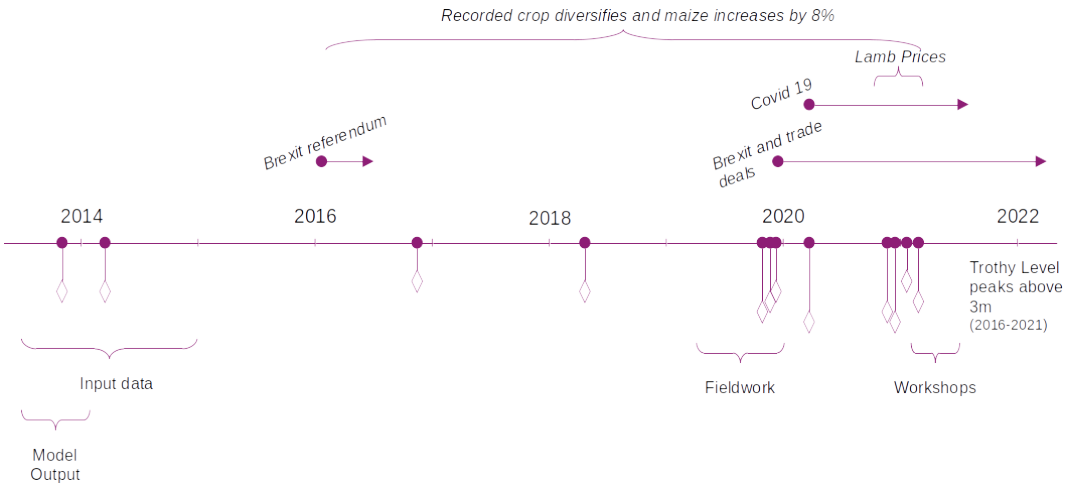


Figure 11.2: Timeline showing the data against selected historical and geographical context

Figure 11.2 shows that the data relate to different timescales. Whilst the modelled data was for the 2013/14 floods (with the 2015 land cover data), the LMs' knowledge from fieldwork and workshops set the case within the contemporary timeframe of the study. Therefore, the full timescale for which 'data' has been provided is 2013 - 2021. Only using our land cover data situates the study in the past; however, the LMs' knowledge reflects on the past floods and relates that to the contemporary context. By the time this thesis is published (late 2022) the socio-cultural and physical context will have changed;

- two changes in the prime minister
- very few floods in 2021 - 2022

- considerable concern about increasing temperatures with the UK reaching its highest recorded temperature (over 40oC on Tuesday 19th 2022)
- a March so dry there was a wildfire on the commons of the Sugar Loaf mountain, visible from Skirrid Fawr - the highest peak in the Trothy catchment.

During the 2019 interviews, floods felt a long way in the past, but by the 2021 workshops, they were at the forefront of everyone's mind. By 2022, the serious concern of drought will likely be a greater priority in the catchment. The lived experience of LMs does not invalidate the dataset by being variable but makes the study relevant to the landscape. Without the socio-cultural context, the model findings are likely to be misinterpreted.

For example - catchment resilience to flooding was relatively high before the 2019/2020 floods (section 6.2.1). The following flood events were not just a 'reminder' of the river's behaviour but were the worst ever recorded. The Trothy flood increased from 3.82 to 4.30m - a 12% increase in the flood peak (section 5.3). To achieve a reduction in a peak event of 12% the catchment woodland cover would need to increase to between 25 to 30%, over double the current catchment coverage (sections 5.3 and 8.3.2). Whilst not impossible, it is more likely that a combination of woodland cover and other land management interventions would have a similar impact and may be more easily introduced. This being said, the factors of importance to LMs were not the height of the floods but the time duration and level of erosion and infrastructure damage. In the case of the Trothy, it is not 'overtopping' that is the problem.

Some flood management measures rely on 'spreading out' the peak or de-synchronising flows. Whilst this may have some effect in the Trothy, this may also create a slightly lower peak for an elongated period. Interventions such as tree planting, which actively reduce the amount of water in the system, may be more suitable if the intended outcome is to improve resilience. The question of whether this significantly impacts the water in the system in the summer months is clearly of importance (Buechel et al., 2022; Nisbet and Thomas, 2006); however, evidence of the impact of riparian systems on droughts within catchments like the Trothy is contradictory and needs further exploration (Dugdale et al.,

2020; Ellison et al., 2017; Kosow et al., 2022).

11.1.2 Shedding light on the problem by working with the 'opaqueness' of different data

Each dataset, the model output and the LM knowledges (informed by lived experience) have 'black box' or 'opaque' areas, where we cannot observe exactly what is happening.

I recall standing by the CMS experiment in the CERN Large Hadron Collider; the researcher guiding us around identified the different layers of the experiment. Particles collided in the tube and flew out through the CMS detector. Each ring of the detector had a different purpose, and part of this was to slow down and control the path of the particles as they left. However, the material used was necessarily opaque to the measuring equipment. When I asked the researcher about it, they replied that it was unlikely, but you just hoped nothing interesting happened in there.

Everyone has to deal with the opaque nature of soils; they can't readily experience everything happening beneath the surface and have to make inferences based on contextual data (Beven and Chappell, 2021). Whilst in the case of a scientific methodology, this may involve taking soil cores, representative samples or using trackers for a land manager, this (whilst potentially including the above) will rely more on the knowledge of what does and doesn't grow, how any given field behaves in a storm, the texture of a surface when working or walking on it. LMs are more likely to know the history of land management, whether there have been or are still, maintained drains that might mislead the hydrologist reliant on a limited number of measurements (even if you could measure the whole field, you would, by nature of the experiment, change what you were measuring (Davie, 2008; Newson, 1994)) and the use of aggregation and principles of generalisation. In a mixed method case, these two examples of understanding soil combine to form richer, more valuable data. The scale or extent of each dataset can also be related to opaqueness, the 'beyond' that cannot be seen.

The model encompasses the entire catchment, yet cannot resolve to fine detail, the

argument for doing so being countered by an increase in uncertainties. Land manager knowledges are inherently place-based, resolved to a fine scale (in some areas of interest, and may or may not be developed across an area). Yet, they do not (arguably cannot) encompass the whole catchment, and often knowledge is much stronger in relation to what is 'upstream'. Again, our mixed methods case enables us to bring together these datasets. Being relevant at different scales or utilising different methodological approaches does not make them incompatible; together, they provide a richer picture of the catchment. Each land manager must adapt the aggregated hydrological model output in ways relevant to their own holding. However, the model also brings awareness of the interconnected nature of the catchment, its size and the direct implications of land management on those who are 'downstream'.

This connectivity extends across the whole catchment and speaks to the wider factors identified by participants that influenced their choices, including governance's enabling and barrier-making nature.

11.1.3 Are we dealing with a false dichotomy when we try to 'integrate' qualitative and quantitative

'Context' as an entangled part of the evidence The Socio-ecological systems framework (Ostrom, 2009) has been critiqued for methodological issues around transparency, data validation and comparability (Partelow, 2018). These issues arise from the contextual nature of the socio-ecological cases to which the framework is applied.

Bender (1993, p81) identified lived experience as both "cumulative and reworked". This cumulative process identifies knowledge, including lived experience, as temporally variable and context-dependent. Partelow, 2018 finds that it is this context dependency which causes transparency and comparability issues with SESF (Ostrom, 2009). This assumes that the primary purpose is to measure or model systems to make generalisations. However, whether this is seen as a strength or a weakness regarding lived experience as a reliable form of knowledge, a valid dataset, depends on perspective and one's own

methodological frameworks.

In section 6.2, p 6.1, I discussed the spatial variation of lived experience and how that impacted participants' awareness. Between the interviews and the workshops, the Trothy had broken its record levels 3 times (section 5.3) and the participants were all aware of the significance of these floods, even if they did not personally experience them. These facts are critical in evaluating the data and findings of the thesis. This is not a limitation of the data, but rather an important parameter and reframes the point Partelow (2018) make about methodological transparency. The situational context of these findings is absolutely key to their interpretation but not, however, a fact limited to the socio-cultural qualitative findings. I showed in Chapter 6 the interrelationship between the socio-cultural and the physical landscape, its geomorphology and hydrological behaviours were directly impacted by (and impacting themselves) the social behaviours and management choices of the centuries of inhabitants (including the non-human actors). Therefore, although the scales of change may be different, if socio-cultural findings are inherently context-specific, then the physical characteristics must be as well. The supporting literature (e.g. Wang et al., 2018) and the model output suggest that it is the combination of the land cover changes alongside the climatic events that have led to the three "1 in 100yr"[1] floods during this study. This argument does not prevent us from drawing conclusions from the physical data, nor impact our utilisation of farmer knowledge where the qualitative values of lived experience are included. Both datasets' temporal and spatial contexts are integral in understanding the output from the findings. The situation of the case study was chosen specifically for this purpose.

Even numerical 'values' are not always reliable When we draw understandings from quantitative datasets, we can use statistics to attribute values of uncertainty and extent. These numbers mean little to the average reader (aside from implying that as it has a number, it's been done properly); as Gigerenzer explains "greater precision has *not* led to greater understanding of what the message really is" (Gigerenzer, 2014, p4).

[1] the "1 in 100yr" or 0.01% recurrence interval statistic will need continued revision with climate change, which must significantly question its use as a baseline.

However, they appear to present (I choose my words carefully here) a way to compare quantitative datasets and attribute 'value' to different bits of information. Our inability to do this with qualitative data, particularly data which is cumulative and reworked, is one of the areas that some scientists and policymakers appear to find uncomfortable; relegating values and experience to 'opinion' whilst they wish to solve problems using 'facts' (Krick et al., 2019; Smallman, 2020; Turnhout and Neves, 2019). The frank truth is that the value of a given piece of quantitative data is also cumulative and reworked - tied to the socio-cultural context and frameworks in which that data has been identified (Jasanoff, 1990; Muhar et al., 2018; Nowotny et al., 2003; Turnhout and Neves, 2019). This may seem counter-intuitive for scientists measuring precise characteristics, but each chapter of this thesis has demonstrated (in particular section 6.3 and 8.4) how, on a landscape scale, the socio-cultural is inextricable from the physical characteristics and datasets.

For example, a value of precision may be developed for a model based on the relative accuracy of its parameters, but if the likelihood of that model output being replicated in the real world is dependent on the management choice of, say, Frank who farms the valley round the corner from the old birch, then the quantitative attribute is not a reliable measure of the validity of the output.

The disciplinary datasets are then tied together; the one informs the other. While they can be treated separately, the 'facts' or 'output' presented tell only half a picture. The qualitative understandings are limited by extent and already shaped by frameworks based on scientific knowledges, whether field-based or through extra-local education. The model output is only reliable with the contextual understanding of the catchment. It applies to no given scenario without the qualitative understandings that frame and define the catchment, the need for change and the change/challenge itself. Yet, whilst this is well supported in the literature (Sarewitz, 2004; Turnhout and Lahsen, 2022), it is not reflected in how governance or science structure and engage with knowledge or 'evidence'.

The drysi gwir The qualitative and quantitative, the empirical measurements and lived experience, are then part of the same entangled puzzle, which I'm calling the drysi gwir[2]. This approach develops and extends that of Raymond et al. (2010) to data 'integration', by drawing on Bender's (1993) call to 'enmesh' and entangle perspectives, rather than Raymond et al.'s process of identification and evaluation. It is, therefore, a reframing of interdisciplinary approaches away from (though still utilising) their disciplinary roots. It is a little-discussed but implicit consequence of the co-productionist approaches to participation (Chilvers and Kearnes, 2020) in which society is not an externalised party but an integral part. This reframing is fascinating but also really tricky, hence why Chilvers and Kearnes (2020) call for significant further STS study of these understandings. The ability to apply disciplinary rigour to mixed methods datasets in case studies is one way that interdisciplinary approaches have been managed. However, this often inherently returns to the disciplinary structures,

One option for exploring a more holistic data picture is to identify the 'subject' the data explores and the fuzzy boundaries between data (Figure 11.3). The examples I presented above include the limitations, or rather the extent of the data, to support us in understanding how they build a richer picture.

This analysis helps us identify how the data is framed and, therefore, how it may be valued, presented or applied.

For example, the recommendations given on the datasheet (Appendix XIII) were situated within the socio-ecological context of the landscape developed through both the modelling and fieldwork, yet they are framed from the perspective of the model findings. Whilst relevant, they do not form the overarching recommendations of the thesis.

This section has focused on the fine detail of how I have been able to work with both the qualitative and quantitative datasets in a way that goes beyond 'integration', which would utilise only the aspects in which the data is comparable. Instead, the approach I have taken values the whole of each dataset, identifying where they support and expand on

[2]in particular, I find the closest English terms weighted towards non-animate, technocratic or digital uses

similar problems and extending beyond that to meet the more complex 'wicked' challenge.

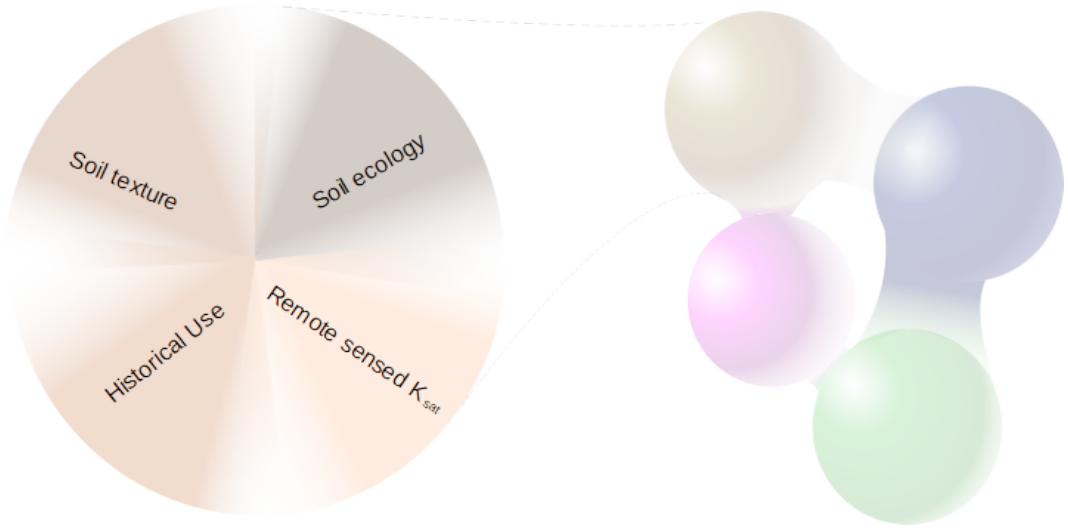


Figure 11.3: The fuzzy boundaries of soil data (historical use and physical characteristics may situate the soil as it is, soil ecology and future use indicate what it might become) entangle with the fuzzy boundaries of other data sets.

Methodological debate is needed at these fuzzy boundaries, however, the disciplines leading these challenges tend to have arisen from the physical sciences and solutions are heavily weighted by those disciplines. Further and more involved engagement from the social sciences and from outside institutional science itself, particularly stakeholders such as land managers or flooded communities, is needed to navigate these 'fuzzy' boundaries and ways in which we integrate different data and knowledges.

11.2 How a richer understanding reflects on decisions: learning from entwined systems and entangled data

The analysis so far has focused on the synthesis of data to go beyond the integration of datasets and explore the 'fuzzy boundaries' and the richer picture this wider lens allows. Whilst maintaining disciplinary rigour, all the datasets are understood as part of one picture, exploring how they are co-produced, where they are complimentary, and where knowledges enable additional perspectives 'opaque' to each dataset standing on its own. Through this, I further strengthen the findings supporting the relevance of the knowledge

and expertise of land managers and demonstrate how fundamental it is to understanding landscapes, particularly the potential of landscape change through the lens of increased tree cover for NFM.

In the next section, I shall review the data regarding the second key aspect of the thesis aims, understanding decision-making by both the practitioner and at the science/policy interface. The literature review demonstrated the complexity of decision-making drivers and how thinking about and governance of landscapes could be shaped by not only the socio-cultural but also phenomenological understandings of landscape. In Chapter 6, the evidence from fieldwork and knowledge exchange with LMs showed the complex knowledge culture that LMs developed and drew from. In section 10.2.3, the analysis of the participatory workshops explored how this complex knowledge culture (now including the model knowledge) was situated in a wider socio-political landscape, where agency, connectivity and governance structures all contributed to identifying barriers and pathways to making, and deciding to make change.

In the first part of this section, I focus on how knowledge is produced and becomes policy, highlighting how both local and external knowledge needs to be integrated into this process and the implications for data collection, analysis and application. Due to the nature of writing, this may appear to follow a linear science-policy model in the layout of each part, however, I draw on the literature and frame this as a cyclical co-productive model. I critique the linear model further in the second part of this section, reflecting on the suitability of current governance structures and policy approaches in light of the connected yet heterogeneous co-produced landscapes and how change, specifically tree planting for NFM, may be enabled.

11.2.1 Making knowledge and policy: Exploring the practice of 'making the best decision' through the practices of data collection, analysis and application

The order of the following four sections should be, at its simplest, cyclical and not linear and sits outside the linear science-policy model. The nature of writing has to have it positioned in a logical order: figure 11.4 shows how these aspects are situated.

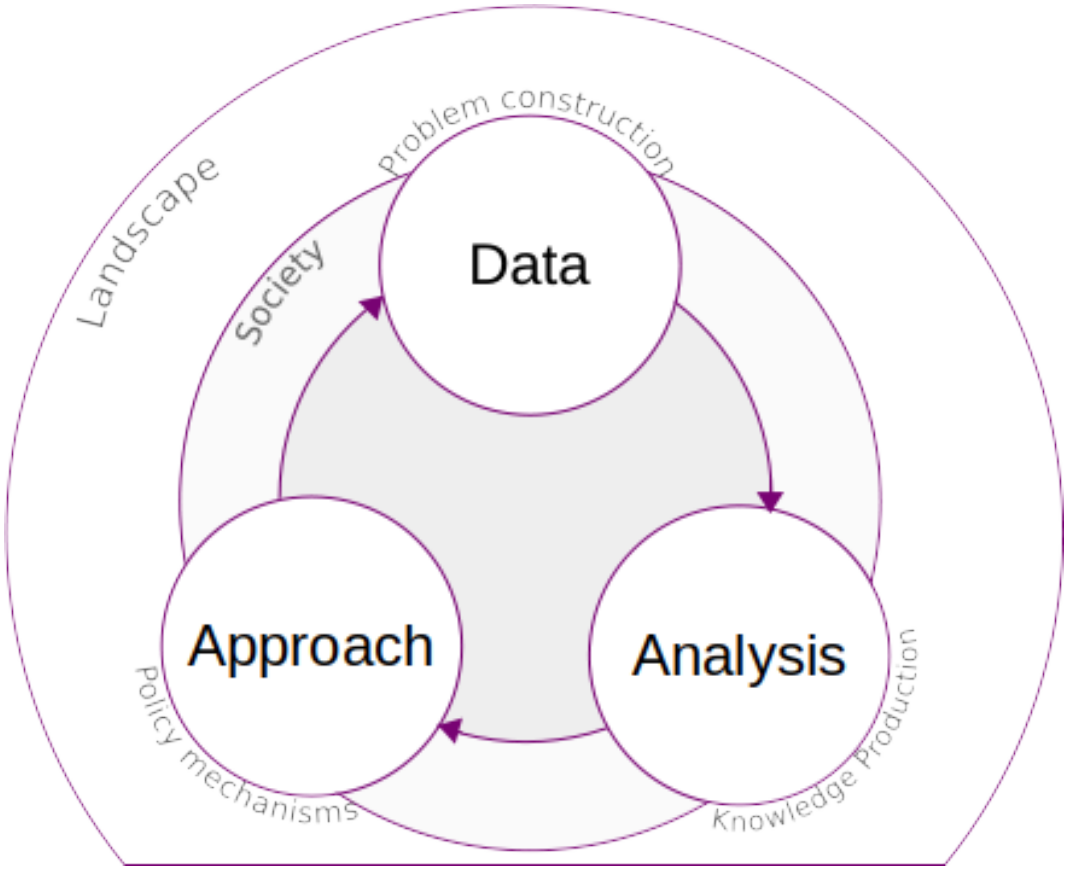


Figure 11.4: A schematic restating the cyclical nature of the knowledge production within landscapes, developed from fig2.9. Whilst this may seem obvious to some, this figure is my response to the linear framing imposed by the written structure, something which may itself need re-evaluating in light of our continued inability to move away from these structures at the knowledge-policy interface.

Re-'situating' data for better decision-making in light of more equal and richer knowledge frameworks

Interviewees and Workshop participants specifically identified the importance of new knowledge on changing environments in informing their decision-making. Monitoring and data gathering for adaptation and decision-making will be required if understanding and suitable adaptation and resilience to local and global challenges are to continue. As well as the questions of 'what' data, somewhat tackled in section 11.1.3, there are also the questions of how, by whom, and for whom.

Lived experience, with much of LM knowledge, is cumulative and reworked However, Bender, 1993, also attributed the same qualities to the landscape. While the 'scientific' methodology can (as this thesis demonstrates) integrate some iterative processes, the institutional structures of University requirements, grant structures, defined contracts and project timetables, tend towards linear projects. These projects are, therefore, temporally limited (with a few significant examples), with expectations of outputs that may be audited and evaluated (and therefore finalised); this thesis is, by its nature, an example of this. Institutionally led projects are also spatially limited, often by accessibility, prior studies or, again, funds. The studies are 'cumulative and reworked', developing on previous literature, but are limited by access to and the focus of those literature (including significantly, language barriers), which are often (by the necessity of needing a focus) directed by discipline. LMs, by contrast, have a much broader range of knowledge collections to draw on, targetting the challenge rather than the discipline. Though disciplinary-type networks can be compared to those created by communities, the internet is significantly extending these communities (Rust et al., 2022), though language and cultural barriers are also significant here. LMs' 'methodology' is like that of a complex mixed methods case study, identifying one, usually spatial, but also culturally and environmentally defined context, and applying relevant strands of knowledge to that case in a way in which different data inform each other (recalling that LMs rarely relied on Lived Experience alone p 6.4). A distinct difference, however, between the scientific and LM methods

is the iterative nature. LMs demonstrate a cumulative and iterative approach to data collection, analysis and application, which reflects the long timescales over which LMs knowledge is situated (from past to future) and is reflective of the nature of the changing landscape in which they work. They may celebrate milestones but the job is never done, the landscape is a 'work in progress' (Ingold, 1993).

Long-term monitoring projects, reliant on scientific approaches, can be expensive to deliver and hard to manage, with multiple relevant parameters needing data collection and ground truthing. The 'use' of citizen science to gain additional long-term data has been well evidenced (e.g. Paul et al., 2019; Stilgoe, 2009).

The Defra NFM projects monitoring and evaluation tool[3] is set up to support data collection for the Defra-funded NFM projects (Environment Agency, 2021a). Many of these projects have been implemented with the 'wider benefits' of NFM as a key focus (e.g. Herefordshire Council, 2022). The data monitoring, however, records only NFM-related data and the value of this 'at length' monitoring in relation to the impact of trees is debatable. Many projects include little information other than that woodland has been planted, or stating that flood impact is 'high' (occasionally medium, rarely low) when woodland has had little chance to develop. By attempting to simplify, quantify and centralise data, the quality and accuracy of data collected is highly varied as it has had to be generalised, losing its place based variety. Localised data 'hubs' supported by methodologies adaptable to different projects may have been a more valuable way of collecting data. The data hub does, however, bring attention to the importance of ongoing monitoring and evaluation and should be lauded for this change in practice. While significant funding is available for NFM projects in Wales, and the monitoring is a requirement of any bid, the type or output of monitoring and data collection is unclear ("Guidance", 2020). A more 'place-based' approach may be being devised; however without frameworks outlining the types of monitoring that may support ongoing adaptation and delivery, it is unlikely that projects will conduct or realise the need to conduct baseline data collection of either physical or cultural variables.

[3]The Rivers Trust, n.d.

Of additional concern, the second two questions I raised, by whom and for whom, are crucial and need to be properly explored in the current science-policy practices. The current data collection methods all sit within the 'science to the rescue' frameworks, maintaining the status quo where the power over and management of 'knowledge' is held by centralised institutions (Chambers, 2006). As well as holding this data, despite some good practice, its interpretation and use is again primarily retained at the science-policy interface with access and application on the ground being both socially and financially restricted (Smallman, 2018, Lupia, 2021). As outlined in the literature review, evidence-based policy currently relies almost primarily on 'science' with the assumed exclusion of the socio-cultural (section 2.5.4). The inclusion of socio-cultural knowledges as part of this evidence recognises the socio-cultural frameworks of science itself and that relevant knowledges are held externally to scientific practices and organisations and do not just supplement 'scientific' evidence but are fundamental in enabling the richest, most accurate knowledges of landscapes and landscape change.

When project evaluations require ongoing monitoring, evaluation and adaptation, this must be recognised within this context and not just as scientists gaining additional data resources. The cumulative implications of lived experience mean that land managers essentially store and retain long-term information about their farms/landscapes over decades. Due to the heterogeneity of catchments, holdings within catchments, socio-cultural and physical changes, monitoring and adaptation will be necessary on an individual, place-based scale to supplement and suitably apply 'scientific' knowledges. Enabling land managers to take ownership of the monitoring, data and adaptations working alongside science/policy-led research addresses multiple factors, engagement, available resources and best practices.

Therefore, the best monitoring programs will use integrated approaches - utilising the expertise of hydrological models, remote sensed data and empirical measurements, alongside the lived experience and wider knowledges of land managers. In order to enable adaptation informed by this monitoring, this integrated knowledge must be open to (if not held by) the local communities and LMs as they have the agency to adapt and implement

changes.

Frameworks of analysis need to be situated by both local and external expertise

Some research has presented findings within a framework of limitations and limits (e.g. Buechel et al., 2022; Chappell, 2006); a justified analysis but with language that warns against particular actions or presents them as having 'limited effectiveness', a distinctly negative phrasing for policy making. This research is often conducted without relation to or active dialogue with the socio-cultural contexts of land management practices.

The model output demonstrated that in this catchment, no intervention would prevent flooding during extreme (above the 3.5m baseline peak) events, findings which are reflected in the literature (Cooper et al., 2021). The model also showed (section 8.3.5) that tree loss or extensive bare soil (occurring, for example, when later crop harvests such as maize, prevent cover crops being sown) may have more significant adverse impacts than the positive ones of increased tree cover.

When these findings are analysed alongside the workshop and interview findings, which demonstrated decisions and management practices rooted in the co-production of landscapes and integrated management approaches, the analysis frameworks significantly change. No manager suggested introducing an intervention as significant as increased tree cover purely for flood management; discussions inherently included the multiple impacts of trees. At the same time, no land manager would consider a single intervention the only influencing factor of their land on its hydrological behaviours. Integrated water management is an inherent part of maintaining and managing the landscape. These findings indicate that any increase in trees, considered to have significant wider benefits and implications for the landscape, should be included in any NFM plan for the catchment.

Single purpose approaches conflict with integrated practices

Land managers drew on complex knowledges and multiple factors to make decisions (section 6.3.1 as in Morris (2006)). In addition, increasing tree cover within the catchment

would be enabled if it met multiple heterogeneous factors, dependent on both the physical landscape and the complex combinations of drivers, individual to each LM (reflecting Emery et al. (2013)). As the model output showed, enabling increased tree cover is a greater priority than the strategic direction of location. Exceptions to this might include extensive tree planting interventions (or, in fact, any significant large-scale landscape change) where the impact on low flows, localised flooding or changes in hydrological behaviour are hard to infer without running heuristic models - directly informed by management plans. This means that interventions suitable to LMs and within the heterogeneous holdings of the catchment can be supported in regards their NFM impacts.

If the 'extent' of increased tree cover should be as great as possible for NFM, the size and location of interventions are then driven by the other multiple priority factors. These might include improving (or maintaining) biodiversity, woody crops, integrated water management, bank erosion or broader farm-integrated improvements (aesthetic and functional). Agroforestry, for example, silvopasture or alley cropping, might be of particular interest within the catchment due to the potential farm benefits alongside the benefits of increased tree cover on predominantly arable ground or to stabilise banks on steep pastures.

Integrated approaches by which LMs use multiple strategies to manage water within their holdings (and importantly, with awareness of the wider catchment impact) are both more likely to be acceptable and, fitting with LMs' multiple priorities more likely to be effectively managed. In particular, interventions which support both flood, quality and drought might be of particular importance, as concerns about trees 'using up the water' demonstrate (quote 42).

An integrated approach reflects successfully implemented projects at catchment scales. Pontbren (Wynne-Jones, 2017) and the Cotswolds project (Short et al., 2018) have had significant monitoring and evaluation. Unfortunately, however, the monitoring of multifunctionality is 'virtually non-existent' (Kumar et al., 2021); most projects that do monitor focus only on one outcome or will not show the impact of tree cover changes for many years (Dixon et al., 2018).

Therefore, how the physical characteristics such as species, type and location of planting affect the different qualities and quantities of water as an integrated system is a significant area of research and interdisciplinary approaches across scientific disciplines are needed to address this. The lack of scientific evidence suggests that smaller interventions, which can be adapted and monitored, may be more suitable for most holdings than extensive interventions. These smaller-scale interventions are also more acceptable to LMs as found across Wales (Wynne-Jones, 2013). This also relates to the average size of holdings (figure 5.7) and the importance of temporality (Riley, 2008), the benefits of maintaining diachronic integrity rather than rapid, large-scale change (Wynne-Jones et al., 2022).

The impact of multiple, diverse interventions needs to be supported by significant further research about the impact of management practices on both water quality and quantity. Those conducting research in these areas will need to integrate both scientific and land manager expertise, and importantly, the expert drivers of this research could be situated with either or both, the scientific institution or the Land Manager themselves. By flattening the hierarchy of expertise (Carolan, 2006) and recognising knowledge exchange and diverse knowledge cultures (Morris, 2006) in this framework, scientific methods can be used to validate certain datasets, whilst the priority of local place-based knowledges can be used to prioritise and critique others.

Different combinations of interventions may be more or less suitable for different holdings and catchments (11). Running models and providing supplementary information can enable LMs to inform and interpret the most suitable interventions within their catchment and holding 33. Care must be taken to ensure that integrated knowledges are being applied at all times and that reliance on models and extra-local information is not leading direction without analysis of local socio-ecological landscape suitability.

11.2.2 Governance and 'solving' the drysi gwir of increased tree cover for NFM

The drysi gwir, whole puzzle picture of the research responds to the literature framing of landscapes and wicked challenges. It shows that complex socio-cultural drivers informed by complex knowledge cultures are situated within co-produced policy and bio-physical landscapes. Multiple factors impact directions of change; governance, through incentive or regulation, plays a part in shaping this.

Governing bodies were rarely identified in a positive frame, with governance structures, regulations and incentives being confusing, poorly communicated or on occasion acting to contradict desired outcomes (section 6.2.2). This portrays very delicate networks in which trust and reciprocity are tentative and greatly tried. The interrelationships between knowledge development and the impact of policy support and regulation are key. For example, although model output may have served to clarify thinking and support the concept of farm-suitable trees in some cases, conflict with policies could quickly erode this.

In order to explore these relationships and provide solutions for moving forward, I draw out two key themes of the drysi gwir that are evident throughout all the data: connectivity and heterogeneity.

Connectivity

Whilst the response was less significant than extent, the model output showed that strategic choices in the location of increased tree cover had different impacts on the cumulative flow of the river. This demonstrates the connectivity of the catchment and the importance of the cumulative impact of many different actions within the catchment.

Whilst it is suggested that diverse approaches mean that changes in a large catchment are often hard to identify or measure (Dadson et al., 2017), wholescale take up of certain practices may have either positive or negative effects. For example, market support for a specific crop making it harder for farmers to drill a cover crop before winter storms

begin, or incentives and local examples supporting the reinstatement of wider, complex hedgerows across the catchment. Either of these two options is possible, and many others, that may create significant change in catchment hydrology within a relatively short time.

However, the workshops and interviews demonstrated that this overall connectivity was not well represented in land manager perspectives. Awareness of the connectivity of catchment hydrology was limited to locality and experience, ensuring upstream impacts were more evident than downstream effects. Whilst community ownership has been shown to engage land managers in projects (Pasquier et al., 2020; Short et al., 2018; Wales Rural Observatory, 2013; Whitman et al., 2015), the integration of and access to extra-local knowledge can be a difficult factor. Whether top-down or bottom-up initiatives are involved, the importance of governance choices in enabling this can be seen. The WILD approach (Black et al., 2021; Short et al., 2018), demonstrating an integrated local delivery (ILD) system, required the support of an expert facilitator.

Clearly an awareness of the connectivity of the catchment is a primary step in engaging land managers with the implications of land management. What is interesting is that decades of regulation in regards pollution does not appear to have developed this awareness (Lowe et al., 1997; Thomas et al., 2019), distancing farmers from the river rather than engaging them with it. Changing the approach to enable ownership of the problem and the solution may be a strategy with greater impact.

Heterogeneity Connectivity may erroneously suggest that generalisation or similarity of approaches across a catchment is suitable; however, this is far from the case. Prescriptive, generalised approaches only work if everyone is starting from exactly the same baseline, which is evidently not the case. The findings have reiterated the social and physical heterogeneity (section 10.2.3, 6.3 and 8.4) within and of the catchment. The differences in strategic planting reflected the heterogeneity of spatial change in different locations, whilst also being directly linked to land management choices. Replacing arable land had a greater impact than replacing pasture. This is not a physical or social analysis, but a complex interweaving of both. The choice to grow arable is determined by

complex factors, including the primary objectives of the farm, the economic context, the personal preferences of the farmer and the suitability of the site's physical characteristics. The physical characteristics of the site are then impacted by that very choice, the soil structure, hydrology, biodiversity and impact on the wider catchment are all implicated in change.

Prescriptive governance The implications of connectivity do not suggest applying the same rules to everyone within the catchment, though this does not play well with our understandings of equality and the simple way in which it is often treated. Despite heterogeneity of landscapes being clearly implicated in Welsh Government rhetoric and focus on place-based solutions, including the place-based structure by which NRW has now become institutionally organised (Daron Herbert, 2019. Its policy actions, whilst well-meaning, do not reflect this. The recent declaration of the entire of Wales as an Nitrate vulnerable zone (NVZ), goes against the principle of place-based interventions, has had significant effect on the perception of government's attitudes towards farming (see sections 6.2.2, p143 and 10.2.3, p258) and reflects on the dangers of interpretation of prescriptive policies by both 'society' and the governments prescribing them. The Nitrates Directive[4] is a European regulatory tool designed to "protect waters against nitrate pollution from agricultural sources" (NRW, 2022). On checking the NRW website in July 2022, the NVZ page has not been updated since March 2022 and gives the previous percentage of land designated as an NVZ - only 2.4%. The arguments as to the justification for this change are ongoing, principled and value-based, yet the regulatory measures are argued to be 'evidence' based. This seemingly intractable position is directly relevant to our discussion of enabling increased tree cover for NFM. It has a significantly negative impact on communities already frayed relations with externalised decision makers (section 6.2.2). In addition, the approach of policymakers in Wales continues to develop this prescriptive nature. The recent announcement that the SFS will require all farms to have at least 10% tree cover seems positive, and it could be argued that it is certainly supported by

[4] Council Directive 91/676/EEC, http://data.europa.eu/eli/dir/1991/676/2008-12-11

the model. But it allows for no heterogeneity in approach; it will also be determined by people arguing about what counts as tree cover, a complex debate in itself. Will a coppiced crop count? Will farmers with greater than 10% cover be incentivised to reduce tree cover down to 10% on the implied basis that that will be the baseline from which grants for increasing tree cover will be implemented? Does a tree have to be above a certain height? The need for flexibility for social factors has been highlighted by farmers (FarmingUK, 2022) but my research clearly demonstrates that this is entwined with the need to account for the heterogeneity of physical and ecological characteristics as well.

So whilst government rhetoric is place-based, policymakers' work is well-meaning and aims to achieve the urgently needed change for climate, nature and future generations. The denial of complexity and the linear prescriptive approaches of policy situate policy and formal governance as a barrier rather than an enabler.

Raymond et al. (2010) identified two further challenges of knowledge integration to the ontological challenge discussed at the start of this chapter, the challenges of epistemology and application. Whilst I have laid out an alternative framework for knowledge as entangled (drysi gwir) rather than integrated, the challenges are still relevant. The way in which knowledge is produced in the LM knowledge culture (Morris, 2006) is more reflective of the co-production of landscape and the concept of a holistic entangled knowledge (drysi gwir), and LMs' application of knowledge reflects this. The linear science-policy model, however, with prescriptive rather than iterative or adaptive approaches, reflects neither landscape, land manager nor the entangled nature of the 'wicked' challenge itself. It is unsurprising then that there are 'barriers to uptake' (section 2.3.3) and that conflict occurs.

Policy tools are needed that acknowledge and enable heterogeneity; they must avoid generalisation and prescription. As the participants stated, solutions and policy tools should facilitate and provide knowledge that land managers can adapt to their own unique socio-ecological and physical circumstances, giving them both ownership and enabling their expertise.

The need for connectivity (an overview most easily facilitated by wider institutions or

public bodies) and heterogeneity (best informed by local expertise and place-based knowledges) supports the extant literature exploring the benefits of polycentric governance (see Short et al., 2018, Garvey and Paavola, 2022 as discussed in the literature review section 2.5.4). The findings of this thesis directly support the benefits of enabling polycentric governance, approaches which utilise both local individualised drivers and expertise, within the context of centralised governance, which has both the connections and funding to monitor and facilitate communication across larger scales such as river catchments. This leads to the need to support innovation and communication, as well as facilitating and enabling access to data collection, monitoring and adaptation. I reflect and expand on these key suggestions in the concluding chapter, Chapter 12, section 12.4 – *'Implications and solutions for policy and practice'*.

Chapter 12

Conclusion

Contents

12.1 Endings, beginnings and cycles **297**

12.2 Response to aims and contributions to knowledge **298**

12.2.1 Objective 1: 298

12.2.2 Objective 2: 299

12.2.3 Objective 3: 300

12.3 Interdisciplinary reflections and future research **302**

12.4 Implications and solutions for policy and practice **304**

12.4.1 New ways of finding evidence: 305

12.4.2 New ways of governing 306

12.5 Concluding remarks **308**

12.1 Endings, beginnings and cycles

While this research began with a conversation between two geographers from different disciplinary backgrounds, this thesis goes beyond that conversation and those disciplinary bounds. I did not intend on crossing quite so many boundaries, but that is where the research led.

To structure this conclusion, first, I will respond to the aims of the thesis and set out where I have contributed to knowledge, directly building on and supporting literature and new and original perspectives. I will then reflect on the practice of doing interdisciplinary research and where further research building on my work is needed. I finish with the most challenging yet practical section, the implications for policy and practice. This situates my work where it is most relevant, responding not to the conversation of my supervisors but to the context of the world and the challenges that were being set when I began this thesis and that are still, if not more, relevant now that I have finished.

12.2 Response to aims and contributions to knowledge

This thesis aimed to explore how land manager (LM) knowledge and expertise would inform their decision-making and how compatible/relevant that knowledge was alongside knowledge(s) that currently inform the science policy decision-making around tree cover expansion for Natural Flood Management. I set three objectives to meet this aim and respond here to each of those objectives.

12.2.1 Objective 1:

to identify land managers' relevant knowledge and expertise and how this impacts their decision-making and political behaviour

Land managers (in this catchment primarily but not exclusively farmers) were experts in their f/fields, both the relevant fields to their type of land management and the physical fields in which they worked. They held significant relevant knowledge regarding the implementation of increased tree cover for NFM (Trees for NFM) in the catchment. This included their lived experience, which informed their understanding and was a significant factor in their decision making. Lived experience, as part of a complex knowledge culture, provided evidence (critiqued and evaluated against additional local and extra-local knowledge) which informed current practice and could be used to evaluate the impact of

potential change. This directly impacted farmers'/LMs' decisions about the suitability of interventions and informed their political position concerning policies they saw as external or 'out of touch'.

By taking a phenomenological approach and enmeshing the previous socio-cultural work relating to decision-making, I revealed important aspects of LM decision-making and political behaviours. I identified lived experience as part of farmer knowledge culture, a way of knowing landscape that informed and went beyond the 'way of knowing' through scientific practices.

12.2.2 Objective 2:

Explore the integration/compatibility of different knowledges for decision-making, including land manager knowledge and expertise and hydrological modelling of alternative scenarios, focusing on factors which would inform the efficacy of tree cover expansion for natural flood management (Trees for NFM)

LMs knowledge culture includes both scientisable and non-scientisable ways of knowing the landscape. By scientisable, I mean knowledge that could inform and improve scientific practice and methods. Regarding hydrological modelling, land managers provided a depth of qualitative and quantitative knowledge that directly informed and improved the perceptual model, the setting of parameters, model calibration and the analysis of results.

In understanding Trees for NFM as 'wicked' it became clear that the non-scientisable knowledge, knowledge that couldn't be measured or applied to scientific methods, was also directly relevant to understanding how tree cover expansion might impact NFM in the catchment.

In the framework of integration or compatibility, these knowledge 'types' appear in-

compatible. Some knowledge cannot be translated from the socio-cultural to the bio-physical. However, this did not reflect the way in which LM knowledge culture was formed or presented. Lived experience was rarely identified in isolation, and categorising 'types' of knowledge became difficult. Approaching the problem epistemologically rather than ontologically did not untangle this, as the experience of undertaking an action may have developed as much knowledge as the data collected in completing it.

This supported the view of an entangled knowledge culture, which, in part, led to my use of the drysi gwir concept. A framing of the challenge that did not attempt to translate one knowledge into another, but looked for the gaps and the overlaps, where the different knowledges could inform a richer understanding. Taking a phenomenological approach helped draw together the physical and social sciences. Understanding knowledge through lived experience, being with and being in, drew in the importance of the physical, material interactions. It helped bridge disciplines by recognising that the physical characteristics of processes and space were entangled with the socio-cultural associations of place. Landscape, in this respect, is not a 'cusp' concept but a bridging one. It is a way of doing rather than theorizing interdisciplinarity. As a concept, this is then more reflective of the way in which land managers themselves engage with and know the landscape and is a significant contribution to academic knowledge.

12.2.3 Objective 3:

Critique the current science/policy interface and decision-making process alongside farmer/model knowledge integration for usefulness in enabling management interventions that i) deliver NFM and ii) are acceptable to multiple stakeholders

The current science-policy interface does not reflect the way in which landscapes are co-produced, entangled or managed. Prescriptive interventions account for neither the connectivity nor heterogeneity within and between catchments. Land managers felt exter-

nal to and at conflict with this system. This did not, however, reflect on their willingness to engage in the challenge or their personal opinions about meeting the same objectives as targetted by the science-policy institutions. At the time at which this research took place, farmers wanted to plant trees, they wanted to improve their environment, to improve the quality of the river and its behaviour, not to prevent it flooding but to keep it at a manageable level, they wanted to engage with new knowledge and they wanted to talk to people about it. However, unexplained decisions and prescriptive approaches have countered positive rhetoric and engagement within the Welsh government system. The importance of socio-cultural evidence is recognised and reflected in disciplinary teams, impact assessments and targets. However, the impact of measurementality and a lack of integrated approaches is also reflected in those same structures of teams, impact assessments and targets.

These reflections directly impact the ability to develop management interventions that can deliver Trees for NFM and whether they would be implemented within catchments. Framing the evidence, the knowledge puzzle, as the drysi gwir, the science-policy interface attempts to resolve a challenge whilst missing a vital piece of the evidence. There is no mechanism to either influence the design of interventions or to adapt interventions to unique places once they have been formalised in the official policy jargon. This creates conflict and a lack of uptake as interventions designed in the rhetoric of generalisation and equality to be suitable everywhere, cannot account for the connectivity of heterogeneous actors and landscapes, and end up being suitable nowhere. [1]

Whilst I have developed the scientific contribution to 'Trees for NFM', I have done so within the context of a socio-ecological landscape. As called for by Turnhout and Lahsen (2022), I have done science differently. Doing so has led to new findings and reflections. While I have contributed to knowledge through the writing of this thesis,

[1] I should note that the Welsh Government, with its steps into co-design and the sustainable farming scheme, appear to be significantly ahead of England and the destabilising / internalising actions of the government towards their own formative environmental land management system.

they are not solely 'my' contributions. The interviews and input with land managers framed and shaped the hydrological model results, and the final analysis of implications was also worked through with them. The drysi gwir concept is one that I have developed for understanding and analysis, but the knowledge through which it was developed was both mine and theirs. All the work I have completed has drawn on the knowledge of the participants, the wider community and the environment, the landscape itself. This is my thesis. I will be the one who gets to wear the doctoral gown, but the contribution to knowledge is not just mine; it is ours.

12.3 Interdisciplinary reflections and future research

Although part two and part three of the thesis, the fieldwork and hydrological modelling, have solid disciplinary foundations, they are both inherently interdisciplinary. Undertaking the fieldwork required both physical and social data collection. I did not find, however, that I was straying into one discipline or another but that there was a natural space in which the two disciplines, in the 'real' world, were only theoretically separate. In part, this was due to taking a phenomenological approach; understanding the material characteristics of the space was a natural part of understanding the role the material played in the socio-cultural understandings. Other factors, such as the use of maps, enabled me to find the common ground in place between the methodologies of recording lived experience and physical characteristics for future GIS manipulation.

Being boundary-crossing requires humility and is hard. Unlike many PhDs where one is striving to become the expert in your field, the expertise lies in the crossing of boundaries themselves. One is never an expert in any given discipline, and there is a continuous need for 'checking in' with those who are.

Being boundary-crossing (and never being 'the' expert) also enables a privileged position. The 'checking in' is akin to learning different instruments whilst remaining as the

conductor. Understanding the methods and language of each discipline is needed even though you may defer to someone better at it than you are. The conductor might not be the best at playing the violin, but they know how the different instruments relate to each other to better communicate the whole piece. Being boundary-crossing allowed me to connect ideas in different ways to those visible from within disciplinary or institutional silos.

Here, however, I encountered significant challenges, as detailed in section 10.3.3, in finding my way across the extant institutional structures. While I recognised the need for humility regarding my knowledge, I also had to demonstrate considerable stubbornness and resilience in getting access and being where I needed to be. This additional challenge was hard, isolating, and unnecessary. There is a significant need for interdisciplinary, participatory spaces. These are needed to enable the boundary crossing of individuals between disciplines without feeling that they are 'trespassing' in other spaces. More importantly, they are needed to enable the 'crossing-in' of knowledge holders external to those institutions and extant power bases.

Future Research: This thesis raises disciplinary and interdisciplinary questions for future research. Those areas that reflect the co-production of landscape and the integrated management of heterogeneous yet connected landscapes would be of particular value. For example, how might water quality interventions interact with water quantity interventions? Can methods of preventing floods also help store water in drought? Does our social perception of privacy affect our understanding of the collaborative nature of our actions, and what implications does this have for ethical considerations in an interdisciplinary study?

Whilst both projects could be situated within a physical science lens it is important to recall the learnings from the drysi gwir concept. Approaches in case studies would be situated within the socio-ecological landscape of that case. The socio-cultural factors

must be recognised as more than just 'context', directly affecting the research framing, practice and analysis. Projects must be shaped and explored alongside the land managers/communities who hold the relevant knowledges in that landscape. This does not require all physical scientists to reinvent the wheel and learn sociology but may need interdisciplinary, participatory teams to shape and evaluate project progress.

From a more socio-cultural perspective, further work is needed to understand knowledge cultures and the many ways in which landscapes can be 'known'. Concerning Trees, for example, do foresters 'know landscapes' in a similar way to farmers? Historically, woodland management was a part of farm work, but has the separation of these two industries impacted the way in which land is known? Does this itself have an impact on increasing tree cover? My work was predominantly with farmers, and different factors influenced the way in which individuals incorporated different understandings of their landscape. In the 'missing voices' section, I identify some key human actors I couldn't include, and in the more-than-human section, the non-human actors, and how they may experience (if 'know' is too controversial) landscapes.

Reflecting on the drysi gwir suggests it is essential for socio-cultural theorists to engage with the material / physical qualities of the landscape; whilst phenomenological approaches are informative here, I repeat that the wheel does not need reinventing. Engaging with the physical and ecological sciences to explore characteristics, behaviours, and processes will bring insights; without these, any exploration of landscape, the environment (even a focus on the socio-cultural within landscape) will be missing critical pieces of evidence.

12.4 Implications and solutions for policy and practice

In section 11.2.1, I put forward a strong critique of the current knowledge and decision-making processes centralised at the science-policy interface. This problem is not confined

to Trees for NFM but has been recognised widely in environmental science (section 2.5.4). I do not go as far as to call for a moratorium as Turnhout and Lahsen (2022) do. This thesis supports their findings whilst acting as the 'alternative' science they call for. In doing this, the findings and methodology have direct implications for current practices and suggest actions that may be taken to either rewrite or repair how knowledge-policy is constructed for environmental decision making.

12.4.1 New ways of finding evidence:

The drysi gwir concept suggests that the science-policy interface makes decisions while missing key pieces of evidence. There needs to be an adequate way in which lived experience, or any aspect of wider land manager knowledge can be adequately included in the current science-policy interface. 'Consultations' are not hitting the notes; at best, they're allowing communities to be in the audience, but the players have already been assembled and the program decided. Citizen science approaches frame wider knowledge holders and expertise as instruments, adding to the resources available to the already trained musicians. In fact, it's more akin to an orchestra missing the entire violin section. The knowledge isn't the same as those already held in the room; without it, the music is incomplete, in many cases, missing the melody. I'm pushing the analogy a bit, but instead of trying to make all the players play the same piece, knowledge needs to be recognised as complementary. A richer understanding is formed by exploring where knowledges are in tune, where there are gaps and where there appear to be dissonances – areas that seem to be at odds and unresolved.

In practical terms, this involves talking and, more importantly, listening. This is hard work, and governments have limited resources. One central individual cannot listen to every other individual's perspective. However, one person may talk to ten others, who may each also talk to ten others, and (as we learnt to our detriment over the last few years) that contact is exponential. This approach involves resourcing people, getting feet on the ground and developing relationships. Resourcing people is expensive, but millions are currently directed into schemes that are not achieving their objectives. An expensive

resource that achieves something is better than a cheaper approach that gets nothing done.

12.4.2 New ways of governing

The importance of heterogeneity supports suggestions that more ownership/power needs to be held by communities and individuals in order to adapt interventions to make them suitable for unique places. The connectivity of the catchment, however, indicates a pivotal role for government/policy-makers/scientists who can take a broader perspective. Setting whole catchment objectives, identifying challenges, monitoring and facilitating communication and adaptation as contexts (climates/disease/water needs/food production and markets) shift.

Enable Polycentric governance - Rather than creating a top-down vs bottom-up dichotomy, this research suggested that polycentric, flexible approaches were needed. Participants themselves suggested the possibility of an 'offsetting' approach, where heterogeneous landowners could work together to ensure a catchment objective could be delivered in a way that suited the different needs of different landowners. They were not, however, in a position to drive this type of intervention themselves. They needed support in both knowledge and facilitation – a wider perspective that could identify the cumulative impacts, communicate between parties and direct grant funding in flexible ways.

Support innovation and facilitate communication – Innovative practice will be needed to shift the management and skills of landscape management to deal with a more wooded landscape. This innovation does not need to be led by centralised governments, but centralised government is in a uniquely strong position to facilitate it. A practical solution on the Trothy would be to reinstate a coppicing practice along the river. A centralised party need not lead this but it could be financed and managed by small industries. However, the initial capital, organisation and facilitation of knowledge, adaptation and management is an area in which few small industries could invest. If a case study model

was set up with government support, this could then be used to test and trial methods, to meet multiple governance objectives. This model would then provide experiential evidence of what worked and didn't work in facilitating future practice and investment into other catchments.

Facilitate and enable access to data collection, monitoring and adaptation - many farmers expressed a desire to support the improvement of the river catchment to meet government objectives. LMs wanted to engage with scientific knowledges in order to improve their own decision making. They were also able to collect and supply data to both other land managers and the wider scientific community. Currently, the 'open science' movement primarily revolves around sharing data between scientists. Publications are obscure, and data management and analysis are an esoteric pastime. Facilitating better access to both understand and contribute to data, from the methods of data collection to the implications of its analysis, is a key role that governments could play to create a paradigm shift in environmental land management. This must be situated within the new 'knowledge-policy' understanding of the drysi gwir, or it risks reinforcing measurementality and the exclusion of certain knowledge that is contributing to the mess we are currently in.

With the qualification that swift action is necessary, these suggestions could be achieved through incremental and achievable change. They do not require a paradigm shift how the extant institutions function, certainly regarding successfully implementing tree cover expansion for NFM. However, they require a paradigm shift in how these challenges are viewed. Interventions for NFM cannot be implemented without considering integrated water governance and must involve the engagement of multiple governmental departments. Attribution of expertise must be widened to include those actively engaging in land management when questions involve the management of the land.

12.5 Concluding remarks

This conclusion identifies and refines the implications of the thesis findings, and it is the chapter I have found hardest to complete. One reason is that whilst the thesis is complete, the challenge is, at best, a work in progress. Water in the UK and its rivers is in an objectively terrible state; the country is still not meeting its tree planting targets; tree 'planting' rather than growing functioning woodlands for multiple benefits is still the policy target to meet. Even as I state this, I reflect that there will never be a time at which these challenges have been 'met'. Change will continue, and landscapes will always be a work in progress.

My conclusions, therefore, are not just a response to the conversation of two disciplinary researchers but are set within this context. They are proactive, challenging, and directed at change. I am not writing like this for the purpose of being an activist but because, as with the synthesis, action is the implication to which the research has led. Water shifts, trees grow and change happens. We are uniquely positioned to direct that change and I doubt the collective awareness of this has ever been quite so high. We need to work with, to be in, our landscape, our environment, in new ways; so that we, it, don't destroy our way of life, our ability to live.

Water connects everything within a catchment, breaking the boundaries we set around our physical spaces. Trees connect us through time, linking past to present to future. Our landscapes are integrated, entangled in ways that measurementality and siloed approaches cannot account for. I am not calling for the boundaries to be broken, but for us to recognise them as they are and be able to cross them when we need to. I am calling for humility, in the way in which we frame our own positions as knowledge holders and the way in which our decisions are made and enact change in our landscapes. I am calling for actual, not literal, boots on the ground, whilst being aware of the path we are treading and where it is taking us.

When I finish this thesis, I will go out onto a hill and plant a tree. I will water it, and I will watch it grow. If I carefully consider how it may survive within that landscape,

it may see decades more change than I will. It will not be one tree alone, but part of a functioning system within a complex, entangled landscape. It will be entangled with and have implications for the social and cultural, the ecological and the material landscape in which it is rooted. It may even help prevent a flood.

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Appendices

Appendix I: Enlarged Graphs and Figures

I.1 Chapter 2. Literature Review

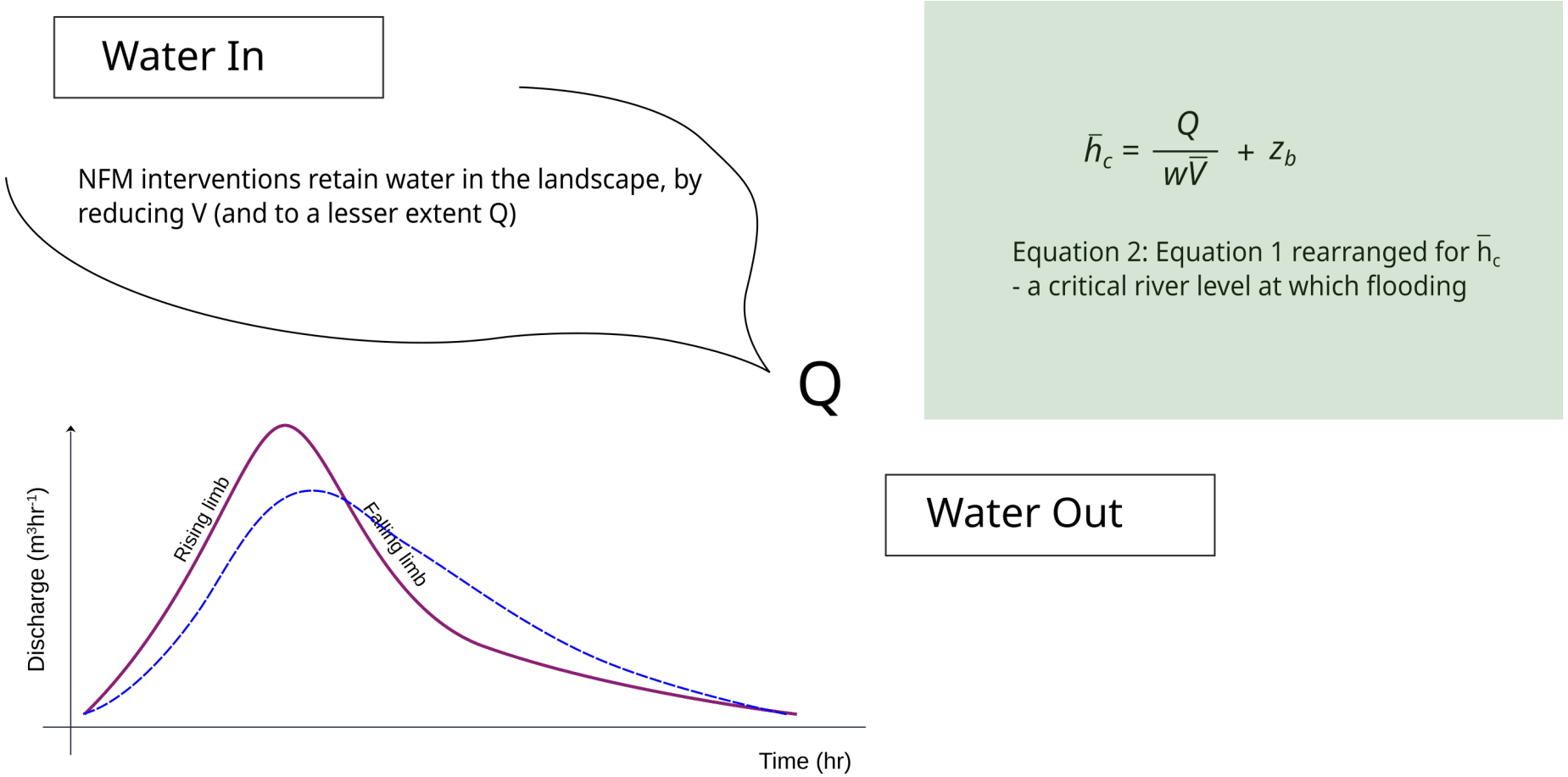


Figure 2.2: the equation rearranged for hc, and the impact of 'slowing the flow', shifting the discharge from the peak to the falling limb of the stormflow hydrograph (Wells et al., 2017, Thomas and Nisbet, 2007) (p 19)

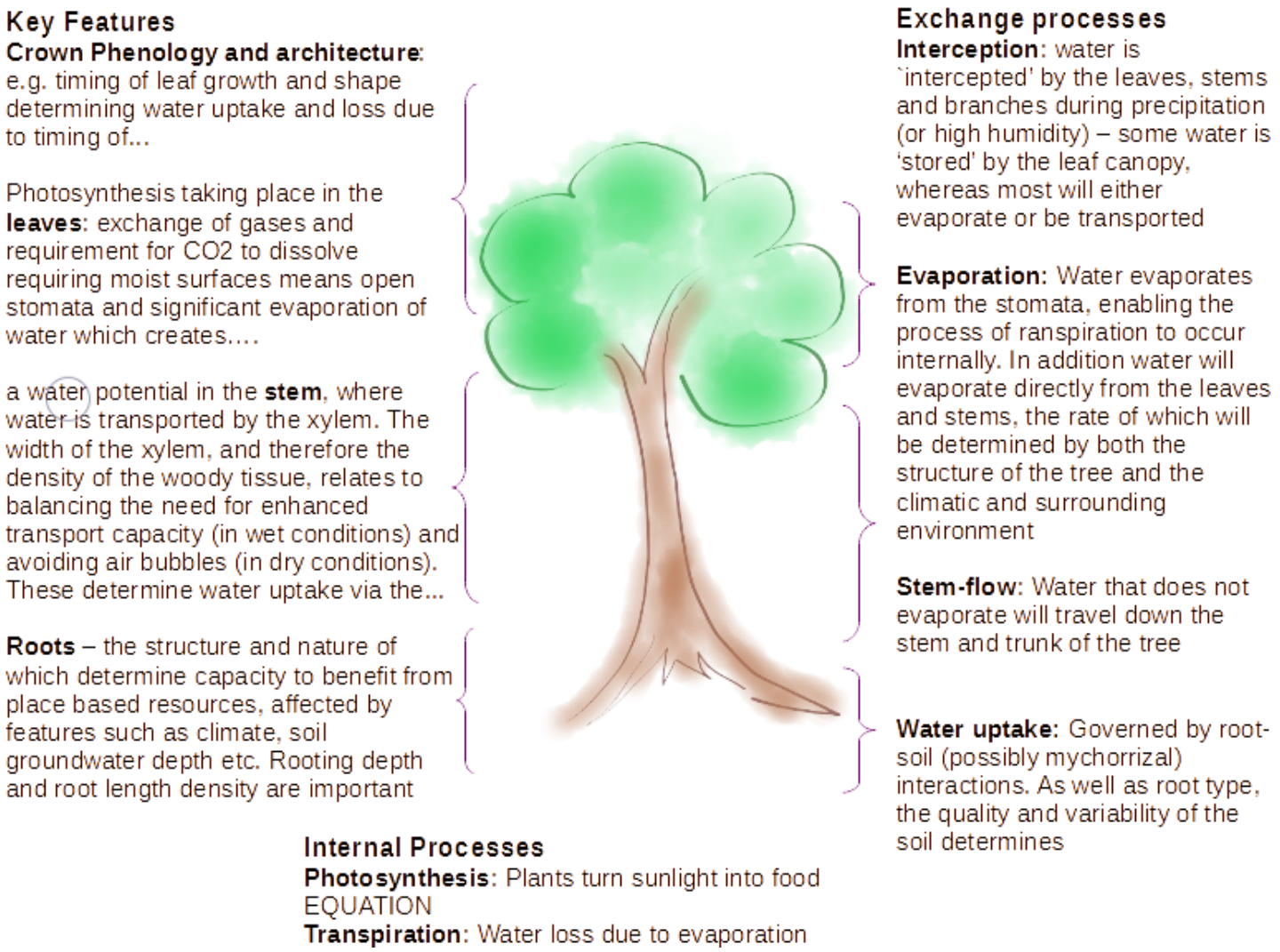
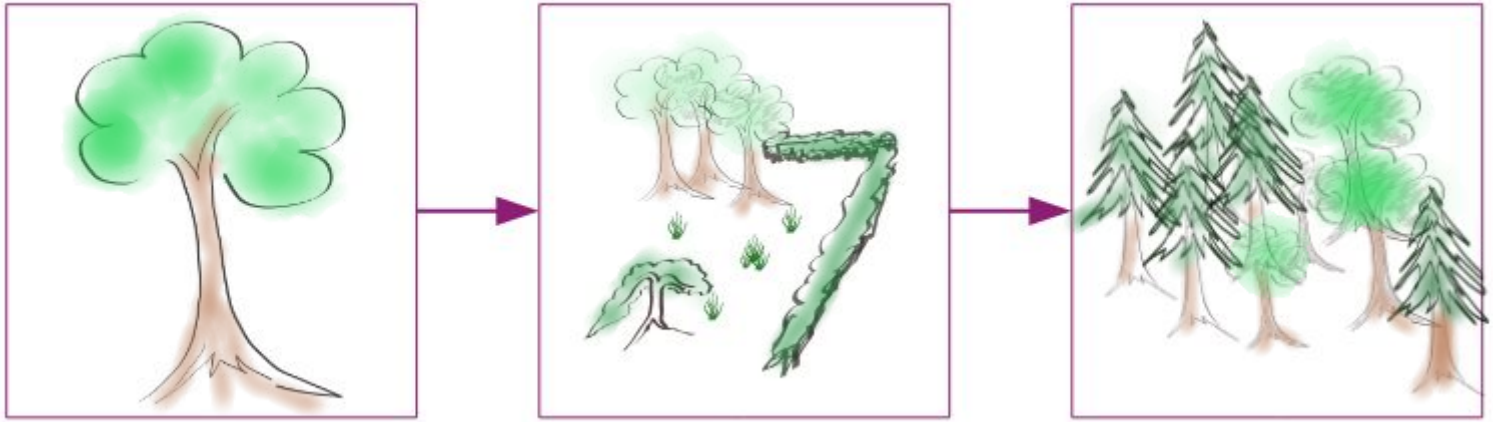


Figure 2.4: Diagram and details adapted from IUFRO, 2018; Lambers and Oliveira, 2019 (p 25)



Plant ecophysiology

Key Features:
Crown
Phenology/Architecture
Leaf
Stem
Root

Processes
Photosynthesis
Transpiration
Evaporation
Stem flow
Water Uptake

Forest Hydrology

Key Features:
Phenology
Species type
Stand density
Undergrowth
Species diversity
Leaf Area Index (LAI)

Processes:
Evapotranspiration
Infiltration
Overland flow
Subsurface flow

Figure 2.5: Diagram and details adapted from IUFRO 2018, Lambers 2019, Cooper et al 2021 (p 26)

I.2 Chapter 3. Methods Overview

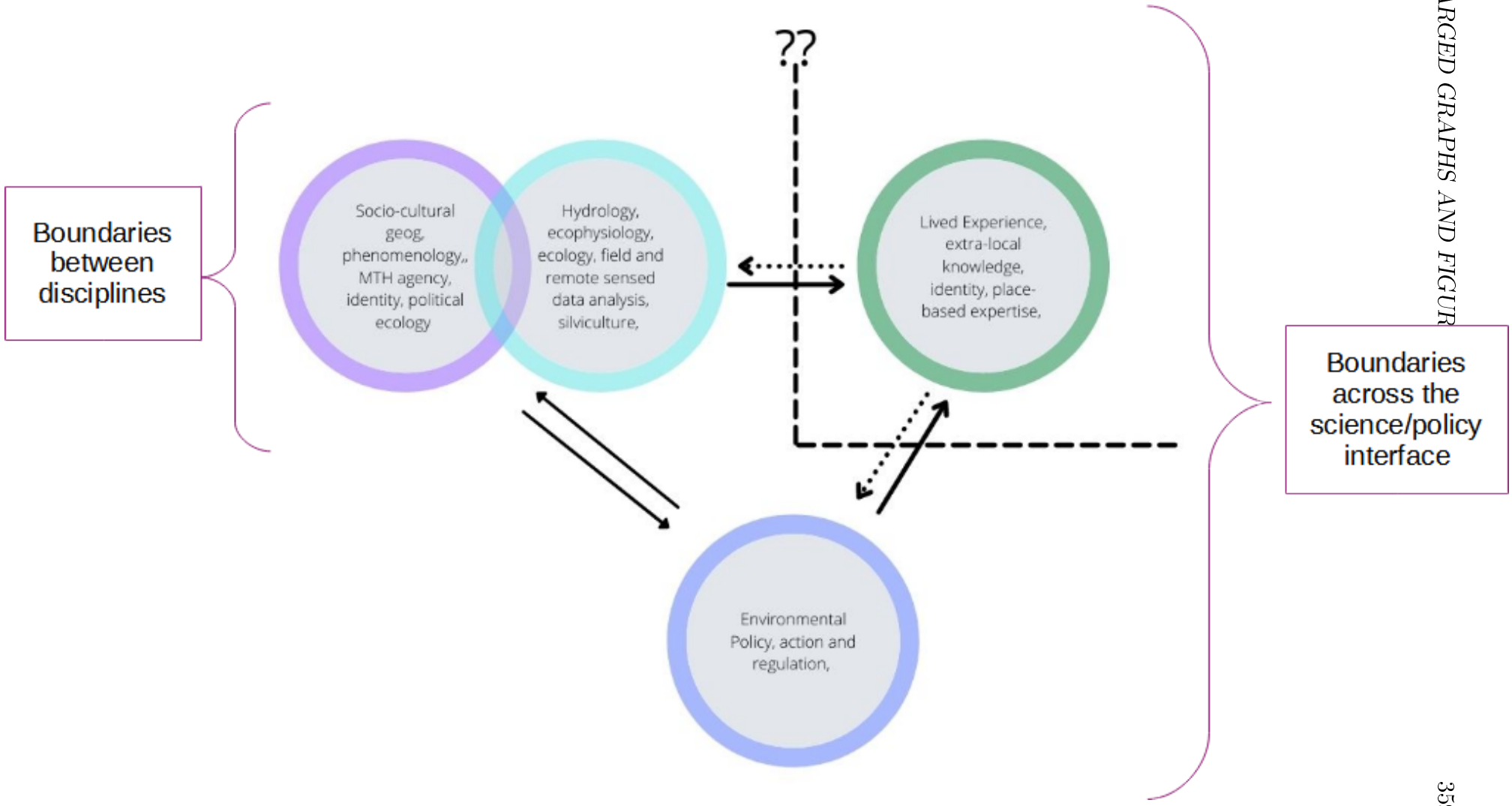


Figure 3.1: identifies the boundaries between physical and human geography; the boundaries between scientific, policy and local / place-based expertise (p 76)

I.3 Chapter 5. Case Study

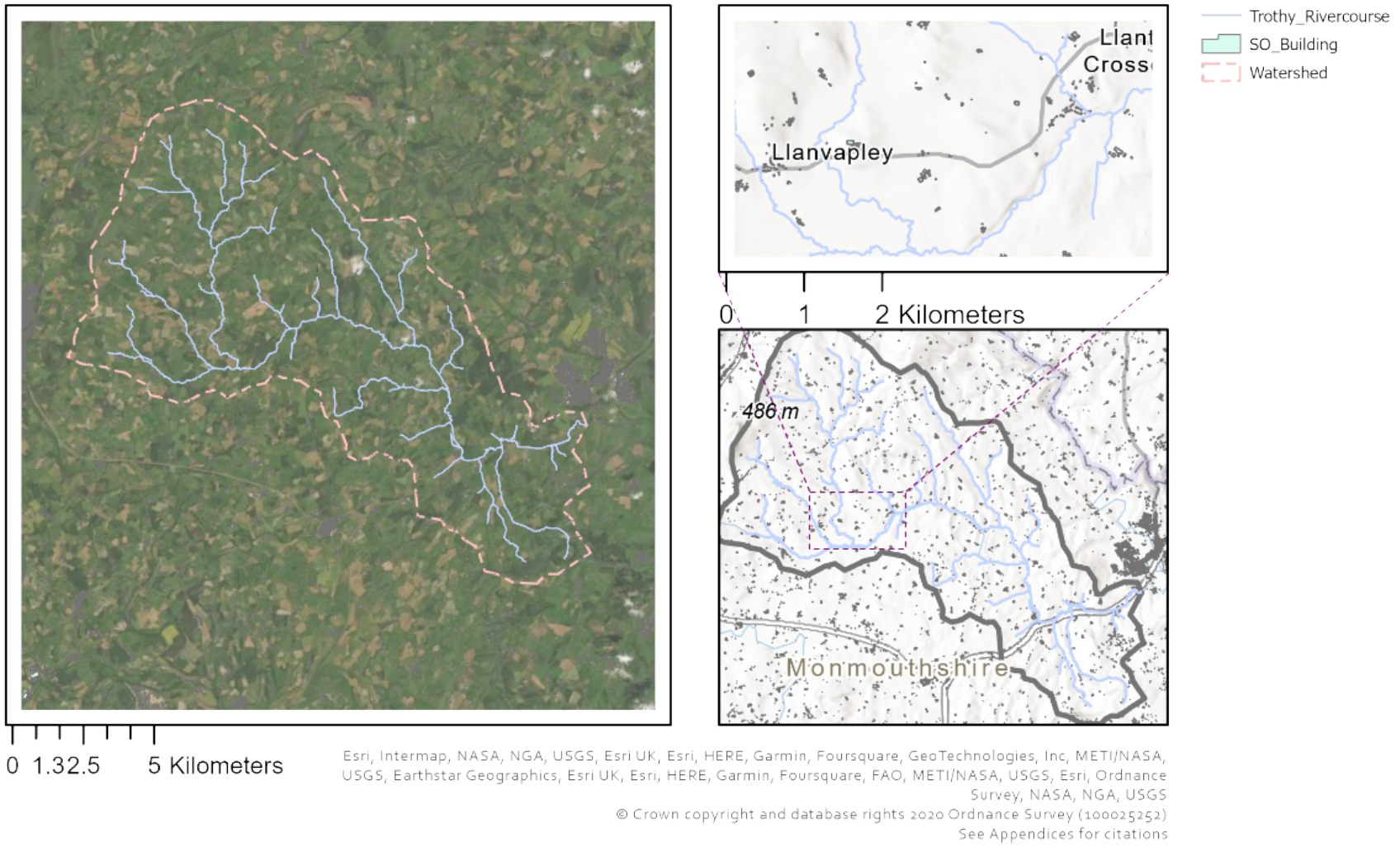


Figure 5.8: Catchment watershed and River Trothy overlaid with the OS vector data for buildings (see credits and Appendix XIII) (p 108)

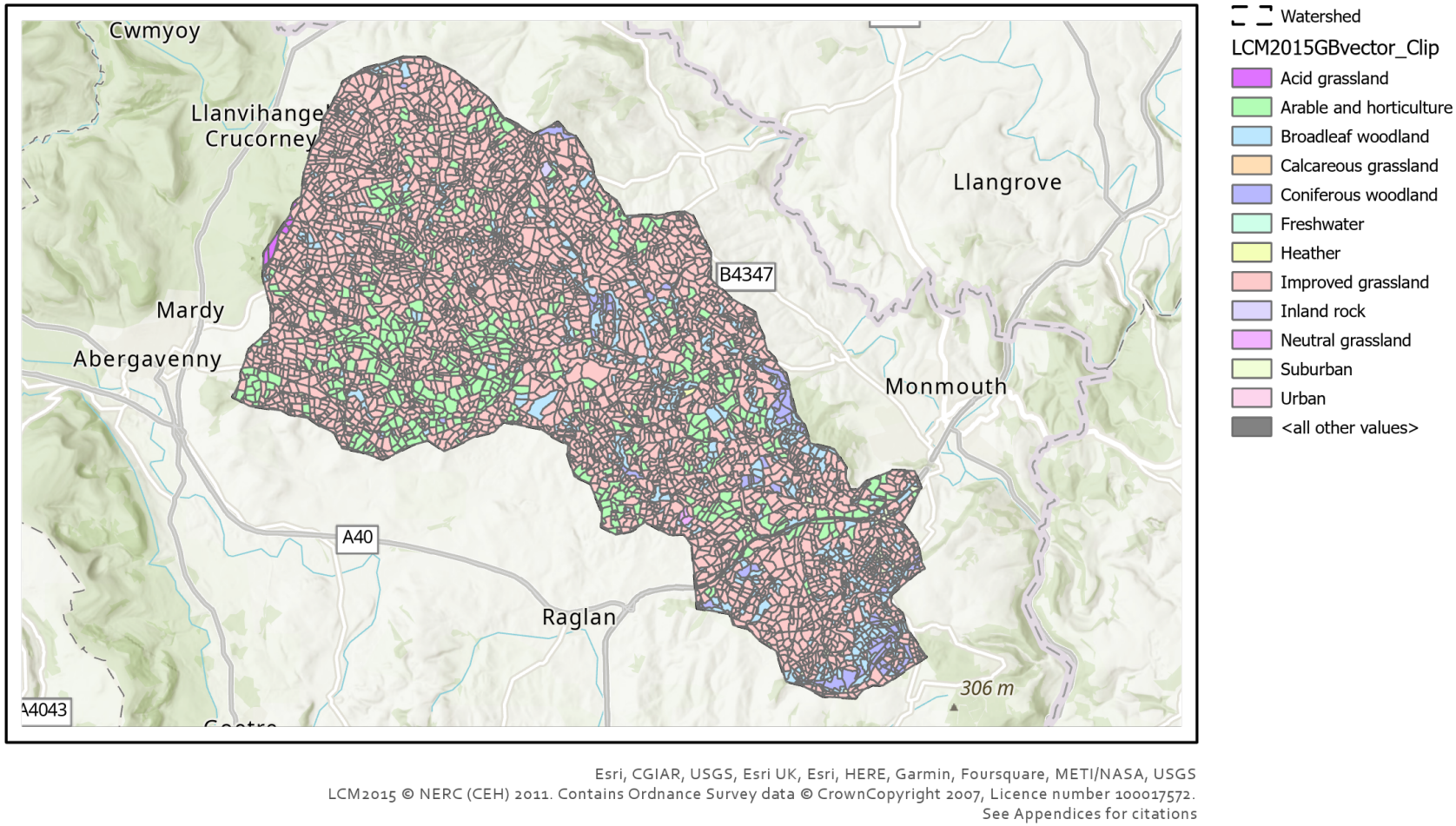


Figure 5.9: Categorized Land Cover data from the CEH 2015 dataset (see credits and Appendix XIII) of the Trothy River Catchment (p 109)

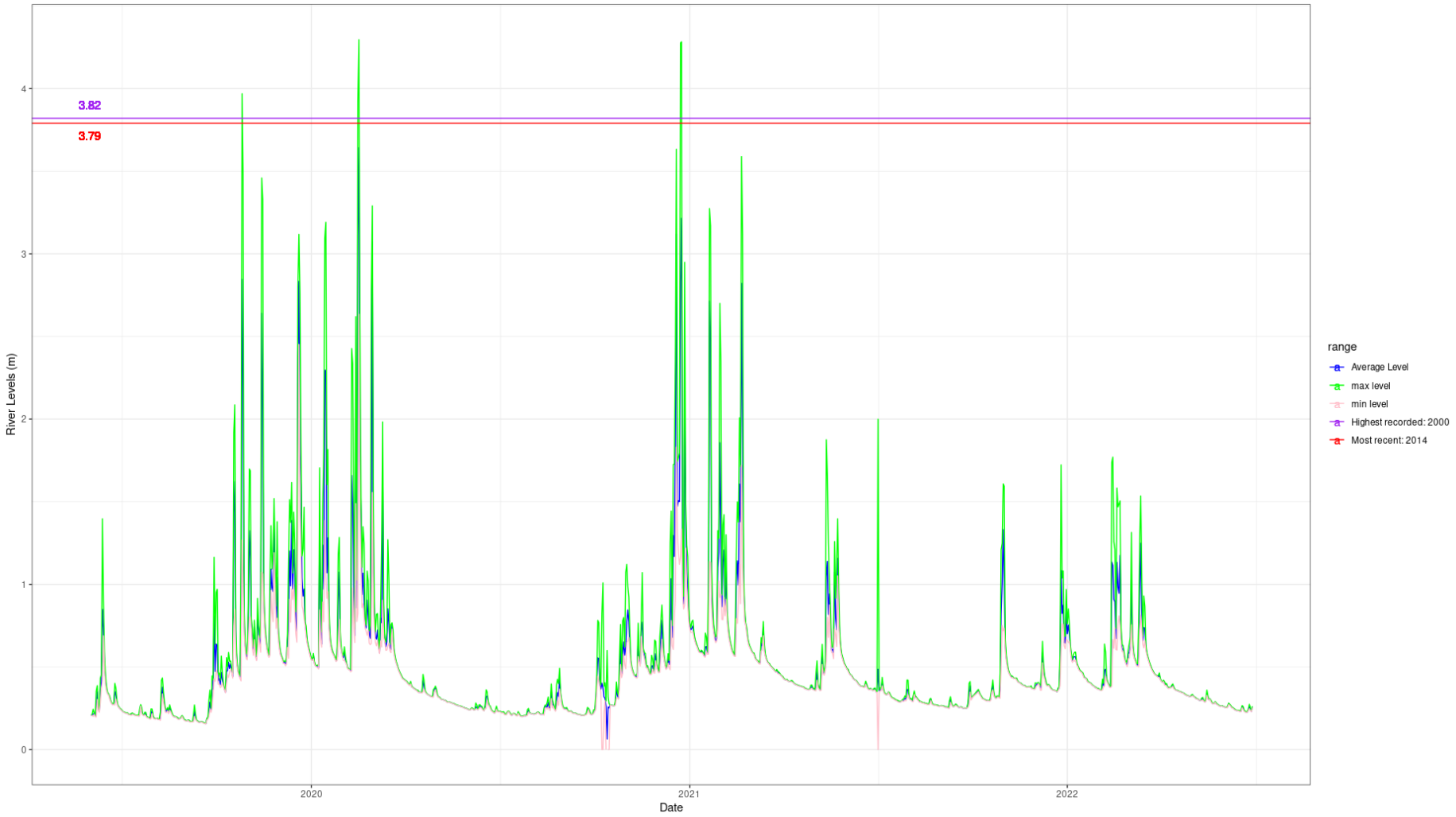


Figure 5.14: Trothy River levels between 1st June 2019 and 30th June 2022, whilst the Trothy flooded on multiple occasions, it broke its highest ever recorded levels on three separate dates, October 2019, Feburary 2020 and December 2020 (p 114)

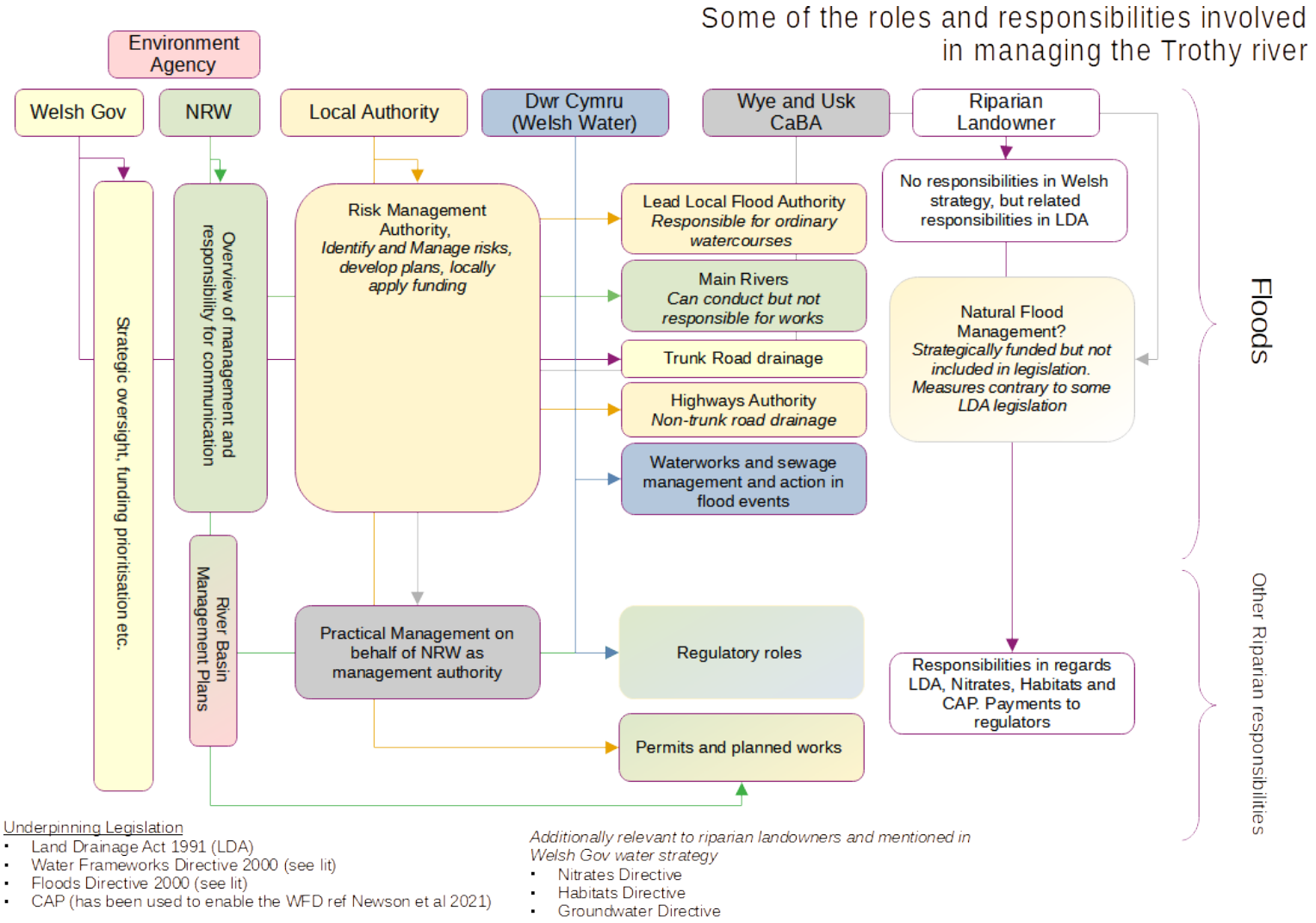
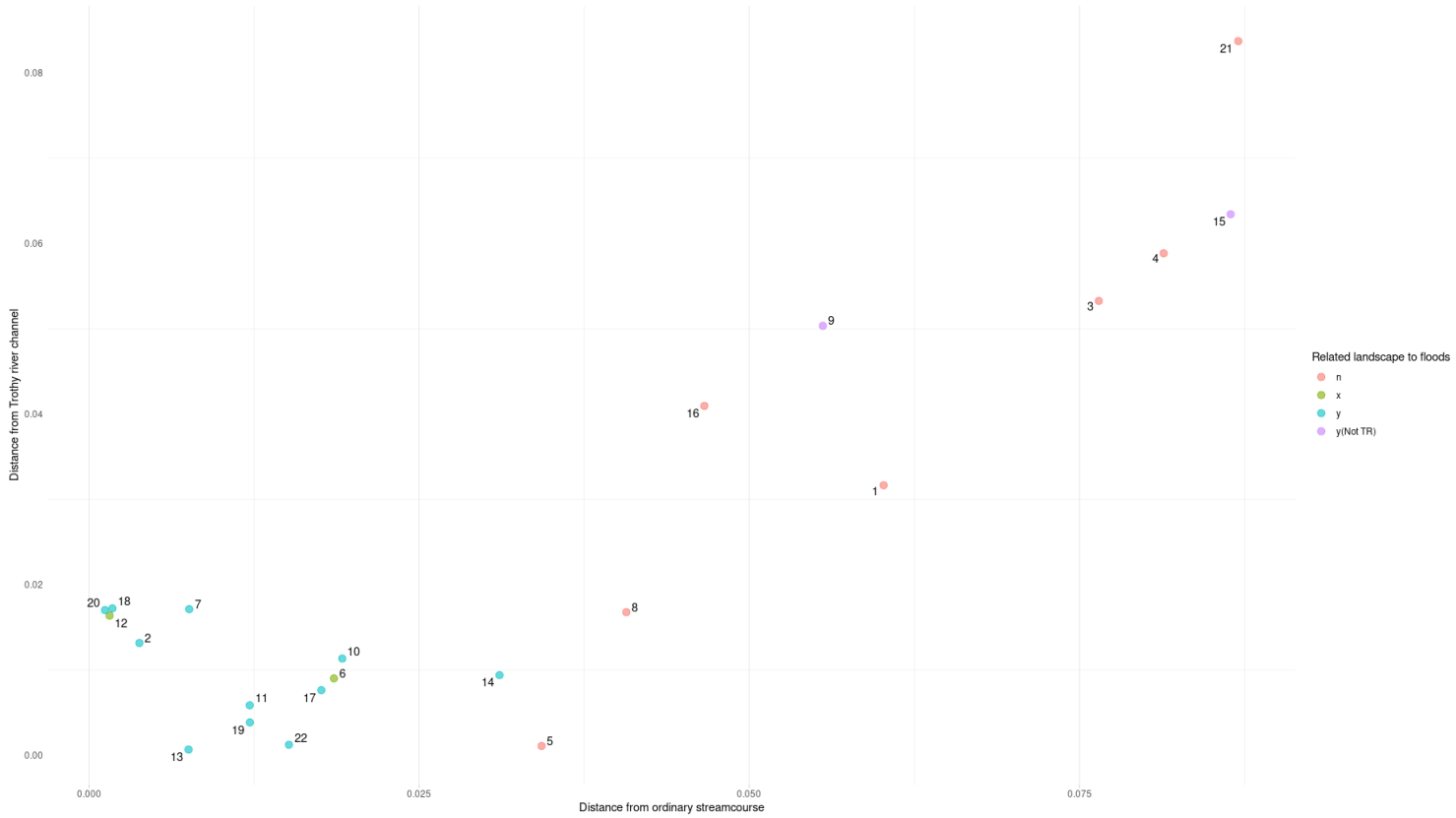


Figure 5.15: This figure maps some (but not all) of the relevant roles and responsibilities in decision making and management of the river. (p 115)

I.4 Chapter 6. Fieldwork

Furthest from river



Closest to river

Figure 8.2: Abstract showing the relationship between participants perception/narrative of the relationship between landscape and river, to the distance from and thus experience of the river itself. (p 190)

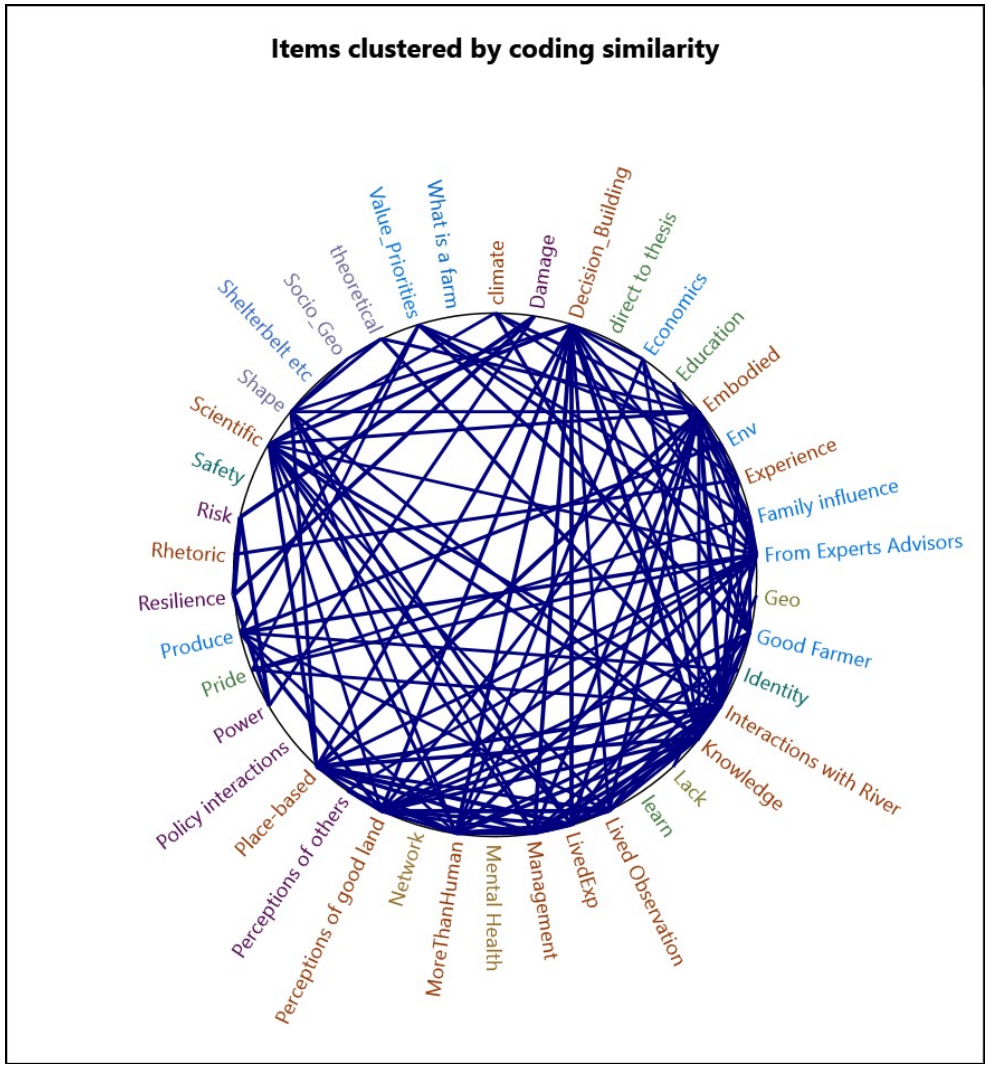


Figure 6.7: Network of intersecting codes
NVivo cluster analysis of codes for Harrys interview to demonstrate the complex web of narrative and decision making *(Jacquards coefficient at a lower limit of 0.6 for similarity)* (p 148)

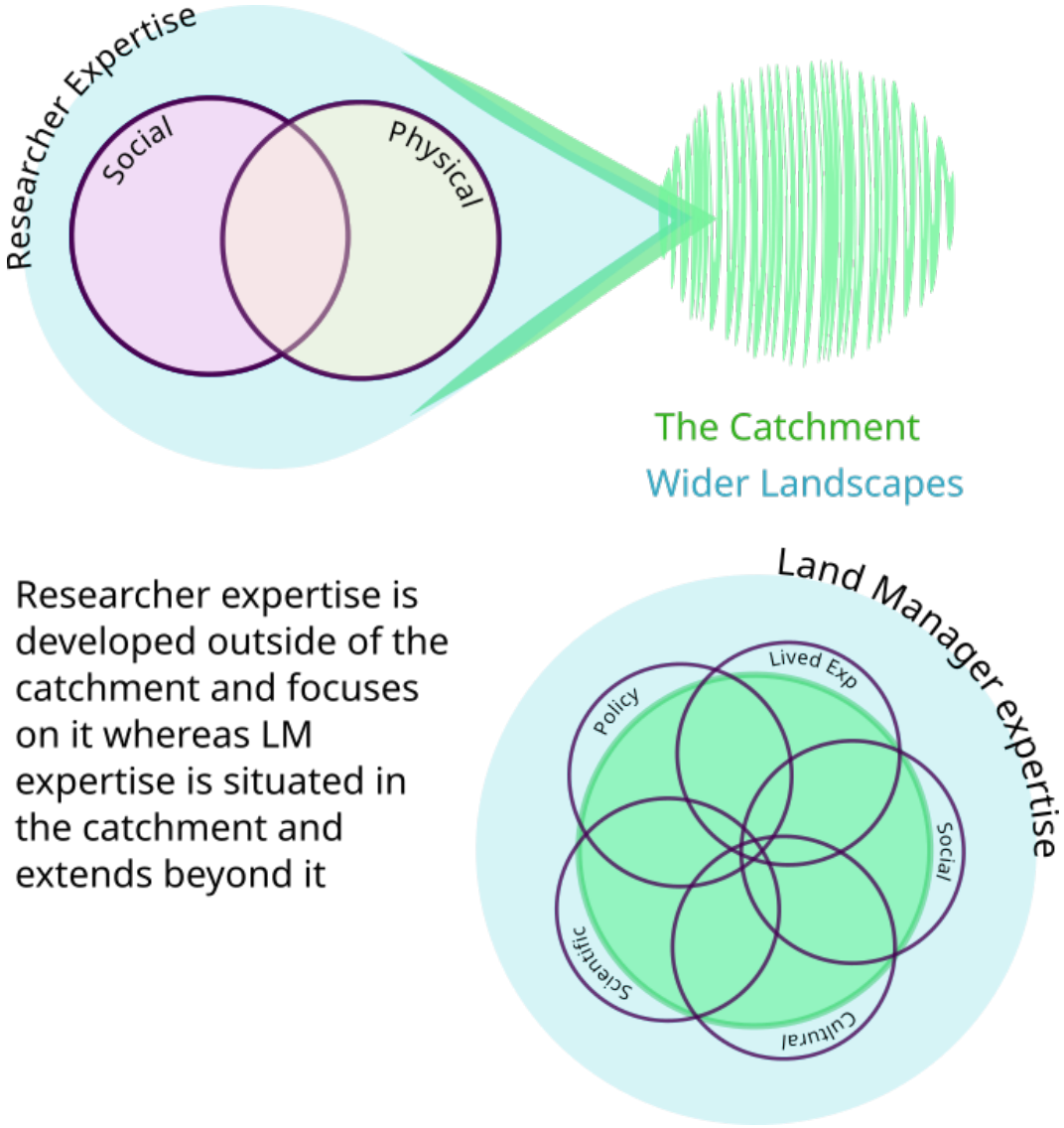


Figure ??: a visualisation of researcher and land manager expertise; how they are integrated and how they are framed. (p 156)

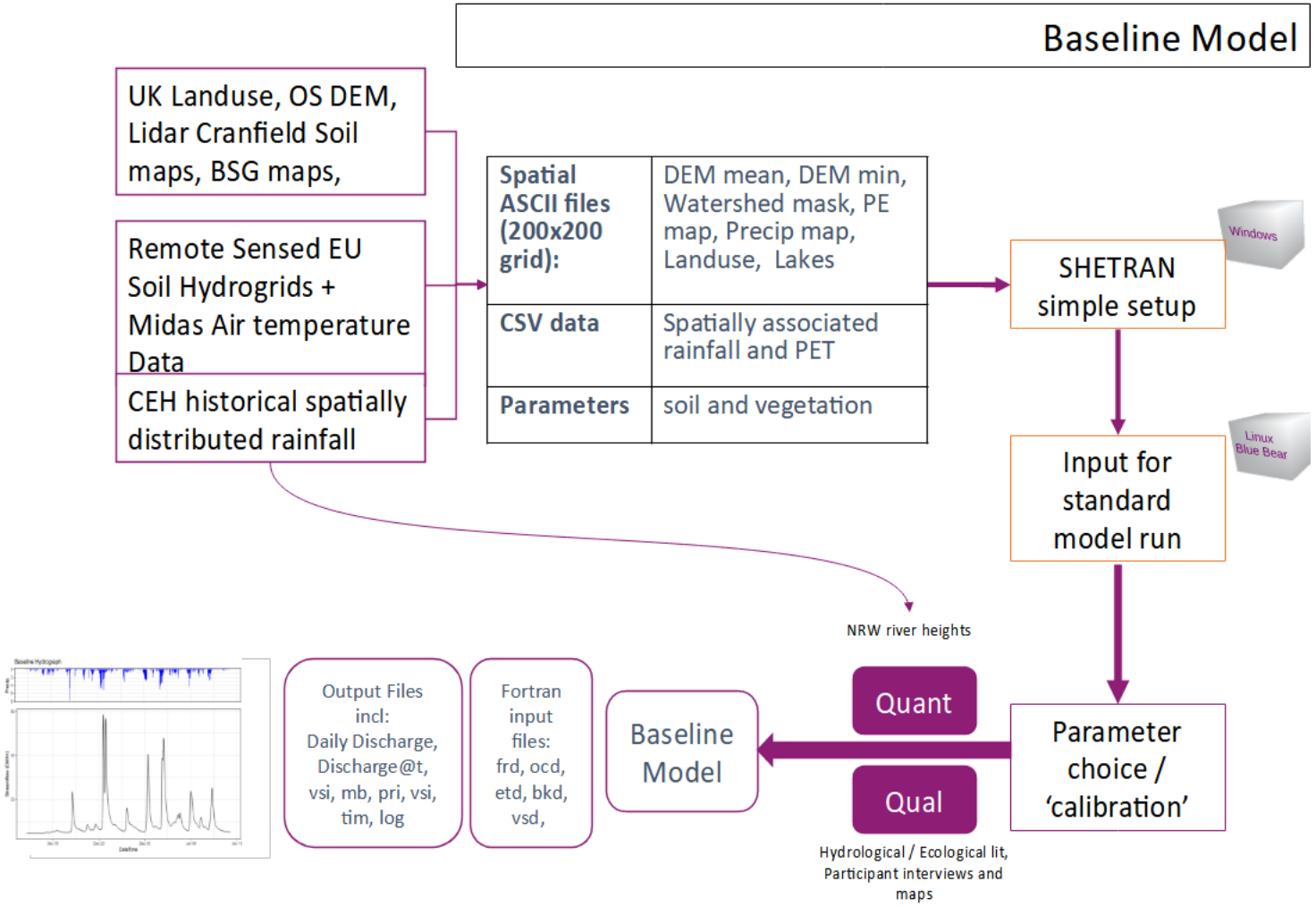


Figure 7.6: Workflow to develop the baseline model of the Trothy catchment 2013-2014 (p 180)

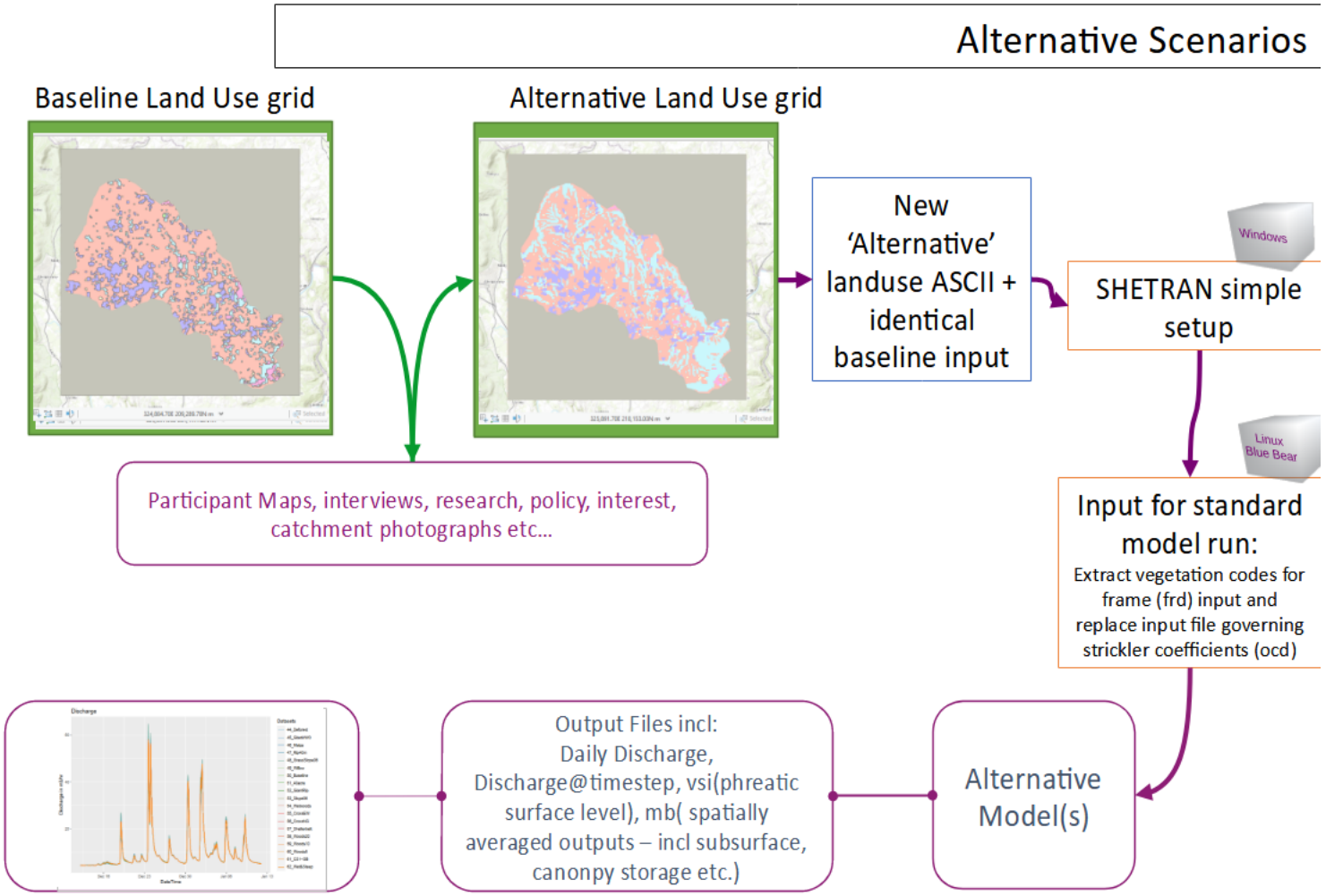


Figure 7.7: Workflow to develop the alternative landcover scenarios of the Trothy catchment (p 181)

I.6 Chapter 8. Models

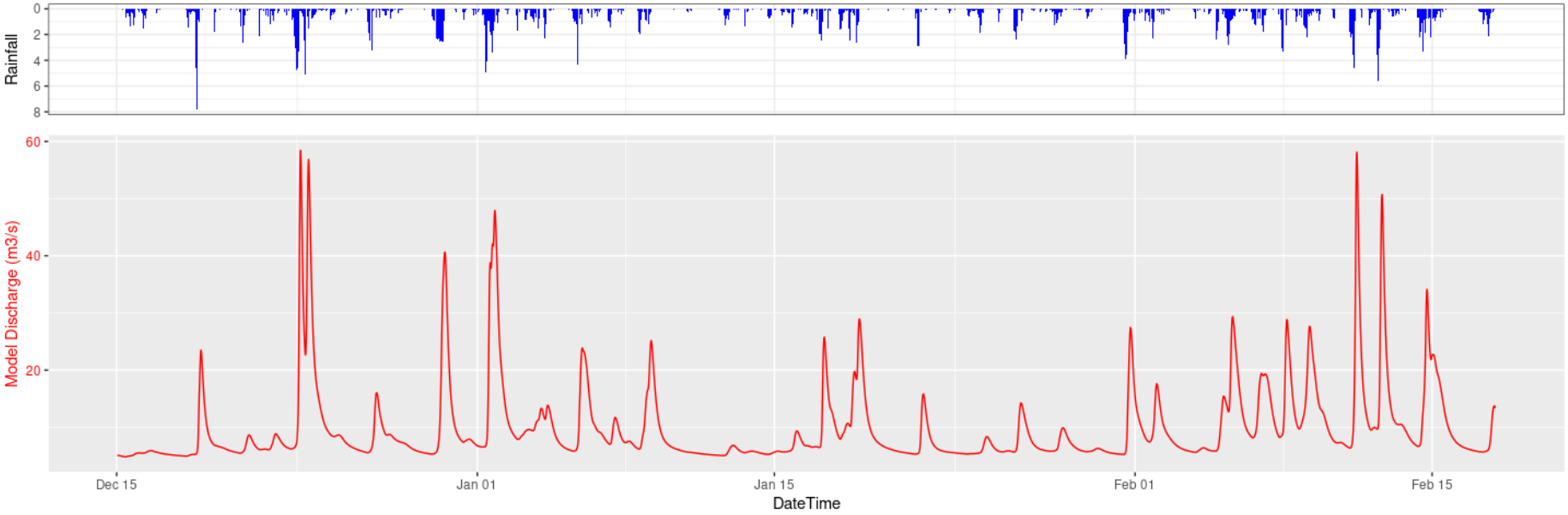


Figure 8.2: The Baseline Hydrograph for the evaluation period Dec 2013 - Feb 2014 (p 190)

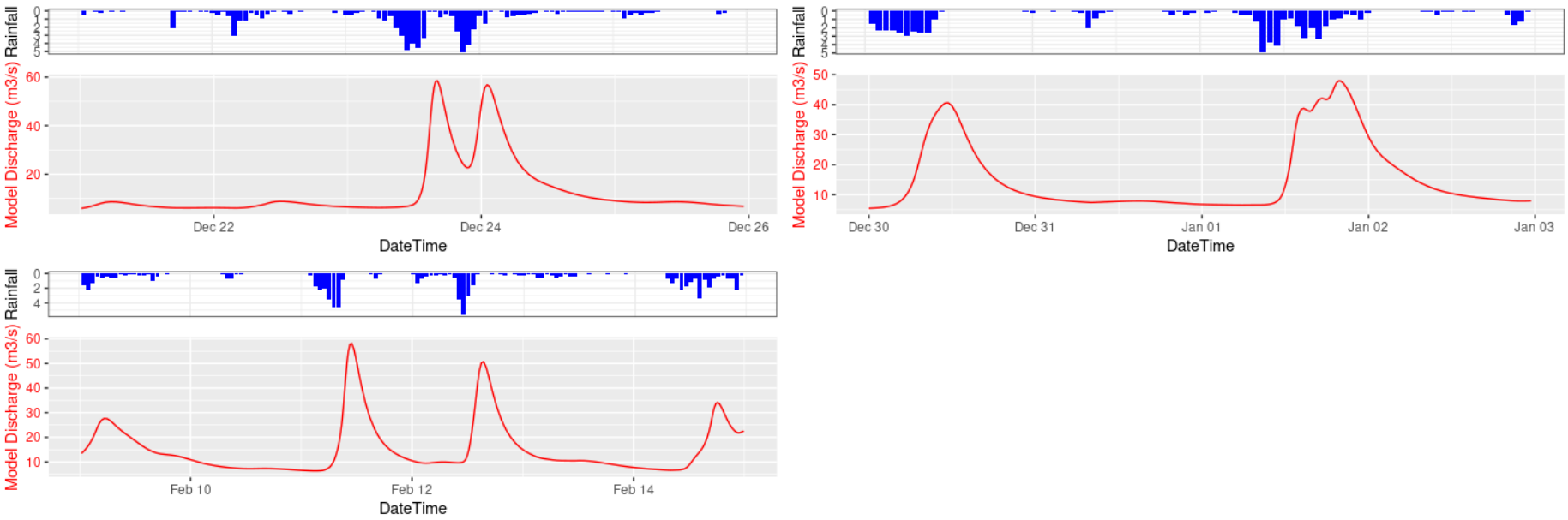


Figure 8.3: Baseline Hydrographs for the 2013-2014 flood events (p 190)

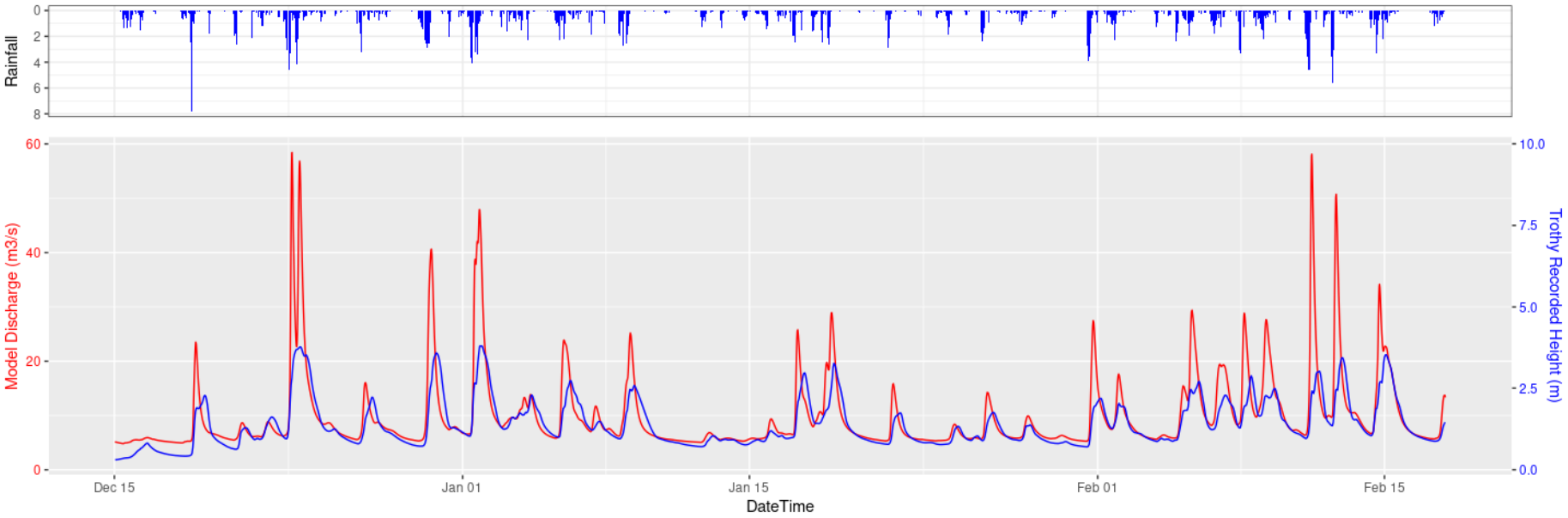


Figure 8.2: The Baseline Hydrograph overlaid with the observed NRW levels data (p 190)

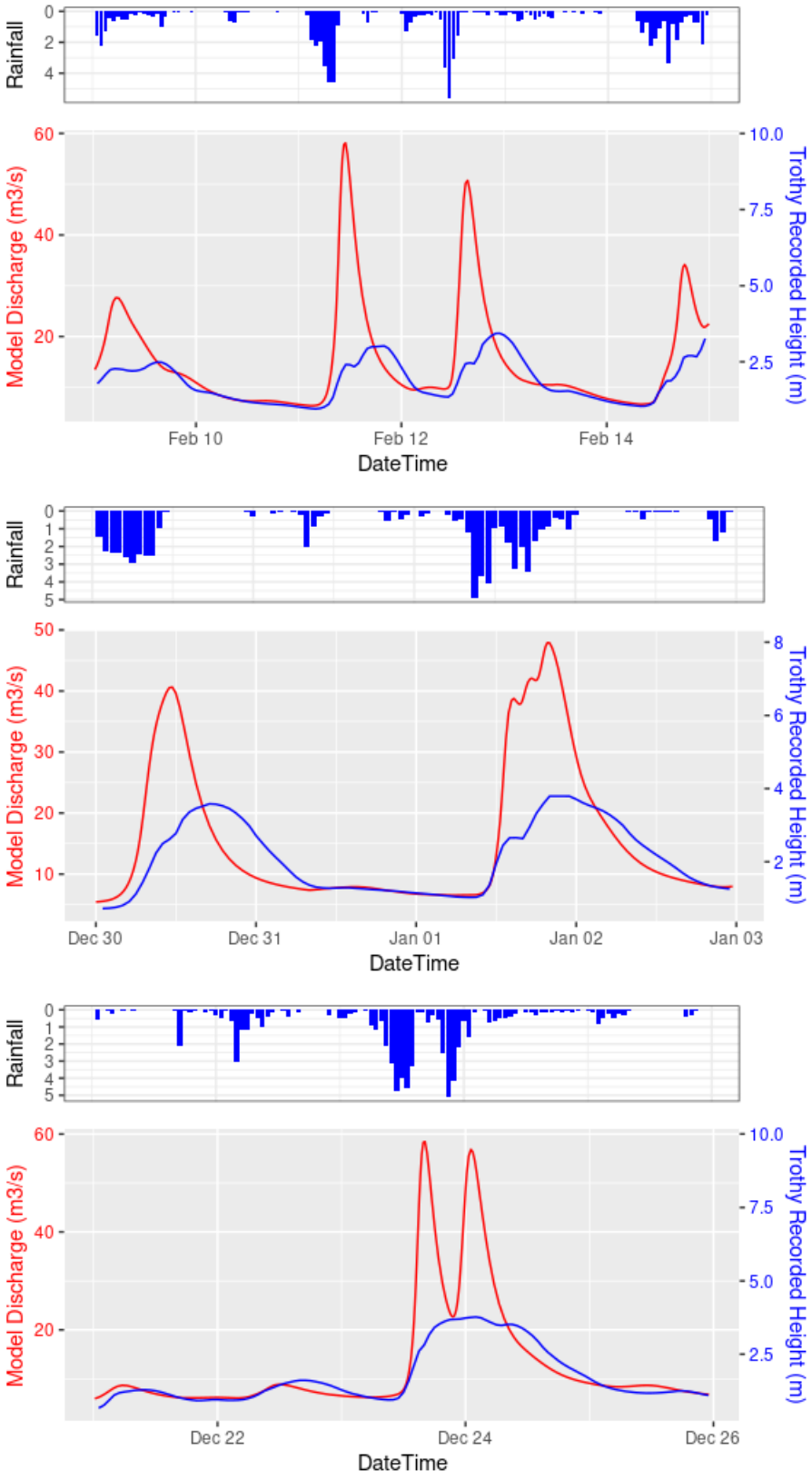


Figure 8.5: The Baseline Hydrograph overlaid with the observed NRW levels data for the flood events (p 192)

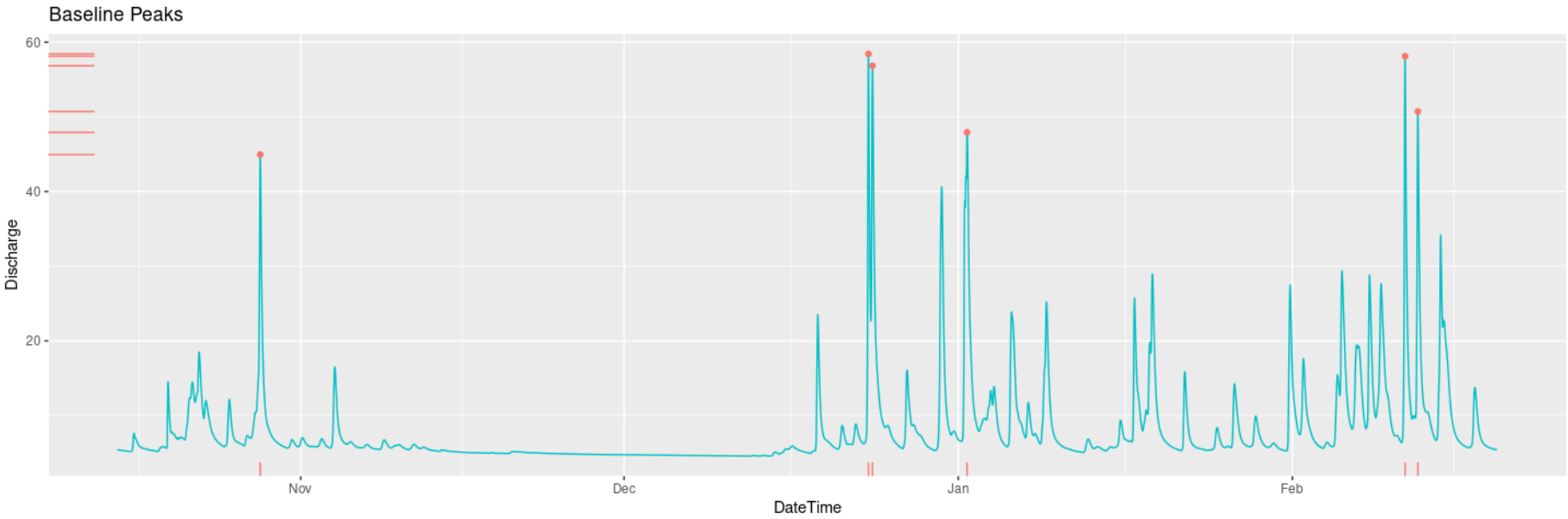


Figure 8.8: Shows the peak events, the flood events relate to the Christmas eve, New Year and February peaks (p 199)

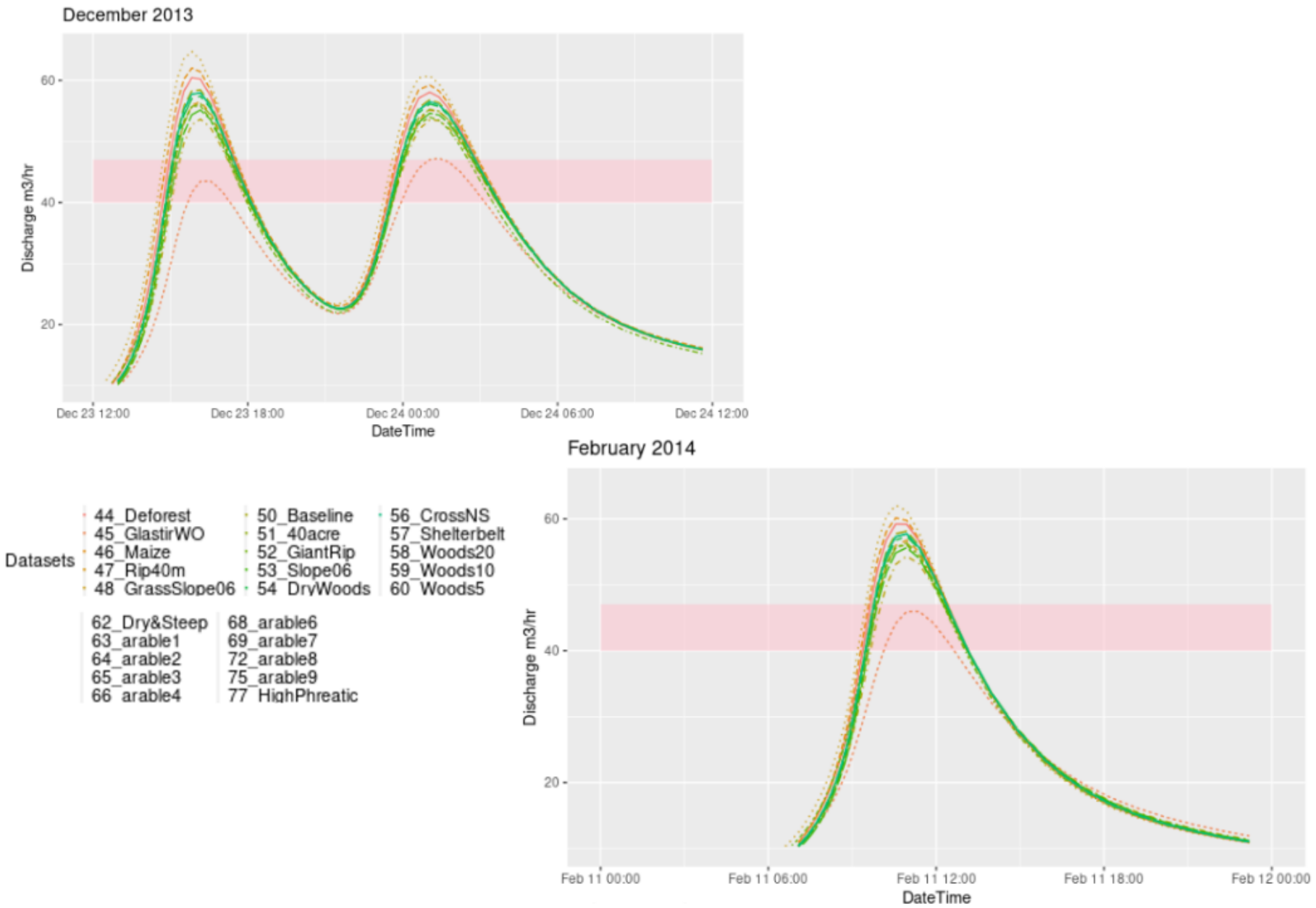


Figure 8.9: Flood event Discharge graphs for all model runs, with a band the range at which flooding may be expected to occur throughout the catchment (p 200)

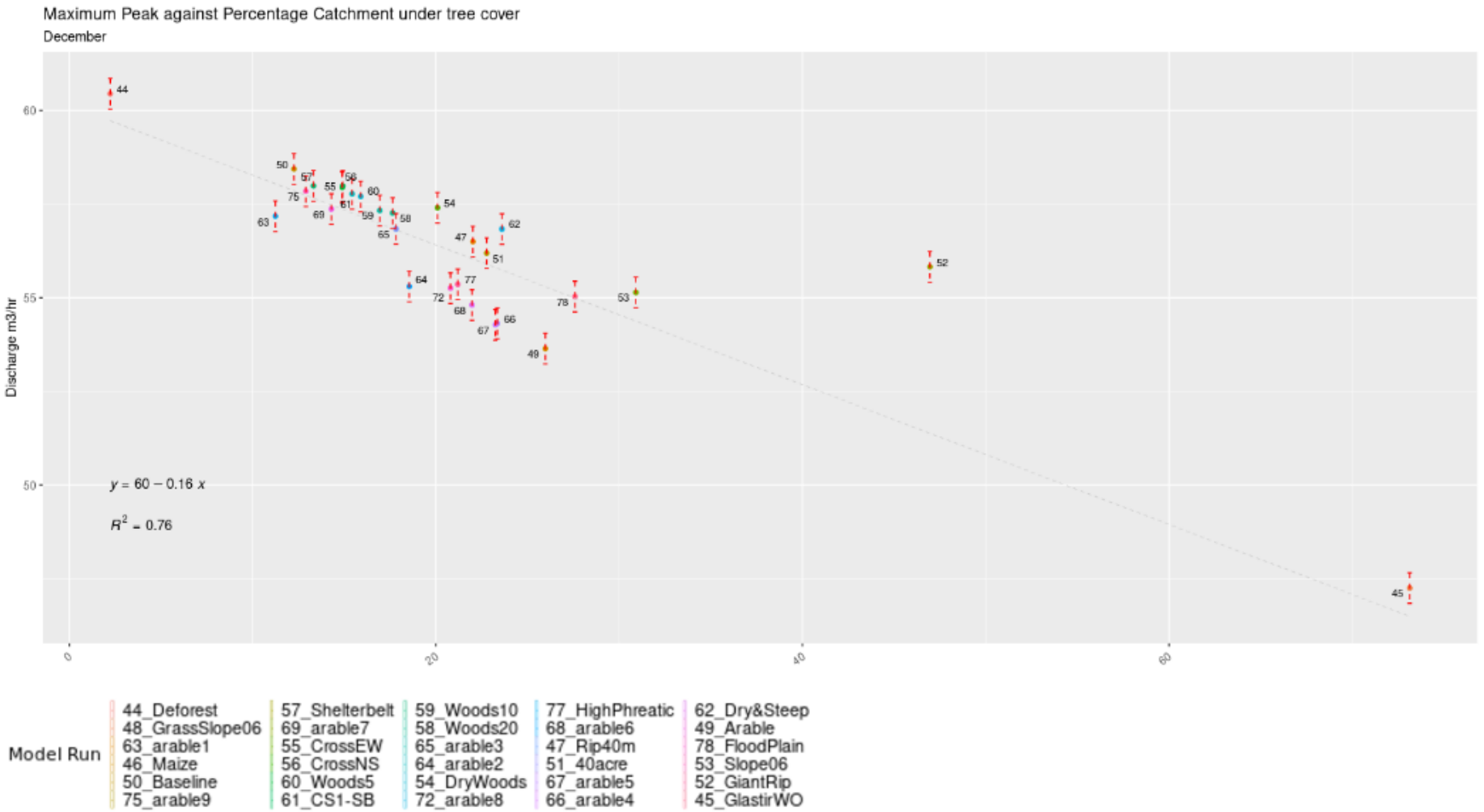


Figure 8.10: Graph showing the maximum discharge of each model run during the December flood, against the percentage catchment woodland cover of each model run (p 201)



Figure 8.11: shows the percentage change in discharge against woodland cover with the linear regression calculations for the December (largest flood event in Baseline) and taking the maximum of each model run from the December and February floods (p 204)

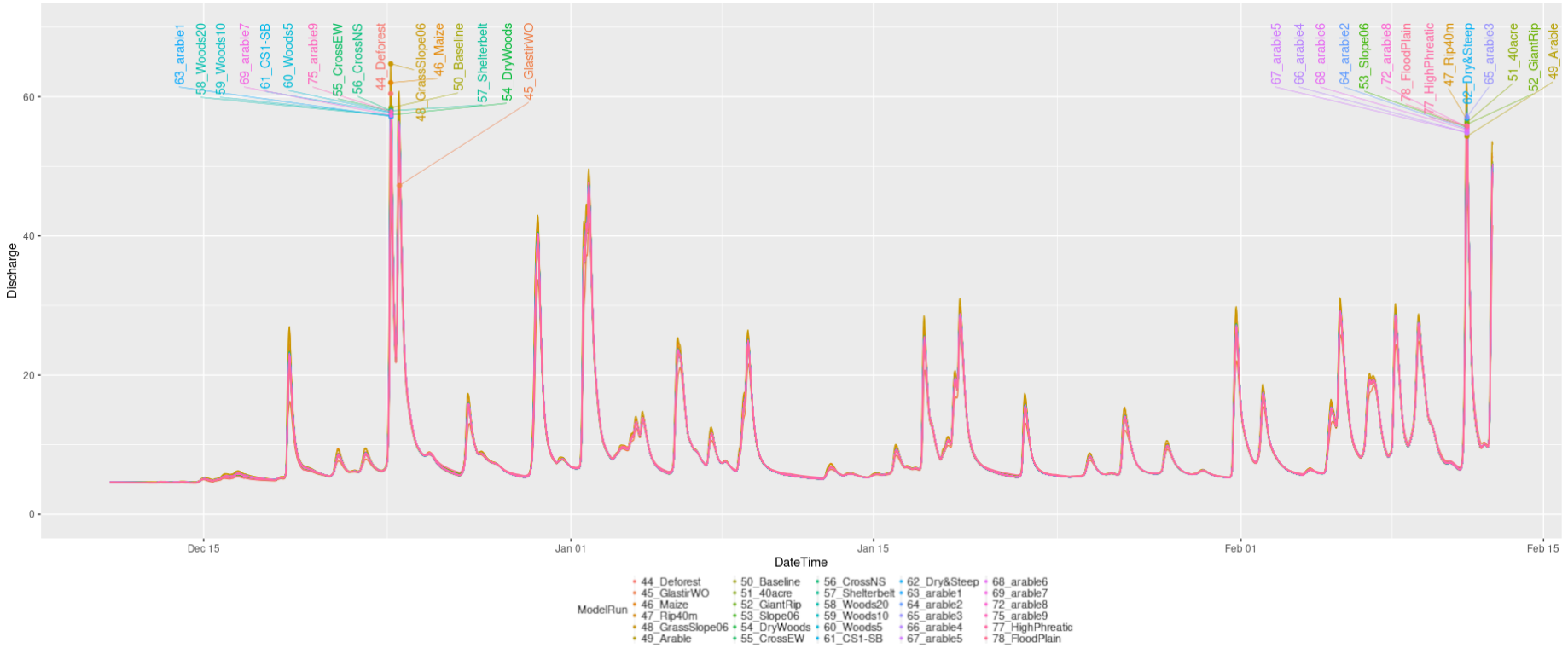


Figure 8.16: shows that different alternative scenarios changed when the maximum peak occurred, shifting from the relatively dry December to the more saturated event in February (p 209)

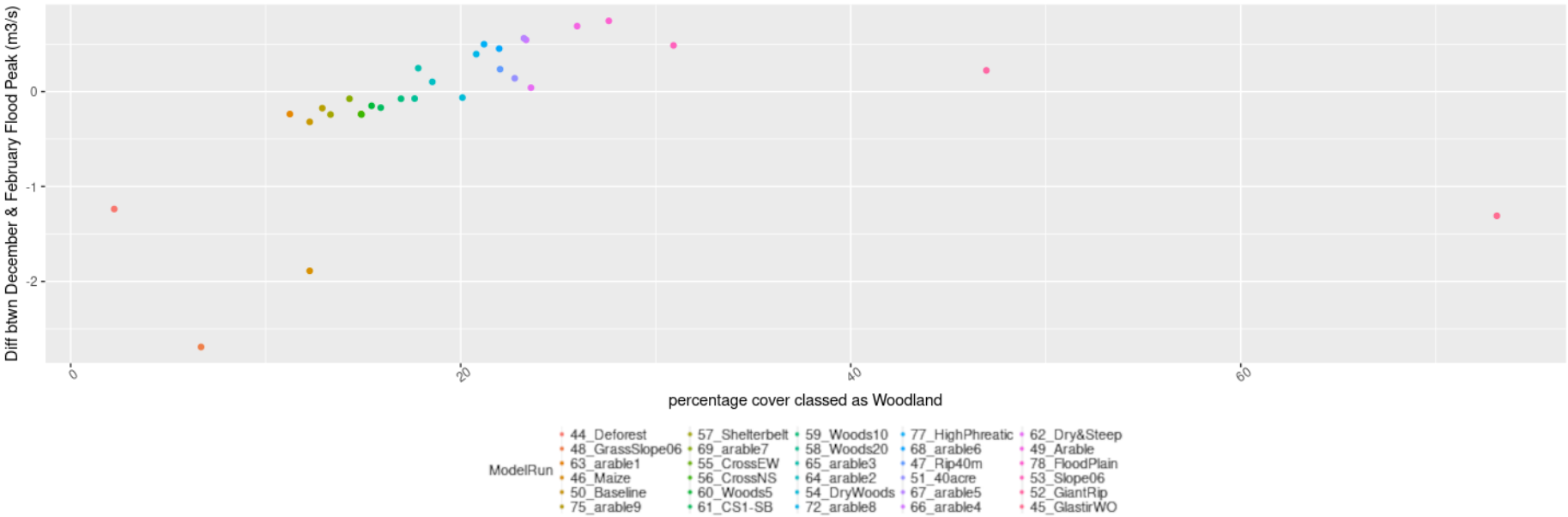


Figure 8.18: shows the difference between the December and Feburary peaks for each Model Run. This is plotted against the percentage woodland cover, appearing to show a shift to a February (saturated ground) maximum flood event at about 18-20% woodland cover, but that this effect is not consistent above 30% woodland cover (p 211)

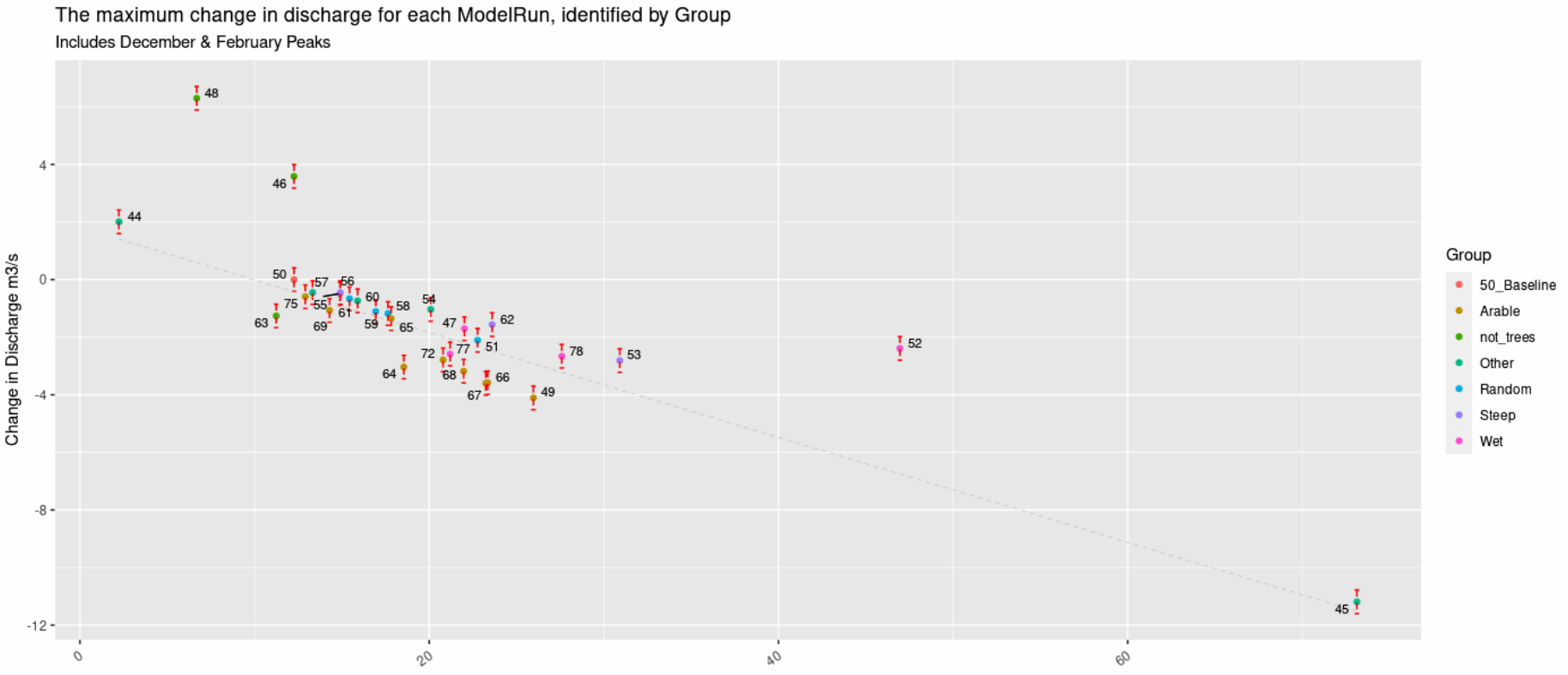


Figure 8.19: shows the maximum change in discharge for each model run identified by group (p 213)

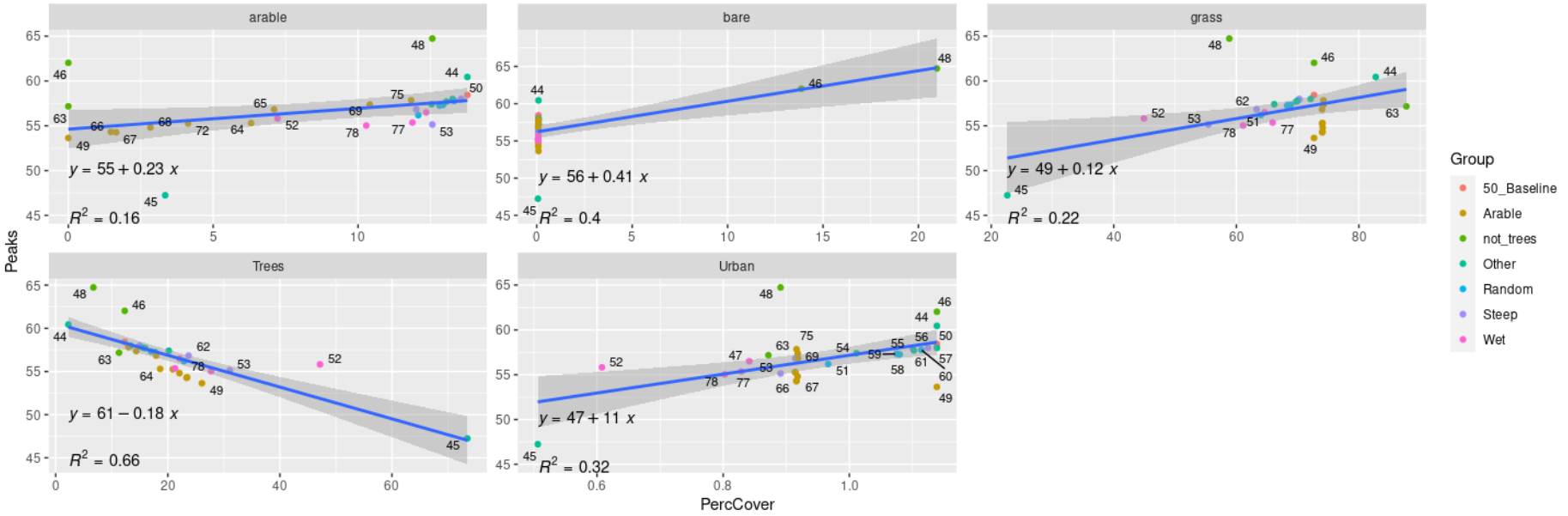


Figure 8.25: Plots discharge against percentage land cover for the largest other landcover codes used in the SHETRAN model runs (p 218)

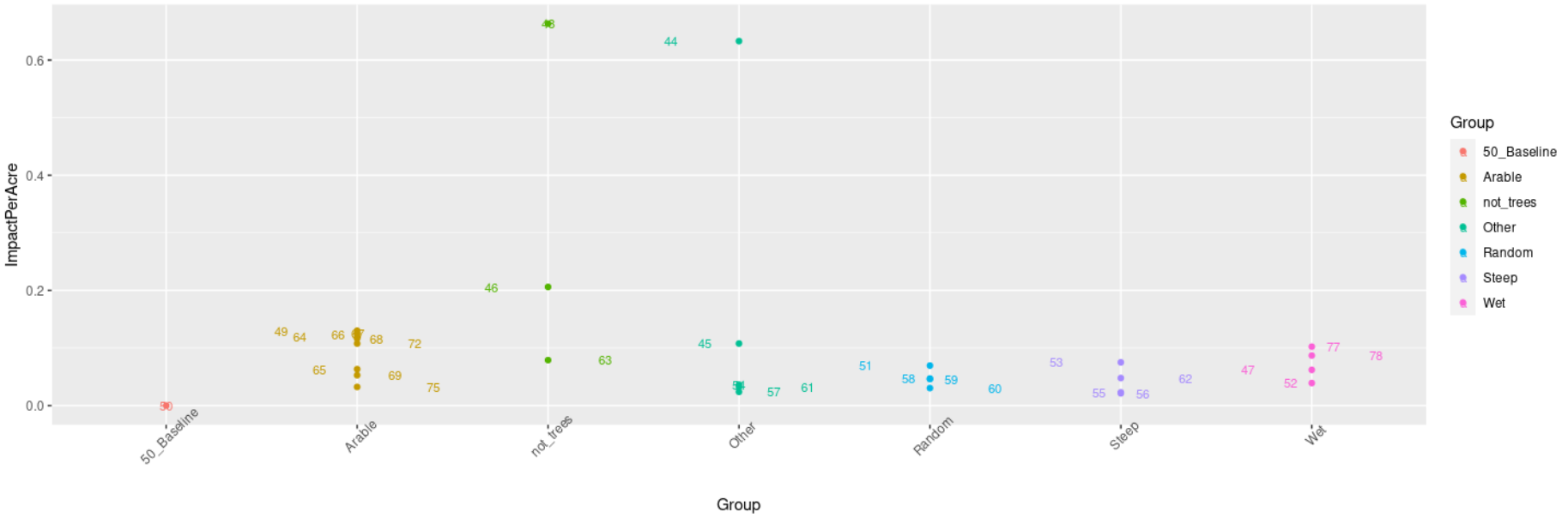


Figure 8.26: shows the Impact per Acre graph with the loss models added back in to the data (p 219)

I.7 Chapter 10. Workshops

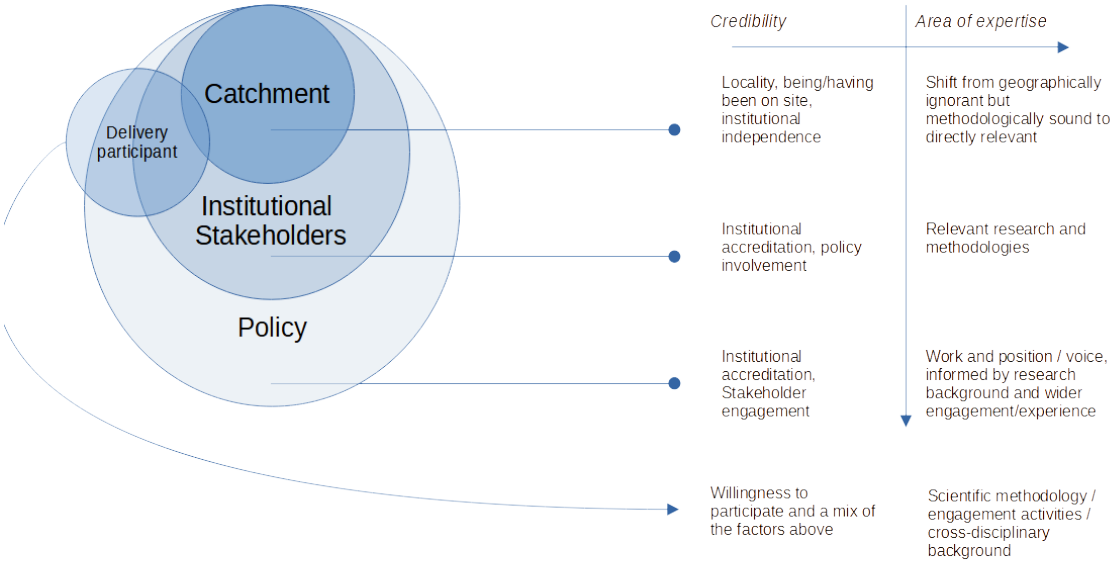


Figure 10.2: Intersecting social groups attribute and identify expertise differently (p 268)

I.8 Chapter 11. Synthesis

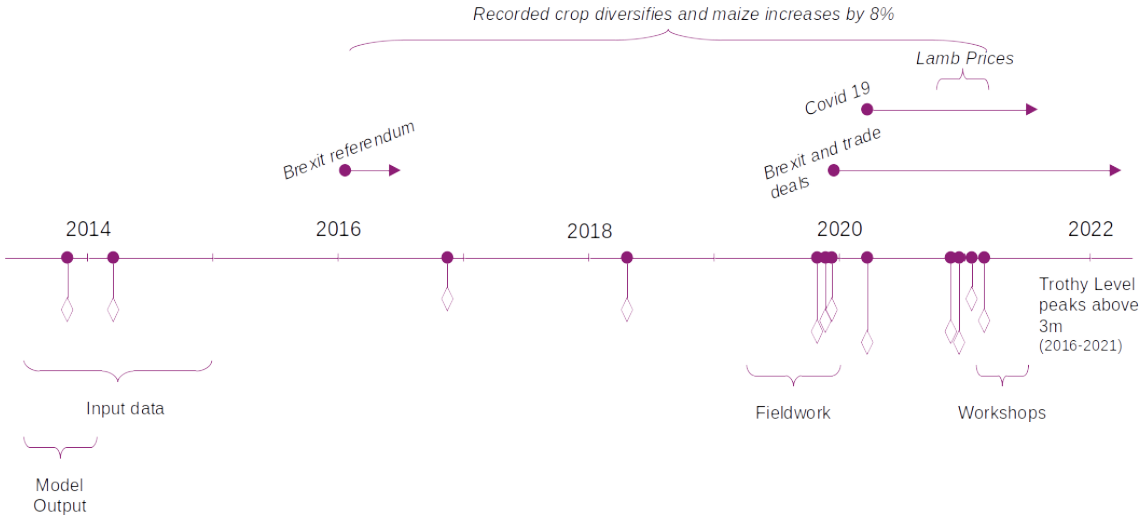


Figure 11.2: Timeline showing the data against selected historical and geographical context (p 276)

Appendix II: Remote sensed and Secondary data

Additional Data collection details

Dataset: Photographs
Targets: River characteristics, Wider catchment, detail on participant sites

Multiple site visits for observation of river characteristics and catchment were made, using public footpaths and agreed access to enable a broad overview of the river catchment. The abundance of public footpaths in the area meant access across the catchment was possible, however limited vehicle parking and access meant long walks and sturdy boots.

During participant interviews photographs were taken at suitable times to record key features or information being discussed, particularly where walking interviews took place. In cases where interviews took place 'at the farm table' the researcher would get permission to photograph key sites or features from the farmer and take these after the interview where necessary.

Visits to conduct drone photography were arranged separately and conducted primarily to view river vegetation and wider catchment characteristics. The Drone photography provided a different perspective to the visual images.

Equipment	GPS accuracy	Benefits	Disadvantages
Panasonic camera		Easy access, large storage, good accuracy of location of observer, waterproof and suitable for use in a range of weather conditions	Could be obtrusive during interviews, and researcher had to be careful not to affect the flow of conversation. Perspective limited to that of observer
OnePlus 3T		Easy access and reliably available to researcher, long battery life,	Insecure to use/carry on rough ground. Only suitable for generalised imagery due to uncertainty of location data. No use in the rain.
Mavic Mini Drone		Able to capture wider range of perspective and images than cameras fixed to observer position. Accuracy of GPS and spatial positioning means that images can be used as raster data for ecological / geomorphic landscape analysis	Limited battery life and storage, Limited suitability of locations (this goes beyond the legal requirements as there is a responsibility on behalf of the researcher to ensure no or minimal disruption to local livestock or wildlife) Cannot be flown in wet and windy weather.

Dataset: GPS locations and routes
Equipment: Garmin ETrex10 outdoors; Panasonic Lumix, GPS enabled; Mavic mini 3
Method:
On site visits GPS locations were taken and recorded. These were used to confirm the identification of key features and to locate walking routes. Despite the accuracy of these readings, given the aggregation of data for the modelling, this data was rarely used to input into the final analysis. The less accurate GPS data recorded by the camera was enough to locate key features on the maps. It did act however as a useful source for the researcher to check locations and has been recorded with the final dataset.
Combining this dataset with drone photography however provides an excellent dataset for ecological or geomorphic research and has significant future potential as a possible interdisciplinary tool where routes and images/videos taken by researcher and/or participant could then act as a focus for deep dive conversations with land owners/managers.

Dataset: River characteristics and flow

River flow measurements were planned for the spring of March 2020, with HRA (Appendix - Ethics) and methodology planned. However the Covid-19 pandemic stopped all data collection, and the site being across the Welsh/England border meant that the researcher was unable to conduct the flow measurements safely. Either Wales or England were in lockdown, or the second team member was unavailable (as this had to be a member of the researchers 'bubble' during significant periods of this year).

Secondary data sources

Dataset	Source	Reference	Copyright & References

River:

River height data	NRW - datadistribution@cyfoethnaturiolcymru.gov.uk https://riverlevels.uk/trothy-mitchel-troy-community-mitchel-troy#.YwYLvnYo_cs		Open Government Licence. Contains Natural Resources Wales information © Natural Resources Wales and database right. All rights reserved.
River flow data	NRFA	https://nrfa.ceh.ac.uk/data/station/meanflow/55022	The Licensor grants to the Licensee a non-exclusive, non-transferable, royalty free licence to Use the Data subject to the conditions below. The Licensor grants to the Licensee a non-exclusive, non-transferable, royalty free licence to use the API commercially and non-commercially subject to the conditions below. Your licence does not permit You to sub-license the API or the Data for any purpose. Acknowledgement: Data from the UK National River Flow Archive https://eidc.ceh.ac.uk/licences/nrfa-data-terms-and-conditions-for-api-access-to-time-series-data-and-metadata/plain

River Levels data was received from NRW data distribution (see notes below), this provided hourly data. In addition, long term average data was downloaded from Riverlevels.uk

Soils:

ESDAC:	https://esdac.jrc.ec.europa.eu/content/3d-soil-hydraulic-database-europe-1-km-and-250-m-resolution https://onlinelibrary.wiley.com/doi/full/10.1002/hyp.11203	Tóth, B., Weynants, M., Pásztor, L., Hengl, T. 2017. 3D Soil Hydraulic Database of Europe at 250 m resolution. Hydrol. Process., doi: 10.1002/hyp.11203.	Open Data Commons Open Database License (ODbL)
SoilGrids – soil depth (ISRIC	data retrieved 6.12.2020 from: https://soilgrids.org/#!/?lon=-2.8761922321727 41&lat=51.83915216369533&layer=ORCDRC_M_sl2_250m&vector=1&showInfo=1	Shangguan, W., Hengl, T., Mendes de Jesus, J., Yuan, H., & Dai, Y. (2017). Mapping the global depth to bedrock for land surface modeling. *Journal of Advances in Modeling Earth Systems*, *9*(1), 65–88. https://doi.org/10.1002/2016MS000686	This version of SoilGrids is available to you by ISRIC — World Soil Information under the CC-BY 4.0 License
Cranfield / LandIS Soils	https://www.landis.org.uk/soilsguide/soilscapes_list.cfm		Cranfield University 2022. *The Soils Guide*. Available: www.landis.org.uk.

Guides			Cranfield University, UK. Last accessed 24/08/2022
SHETRAN appendix data	https://research.ncl.ac.uk/shetran/Documentation.htm		
BSG	Using: EDINA Geology Digimap Service, <https://digimap.edina.ac.uk>, Downloaded: 2019-12-07 11:12:29.195	UK Hydrogeological Maps [SHAPE geospatial data], Scale 1:625000, Tiles: GB, Updated: 13 August 2010, BGS, DigMapGB-625 [SHAPE geospatial data], Scale 1:625000, Tiles: GB, Updated: 17 August 2010, BGS, DiGMapGB-50 [SHAPE geospatial data], Scale 1:50000, Tiles: ew214,ew215,ew232,ew233, Updated: 30 November 2016, BGS,	Free for commercial, research and public use. See http://www.bgs.ac.uk/about/copyright/acknowledgements_published.html for acknowledgement that must accompany the reproduced BGS material.

Extracted parameter data from ESDAC: Soil parameters for up to 2m. This data was checked against the ranges identified for soil types in the LandIS Soils guide.

Cranfield/LandIS online viewer was used as the guide to aggregate BGS polygons of the soil distribution in the catchment – linking the soil types to those identified in the Soilscapes soils guide.

As part of the calibration / parameter setting process the impact of a 9th layer – as a boundary to ground layer was selected using SHETRAN appendix values for deep soils

BSG data was used to check impacts of geology in area - not limestone important and maps to set parameters for 9th base to ground layer. Used soils parameters and details to check against the ESDAC data that parameters set were within suitable range for soil types.

Method

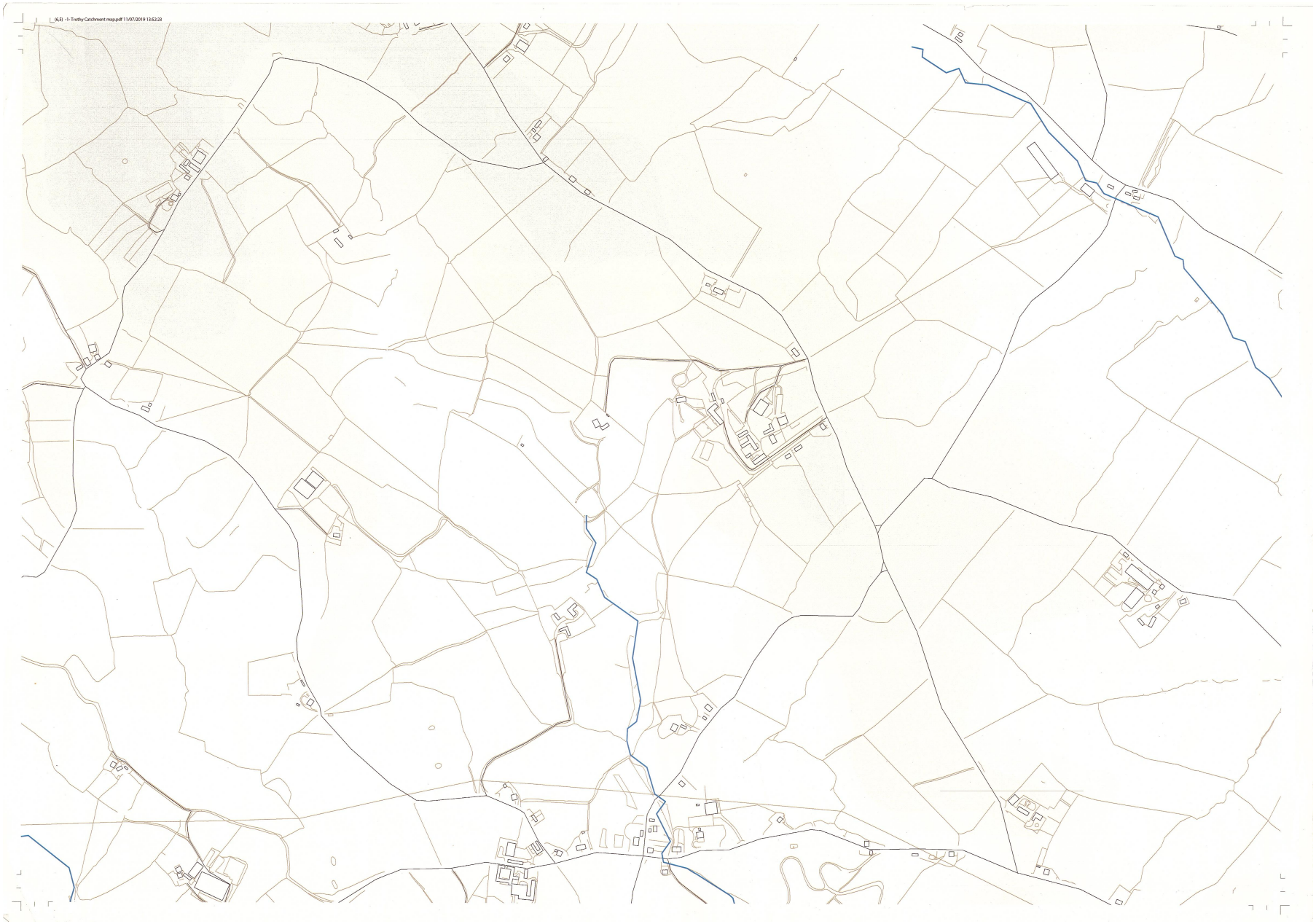
- Imported Raster Data for parameters and cropped to catchment
- Treated 0 - 30cm as topsoil data, and 60 - 2m as subsoil data (ref website and papers)
- Took a mean for topsoil and a mean for subsoil
- Aggregated to Cranfield polygons (the division by this was reflected in interviews, and supported by work in fields) using zonal statistics
- Extracted data to csv
- Checked parameters were within suitable ranges for catchment (reference BSG and Cranfield data)
- Added a 9th type across catchment - subsoil to 25m matching SHETRAN appendix values (supported in…) as a boundary to ground. (ref veronica / SB work)

Land Cover:

Land Cover	CEH Landcover data for 2015 accessed via digimap.edina research licence	DOI for LCM2015 25m raster data for Great Britain: 3) Rowland, C.S.; Morton, R.D.; Carrasco, L.; McShane, G.; O'Neil, A.W.; Wood, C.M. (2017) Land Cover Map 2015 (25m raster, GB). NERC Environmental Information Data Centre. https://doi.org/10.5285/bb15e200-9349-403c-bda9-b4300938o7c7 DOI for LCM2015 Vector data for Great Britain: 1) Rowland, C.S.; Morton, R.D.; Carrasco, L.; McShane, G.; O'Neil, A.W.; Wood, C.M. (2017) Land Cover Map 2015 (vector, GB). NERC Environmental Information Data Centre. https://doi.org/10.5285/6c6c9203-7333-4d96-88ab-78925e7a4e73	'LCM2015 © NERC (CEH) 2011. Contains Ordnance Survey data © Crown Copyright 2007, Licence number 100017572.'
DEM	OS terrain 5 dtm Under licence at digimap.edina	OS Terrain 5 [ASC geospatial data], Scale 1:10000, Tiles: so20ne,so21ne,so21se,so22se,so30ne,so30nw,so31ne,so31nw,so31se,so31sw,so32se,so32sw,so40ne,so40nw,so41ne,so41nw,so41se,so41sw,so42se,so42sw,so50nw,so51nw,so51sw,so52sw, Updated: 24 June 2019, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service, <https://digimap.edina.ac.uk>, Downloaded: 2019-11-21 12:32:02.744	Ordnance Survey Educational User licence © Crown copyright and database rights 2020 Ordnance Survey (*100025252*)
OS vector data	OS vector data Under licence at digimap.edina	OS Open Rivers [SHAPE geospatial data], Scale 1:25000, Tiles: GB, Updated: 18 October 2018, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service, <https://digimap.edina.ac.uk>, Downloaded: 2019-06-20 14:59:53.584 OS Open Map - Local [SHAPE geospatial data], Scale 1:10000, Tiles: so, Updated: 19 March 2019, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service, <https://digimap.edina.ac.uk>, Downloaded: 2019-06-20 14:59:53.584	Ordnance Survey Educational User licence © Crown copyright and database rights 2020 Ordnance Survey (*100025252*)
Inspire polygons	Gov.uk/land-registry	https://use-land-property-data.service.gov.uk/datasets/inspire/#conditions.	Open Government Licence. Under: these conditions © Crown copyright and database rights 2022 Ordnance Survey 100026316. This information is subject to Crown copyright and database rights [year of supply or date of publication] and is reproduced with the permission of HM Land Registry. The polygons (including the associated geometry, namely x, y co-ordinates) are subject to Crown copyright and database rights [year of supply or date of publication] Ordnance Survey 100026316.
Historic Maps	Historic maps Under licence at digimap.edinahttps://digimap.edina.ac.uk/help/copyright-and-licensing/historic_eula/	1:2 500 County Series 2nd Revision [TIFF geospatial data], Scale 1:2500, Tiles: monm-so3313-3,monm-so3314-3,monm-so3315-3,monm-so3316-3,monm-so3317-3,monm-so3318-3,monm-so3413-3,monm-so3414-3,monm-so3415-3,monm-so3416-3,monm-so3417-3,monm-so3418-3,monm-so3513-3,monm-so3514-3,monm-so3515-3,monm-so3516-3,monm-so3517-3,monm-so3518-3,monm-so3613-3,monm-so3614-3,monm-so3615-3,monm-so3616-3,monm-so3617-3,monm-so3618-3,monm-so3713-3,monm-so3714-3,monm-so3715-3,monm-so3716-3,monm-so3717-3,monm-so3718-3,monm-so3813-3,monm-so3814-3,monm-so3815-3,monm-so3816-3,monm-so3817-3,monm-so3818-3,monm-so3913-3,monm-so3914-3,monm-so3915-3,monm-so3916-3,monm-so3917-3,monm-so3918-3,monm-so4013-3,monm-so4014-3,monm-so4015-3,monm-so4016-3,monm-so4017-3,monm-so4018-3, Updated: 30 November 2010, Historic,	© Crown Copyright and Landmark Information Group Limited 2022. All rights reserved. (1980, 1920, 1960, 1970).

Appendix III: Participant Maps

Example of the A2 blank maps taken to participant interviews for PGIS (this location was not used). Maps include the OS buildings and field boundaries, and DEM data specified in Appendix II


(6,5) -I- Trothy Catchment map.pdf 11/07/2019 13:52:23

Appendix IV: Participant information

Table 1: Participant data

Site	Type	Code	Primary use of land	Secondary Use of Land	Size	Initially against trees	Would plant	size of plant	Knowledge of floods	Plant for NFM	Plant for other?	Preventing factors	Supporting factors	Format	Data	Map	Int	Wrkshp
1	farm	Frank & Tom	Food & Drink		300	y	y	1		n	y			Farm Table	y	n	y	
2	smh	Anne & Peter	Env	Food & Drink	15	n	y	3	y	y	y	meadow / env	Coppice, flood prevention, env, replace	Table & Walking	y	y	y	y
3	home + land	Michael	Food & Drink	Env	150	y	y	<1	n	n	y	regulations	personal non-natives (v small scale, individual trees)	walking	y	y	y	y
4	farm		Food & Drink		400	y	yn	<1		n	y	food production, lived experience of conifers	family influence (oak trees), replace	Onsite interview	Notes & consent / no recording	n		
5	Estate	Roger	Food & Drink		280 + 310	y	y	10-25acres + hedgerows	n	n	y	food production	steep slope slippage, hedgerows	Farm Table	y	y	y	
6	other	Barry	Product		18	y	yp	<1	n	y	y	space	family influence (orchard) and benefit	Walking	y	n	y	
7	Estate		Food & Drink		540	np	yn		y			Planted 4000 trees in 97	management and maintenance of riverbank	Walking	Notes & consent / no recording	n		
8	other	Morgan	Food & Drink		50	y	y	8	y	n	y	disease, climate on land,	usefulness of land, alder as windbreak	Walking	y	n	y	
9	farm	Jack	Amenity	Food & Drink	141	n	y	>40	yn	y	y	policy interaction / regulations	farm forest, orchard, shelterbelts	Walking & Table	y	y	y	y
10	home + land	Richard	Env	Food & Drink	40	n	y	25-30	y	n	y	Governance/Regulation	Env / economics / shape	Walking	y	n	y	
11	farm/other	Arthur	Food & Drink		130	n	y	?	n	n	y	Space	biofuel boiler, amenity, hens	Farm Table	y	y	y	
12	Engineer								y					Table & Walking	Notes & consent / recording	n		
13	farm	John	Food & Drink		150	y	y	10		n	y	quality of land	understory planting Ash / management and maintenance		y	y	y	
14	farm	David and Jane	Food & Drink		400	y	y	25-30	y	n	y	Monoculture / observation of disease	neighbours amenity woodland /son's influence / steep ground		y		y	
15	farm	Harry	Food & Drink		550 total	y	n		n (y Lugg)			tenant farmer / SSSI	Shelterbelts and steep slope woodland retained / required and well managed		y		y	
16	farm	Cliff and Beth	Food & Drink		300	yn	y	10	y	y	y	150 acres rented land, requirements for farm practice, policy interaction	Env /improves farmland for main practice / water quality		y	y	y	
17	smh	Laura	Amenity	Food & Drink	13	n	y	<1	y	n	y	size and availability	amenity and guests	Farm Table and walking	y	n	y	
18	farm	Brigit and Arthur	Food & Drink		60	n	y	<10	y	y	y	land for food	interactions with river, erosion, hedgerows	Walking and Farm Table	y	y	y	
19	Estate	Matthew	Food & Drink	Amenity	1200 & 180	ny	y	>40	y	y	y	use of space / farmland	env, history; wider benefits		y	y	y	y
20	smh	Gareth	Amenity	Food & Drink	13	y	y	<1	y	n	y	usefullness, small acreage, knowledge	family amenity / hedgerows	Farm Table	y	y	y	
21	NGO		Amenity			n	y	!=	y	y	y	Ownership of land / Brecon Beacons NP and visual line of mountain	Actively planting / managing land for woodland and would like opportunity to buy more land to expand woodland.		email			
22	Estate	Catherine & Mark	Amenity	Food & Drink	>1000	ny	y	<20	y	y	y	shape / amenity of golf course	community involvement, improvements to course	Farm Table & walking	y	y	y	
23	*Farm*	*Lucy*	*Food & Drink*												*y*			*y*
24	*Woodland*	*Pat*	*Env*															
25	*farm*	*Meg*	*Food & Drink*	*Training*											*email only*			*np*

Appendix V: Ethics Approval and HRA documentation

Updated 25/02/15

UNIVERSITY OF BIRMINGHAM
APPLICATION FOR ETHICAL REVIEW

Who should use this form:

This form is to be completed by PIs or supervisors (for PGR student research) who have completed the University of Birmingham's Ethical Review of Research Self Assessment Form (SAF) and have decided that further ethical review and approval is required before the commencement of a given Research Project.

Please be aware that all new research projects undertaken by postgraduate research (PGR) students first registered as from 1st September 2008 will be subject to the University's Ethical Review Process. PGR students first registered before 1st September 2008 should refer to their Department/School/College for further advice.

Researchers in the following categories are to use this form:

1. The project is to be conducted by:
   - staff of the University of Birmingham; or
   - postgraduate research (PGR) students enrolled at the University of Birmingham (to be completed by the student's supervisor);
2. The project is to be conducted at the University of Birmingham by visiting researchers.

Students undertaking undergraduate projects and taught postgraduate (PGT) students should refer to their Department/School for advice.

NOTES:

- An electronic version of the completed form should be submitted to the Research Ethics Officer, at the following email address: aer-ethics@contacts.bham.ac.uk. Please **do not** submit paper copies.
- If, in any section, you find that you have insufficient space, or you wish to supply additional material not specifically requested by the form, please it in a separate file, clearly marked and attached to the submission email.
- If you have any queries about the form, please address them to the Research Ethics Team.

X Before submitting, please tick this box to confirm that you have consulted and understood the following information and guidance and that you have taken it into account when completing your application:

- **The information and guidance provided on the University's ethics webpages (https://intranet.birmingham.ac.uk/finance/accounting/Research-Support-Group/Research-Ethics/Ethical-Review-of-Research.aspx)**
- **The University's Code of Practice for Research (http://www.as.bham.ac.uk/legislation/docs/COP_Research.pdf)**

UNIVERSITY OF BIRMINGHAM APPLICATION FOR ETHICAL REVIEW	*OFFICE USE ONLY:* Application No: Date Received:

1. TITLE OF PROJECT

Forest, Flood and Farmer: Exploring perceptions and preferences of landscapes and how these might impact planting trees for Natural Flood Management

2. THIS PROJECT IS:

University of Birmingham Postgraduate Research (PGR) Student project x

3. INVESTIGATORS

a) PLEASE GIVE DETAILS OF THE PRINCIPAL INVESTIGATORS OR SUPERVISORS (FOR PGR STUDENT PROJECTS)

Name: Title / first name / family name	Dr Simon Dixon
Highest qualification & position held:	PhD Lecturer in Geography
School/Department	LES: Geography
Telephone:	
Email address:	[redacted]

Name: Title / first name / family name	Dr Steven Emery
Highest qualification & position held:	PhD Lecturer in Environment and Society
School/Department	School of Geography, Earth and Environmental Sciences
Telephone:	[redacted]
Email address:	[redacted]

b) PLEASE GIVE DETAILS OF ANY CO-INVESTIGATORS OR CO-SUPERVISORS (FOR PGR STUDENT PROJECTS)

Name: Title / first name / family name	
Highest qualification & position held:	
School/Department	
Telephone:	
Email address:	

c) In the case of PGR student projects, please give details of the student

Name of student:	Jennifer Knight	Student No:	
Course of study:	PhD Geog and Env Sci FT	Email	[redacted]
Principal			

4. ESTIMATED START OF PROJECT Date: May 2019

ESTIMATED END OF PROJECT Date: August 2022

5. FUNDING

List the funding sources (including internal sources) and give the status of each source.

Funding Body	*Approved/Pending /To be submitted*
Leverhulme Trust & University of Birmingham	Leverhulme Scholar through the Forest Edge program: Approved

If you are requesting a quick turnaround on your application, please explain the reasons below (including funding-related deadlines). You should be aware that whilst effort will be made in cases of genuine urgency, it will not always be possible for the Ethics Committees to meet such requests.

6. SUMMARY OF PROJECT

Describe the purpose, background rationale for the proposed project, as well as the hypotheses/research questions to be examined and expected outcomes. This description should be in everyday language that is free from jargon. Please explain any technical terms or discipline-specific phrases.

I am an interdisciplinary researcher so my work is situated in both physical and human geography; specifically in the area of rural landscape studies and land-use change.

How do land-manager perceptions and preferences impact planning forested landscapes for Natural Flood Management.

The paradigm shift in political support for the benefits of forested landscapes sits alongside the changes in Flood Management since the 2007 disasters. There is increased funding for tree planting for Natural Flood Management (NFM) despite uncertain scientific evidence, with little data for efficacy in large sites or the impact of woodland management. NFM can be seen as a 'Wicked' problem and becomes an example where democratic discussion and 'extended peer communities' may be the relevant experts. However, current policy and planning is technocratic and teleological, a process to which has encountered significant 'social' barriers. This research starts with the 'social', examining perceptions of landscapes and how these inform Land Manager preferences. Focusing on a case study river catchment the research methodology will combine a phenomenological approach including walking interviews and participatory mapping, with a quantitative case study modelling the hydrologic and hydraulic behaviour (the flooding characteristics) of the river catchment in a known flood event. Alternative land-use identified alongside land-managers will be used to explore the impact of changes on this event. Questions the research tackles include:

- Can a qualitative understanding of lived experience explain the political behaviour and preferences of Land Managers when considering forested landscapes for NFM?
- Can 'socially' determined parameters be integrated into traditionally quantitative methodologies of planning for land-use change?
- How does farmer/ land manager knowledge and expertise inform the process of planning forested landscapes for NFM? Does involvement in this process affect the uptake and long-term planning of Land Managers?

Taking a strongly participatory approach and placing the Land Managers as 'expert' the research may also throw light on the efficacy of the current process of land-use planning.

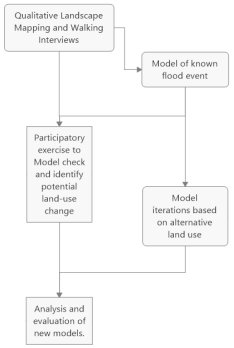
7. CONDUCT OF PROJECT

Please give a description of the research methodology that will be used

My research methodology is an interdisciplinary case study, taking a mixed methods approach: semi-structured walking interviews, participatory mapping, GIS modelling, participatory analysis.

Research will take place within a single river catchment: four potential case studies have been identified and the location will be confirmed on suitability criteria stipulated by both the physical and social requirements. These will include the availability of data required for the physical modelling of the hydrological behaviour of the catchment and access to participants

The research will involve multiple stages in order to incorporate online physical data with participatory social data from fieldwork. To clarify I have included a brief flow chart below



Stage 1A: will use participatory mapping to identify participants perception of their landscape and knowledge of the land use. This will be followed by a semi-structured walking interview around the landscape. The walking interview complements the mapping activity by emplacing the research, enabling access to site and the GPS recording of physical and social features identified during the mapping activity and including ones that may have been missed. Walking interviews have also been shown to improve relations and positionality of the researcher, placing the guide as expert and empowering participants.

Data collected/created will include the audio recordings and subsequent transcripts of activities and interviews. Co-created maps, Photographs, GPS data plots and annotations to maps that will be cross-referenced with the interview transcripts. Informed consent will be gained for all data collection (see below)

Stage 1B: This will involve the collection of data in regards the physical characteristics of the site and supplementing this with expertise of the land owners gained in the qualitative interviews in regards flood characteristics of the site.

Data collected/created: there is significant online data for the catchment areas proposed. The walking interviews in the first stage will also allow for 'ground truthing' features and GPS locations. Further physical data collection may be necessary for which HRA procedures will be followed. *A completed HRA form is attached, all known features of the catchments are covered by this form, however this will be updated if upon choice of catchment area additional risks are identified.*

Stage 2A: The depth of the third stage will depend on the data collected during the first stage. Both the first and second stages will follow the principles of a semi-structured interview, ensuring that all the 'themes' set by the researcher are covered. The way they are divided between the two sessions will depend on the level of expertise of the land managers. I have attached an interview schedule which includes the guiding questions that will be covered during the combined interviews – I have made clear where themes will fall in the first or second interview and have outlined themes which may be context dependent.

Context and/or local expertise may require the facilitation of access to external expertise through the means of a workshop or researcher provided contacts. This may be to support land managers awareness of different tree planting methods or styles. Contacts with the Forestry Commission, Woodland Trust, Confor etc. are actively supporting understanding of woodland creation. By accessing a range of 'experts' across the industrial and ecological areas a balanced input could be provided to participants. A note on positionality: the researcher must ensure, through discussion with participants, that they have access to expertise they are interested in, rather than just that deemed appropriate by the researcher.
During a workshop the researcher may take the part of 'participant observer', fulling informing all attendees of their position and obtaining written consent for any data collected. Data collected would include the researchers field diary.

Stage 3: Analysis and Evaluation. In addition to analysing data 'in the lab' participatory methods will be used. The method chosen will depend on social characteristics of the catchment. Method A: a focus group discussion (*a separate consent form that is specific to workshop/focus group situations has been included and is discussed below)*. Method B: Some participants may wish to comment on the maps/models outside of a group scenario which could be facilitated by email / annotations, a further 'interview' with the researcher.

8. DOES THE PROJECT INVOLVE PARTICIPATION OF PEOPLE OTHER THAN THE RESEARCHERS AND SUPERVISORS?

Yes **x**

Note: 'Participation' includes both active participation (such as when participants take part in an interview) and cases where participants take part in the study without their knowledge and consent at the time (for example, in crowd behaviour research).

If you have answered NO please go to Section 18. If you have answered YES to this question please complete all the following sections.

9. PARTICIPANTS AS THE SUBJECTS OF THE RESEARCH

Describe the number of participants and important characteristics (such as age, gender, location, affiliation, level of fitness, intellectual ability etc.). Specify any inclusion/exclusion criteria to be used.

Participants will be selected based on their association with the river catchment chosen for the case study. Participants will live and/or work within the catchment ideally with a responsibility for land management/land-use. The number of participants will be determined by uptake and the size of the catchment, I will be aiming for around 25 – 40 participants in total as multiple data collection will be taking place.

Other than this there is no other specific criteria other than that participation will not include any vulnerable groups and the participants have to be over 18. There will be a mix of gender, age fitness level, and educational background.

10. RECRUITMENT

Please state clearly how the participants will be identified, approached and recruited. Include any relationship between the investigator(s) and participant(s) (e.g. instructor-student).

Note: Attach a copy of any poster(s), advertisement(s) or letter(s) to be used for recruitment.

Recruitment of participants will use three approaches:

- Identification of contact through groups who work with land managers in the area including the Rivers Trust, EA and NFU. Followed by personal contact, a copy of the email to be sent to potential participants is attached.
- Personal contact using publicly available contact details: by identifying the location and name of farms from maps publicly available contact details (i.e. yellow pages) can be used to contact and recruit participants.
- Snowball sampling: through recommendation from other participants; as the focus of the case study is a single catchment area it is very likely that participants will have contact with each other and may be able to forward the researchers to additional participants.

11. CONSENT

a) Describe the process that the investigator(s) will be using to obtain valid consent. If consent is not to be obtained explain why**.** If the participants are minors or for other reasons are not competent to consent, describe the proposed alternate source of consent, including any permission / information letter to be provided to the person(s) providing the consent.

Informed consent will be gained from all participants from whom data is collected. All participants will be given a participant information sheet and consent form, and the purpose of these will be clearly explained. In some cases, verbal consent will be confirmed if interviews are held by phone or whilst in the field where a consent form would be impractical. The researcher will clearly explain the details in the consent form and will ensure that a copy is sent to the participant.

Confidentiality will be maintained in all published materials. In order to maintain appropriate levels of confidentiality during participatory analysis of catchment levels of annotation / labelling will be agreed with participants prior to researcher created models being shared with the wider catchment. This is clearly explained in the consent form (*attached)*

Two consent forms are attached, the second is relevant to any workshops or focus groups held during the period of time of the research to reflect the appropriate change in management of confidentiality.

Note: Attach a copy of the Participant Information Sheet (if applicable), the Consent Form (if applicable), the content of any telephone script (if applicable) and any other material that will be used in the consent process.

b) Will the participants be deceived in any way about the purpose of the study? **No x**

If yes, please describe the nature and extent of the deception involved. Include how and when the deception will be revealed, and who will administer this feedback.

12. PARTICIPANT FEEDBACK

Explain what feedback/ information will be provided to the participants after participation in the research. (For example, a more complete description of the purpose of the research, or access to the results of the research).

Participants will be given the opportunity to participate in the analysis and evaluation stage of the research. In addition, participants will be given a copy of co-created maps relating to their own properties and a summary of the findings upon the project completion. Generic maps giving an overview of the catchment that are used for the analysis will be available for the community to access.

13. PARTICIPANT WITHDRAWAL

a) Describe how the participants will be informed of their right to withdraw from the project.

The consent form will confirm that all participants will have a right to withdraw from the project up to three months after the collection of data or by November 2020, whichever date is earlier.

A deadline has been set as once the alternative models had been created it would be impossible to identify and withdraw data on characteristics that were across borders or applicable throughout the catchment.

b) Explain any consequences for the participant of withdrawing from the study and indicate what will be done with the participant's data if they withdraw.

There will be no consequences for they participant if they withdraw. If a participant withdraws from the study any data collected from that participant will be deleted in its entirety.

The consent form for the workshop / focus group will explain that withdrawal at this stage will involve the deletion of all data as is practically possible, as in some cases it may be difficult to ascertain who is speaking in recordings / transcripts. All personal or identifying data will be deleted.

14. COMPENSATION

Will participants receive compensation for participation?

i) Financial ☐ ☐ **No x**

ii) Non-financial ☐ **No x**

If **Yes** to **either** i) or ii) above, please provide details.

If participants choose to withdraw, how will you deal with compensation?

15. CONFIDENTIALITY

a) Will all participants be anonymous? **No x**

b) Will all data be treated as confidential? **Yes x**

Note: Participants' identity/data will be confidential if an assigned ID code or number is used, but it will not be anonymous. Anonymous data cannot be traced back to an individual participant.

Describe the procedures to be used to ensure anonymity of participants and/or confidentiality of data both during the conduct of the research and in the release of its findings.

All identifying data stored as hardcopy will be stored in a locked filing cupboard.
All identifying data stored digitally will be password protected.
These data will only be visible to the researchers until the project has concluded. On conclusion of the project the data will be stored in accordance with the 'Concordat on Open Data' as adopted by the University. Participants are fully informed of this in the consent form.

All published/open source data will use pseudonyms for any identifying personal data. Properties/farms will be categorised by type rather than name and given pseudonyms where appropriate.
The use of maps, particularly those that have been co-created by the participants and researchers will be carefully managed to maintain confidentiality:

- Maps hand drawn by participants: Confidentiality to be maintained by the redaction of any identifying labels for publication of data. Participants to agree in discussion of the researcher if any features should be redacted when data is made available through Open Source at the end of the project.
- Maps / models created by the researcher for analysis and evaluation: in order to carry out participatory research, maps of potential land-use change will be shared with other participants within the catchment. It is most probable that participants will know who owns/manages other areas of land. The researcher will ensure that confidentiality of manger views and input is maintained by generalising the information that is shared in maps that include participant data. The minimum requirement would include the 'hydrological roughness' or the areas of land, however levels of confidentiality in regards type, function and location of change will be discussed with the participants.
- Maps / models created by the researcher (or co-created with the participant) that are used for publication: confidentiality to be maintained by redacting identifying information and **specific** locations in published material. The catchment itself will be discussed in detail however 'regions' and 'types' will be identified and annotated rather than specific farms.

I shall conduct my research in accordance with the University of Birmingham 'Code of Practice for Research' and the University of Birmingham 'Code of Ethics'.
Confidentiality will be afforded unless in the circumstance of an 'adverse event' (an event arising in during the research in which harm is done or may be done to any parties; section 12 – Code of Practice), or in the event of a person in the interview being in significant and immediate danger, in which event I would inform the appropriate authority depending on circumstances.

If participant anonymity or confidentiality is not appropriate to this research project, explain, providing details of how all participants will be advised of the fact that data will not be anonymous or confidential.

16. STORAGE, ACCESS AND DISPOSAL OF DATA

Describe what research data will be stored, where, for what period of time, the measures that will be put in place to ensure security of the data, who will have access to the data, and the method and timing of disposal of the data.

Throughout the project hardcopy storage of data will be in a locked filing cabinet. Digital storage of data will be in a password protected folder, and backed up to a UoB secure server. I will retain auditable consent forms, co-created documentation including maps, and transcripts for publications following completion of the PhD. Relevant notes made in personal field journals will also be stored in this manner.
During transit after fieldwork data will be kept secure; electronic data will be kept on password secured usb or laptop. Hardcopy data including transcripts, personal notes/journal, consent forms, audio recordings will be kept on my person.

At the conclusion of the project I shall assess what research data should be retained.
In accordance with the University of Birmingham's data storage regulations, the retained data will be kept for ten years and may be used in future academic publications following the publication of the PhD thesis. After due process including further scrutiny by the supervisors and confirmation of confidentiality, the retained data will be made openly available in accordance with the 'Concordat on Open Data' as adopted by the University. Data will be deposited in a suitable repository. All data will be kept confidential and the researcher will maintain the rights to data sharing and use.

Participants will be informed at the beginning of the project that the intention is to make the data available as 'Open Data' on the conclusion of the project. This will be made explicit on the consent forms obtained *please see attached*.

Data Management Plan training has been booked for 12th March and the Plan will be completed before the end of March utilising DMPonline.

17. OTHER APPROVALS REQUIRED? e.g. Criminal Records Bureau (CRB) checks or NHS R&D approvals.

x NOT APPLICABLE

If yes, please specify.

18. SIGNIFICANCE/BENEFITS

Outline the potential significance and/or benefits of the research

This research has significant potential impact in regards:

- Improving our understanding of land managers preferences for tree planting in landscapes
- Improving our understanding of catchment/community and individual perceptions of water; its management and impact.
- Identifying barriers and pathways to land use change
- Collecting data that may continue to be used to examine the impact of land-use changes on flooding in a catchment scale context
- Improving our understanding of Land Owners / Managers relations with their landscapes
- Developing our knowledge of the impacts of land-use change
- Developing our knowledge of agricultural managers expertise and how this expertise may inform policy
- Impacting policy for both tree planting and Natural Flood Management
- Collecting data that may continue to be used to examine long-term land-use / land-use change

19. RISKS

a) Outline any potential risks to **INDIVIDUALS**, including research staff, research participants, other individuals not involved in the research and the measures that will be taken to minimise any risks and the procedures to be adopted in the event of mishap

Risks to participants

There are no vulnerable participants (all participants must over the age of 18), no 'sensitive' topics for data collection and walking interviews will take place on land which participants manage, work or live ensuring that they are comfortable and familiar in the environment.

There is a low risk of identification of participants and/or organisations through the publication of findings. This would be minimised using pseudonyms and coding of identifying data, as well as consent procedures.

There is a low risk of conflict within the community over land use choices. To minimise the this the following precautions will be maintained:

- Levels of inclusion of sensitive, or information perceived as sensitive on maps to be agreed with participants before maps are shared with the community,
- focus groups / workshops held only if appropriate within the community environment
- participants aware that participation is fully voluntary in any of the stages of research and consent / withdrawal procedures as described

The project will be dealing with the discussion of flood management in an area that can and does flood farmers land regularly. Theoretically changes in land use will affect the hydrology (flood characteristics) of the catchment which could have perceived positive or negative impacts for the farmers concerned. There is a risk of participants being upset during the discussion around flooding, the following key points have been considered:

- Partaking in the project is entirely voluntary and interviewees will be aware of the topics to be discussed prior to the interview, enabling them to opt out if concerned.
- Changes in land use are hypothetical and will be based on suggestions from the land owners – ensuring that they have ownership of the situation and the ability to make change only as they feel is appropriate
- The 'walking' interview technique, semi-structured interview schedule and participatory processes are designed to ensure that the interviewees are co-creating the knowledge, this gives them a level of empowerment
- Interviewees are able to opt out at any time before, during or (within a limited period) after the interview
- The researcher will maintain awareness of sensitive issues throughout the interview and manage the interview appropriately if topics become of concern (allowing time if the interviewee wishes to continue, changing the topic of questioning if not).

Risks to researchers

Researchers will be conducting lone working and will be completing fieldwork in countryside locations in the UK. A full risk assessment will be completed (please see provisional HRA attached – this will be updated on confirmation of catchment site), ensuring that risks are minimsed. The researcher will also follow any Health & Safety or Hygiene procedures that are in place at sites visited.

b) Outline any potential risks to **THE ENVIRONMENT and/or SOCIETY** and the measures that will be taken to minimise any risks and the procedures to be adopted in the event of mishap.

As above, the researcher will undertake any Health & Safety and Hygiene protocols in place at sites visited to ensure that any risk to the environment is minimised.
There are no risks to society through the collection of data. The possible implementation of flood risk strategies may be informed by the results of the project. Any implementations of land use change as a result of the study will be subject to the current rules and requirements in place by the Environment Agency in regards work done to water courses that demonstrate flood risk. By sharing the data with the community the risk to society is lessened (from the current) through increased awareness of flooding and the impact of land use changes.

20. ARE THERE ANY OTHER ETHICAL ISSUES RAISED BY THE RESEARCH?

No x

If yes, please specify

21. EXPERT REVIEWER/OPINION

You may be asked to nominate an expert reviewer for certain types of project, including those of an interventional nature or those involving significant risks. If you anticipate that this may apply to your work and you would like to nominate an expert reviewer at this stage, please provide details below.

Name
Contact details (including email address)
Brief explanation of reasons for nominating and/or nominee's suitability

22. CHECKLIST

Please mark if the study involves any of the following:

- Vulnerable groups, such as children and young people aged under 18 years, those with learning disability, or cognitive impairments ☐
- Research that induces or results in or causes anxiety, stress, pain or physical discomfort, or poses a risk of harm to participants (which is more than is expected from everyday life) ☐
- Risk to the personal safety of the researcher **x – *minimised through completion of Health & Safety Risk assessment: 'living document' provisional report attached***
- Deception or research that is conducted without full and informed consent of the participants at time study is carried out ☐
- Administration of a chemical agent or vaccines or other substances (including vitamins or food substances) to human participants. ☐
- Production and/or use of genetically modified plants or microbes ☐
- Results that may have an adverse impact on the environment or food safety ☐
- Results that may be used to develop chemical or biological weapons ☐

Please check that the following documents are attached to your application.

	ATTACHED	NOT APPLICABLE
Recruitment advertisement	X	☐
Participant information sheet	X	☐
Consent form	X	☐
Questionnaire	☐	X
Interview Schedule	x	☐

23. DECLARATION BY APPLICANTS

I submit this application on the basis that the information it contains is confidential and will be used by the University of Birmingham for the purposes of ethical review and monitoring of the research project described herein, and to satisfy reporting requirements to regulatory bodies. The information will not be used for any other purpose without my prior consent.

I declare that:

- The information in this form together with any accompanying information is complete and correct to the best of my knowledge and belief and I take full responsibility for it.
- I undertake to abide by University Code of Practice for Research (http://www.as.bham.ac.uk/legislation/docs/COP_Research.pdf) alongside any other relevant professional bodies' codes of conduct and/or ethical guidelines.
- I will report any changes affecting the ethical aspects of the project to the University of Birmingham Research Ethics Officer.
- I will report any adverse or unforeseen events which occur to the relevant Ethics Committee via the University of Birmingham Research Ethics Officer.

Name of principal investigator/project supervisor:	Steven Emery
Date:	27.2.2019

Please now save your completed form, print a copy for your records, and then email a copy to the Research Ethics Officer, at aer-ethics@contacts.bham.ac.uk. As noted above, please do not submit a paper copy.

School of Geography, Earth and Environmental Sciences Field and Practical Work Hazard and Risk Assessment (HRA) and Safe System of Work (SSW)

UNIVERSITY OF BIRMINGHAM

STAFF & DOCTORAL RESEARCH

Before commencing any field work activity this form must be completed and submitted with any supplementary information to the email **gees-safety@contacts.bham.ac.uk**.

Trip summary	
Trip and/or Research Title	Forest, Flood and Farmer: Exploring perceptions and preferences of landscapes and how these might impact planting trees for Natural Flood Management
Trip date(s):	01/3/2019 – 30/11/2020
Location (including country)	UK: River catchment tbd in South West counties of England or Monmouthshire, Wales
Activity description: (broadly describe the activity in a paragraph or so. Full detailed methods/activities should be listed in Safe System of Work below).	Interviews with farmers and walking interviews / tours of catchment areas managed.
Risk assessment file name:	May2019_resHRA_JKnight_MidlandsUK
Date of assessment:	
Risk assessment completed by*: *(assessor – usually person carrying out activity, or fieldtrip leader)*	Jenny Knight
Agreed by*: *(Academic supervisor, PI, or module leader)*	Steven Emery & Simon Dixon
Major residual risks *(give details of any significant risk after controls). Risk scoring table athe end of this form*	N/A

** for information or support completing this form see University safety webpages http://www.birmingham.ac.uk/university/governance/policies-regs/health-safety.aspx or email 'gees-safety@contacts.bham.ac.uk*

Contact details		
	Name	**Contact number**
Field party leader:	Jenny Knight	[redacted]
Group Members: Identify first-aiders – (FA)*	None	None
School office contact:	**Gretchel Coldicott**	[redacted]

Field base/accomodation:	N**o planned overnight stay – addresses of each interview / site visit to be included in schedule and confirmed with home and school contact before attendance at any visit.**	

** at least 1 trained Field First Aider per groupd is required on all fieldwork, including day trips, where 'work' is done if the activity is part of a groupd work. Day-trips that are classed as 'visits' to urban areas are exempt.*

International/air travel	
Destination country(s):	N/A
Is your overseas destination safe to visit as defined by the Foreign & Commonwealth Office? (Consult the FCO Website: http://www.fco.gov.uk/)**:**	N/A
Has University Travel Insurance been applied for? This is required if any part of your journey is by aircraft (both UK and international destinations). Apply online: www.travel.bham.ac.uk	N/A
Have you checked if you have the appropriate visa and/or authorization for research and/or field work in an overseas destination? Best to check entry requirements and visa types in the relevant official Consulate/Embassy website of the country you plan to visit.	N/A
Please tick to confirm you have read the University's '**Travelling and Working Abroad Guidance**', and completed the checklists within (https://intranet.birmingham.ac.uk/hr/documents/public/hsu/hsuguidance/24twa.pdf)	N/A
If the location for your activity is an EU country, have you applied for a free European Health Insurance Card (EHIC)? An EHIC is in addition to travel insurance. Apply on line at: https://www.ehic.org.uk/Internet/home.do	N/A

Medical and first aid needs	
Have medical forms been completed for all staff? (Forms are completed on a voluntary basis and are to be held in accordance with Data Protection law and destroyed at end of fieldwork).	N/A
Any action required? (e.g. emergency medication to be carried)	N/A
Number of first-aid kits required*: (Each first aid kit is suitable for 20-25 persons)	N/A – Personal first aid kit to be used
Special medical supplies or equipment needed*?	N/A
Number and type of emergency shelters required*: (for remote and/or mountain environments - 2, 4, 8 and 12 person shelters available)	N/A

**requests should be sent to Richard Johnson or Aruna Mistry*

Communication plan	
Is **ANY** lone working planned or likely during the trip?	**Yes**

Keeping contact and checking-in

[Provide details of how party members will maintain contact with each other and supervisors/school office, including schedules for any regular/safe-return check-ins which may be needed, and what follow up action should be taken. Requirements will vary according to trip personnel, the level of risk associated with the location and complexity of the work. **Lone working** requires regular check-ins (hourly text or call) with appropriate person (e.g. supervisor, friend or family), who should hold a copy of this form.]

I will complete a schedule of fieldwork which details my precise whereabouts and movements, once ethical approval has been granted. I will provide a copy of this schedule to both of my supervisors, Dr. Steven Emery and Dr Simon Dixon, Gretchel Coldicott in the school office and my personal contact: Sara White

I will check-in hourly with one of my supervisors, via text and email and confirm completion of fieldwork at the end of each day.

I will also check in with my sister, Sara Rebecca White, she will also hold a copy of this form

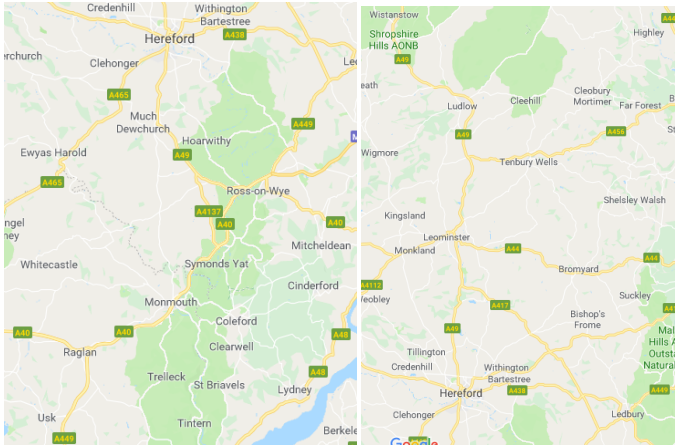
Mobile phones

Mobile phone service is good in the majority of county areas to be covered. I will ensure I am aware of any specific 'blackspots' in the catchment prior to lone working.

**requests should be sent to Richard Johnson or Aruna Mistry*

Supporting local information

Locality map(s):



Land use permission (as applicable)**:**

n/a

Other (as applicable)**:**

Access will not be undertaken on farms if there are any hygene or biological warnings. In addition no site visits will involve the transfer of biological materials. All protocols followed on farm premises will be adhered to for hygene purposes. In addition the researcher will ensure that hands and boots are washed after each visit. Despite there being no requirement for this, it is good practice in both personal and plant / biohealth and safety

Vehicles (where known)

Driver(s)/company:	**Vehicle registration:**	**Listed on Driver's Register*?**	**Insured for business use**?**
Jenny Knight	KR13VHH		Insured for commuting purposes under which travel to and from site would be included.

**if using school vehicle, driver's licence(s) must be checked and logged with Jamie Peart*
***if using own vehicle, insurance must include cover for business use*

Local emergency services (as applicable)

Local A&E department:	The County Hospital Stonebow Road Hereford HR1 2BN **01432 372914**
Local GP: (residential trips only)	N/A
e.g. mountain rescue:	N/A
e.g. Coastguard:	N/A
…	

Emergency response procedures*

N/A

Specific hazard reporting

Do manual handling activities take place?	N/A
If yes, have you completed a manual handling assessment? (assessment must be appended to this form)	N/A
Will dangerous or hazardous equipment be used?	N/A
If yes, have you completed a Standard Operating Procedure? (SOP must be appended to this form)	N/A
Are chemical hazards involved?	N/A
If yes, have you completed a Chemical Hazard and Risk Assessment (CHRA)? (assessment must be appended to this form and approved by lab manager)	N/A
Are biological hazards involved? (e.g. sewerage works, farms, microbiological samples)	N/A
If yes, have you completed a Biological Hazard Risk Assessment? (assessment must be appended to this form and approved by biological safety officer)	N/A
Are compressed gasses to be used?	N/A
If yes, have you completed a COSHH and online safety course? (assessment must be appended to this form and approved by lab manager)	N/A

Risk Scoring System

The scoring system is provided as a tool to help structure thinking about assessments and to provide a framework for identifying which are the most serious risks and why.

Risk Rating = Severity (S) x Likelihood (L)

Guidance

Consider each activity involved in the trip/project & the hazards that may arise from them; include any equipment that may be used, individual & team capabilities, and any potential health issues.

Think about what could happen; how severe could the outcome be (S) & how likely is it to occur (L)?

Use the guide below to score each (S) & (L).

Multiply S x L to give the Initial Risk rating (IR).

Where the IR is 3 or above, appropriate measures must be put in place to reduce to an acceptable level of risk.

With the control measures in place, review the S & L ratings & multiply these to give a Residual Risk Rating (RR).

Initial Risk Rating (IR)

= Severity (S) x Likelihood (L)

Where IR ≤ 3 control measures are required.

Residual Risk Rating (RR) is calculated after control measures.

Field	Rating	Score	Description
Severity (S)	High	3	Hazard capable of resulting in death, severe injury or illness, or major loss/damage to equipment, buildings or the environment.
	Moderate	2	Hazard capable of resulting in injury or illness requiring absence from work, or damage to equipment/environmental.
	Low	1	Hazard capable of resulting in minor injury requiring first aid, or inconsequential loss of equipment or environmental impact.
Likelihood (L)	High	3	Likely to occur frequently or the hazard exists permanently.
	Moderate	2	May occur in time – hazard exists intermittently or the operation occurs occasionally.
	Low	1	Unlikely to occur – hazard exists infrequently and there is a low expectation of occurrence.
	None	0	Hazard removed completely or effect of potential hazard made impossible by design (applies only to residual rating).
Risk Rating (IR/RR)	High	6, 9	Priority risk. Must be reduced to a level that is acceptable through practical and effective control measures.
	Moderate	3, 4	Lesser priority risk. Should be assessed to see if further control measures can be applied to reduce to low risk.
	Low	0, 1, 2	No further action is required but should continue to be monitored.

Risk Assessment

The Initial Risk Rating (IR) is derived **before** the application of any control measures i.e. this is the risk of conducting the activity or operation in the absence of control.
The Residual Risk Rating (RR) is the risk presented by the activity or operation if it were to be completed with the identified control(s) applied.

Review the control measures to identify any actions which need to be completed before a suitable **Safe System of Work** can be established and implemented.

Major Residual Risks need to be flagged in **Trip Summary**, page 1.

		Initial Risk Rating				Residual Risk Rating		
Activity or hazard	**Potential hazard effect**	**S**	**L**	**IR**	**Control measures**	**S**	**L**	**RR**
Lone Working (Personal Safety and Security	Personal attack or injury	3	1	3	Check-in with supervisor and personal contact prior to and subsequent to interviews	3	1	1
Machinery on Farms	Injury caused by machinery	3	1	3	Avoid machinery on farms and if encountering machinery with the farmer ensure that I maintain a safe distance.	1	1	1
Livestock on Farms	Injury caused by animals	3	1	3	Avoid contact with animals on farms, and ensure that only entering areas with livesstock in the precesnse of the farmer and remain well apart from any animals. Use insect repellant.	1	1	1
Working near water courses	Injury caused by exposure or submersion	3	1	3	Maintain a safe distance from water courses at all time, be clear about routes and do not cross watercourses unless suitable crossings are available	1	1	1
Falling debris / rocks / tree branches	Injury from falling objects (rocks / tree branches)	2	1	3	Take a hard hat which can be worn in areas considered dangerous, do not enter areas where PPE would be ineffective	2	1	1
Working on loose / uneven / steep ground	Injury caused by fallin or slipping	1	1	1	Wear appropriate footwear (e.g. walking boots), follow routes as planned and ensure to take care on steep ground	1	1	1
Exposure to weather	Illness from cold or wet weather, sunstroke / burns / dehydration from hot weather	1	1	1	Wear appropriate clothing (waterproofs along with hat, scarf, down jacket in cold weather). Apply and carry sun cream udring sunny/warm weather, carry water.	1	1	1
Travelling to sites	Road accident	3	1	2	Do not drive in adverse weather conditions, maintain all expected safety regulations whilst travelling, check-in with contacts before and after travelling	3	1	1

Safe System of Work (SSW)
The Safe System of Work (SSW) is a method statement that describes succinctly the working procedure to be followed in order to carry out the activity safely, taking into account the issues identified in the risk assessment above and highlighting key steps or precautions. It is **not** necessary to be comprehensive or repeat material if suitable procedures already exist elsewhere; refer to other documents (eg standard operating procedures) where appropriate.

There may be multiple SSW for a single trip (eg separate SSW for collecting water samples from stream and collecting soil samples).

Activity			
Safety equipment required			
Working procedure			
Emergency procedure			
Environmental considerations			

Risk Assessment Checklists

The risk assessment should include consideration of all issues which present significant hazards. The checklists provided below are generic and intended to assist thinking during the assessment process, but are **not exhaustive**. There may be other factors associated with specific activities in your work.

Checklist of possible hazards

Environment/location	Operational/activity	Equipment	Substances
• Weather conditions: – cold, hot, rain, snow, sun, wind • Mountain, remote or wild country • Cliffs, pits and quarry faces • Steep or high banks • On/in/near flowing or standing water • Coastal or tidal areas • Roadside working • Urban or industrial areas • Contaminated ground • Wild animals, livestock or insects • Access to welfare facilities • Working in public spaces • Socio-political differences and stability • Language differences • Accommodation	• Travelling to and from site • Driving off-road • Use of taxis, car hire • Health, **individual health** and fitness, stamina • Manual handling (lifting heavy items or repetitive tasks) • Lone working • Proximity of plant or machinery • Slips and trips • Falling from heights/falling objects • Working with contractors • Failing light • Public protests or demonstrations	• Augers • Digging tools • Rock hammers • Generators and electrical equipment • Lifting equipment • Machinery • Operation of vehicles	• Biological hazards • Chemical hazards • Contaminated samples (water, soils etc) • Dust • Explosive materials • Flammable materials • Radiation (ionising or non-ionising)

Checklist of possible control measures

Communications & management	Personal protective clothing	Safety Equipment	Training
• Mobile/satellite phone, radio • Communication plan • Maps/sat-nav/directional aids • Emergency response plan (ERP) • Emergency contact list • Location of A & E/medical facilities	• Weatherproof jacket & trousers • Protective/non-slip footwear • Weatherproof hat • Gloves/gauntlets • Overalls/disposable suits • High-visibility wear • Sun protection clothing • Safety glasses/goggles • Ear plugs/ear defenders • Hard hat	• First-aid kit • Food & drink • Sun protection cream • Insect repellent • Torch/headtorch	• Off-road driving • Field first-aid • Personal security • 2-way radio

Dear Sir/Madam…Mr/Mrs

I am emailing to ascertain your interest in a research project that works with the expertise of local land managers to explore land-use change within a river catchment.

My name is Jenny Knight and I am conducting a Doctoral Research project **exploring the perceptions of and preferences for landscape of land-mangers, and how these may inform and impact tree planting for Natural Flood Management (NFM**).

In contrast to traditional flood management, this research places local expertise at the start and heart of the process. With the premise that the experts on a landscape are those who live and work there.

This research aims to identify local knowledge and understandings of the landscape in order to model a known flood event. This will then be used as a 'baseline' through which alternative land-use scenarios will be explored. These scenarios will take into consideration the physical characteristics of land-use change, with a focus on tree-planting. The parameters for tree planting (whether, what and where) will be set according to the preferences and values of the land-managers. The scenarios will then be analysed for their impact on flood management and other benefits, ideally with the priorities informed by land managers.

I am currently identifying which catchment area would be suitable for this project and ***river name*** catchment would make a particularly interesting study.
The success of this study is entirely reliant on accessing the expertise and participation of local land-managers within the catchment.

If you would be interested in participating or discussing this project further, please contact me as soon as you are available to do so on [redacted] I will be finalising a choice of catchment on the 31st May and would be delighted to hear from you prior to this.

With kind regards

Yours faithfully … sincerely

Jenny

Jenny

Interview Schedule

- Introductions
- Review process, previously discussed by email
- Confirm consent and signed consent form received
- Introductory Questions
- Mapping Activity
- Walking Interview

Introductory Questions

We will start with some standard demographic questions to both support later analysis and help put participants at their ease. These will include

- What would you describe as the main purpose or output of the land/farm (arable, livestock, other)
- How long have you/your family worked/lived here?
- What age bracket would you place yourself in?
- How many people live/work here with you?
- Gender of key decision makers?
- Size of farm?
- Ownership or tenancy?

Additional demographic details, that in the past have been shown to influence agri-environmental decision making, will be identified through the semi-structured interview. These include; past involvement in agri-environment schemes, financial situation.

Mapping activity

The mapping activity will be described as a 'precursor' to the main interview/walking tour. This will enable individuals to engage without the feeling that there is pressure to include all information, or create a 'masterpiece' if they are unconfident about their artistic skills

The 'themes' of the interview will be introduced and the participant asked to sketch a rough map that identifies the areas of 'significance'. The researcher will suggest that an additional aspects could be:

- *Features in relation to water flow or water management*
- *The current 'tree'd' areas of the landscape (from woodland to scrub)*

Interview prompts

Note: these prompts may be split over two meetings, the first is to ascertain perceptions, prior knowledge and understandings. Preferences may not be included in the first meeting if land-managers are not confident about options in regards variety of trees planting options and land-use change.

Perceptions:

- Is this landscape <case study> important to you?
- Could you explain why you identified this <feature from map> as important
- Is there a particular reason you chose this route?
- Can you tell me about the history of <this feature or function>?
- How does your <farm/land> fit in within the rest of <case study>?
- What is the catchment community/ies like?
- What impact, if any, does the river have?

Knowledge/Expertise/Management:

- What are the most significant changes that you've made here?
- How much are the <tree'd areas> managed?
- What is it like here when there are heavy rain / floods?
- What is important about the ecology / environment here?

Preferences:

- Do you have significant future plans / land-use changes in mind for the future?
- If you were to plant trees or tree'd features, what functions would be important? (Economic / Environmental / Water regulation / family)
- Would you have ideas about the type of planting that would be suitable / that you would like?
- Why would different locations be suitable / unsuitable from the <farm>?

Follow-up Meeting

Land Managers will be asked to comment and annotate maps in regards the following guiding themes:

- Uncertainty / Accuracy of known flood event
- Preferences for tree planting: type, density, location
- Area where trees could definitely not be planted of any kind / other land-use changes

Forests for Floods?

Exploring Land Managers perceptions of and preferences for landscapes and the impact of these on planning Natural Flood Management (NFM)

Doctoral Research Project at Birmingham University

Focus Group Participation and Consent Form 2019

- ⇨ **I agree** to participate in the 'Forests for Floods?' project carried out by Jenny Knight of the University of Birmingham.
- ⇨ I am fully aware that I am not obliged to answer any question, but that I do so at my own free will.
- ⇨ I agree to have the focus group recorded (video or dictaphone), so it can be transcribed after the focus group is held.
- ⇨ I am aware that I can make any reasonable changes to this consent form.

Use of Data

Under the EU General Data Protection Act (GDPR) 2018, at the time of their creation recordings and transcripts have a copyright jointly owned by the interviewer (Jenny Knight) and the participant (myself).

I agree to permanently assign my portion of this copyright to the researcher (Jenny Knight).

I understand that the researcher will:

1. Create a transcript of the recordings
2. Archive copies of this material in a secure system

I understand that data from this focus group will be used for the purposes of the research described and this may result in publishing quotes or paraphrasing. When using those quotes the researcher will endeavour to preserve confidentiality.

Data will be stored according to the Concordat on Open Research Data as adopted by the University of Birmingham. This means that researchers in the future may access and re-analyse data collected. All data will be protected and processed in line with current legislation and the Universities 'Code of Practice for Research'.

I understand **that within 3 months of data collection (or by Oct 2020) I shall have the right to:**

1. Deletion of any data associated with the focus group that could be attributed to myself
2. Request the redaction of my input to the focus group from transcripts, as far as is practically possible,

Interviewees name & email address

Interviewees signature *date*

Researchers signature *date*

Forests for Floods?

Exploring Land Managers perceptions of and preferences for landscapes and the impact of these on planning Natural Flood Management (NFM)

Doctoral Research Project at Birmingham University

This research places the farmers / land-managers perspectives at the forefront of planning for land use change. We aim to explore expertise and understandings of their landscapes alongside their preferences for land use and how to adapt in the future. The research will use both socio-cultural and physical data to model a known flood event in the river catchment. We will then continue our work with farmers/land-managers to identify hypothetical alternatives for land-use (with a focus on abundance/type of tree'd areas) and evaluate the scenarios generated.

The research recognises the expertise of owners and managers in their own landscapes and would like to invite managers of land within the river catchment to participate.

The research is focusing on a single case study of the **river name** catchment.

The case study is being developed through online data analysis and physical 'ground truthing'. Key to the research is the expertise of local land-managers.

Participation includes:

- A mapping exercise that identifies features of importance and value within the landscape, and characteristics including 'water' and 'trees'.

  A walking interview/tour of the land, to enable the land manager to discuss with the researcher important features, whether culturally or physically in farm management. The researcher will take GPS locations of key features identified as important by the manager and photographs where appropriate.

- A review of the baseline model created from the physical characteristics and input from the manager. This model will be annotated with any potential areas of tree planting identified by the manager; taking into account form and function.

All participants will be invited to take part in the analysis of final scenarios and evaluation of the project; including the option to make comments or annotations by email.

The mapping exercise will take approximately 30mins and be held at your home/work, unless a more convenient location is preferred and agreed. The walking interview/tour may take as long as is required by the manager and the researcher will make themselves available throughout the day.

A follow up visit to discuss the baseline model and confirm planting preferences will be decided between the participant and the researcher.

All interviews will be audio recorded and subsequently transcribed to enable the interviewer to focus on the discussion. Confidentiality will be maintained in all transcripts.

About me

I am a Doctoral Researcher at Birmingham University completing a PhD in Geography and Environmental Sciences. My interest in rural futures and the impacts of landscape change arose from my interest in science, environment and policy alongside a love of the outdoors. I am a keen hiker and rock climber and I grew up on a small-holding in South Wales. The landscapes I know and love, and the lifes of those who work those landscapes, the viability of our traditional agricultural practices are being fundamentally challenged. The rate of change, (whether due to climate, the requirement to protect the environment, or planting trees to ameliorate flood risk) has increased. My interest in these landscapes has been lifelong and this work has given me the opportunity to question our understandings and the processes and policies that are currently implemented.

Having taught Physics and completed postgraduate studies in London I was delighted to move back 'home' to the West Midlands for my Doctoral Research.

I am funded by the Leverhulm Trust through the Forest Edge program at Birmingham University. BIFoR (the Institute of Forest Research) focuses on understandings of forested landscapes in light of climate change. This is an ideal position from which to question the difficulties change may pose on rural communities.

Research and use of data

The data from this research will be used as part of my doctoral thesis and for publishing papers from that research. Data including any maps, photographs, and interview transcripts and catchment hydrology/geomorphic data will be archived on secure servers and stored according to the concordat on Open Research to enable future analysis. Maps and models will be made available to participants along with a summary of the research.

All interview data archived will be edited to ensure confidentiality using psydenums and redaction of data as deemed appropriate by both the researcher and participants.

Jenny Knight,

Leverhulme Doctoral Scholar

Department of Geography, Birmingham University

Edgbaston,

Email

Supervisors: Dr Steven Emery & Dr Simon Dixon

Consent to Interview and use of data 2018

The purpose of this document is as follows, please acknowledge each statement:

	Initials
Participants have been fully informed of the research process.	
To confirm participants agreement to a recorded interview	
To describe conditions agreed regarding the use of the maps, recordings and transcripts resulting from these interviews	
To acknowledge the participants right during or after the interview to have specific data deleted	
To acknowledge the participants right to withdraw from the study	
To confirm that there is no renumeration for participation in this study	

Participatory research – Evaluation of project stages

All participants will have the opportunity to view, analyse and evaluate the scenarios developed before archive/publication. This means that more detailed models and maps of the alternative land-use scenarios may be shared amongst the participants. To ensure confidentiality of views and purpose of land managers are maintained the researcher shall:

- Only share models created by the researcher and not original annotations by participants.
- Agree with participants the level of detail that can be included in the alternative scenarios in advance. A minimum requirement would be to include the 'hydrologic roughness' (the rate at which water moves through the catchment).

Use of Data and Data Storage

I understand that at the time of their creation, maps, recordings and transcripts have a copyright held by the University of Birmingham and the interviewee (myself).

I understand that the researcher will:

1. Create a transcript of the audio recordings
2. Archive copies of the transcripts and maps in a secure system

I also understand that data from my interviews will be used for the purposes of the research described in this document and this may result in publishing quotes or paraphrasing from my interview. When using those quotes the researcher will endeavour to preserve confidentiality. The researcher will:

- Will replace all identifying data with pseudonyms/code in transcripts and subsequently published material
- Will agree with the participant if any features in maps should be redacted from published data

Data will be stored for ten years according to the Concordat on Open Research Data as adopted by the University of Birmingham. This means that researchers in the future may access and re-analyse data collected. All data will be protected and processed in line with current legislation and the Universities 'Code of Practice for Research'.

I understand **that within 3 months of data collection** I have the right to withdraw from the study and require deletion of all recordings and transcripts from my interviews, where ever they are deposited

I agree to participate in a recorded interview. I have been made aware of the procedure to be followed. I will have the right to request a transcript of the interview and have the right to have specific data deleted from the transcript.

Interviewees name & email address

Interviewees signature *date*

ERN_19-0315: Notice of amendments to ethics and HRA in light of Covid-19 pandemic

There is no change to Sections 1 – 4 of the project, however they are included below for information:

Section 1 – Title of Project: Forest, Flood and Farmer: Exploring perceptions and preferences of landscapes and how these might impact planting trees for Natural Flood Management

Section 2 – This Project Is: University of Birmingham Postgraduate Research (PGR) Student project

Section 3 - Investigators

Name: Title / first name / family name	Dr Simon Dixon
Highest qualification & position held:	PhD Lecturer in Geography
School/Department	LES: Geography
Telephone:	
Email address:	

Name: Title / first name / family name	Dr Steven Emery
Highest qualification & position held:	PhD Lecturer in Environment and Society
School/Department	School of Geography, Earth and Environmental Sciences
Telephone:	
Email address:	

PGR Researcher Details:

Name of	Jennifer Knight	Student	
Course of	PhD Geog and Env Sci FT	Email	
Principal			

Section 4 – Estimated Start of project: May 2019 / Estimated End of project: August 2022

Included below are sections where there are minor amendments / additions:

Section 7 – Conduct of Project

There are no significant changes to the conduct of the project as fieldwork for stages I and II was conducted pre-Covid impacts.

Stage III involves focus groups and response to project findings by email. These focus groups and any further participant meetings will be held virtually where-ever possible, the possibility of recording a video recording was anticipated when the focus group methodology was chosen, however this will now be the priority method.

Section 12 – Participant Feedback

A key consideration of moving to virtual methodologies is that of access, in order to ensure that there no access issues for members of the catchment who may struggle to feedback online, a paper version, identical to that that would be distributed by email, will be delivered to participants. A return address c/o the Researchers Supervisor at the University address will enable documents to be posted by return. The option to feedback by email will be included in the hardcopy pack.

Section 13 – Participant Withdrawal

Due to delays to fieldwork relating to the pandemic, the date for participant withdrawal has been extended until June 2021 – this change will be reflected on the Focus Group and Participant Consent Forms.

Section 16 – Storage, Access and Disposal of Data

An audio recording and transcript will be made during the virtual recording which will be conducted on the Researchers Birmingham University Zoom account and will be saved on the protected drives as described in the original document. When Zoom creates a recording one is also saved to the cloud, however this is deleted after a time set by the researcher. To maintain the GDPR parameters initially set, the cloud recording will be set to delete as soon as the audio and transcript have been downloaded.

Section 19 – Risks

Given the current global crisis, the methodologies have been adapted to minimise contact with participants for both the safety of the researcher and participants in catchment. Any face to face meetings will only be conducted in scenarios where safety of participants and the researcher can be assured, as advised by University guidelines and using the risk assessment outlined in the British Medical Journal: BMJ 2020;370:m3223. A full HRA has been completed in light of the impacts of the pandemic on the research and is attached with references

There are no other amendments to the key documents.

Forests for Floods?

Exploring Land Managers perceptions of and preferences for landscapes and the impact of these on planning Natural Flood Management (NFM)

Doctoral Research Project at Birmingham University

Online Focus Group Participation and Consent Form 2021

- ⇨ **I agree** to participate in the 'Forests for Floods?' project carried out by Jenny Knight of the University of Birmingham.
- ⇨ I am fully aware that I am not obliged to answer any question, but that I do so at my own free will.
- ⇨ I agree to have the focus group video recorded, so it can be transcribed after the focus group is held.

Use of Data

Under the EU General Data Protection Act (GDPR) 2018, at the time of their creation recordings and transcripts have a copyright jointly owned by the interviewer (Jenny Knight) and the participant (myself).

I agree to permanently assign my portion of this copyright to the researcher (Jenny Knight).

I understand that the researcher will:

1. Create a transcript of the recordings
2. Archive copies of this material in a secure system

I understand that data from this focus group will be used for the purposes of the research described and this may result in publishing quotes or paraphrasing. When using those quotes the researcher will endeavour to preserve confidentiality.

Data will be stored according to the Concordat on Open Research Data as adopted by the University of Birmingham. This means that researchers in the future may access and re-analyse data collected. All data will be protected and processed in line with current legislation and the Universities 'Code of Practice for Research'.

I understand **that within 3 months of data collection (or by Jul 2021) I shall have the right to:**

1. Deletion of any data associated with the focus group that could be attributed to myself
2. Request the redaction of my input to the focus group from transcripts, as far as is practically possible,

Interviewees name & email address

Interviewees signature *date*

Your consent will be confirmed at the beginning of the online recording. Please also return a signed copy of this form to the University of Birmingham c/o Dr Steven Emery by post or email.

Forests for Floods?

Exploring Land Managers perceptions of and preferences for landscapes and the impact of these on planning Natural Flood Management (NFM)

Doctoral Research Project at Birmingham University

A Online Focus Group to Analyse the catchment options and Evalute the project process

This research places the farmers / land-managers perspectives at the forefront of planning for land use change. We aim to explore expertise and understandings of their landscapes alongside their preferences for land use and how to adapt in the future. The research used both socio-cultural and physical data to model a known flood event in the river catchment. We continued our work with farmers/land-managers to identify hypothetical alternatives for land-use (with a focus on abundance/type of tree'd areas) and evaluate the scenarios generated.

The research recognises the expertise of owners and managers in their own landscapes and would like to invite managers of land within the river catchment to participate.

The research has focused on a single case study of the Trothy River catchment.

The case study has been developed through online data analysis and physical 'ground truthing'. Key to the research has been the expertise of local land-managers.

In developing the model scenarios of land use change in the catchment land-managers have provided ground-truthing information in regards the importance of features on their land, local knowledge of flooding and theoretical areas of tree planting suitable within their landscapes.

The researcher has used this input to develop a number of scenarios of land-use change. These scenarios focus on the characteristics of water storage and flows within the catchment and are based around a known flood-event.

We are delighted to invite you to take part in a focus group at a key stage of this project. The purpose of the focus group is to:

- Analyse and discuss the different scenarios both in regards the change in water behaviour and landscape change, and how these might impact decision making within the catchment.
- Evaluate the project process – what has worked, what might you improve and where would you go next..

In light of the current health crisis in the UK and to maintain participant safety the focus group be held online using an appropriate format (for example zooms, or Microsoft teams). The focus group video will be recorded and subsequently transcribed to enable the interviewer to focus on the discussion. Confidentiality will be maintained in all transcripts.

Participants may withdraw at any time, the researcher will ensure that all input is withdrawn where possible given the nature of a group discussion.

About me

I am a Doctoral Researcher at Birmingham University completing a PhD in Geography and Environmental Sciences. My interest in rural futures and the impacts of landscape change arose from my interest in science, environment and policy alongside a love of the outdoors. I am a keen hiker and rock climber and I grew up on a small-holding in South Wales. The landscapes I know and love, and the lifes of those who work those landscapes, the viability of our traditional agricultural practices are being fundamentally challenged. The rate of change, (whether due to climate, the requirement to protect the environment, or planting trees to ameliorate flood risk) has increased. My interest in these landscapes has been lifelong and this work has given me the opportunity to question our understandings and the processes and policies that are currently implemented.

Having taught Physics and completed postgraduate studies in London I was delighted to move back 'home' to the West Midlands for my Doctoral Research.

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Research and use of data

The data from this research will be used as part of my doctoral thesis and for publishing papers from that research. Data including any maps, photographs, and interview transcripts and catchment hydrology/geomorphic data will be archived on secure servers and stored according to the concordat on Open Research to enable future analysis. Maps and models will be made available to participants along with a summary of the research.

All interview data archived will be edited to ensure confidentiality using psydenums and redaction of data as deemed appropriate by both the researcher and participants.

Jenny Knight,

Leverhulme Doctoral Scholar

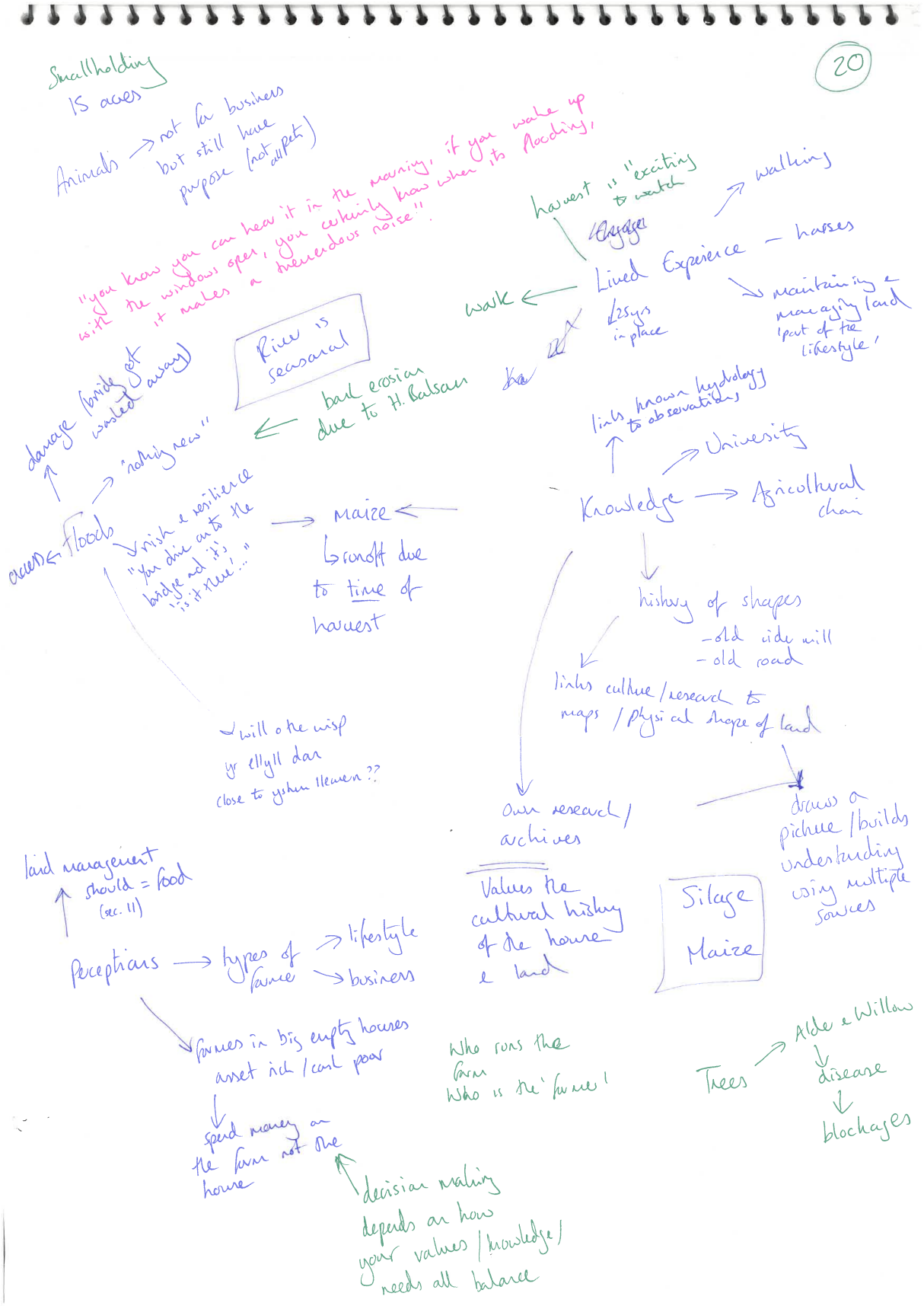
Department of Geography, Birmingham University

Edgbaston,

Email:

Supervisors: Dr Steven Emery & Dr Simon Dixon

Appendix VI: Analytical Mind Maps



Appendix VII: NVivo Coding structures

Codes\\Thematic Framework

Initial code framework for interview analysis

Name	Description	Files	References
A1 Quotes and Pictures		11	48
Decision_Building		17	323
Amenity		3	4
Community influence		6	15
Economics		11	39
Env		7	24
External Advice influence		7	13
Family influence		9	20
Good Farmer	Behaviours / decisions based on social capital building	12	30
Good Farmer contrary	where their position is placed as contrary to 'normally accepted' or 'good farmer' but where that's not actually a 'good' thing. A 'we're different and breaking the mold' approach?	6	9
Internet and Community connection		1	2
Knowledge Shaping	Intelligence can shape knowledge to suit desired outcomes (where one factor leads, others can be moulded to fit the outcome that best suits that factor)	3	4
Legacy		5	8
Lived Experience	Lived Experience directly impacting on decision building	7	11
Management		14	27
neighbour		8	13
Policy interactions		7	33
Governance/Regs	rules and regulations	5	9
Produce	Prioritising the management techniques for the main produce/output focus of the farm/land/business	10	20
Safety		6	9
Space		1	1
Value_Priorities		9	17
What to do where		3	6
Farm_history		1	2
Farmers_and_Trees		17	114
Barriers		10	17
Don't need more trees		5	6
Environmental Rhetoric		5	8
Factors		0	0
Amenity		1	1
Env	'environmental' reasons / biodiversity etc.	1	2
Parkland		0	0
Shelterbelt etc		1	1
Water Management		0	0
Working woodland	coppice, crops etc	1	1
Management		8	13
TreePlanting		15	31
Within Farm Context		14	31
Identity		8	12
Interactions with River		11	99
Damage		5	20
Experience		8	16
Power	links to agency of the river	5	8
Resilience		6	12
Risk		6	17
trees	link to or lack of link to trees?	4	7
Knowledge		18	253
Education		7	20

Name	Description	Files	References
From Experts Advisors		11	19
learn		7	14
Lived Observation		11	42
Maps		7	15
memory		6	18
NRW		2	2
PerceptionValue	'Knowledge' being based on perception and values	4	5
Place-based		14	52
water_knowledge		7	17
Rhetoric		7	12
Scientific	uses or references to scietific knowledge	13	50
expert-external		3	4
runoff		1	2
soil		6	10
LivedExp	What is lived experience of place	16	100
climate		8	9
Rain		1	3
Embodied	Knowing by sensing - feel, touch smell and by physical experience (walking etc.) of the body in space	12	39
Event based		6	14
Geomorphic		0	0
Historical - cultural		6	11
knowing the farm		12	19
Lack	Not experienced therefore not known	6	6
policy	policy interaction through direct impact on place	0	0
Mental Health		6	10
More Than Human	More than human agency	14	42
Ash		3	4
Himalayan Balsam		3	4
Maize		3	5
TB		1	1
Network		5	8
Ownership		2	4
direct to thesis	directly applied to flooding / decision making for NFM / farmers preferences	4	12
theoretical	more theoretical aspects that go beyond thesis	8	12
Perceptions of good land		13	32
Perceptions of others		10	23
Pride	Why are people proud of their trees / landscapes	7	12
Reasoning And Rhetoric		12	24
Shape	spatial shape of landscape affects how we can / are able to interact with it	12	32
Geo		7	10
Socio	'Shapes' / Boundaries and features created by human choices / behaviours and cultures	3	3
Socio_Geo		8	18
Solutions		3	4
Unintentional impacts		5	13
What is a farm		8	9
Word_use	use of words like 'nature', wild, natural etc	5	7

Codes\\Synthesis

Code framework for the evaluation and analysis chapter 10

Name	Description	Files	References
Additional Themes - Participant reflections		0	0
Barriers		3	12
Uncertainties		2	2
Governance		3	17
Heterogeneity		0	0
Geomorphology		1	1
Social		2	3
Spatial		2	3
Impact of non-human actors		1	3
Incentives to act		3	7
Solutions		2	9
What actions where	location of actions and what takes place - determined by perspectives:	3	7
MultiplePriorities		3	10
Who Should Act		2	11
Model Evaluation	Workshop feedback directly relating to the hydrological model	3	21
Limitations_Extent		3	10
What to add		2	4
Model Importance/Relevance	Participant comments that directly relate to how relevant the model is to the way in which they work / the design of interventions	2	5
Participant_EvalOfResearcherReflections	Participants evaluation / comments that directly relate to the researcher reflections	2	2
Participant_Questions		3	7
Participant_Synthesis	Participants synthesis of the model with other knowledge/s	3	22
ExtraLocal		2	2
LExp		3	9
Map		2	2
Model		3	9
RR_Active Learning		3	9
RR_Collaborate or Compromise		1	3
RR_Connectivity		1	1
RR_Limtations and Extents		0	0
RR_MultipleActors		1	2
RR_Opaque Data		2	4

Appendix VIII: creating the SHETRAN PRD file: precipitation data rcode

Rainfall_Extraction

Jenny Sumaya Knight

14/10/2020

R Markdown

This document enables the extraction of rainfall data from CEH GEAR hourly rainfall data. All files and folders in this document are relevant to the git repository trothy_methods, the CEH rainfall data must be downloaded separately from here: CEH GEAR1hr

Reference: Lewis, E.; Quinn, N.; Blenkinsop, S.; Fowler, H.J.; Freer, J.; Tanguy, M.; Hitt, O.; Coxon, G.; Bates, P.; Woods, R. (2019). Gridded estimates of hourly areal rainfall for Great Britain (1990-2014) [CEH-GEAR1hr]. NERC Environmental Information Data Centre. https://doi.org/10.5285/d4ddc781-25f3-423a-bba0-747cc82dc6fa

Extract location coordiates from preprepared grid

A 5 x 5 grid of the catchment was created in arcGIS in order to attain a reasonable distribution of rainfall across the catchment, the coordinates for the centre point of each grid were found, referenced to an index, saved to a csv file and stored in the repository data folder 'weather'

```
CEHPath = '/home/jenny/PhD/DATA/Weather/CEH_GR/'
LocationsPath = 'data/weather/'
FilesPath = 'results/'

#read data: locations for each grid square
File_Loc25 = read.csv(paste0(LocationsPath, 'GridLoc25.csv'),stringsAsFactors = F)
head(File_Loc25)
```

```
##   X  Easting Northing id
## 1 1 333718.8 207053.4  1
## 2 2 337718.8 207053.4  2
## 3 3 341718.8 207053.4  3
## 4 4 345718.8 207053.4  4
## 5 5 349718.8 207053.4  5
## 6 6 333718.8 211053.4  6
```

###Conversion from Gridref to Long/Lat The rainfall data grid squares reference Long/Lat coordinates, so we convert from the British National Grid to Long/Lat coordinates

```
Loc25 = File_Loc25[,2:3]
coordinates(Loc25) = c('Easting','Northing')

# the coordinate system default values are:
# CRS("+init=epsg:4326") #wgs84
# CRS("+init=epsg:27700") #bng

#function (REF Doris)
Gridref2LatLong= function(x) { #input gridC : coordinates in SpatialPoints in BNG
```

```
  proj4string(x) = CRS("+init=epsg:27700")  # BNG-Gridref
  CRS.new = CRS("+init=epsg:4326")
  spTransform(x, CRS.new)
}

LatLong.25 = as.data.frame(Gridref2LatLong(Loc25))
head(LatLong.25)
```

```
##     Easting Northing
## 1 -2.961706 51.75823
## 2 -2.903761 51.75869
## 3 -2.845814 51.75912
## 4 -2.787866 51.75952
## 5 -2.729917 51.75990
## 6 -2.962471 51.79419
```

Finding the matching rainfall gridcell for each of the 25 catchment grid squares

```
#list the rainfall files to check correct path

ncGEAR = list.files(path=CEHPath)

#1 #start with getting the correct Lon.Lat for each grid square
# open 1 file to retrieve the closest Lon.Lat to centre of square > save coordinates in a
↪  file

# First download file and open it in R
net <- nc_open(paste0(CEHPath,ncGEAR[1]))

lon <- ncvar_get(net, 'lon')
lat <- ncvar_get(net, 'lat')

Easting = ncvar_get(net, 'x')
Northing = ncvar_get(net, 'y')
Rainf = ncvar_get(net, 'rainfall_amount'[1])
nc_close(net)
```

The total grid was to large to expand, so extracting a sample I knew was over the catchment enabled me to create a process that would work. This is reliable, as the Easting / Northing data is retained and would result in no data if the location was incorrect.

```
lon1 = lon[400:500]
lat1 = lat[700000:750000]
#grid was to large to expand, so extracting a sample I knew was over the catchment
↪  enabled me to create process (this took 4hrs to work out)
nc_coords = expand.grid(lon = lon1, lat = lat1)
↪  #http://geog.uoregon.edu/bartlein/courses/geog607/Rmd/netCDF_01.htm
nc_pts = SpatialPoints(coords = nc_coords, proj4string = CRS("+proj=longlat
↪  +datum=WGS84"))
```

The final stage was to create a data frame and extract the rainfall coordinates which most closely matched each grid square


```
Loc25Cood = as.data.frame(File_Loc25$id)

#trying xy coords - this works
nc_coords = expand.grid(x = Easting, y = Northing)
↪  #http://geog.uoregon.edu/bartlein/courses/geog607/Rmd/netCDF_01.htm
nc_pts = SpatialPoints(coords = nc_coords, proj4string = CRS("+init=epsg:27700"))


Loc25Cood = as.data.frame(File_Loc25$id)
for(j in 1:dim(Loc25Cood)[1]){
  dist <- sqrt((File_Loc25$Easting[j]-nc_coords$x)^2 +
↪  (File_Loc25$Northing[j]-nc_coords$y)^2)
  min.dist <- min(dist)
  coord <- which(dist==min.dist,arr.ind=TRUE)
  Loc25Cood$X[j] <- nc_coords$x[coord]
  Loc25Cood$Y[j] <- nc_coords$y[coord]
}

for(i in 1:dim(Loc25Cood)){
  Loc25Cood$XIndex[i] = which(Easting == Loc25Cood$X[i])
  Loc25Cood$YIndex[i] = which(Northing == Loc25Cood$Y[i])
}

head(Loc25Cood)
```

```
##   File_Loc25$id      X      Y XIndex YIndex
## 1             1 334000 207000    335   1044
## 2             2 338000 207000    339   1044
## 3             3 342000 207000    343   1044
## 4             4 346000 207000    347   1044
## 5             5 350000 207000    351   1044
## 6             6 334000 211000    335   1040
```

This file was then saved to the results folder as Loc25Cood

Extracting Rainfall data from the origincal netcdf files using the coordinates given

```
#read in the coordinates just generated
Loc25Cood = read.csv(file = "results/location25Coords.nc.csv")

#check the netcdf output and metadata

net1 <- nc_open(paste0(CEHPath,ncGEAR[2]))
net1
Rain_1 <- ncvar_get(net1,
                    varid = "rainfall_amount",
                    start = c(335,1044,1), # last on =1 says i take time series
                    count = c(1,1,-1) #take time series
)
nc_close(net1)
Rain_1
```

```
#set up a dataframe and run the for loop to select the rainfall  - creates a column of
↪  data for each of the 25 grid squares, this can then be saved as a csv file to be used
↪  in SHETRAN

RainfallHours=as.data.frame(matrix(0,nrow=6576,ncol=25))
RainH = list()
for(i in 1:25){
  RainH = list()
  for(d in 1:length(ncGEAR)){
    net1 <- nc_open(paste0(CEHPath,ncGEAR[d]))
    RainH[[d]] <- ncvar_get(net1,
                            varid = "rainfall_amount",
                            start = c(Loc25Cood$XIndex[i], Loc25Cood$YIndex[i],1), # last
                             ↪  on =1 says i take time series
                            count = c(1,1,-1) #take time series
    )
    nc_close(net1)
    RainHours = unlist(RainH, recursive = F)
  }
  RainfallHours[,i] = RainHours
}
```

RainfallHours is exported and saved as a .csv file which provides the required precipitation input (the PRD file detailed in Chapter 7) to run the SHETRAN model for the catchment

Appendix IX: creating the SHETRAN EPD file: potential evapotranspiration rcode

Potential Evapotranspiration (PET) from air temperatire (TAIR)

Jenny Sumaya Knight

22/10/2020

Extract site data for each month where single site location is used

example coding is given, all code will run from this file however data must be downloaded separately from:

```
EPath = '/media/jenny/My Passport/PhD/DATA/Weather/Tair/'
DataPath = 'data/weather/Tair_months/'
LocationsPath = 'data/weather/'
FilesPath = 'results/'

ncTest <- list.files(pattern="Rainf_WFDE5_*",path=Epath)
nc6114 <- list.files(pattern="Tair_WFDE5_CRU_*",path=CopernicusPath)
Loc25 = read.csv(file='/home/jenny/PhD/R_Files/Loc25.csv')


site_lon <- -2.75
site_lat <- 51.75


net1 = nc_open(paste0(CopernicusPath,nc6114[8]))
lon <- ncvar_get(net1, 'lon')
lat <- ncvar_get(net1, 'lat')
t = ncvar_get(net1, 'time')
Tair.array = ncvar_get(net1, 'Tair')
r_brick= brick(Tair.array, xmn=min(lat), xmx=max(lat), ymn=min(lon), ymx=max(lon),
↪  crs=CRS("+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs+ towgs84=0,0,0"))
r_brick = flip(t(r_brick), direction = 'y')
Tairhlist <- extract(r_brick, SpatialPoints(cbind(site_lon,site_lat)), method='simple')
nc_close(net1)
TairHours = unlist(Tairhlist,recursive = F)



site_df_8 = data.frame(hours= t, Tair = t(TairHours))



#site_df_# = data.frame(hours=seq(from = as.POSIXct("2013-12-01 00:00:00",),to =
↪  as.POSIXct("2013-12-31 23:00:00"), by="hours"), RainF = t(RainHours))

write.csv(site_df_8, file = '/home/jenny/PhD/DATA/Weather/Tair/site_dT_8.csv',row.names =
↪  FALSE,)
#write.csv(site_df_6, file = '/home/jenny/PhD/R_Files/Weather/site_df_6',row.names =
↪  FALSE,)
```

The code above creates a csv for the air temperature (TAIR) data for each month - from July 2013 (site_df_1) to March 2014 (site_df_9). Due to the size of the netcdf files, and only requiring nine months of data, this long hand version of running the code each time was more efficient (for me at the time) than working out how to do a for loop to run the lot in one go. It also meant that I could identify any issues with each run, and the processing time for each individually was manageable (for loops working with the netcdf files required greater processing than my laptop could give and were causing R to crash).

combining data

the individual monthly files needed combining into one data file, as this data no longer uses the netcdf files the monthly files are save as part of this folder, however all 'final' csv's have been marked to not save as to not overwrite original files.

```
list_of_files <- list.files(path = DataPath,
                            pattern = "site_d*",
                            full.names = TRUE)
df = list_of_files %>%
    setNames(nm = .) %>%
    map_df(~read_csv(.x, col_types = cols(), col_names = FALSE), .id = "file_name")
 ↪


df$X1 = as.numeric(df$X1)
```

```
## Warning: NAs introduced by coercion
```

```
head(df)
```

```
## # A tibble: 6 x 3
##   file_name                                    X1 X2
##   <chr>                                     <dbl> <chr>
## 1 data/weather/Tair_months//site_dT_1.csv     NA Tair
## 2 data/weather/Tair_months//site_dT_1.csv 994896 286.108337402344
## 3 data/weather/Tair_months//site_dT_1.csv 994897 285.560882568359
## 4 data/weather/Tair_months//site_dT_1.csv 994898 285.229553222656
## 5 data/weather/Tair_months//site_dT_1.csv 994899 284.400909423828
## 6 data/weather/Tair_months//site_dT_1.csv 994900 283.778167724609
```

```
Tair_df = df[,2:3]

colnames(Tair_df) = c("Hours","Tair")
Tair_df$Hours = as.numeric(Tair_df$Hours)
Tair_df$Hours = as.POSIXct((Tair_df$Hours*3600), origin = "1900-01-01 00:00")
Tair_df[!is.na(Tair_df$Hours), ]
```

```
## # A tibble: 6,576 x 2
##    Hours               Tair
##    <dttm>              <chr>
##  1 2013-07-01 01:00:00 286.108337402344
##  2 2013-07-01 02:00:00 285.560882568359
##  3 2013-07-01 03:00:00 285.229553222656
##  4 2013-07-01 04:00:00 284.400909423828
##  5 2013-07-01 05:00:00 283.778167724609
##  6 2013-07-01 06:00:00 283.712585449219
```

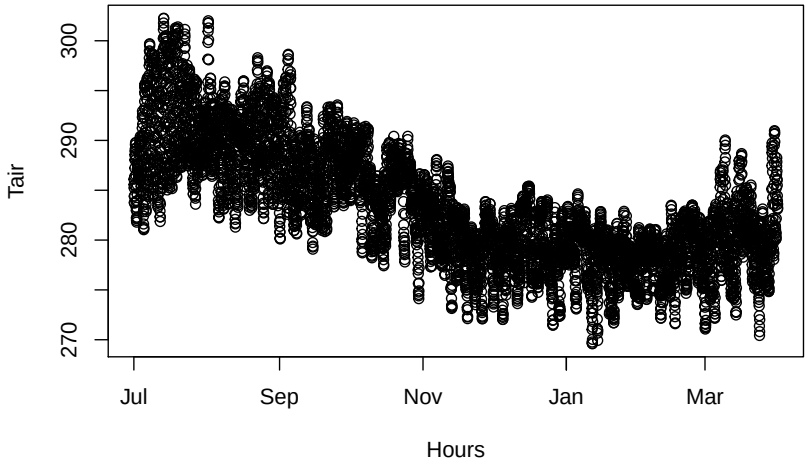


```
##  7 2013-07-01 07:00:00 284.421539306641
##  8 2013-07-01 08:00:00 285.485137939453
##  9 2013-07-01 09:00:00 286.3857421875
## 10 2013-07-01 10:00:00 287.227325439453
## # ... with 6,566 more rows
```

```
Tair_df = na.omit(Tair_df)
head(Tair_df)
```

```
## # A tibble: 6 x 2
##   Hours               Tair
##   <dttm>              <chr>
## 1 2013-07-01 01:00:00 286.108337402344
## 2 2013-07-01 02:00:00 285.560882568359
## 3 2013-07-01 03:00:00 285.229553222656
## 4 2013-07-01 04:00:00 284.400909423828
## 5 2013-07-01 05:00:00 283.778167724609
## 6 2013-07-01 06:00:00 283.712585449219
```

```
plot(Tair_df)
```




```
#write.csv(Tair_df, file = 'results/Tair.csv',row.names = FALSE,)
```

conversion from TAIR to PET using Blaney Criddle formula

This is the simplest method of finding PET, and would not be considered suitable for a model that was being used to attempt to predict future response. However, as both simplification and uncertainty of landuse (to 100mx100m grids), simplification and uncertainty of soils data would have a significant impact on the reliability of the model for this function (and, it can be argued, there being a question over the current use of modelling in the manner which it is done anyway) trying to gain a more accurate PET would not improve the overall reliability and validity of the model. As with the rainfall, the PET gives a realistic 'past' scenario, against which other changes can be evaluated. (this data has been checked against the 2012 CEH data to ensure that it falls within a suitable range for the catchment)

```r
#Find PET using Blaney Criddle formula
#Refs include
# http://www.fao.org/3/s2022e/s2022e07.htm
# https://cran.r-project.org/web/packages/Evapotranspiration/Evapotranspiration.pdf
library(Evapotranspiration)
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```r
library(rgdal)
library(lubridate)
```

```
##
## Attaching package: 'lubridate'
```

```
## The following objects are masked from 'package:raster':
##
##     intersect, union
```

```
## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```r
#https://link.springer.com/article/10.1007/s11269-014-0670-7
#The Blaney-Criddle formula: ETo = p (0.46 T mean +8.13)
#p = daily percent of annual daylight hours for each day

Tair = read.csv(file = 'results/Tair.csv')

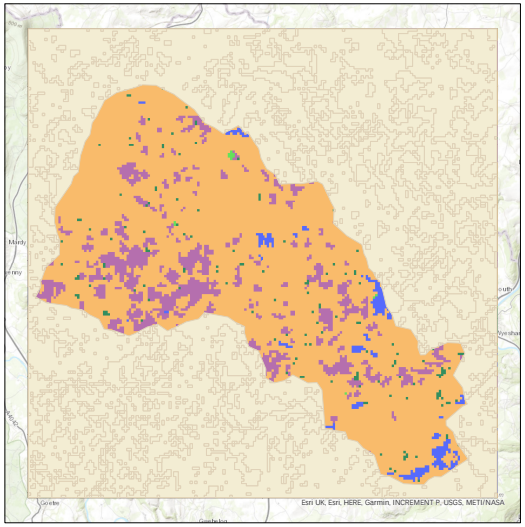

#Hours of sunlight
#Annual daylight hours for Cardiff = 1587h avg sunlight of 4383h daylight
#https://www.climatedata.eu/climate.php?loc=ukxx0030&lang=en
# Sunrise/set times from http://astro.ukho.gov.uk/nao/miscellanea/UK_SRSS/uk_mar.html

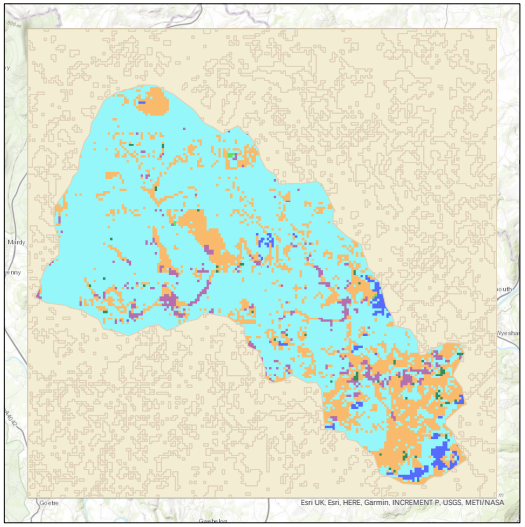
July = c("05:13", "21:24", "2013-07-01")
Aug = c("05:57",    "20:36", "2013-08-01")
Sept = c("06:47",   "19:29", "2013-09-01")
Oct = c("07:36",    "18:21", "2013-10-01")
Nov = c("07:30",    "16:24", "2013-11-01")
Dec = c("08:12",    "16:04", "2013-12-01")
Jan = c("08:12",    "16:33", "2014-01-01")
Feb = c("07:28",    "17:27", "2014-02-01")
Mar = c("06:28",    "18:17", "2014-03-01")

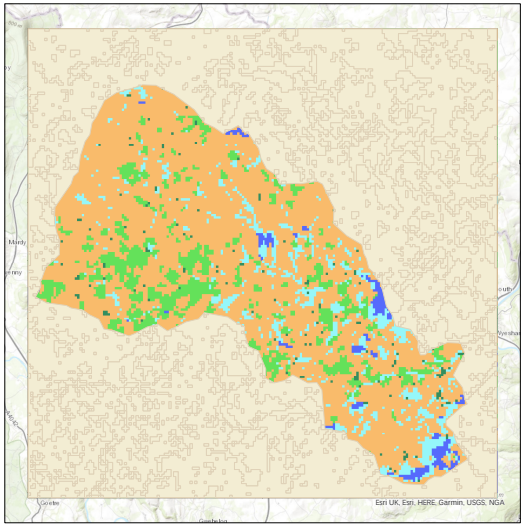
SunriseSet_Times = as.data.frame(rbind(July, Aug, Sept, Oct, Nov, Dec, Jan, Feb, Mar))
 ↪  #dataframe
dim(SunriseSet_Times)
```

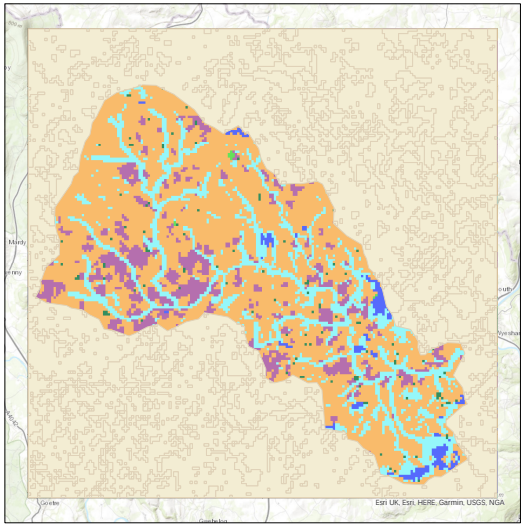
```
## [1] 9 3
```

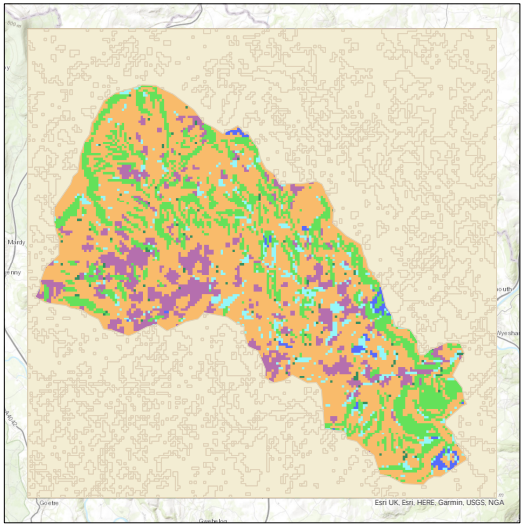
Appendix X: Alternative landcover maps

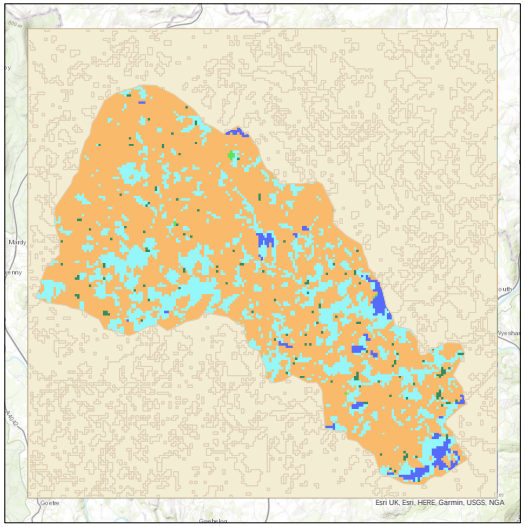

Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
0
2.5
5
10 Kilometers
Deforest_BLeaf
Value
1
2
3
4
5
7

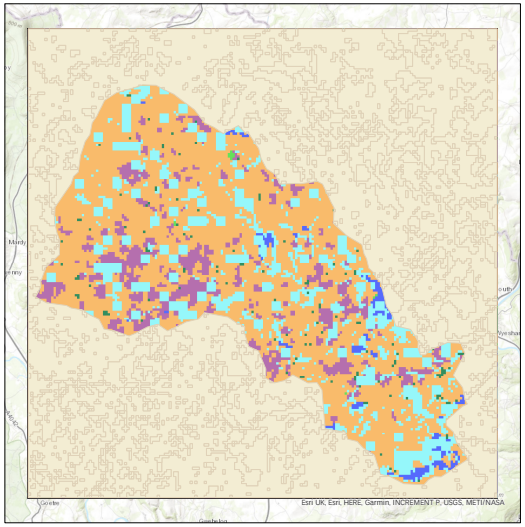

Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
0
2.5
5
10 Kilometers
GlastirWO_Raster
Value
1
2
3
4
5
7

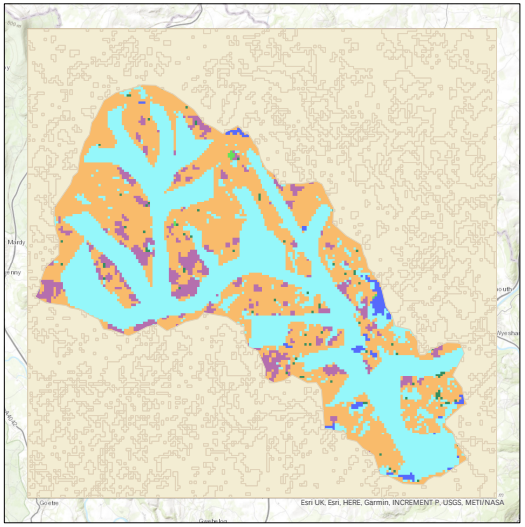

Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
NoArable (Maize)
Value
1
2
3
4
5
7

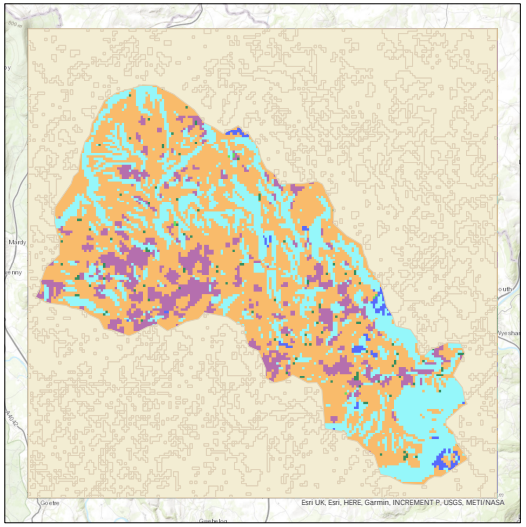

Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
Rip40mR
Value
1
2
3
4
5
7

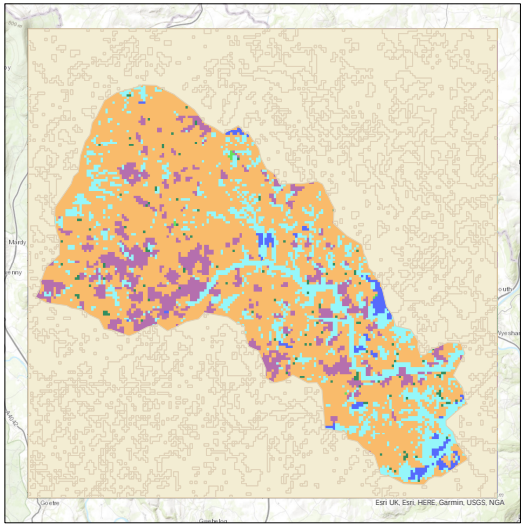

Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
Slope6o_Grass
Value
1
2
3
4
5
7

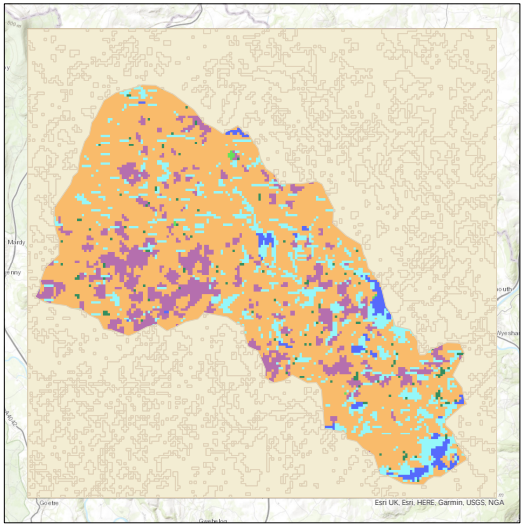

Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
Arable_all (Willow_crop)
Value
1
2
3
4
5
7

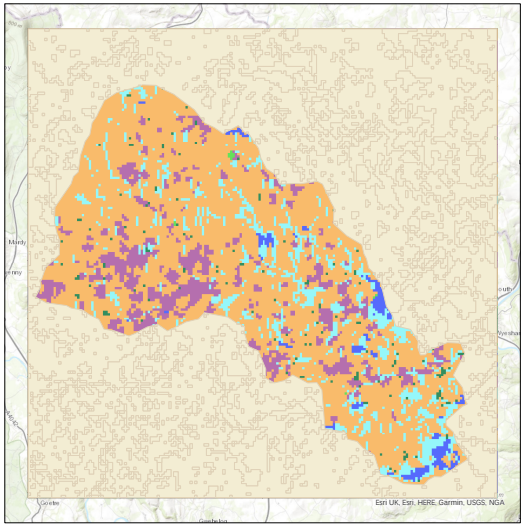

Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
0
2.5
5
10 Kilometers
CS10acres_EW_Raster
Value
1
2
3
4
5
7

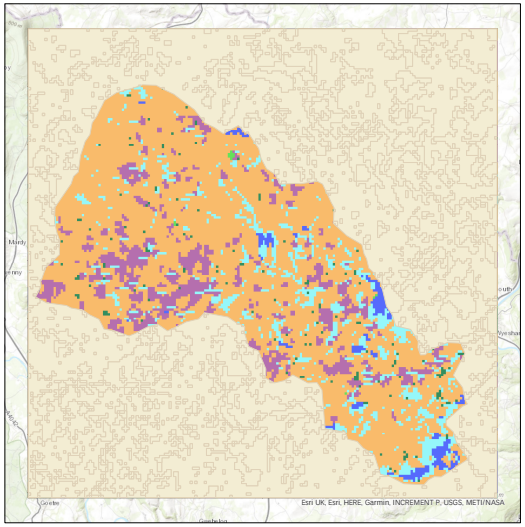

Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
0
2.5
5
10 Kilometers

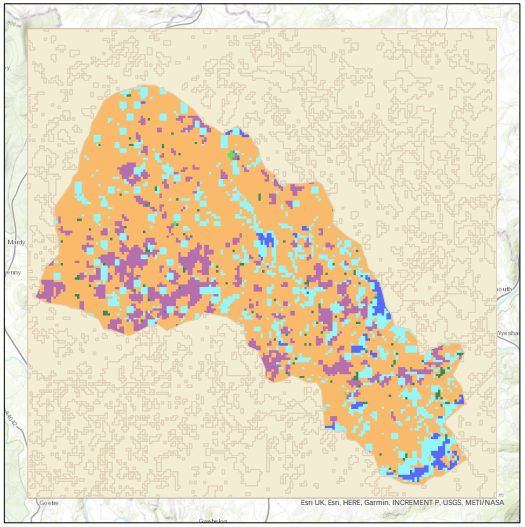

Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
0
2.5
5
10 Kilometers
WoodedSlopeo6
Value
1
2
3
4
5
7

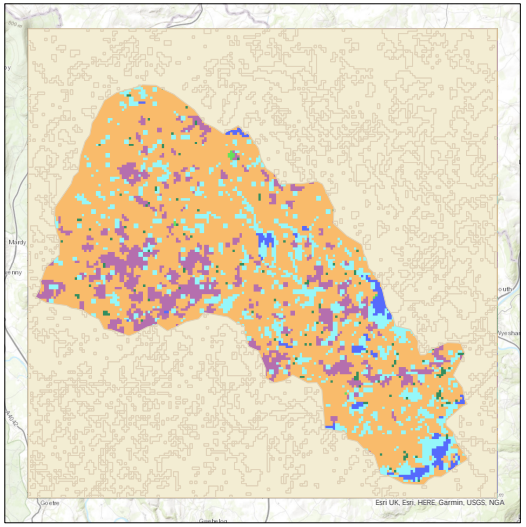

Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
WetWoods
Value
1
2
3
4
5
7

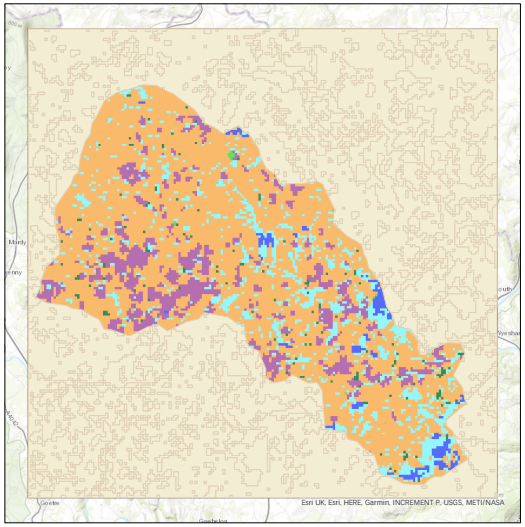

Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
CS10acres_EW
Value
1
2
3
4
5
7

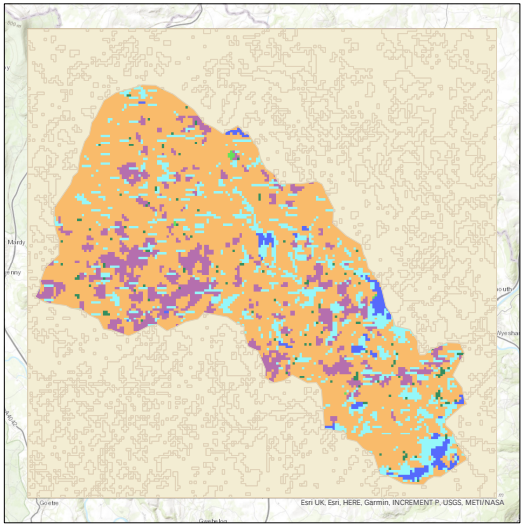

Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
CS10acres_NS
Value
1
2
3
4
5
7

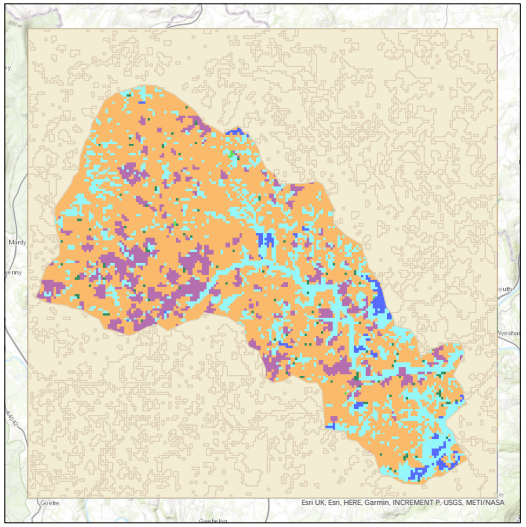

Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
0
2.5
5
10 Kilometers
SB10acres_Raster
Value
1
2
3
4
5
7

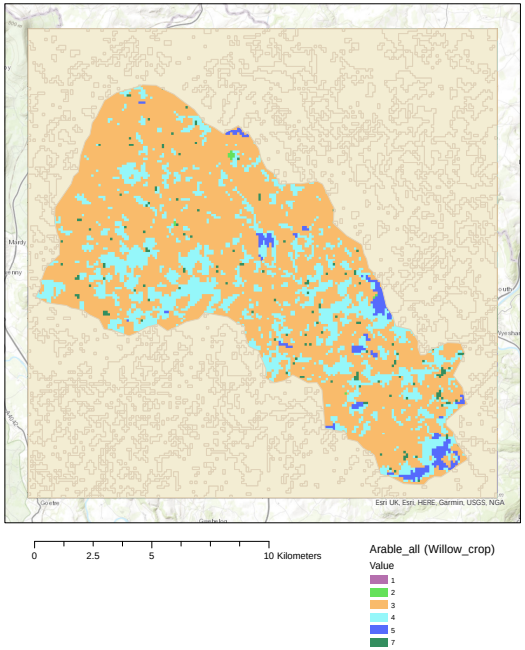

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Wood20AcSq_Raster
Value
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2
3
4
5
7

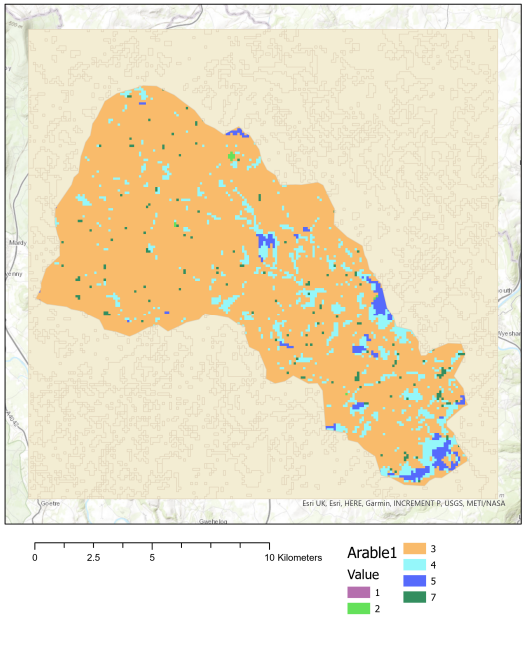

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5
10 Kilometers
Wood10AcrSq_Raster
Value
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2
3
4
5
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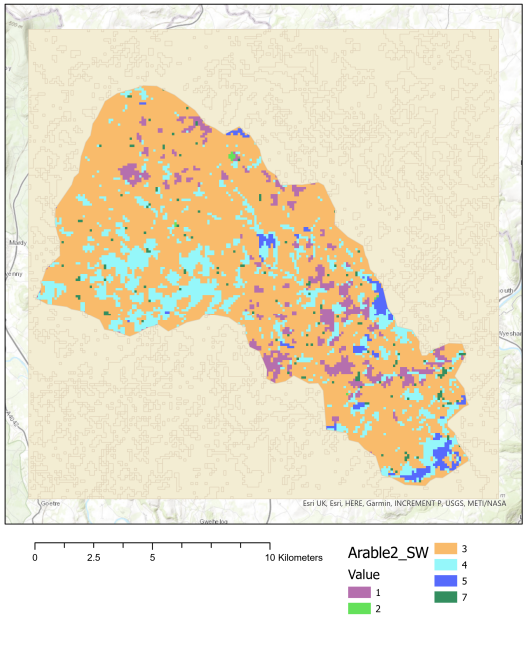

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10 Kilometers
Woods350x5Acres_E_M_PolygonToRaster
Value
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2
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4
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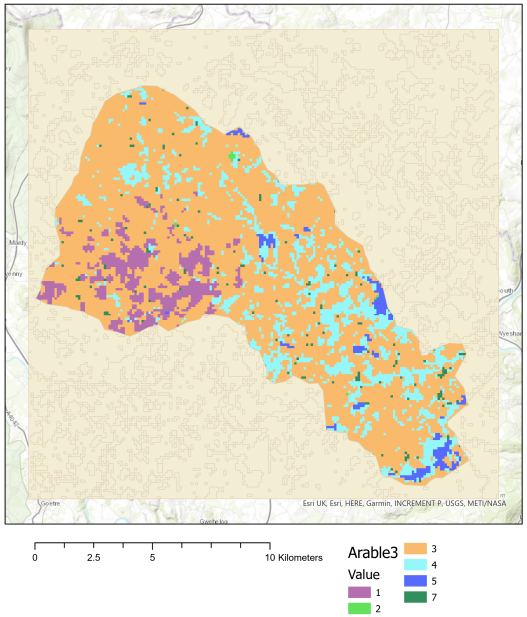

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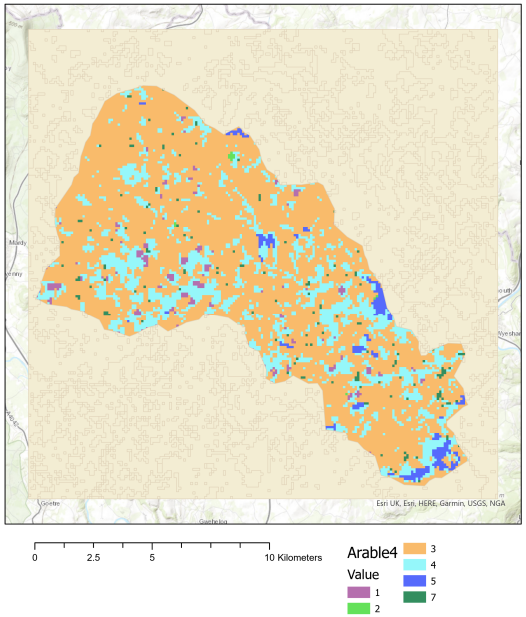

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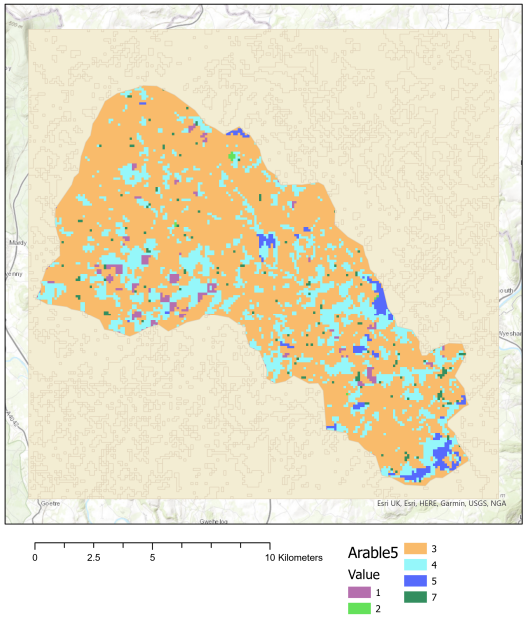

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10 Kilometers
Arable_all (Willow_crop)
Value
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2
3
4
5
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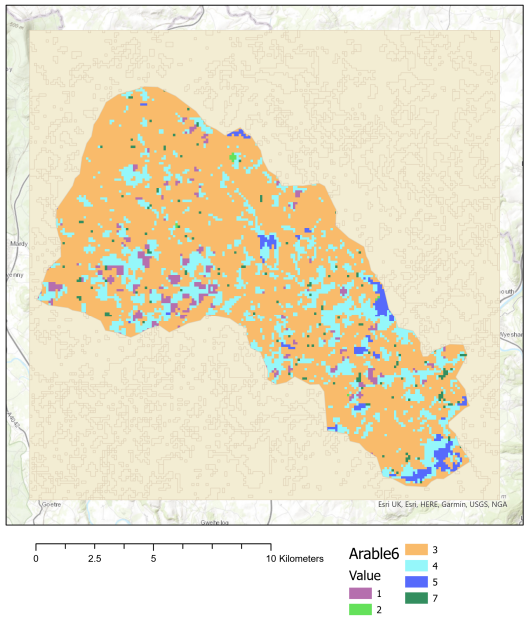

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5
10 Kilometers
Arable1
Value
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2
3
4
5
7

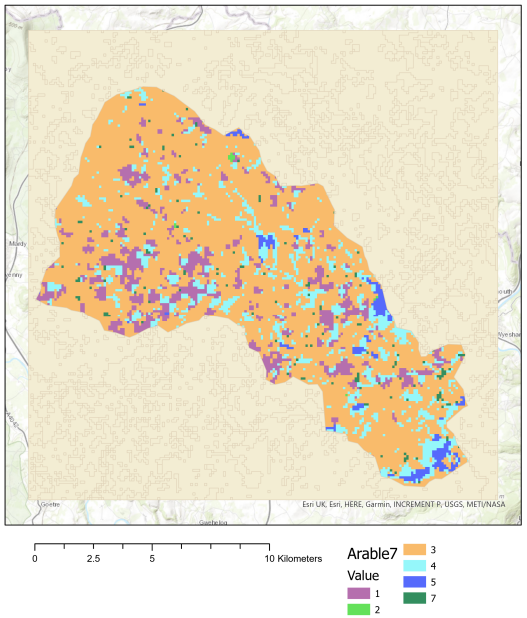

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10 Kilometers
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Value
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3
4
5
7

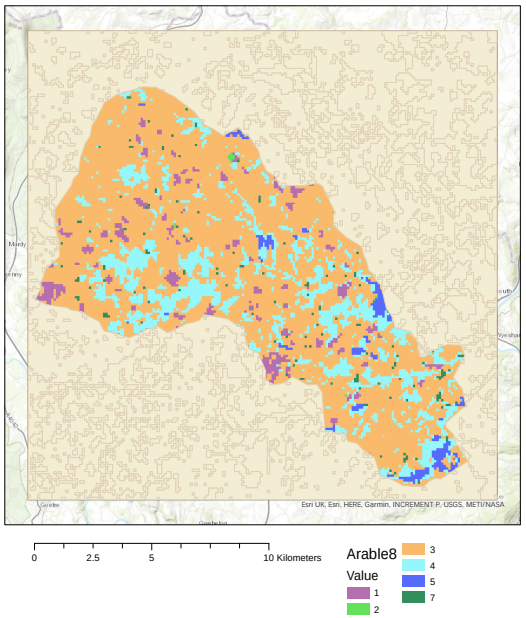

Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
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2.5
5
10 Kilometers
Arable3
Value
1
2
3
4
5
7

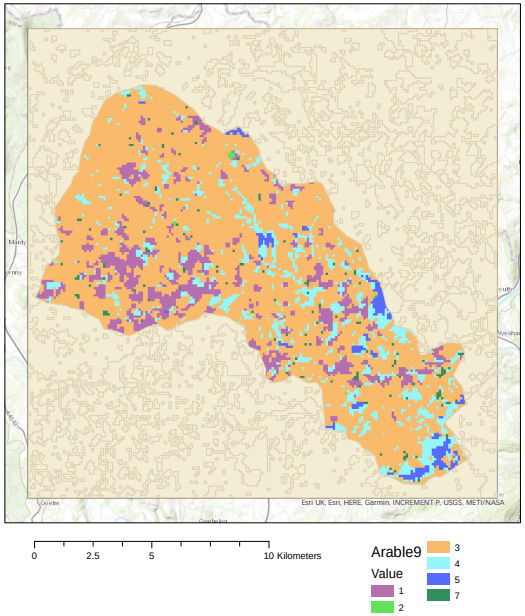

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10 Kilometers
Arable4
Value
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2
3
4
5
7


Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
Arable5
Value
1
2
3
4
5
7


Esri UK, Esri, HERE, Garmin, USGS, NGA
0
2.5
5
10 Kilometers
Arable6
Value
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Esri UK, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA
0
2.5
5
10 Kilometers
Arable9
Value
1
2
3
4
5
7

Appendix XI: SHETRAN baseline parameters

```
SHETRAN Trothy ETD file - Vegetation Parameters

:ET1 - TEST CATCHMENT- ET COMPONENT DATA SET
      F      F      T
:ET3 - DTMET : TIMESTEP FOR INPUT OF RAIN AND MET. DATA
    1.0 1.0000 24.000
:ET5 - MEASPE (0 NOT MEASURED, 1 MEASURED)
      1      1      1      1      1      1
:ET7 - VEGETATION TYPE Arable
      F     0.     0.     0.     0.     0.      3
      7 1.0000 1.50001.40E-5 5.1000      8 1.0000      0      0
:ET9 - CONTROLS FOR TIME VARYING PARAMETERS FOR VEGETATION TYPE
      0      0      0      0
:ET15 - PSI/RCF/FET FUNCTION FOR VEGETATION TYPE
 -1000.    60.    0.0
 -150.0    60. 0.0300
 -50.00    60. 0.1200
 -20.00    60. 0.3000
 -10.00    60. 0.4800
 -1.000    60. 0.6000
 -0.100    60. 0.6000
:ET17 - DEPTH/RDF FOR VEGETATION TYPE
 0.1000 0.3100
 0.2000 0.2280
 0.3000 0.1700
 0.4000 0.1000
 0.5000 0.0720
 0.6000 0.0600
 0.7000 0.0400
 0.8000 0.0200
:ET7 - VEGETATION TYPE BareGround
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      7    0.0    0.01.40E-5 5.1000      1 1.0000      0      0
:ET9 - CONTROLS FOR TIME VARYING PARAMETERS FOR VEGETATION TYPE
      0      0      0      0
:ET15 - PSI/RCF/FET FUNCTION FOR VEGETATION TYPE
 -1000.     0.    0.0
 -150.0     0. 0.0200
 -50.00     0. 0.0800
 -20.00     0. 0.2000
 -10.00     0. 0.3200
 -1.000     0. 0.4000
 -0.100     0. 0.4000
:ET17 - DEPTH/RDF FOR VEGETATION TYPE
 0.1000 1.0000
:ET7 - VEGETATION TYPE Grass
      F     0.     0.     0.     0.     0.      3
      7 1.0000 1.50001.40E-5 5.1000     10 1.0000      0      0
:ET9 - CONTROLS FOR TIME VARYING PARAMETERS FOR VEGETATION TYPE
      0      0      0      0
:ET15 - PSI/RCF/FET FUNCTION FOR VEGETATION TYPE
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 -150.0   120. 0.0300
 -50.00   120. 0.1200
```

```
 -20.00   120. 0.3000
 -10.00   120. 0.4800
 -1.000   120. 0.6000
 -0.100   120. 0.6000
:ET17 - DEPTH/RDF FOR VEGETATION TYPE
 0.1000 0.2500
 0.2000 0.1800
 0.3000 0.1500
 0.4000 0.1200
 0.5000 0.1000
 0.6000 0.0800
 0.7000 0.0600
 0.8000 0.0300
 0.9000 0.0200
 1.0000 0.0100
:ET7 - VEGETATION TYPE DeciduousForest
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:ET9 - CONTROLS FOR TIME VARYING PARAMETERS FOR VEGETATION TYPE
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:ET15 - PSI/RCF/FET FUNCTION FOR VEGETATION TYPE
 -1000.    10. 0.0500
 -150.0    10. 0.2000
 -50.00    10. 0.5000
 -20.00    10. 0.8000
 -10.00    10. 1.0000
 -1.000    10. 1.0000
 -0.100    10. 1.0000
:ET17 - DEPTH/RDF FOR VEGETATION TYPE
 0.1000 0.1780
 0.2000 0.1440
 0.3000 0.1260
 0.4000 0.1080
 0.5000 0.0940
 0.6000 0.0800
 0.7000 0.0660
 0.8000 0.0520
 0.9000 0.0400
 1.0000 0.0270
 1.2000 0.0400
 1.4000 0.0270
 1.6000 0.0180
:ET7 - VEGETATION TYPE EvergreenForest
      F     0.     0.     0.     0.     0.      3
      7 1.0000 5.00001.40E-5 5.1000     15 1.0000      0      0
:ET9 - CONTROLS FOR TIME VARYING PARAMETERS FOR VEGETATION TYPE
      0      0      0      0
:ET15 - PSI/RCF/FET FUNCTION FOR VEGETATION TYPE
 -1000.    10. 0.0500
 -150.0    10. 0.2000
 -50.00    10. 0.5000
 -20.00    10. 0.8000
 -10.00    10. 1.0000
 -1.000    10. 1.0000
 -0.100    10. 1.0000
:ET17 - DEPTH/RDF FOR VEGETATION TYPE
 0.1000 0.1300
 0.2000 0.1200
 0.3000 0.1100
 0.4000 0.1000
 0.5000 0.0900
 0.6000 0.0800
 0.7000 0.0700
 0.8000 0.0600
 0.9000 0.0500
 1.0000 0.0300
 1.2000 0.0600
 1.4000 0.0400
 1.6000 0.0300
 1.8000 0.0200
 2.0000 0.0100
:ET7 - VEGETATION TYPE Shrub
      F     0.     0.     0.     0.     0.      3
      7 1.0000 1.50001.40E-5 5.1000     10 1.0000      0      0
:ET9 - CONTROLS FOR TIME VARYING PARAMETERS FOR VEGETATION TYPE
      0      0      0      0
:ET15 - PSI/RCF/FET FUNCTION FOR VEGETATION TYPE
 -1000.    10.    0.0
 -150.0    10. 0.0300
 -50.00    10. 0.1200
 -20.00    10. 0.3000
 -10.00    10. 0.4800
 -1.000    10. 0.6000
 -0.100    10. 0.6000
:ET17 - DEPTH/RDF FOR VEGETATION TYPE
 0.1000 0.2500
 0.2000 0.1800
 0.3000 0.1500
 0.4000 0.1200
 0.5000 0.1000
 0.6000 0.0800
 0.7000 0.0600
 0.8000 0.0300
 0.9000 0.0200
 1.0000 0.0100
:ET7 - VEGETATION TYPE Urban
      F     0.     0.     0.     0.     0.      3
      7 0.3000 0.30001.40E-5 5.1000      5 1.0000      0      0
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:ET15 - PSI/RCF/FET FUNCTION FOR VEGETATION TYPE
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 -150.0     0. 0.0200
 -50.00     0. 0.0800
 -20.00     0. 0.2000
 -10.00     0. 0.3200
 -1.000     0. 0.4000
 -0.100     0. 0.4000
```

```
SHETRAN VSD file (excluding grids) - Soil Parameters

:VS01 simulation title
           VSS data
:VS02 logical flags: BFAST,BSOILP,BHELEV
      F      T      F
:VS03 integer variables NS,NCSZON,NCRBED,INITYP
      9     35      0      1
:VS04 real variables VSIPSD,VSZMIN,VSZMAX,VSWV,VSWL
    0.0      0      0    1.0    1.0
:VS05 physical property data (IS,IVSFLG,IVSNTB / KX,KY,KZ,THSAT,THRES,SS,N,ALF)
      1      1      0          18(ClayLoamTop)
 0.0080  0.0080  0.0080  0.5500  0.1560  0.0010  1.2290  0.0112
      2      1      0          18(ClayLoamSub)
 0.0550  0.0550  0.0550  0.4890  0.1530  0.0010  1.657  0.00923
      3      1      0          6(SiltyClayLoamTop)
 0.0074  0.0074  0.0074  0.5550  0.1510  0.0010  1.2380  0.0120
      4      1      0          6(SiltyClayLoamSub)
 0.0036  0.0036  0.0036  0.5070  0.1440  0.0010  1.6080  0.00724
      5      1      0          8(ClayLoamTop)
 0.0080  0.0080  0.0080  0.5540  0.1510  0.0010  1.2380  0.0121
      6      1      0          8(ClayLoamSub)
 0.0550  0.0550  0.0550  0.4890  0.1530  0.0010  1.657  0.00923
      7      1      0          12(SandySiltLoamTop)
 0.0090  0.0090  0.0090  0.5510  0.1500  0.0010  1.2390  0.0124
      8      1      0          12(SandySiltLoamSub)
 0.0434  0.0434  0.0434  0.4520  0.0930  0.0010  1.6810  0.00515
      9      1      0          00(SandstoneBaselayer)
 0.5000  0.5000  0.5000  0.5000  0.0930  0.0010  1.6810  0.00515
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    0.2    0.2    0.2    0.2    0.2    0.2    0.2    0.2    0.2    0.2
    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0
    2.0    2.0    2.0    2.0    2.0
:VS08 no. of categories for layer definitions
      4      0
:VS08a category; no. of layers; soil/lith type; depth
      1      3
             9      2      1
        15.000 8.9000 0.6000
      2      3
             9      4      3
        15.000 9.4000 0.6000
      3      3
             9      6      5
        15.000 8.9000 0.6000
      4      3
             9      8      7
        15.000 10.100 0.6000
:VS08c  soil and aquifer distribution grid...
```

Appendix XII: We need to talk about death

FIELD FOREST & FLOOD

SEARCH

Writings and reflections on an interdisciplinary PhD. Highlights include: floods, forests, geography, social science, computer modelling, muddy data collection and a river

We need to talk about death

September 20, 2022

SHARE

In March 2022 I presented at the RGS-IGB PostGraduate midterm conference.

My title was the same as this blog post

"We need to talk about death"

This topic is of significant importance in understanding landscapes and landscape change, but also important for research and researchers more widely.

This is a thesis tangent that I haven't been able to include in depth, so I am including the conversation here (and adding it as an appendix!). Perhaps this is, as a blog post, a more useful place to begin this conversation anyway.

In the summer of 2020 I had already decided to change my research methodologies to account for (what was at the time the worst case scenario but quickly became the reality of 2021. This also meant an application for amendments to my original ethical review.

Part of the original review included both participant and researcher safety. Over the past year and partly due to my involvement in the farming communities the importance and dangers involved with mental health had become increasingly prevelant (CCRI study).

As an interdisciplinary researcher I have always sat on the edge of a number of researcher groups, but none of my research is conducted in a team environment. This became particularly evident during the Covid-19 pandemic. Having been correct in my surmise that further restrictions may be in place, the recruitment for the workshops also took place in a lockdown, which between English and Welsh restrictions was to effectively to extend until the workshops had completed.

This meant that calling participants was done on my own and I was seriously concerned about both the participants well-being and my own mental health under the circumstances.

With participants being older and often isolated, the impacts of the lockdowns could affect both their physical and mental health, and I had no way of knowing in advance their position, how well they were, or if all my participants had survived the pandemic so far. I accepted this as I had already experience death twice, though not to do with Covid. One participant had told me on our first meeting, when I asked if he would be happy for me to contact him again, that he had a terminal illness and didn't expect to survive beyond a further six months. Then in January 2021 my Grandmother passed away. I had seen her for a day in the December and was fortunate that she was living with my parents and did not die on her own.

This was forefront with me as I went through my phone calls. Whilst I managed to engage with a few people by phone, and most were pleased to hear from me, most were either busy, unwilling to immediately commit, or unsure about how much they might be able to offer. I did not find that I was able to open up conversations as well on the phone as I had done in person, and most responded that they would think about it on receiving a follow up email.

I was finding the challenge of speaking to participants by phone (out of the blue after an unprecedented year) difficult, whether conversations were positive or negative. Then the phone was answered by one gentleman, who had been so welcoming when I had visited him on the farm. He was still polite and happy to hear from me, but he had only picked up the phone because he was waiting for the hospice to arrange transport so he could be taken into respite care.

This conversation affected me incredibly deeply in an environment where I had little recourse for support.

As a researcher I was able to reflect that I had put contingency plans in place to adapt methodologies if direct calling

participants was ineffective, or had proved to demanding in comparison to its effectiveness. I reflected on the importance of the process of completing both the Ethical review and the HRA, and how this had put me in a stronger position, and wondered if my physical science colleagues (also engaging with the 'public' during fieldwork) had similar recourse.

As myself, I just sat on the flood of my kitchen and cried.

I encountered a further death during the time I was active conducting fieldwork – during the time the workshops were taking place. Not a participant, but someone well known and liked within the community and co-incidentally (I had not realised they lived within catchment when I started my work) a family friend. Prior to my research taking place two significant deaths of community members had taken place within catchment and I will explain in section ..... why this matters.

The lack of discussion of death in our society has long been recognised (Walter, 1991), the fact that this is reflected in research and academia should not be an accepted (even under the covers) or acceptable approach. Death has direct implications that reflect on precarity and uncertainty that must be part of environmental governance. Death and well-being demonstrate how entangled we as researchers are with our research. Death directly affects the well-being of the community and the research as a member or observer of that community.

Walter, T. (1991). Modern Death: Taboo or not Taboo? ***Sociology***, ***25***(2), 293–310. https://doi.org/10.1177/0038038591025002009

SHARE

Comments

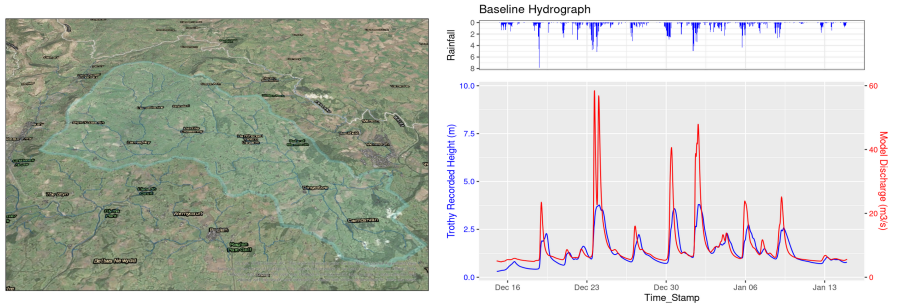
Enter Comment

Appendix XIII: Workshop Datasheet

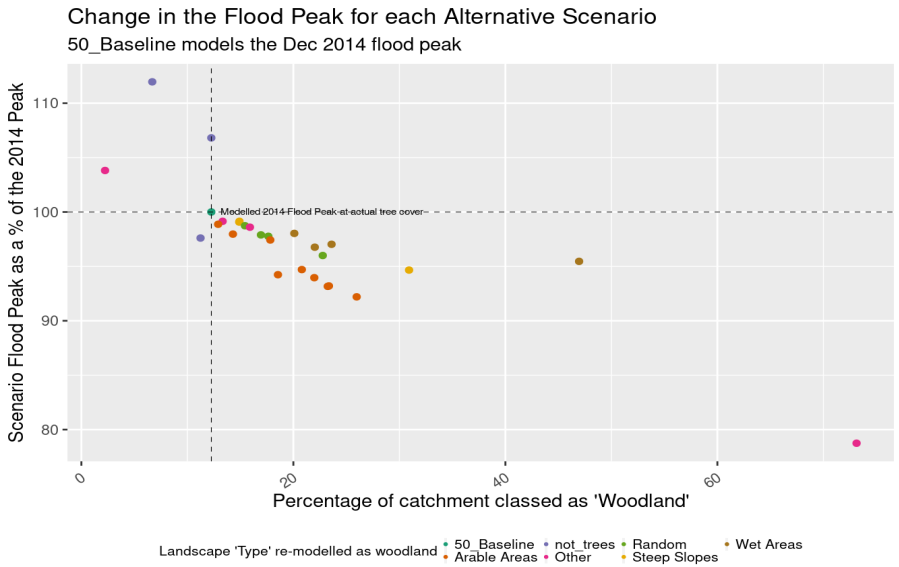
DataSheet

Jenny Knight - March 2021

Trothy Catchment Map and Hydrograph



ArcGIS Online - WebScene of the Trothy River Catchment



Provisional Model Findings and Suggestions for discussion

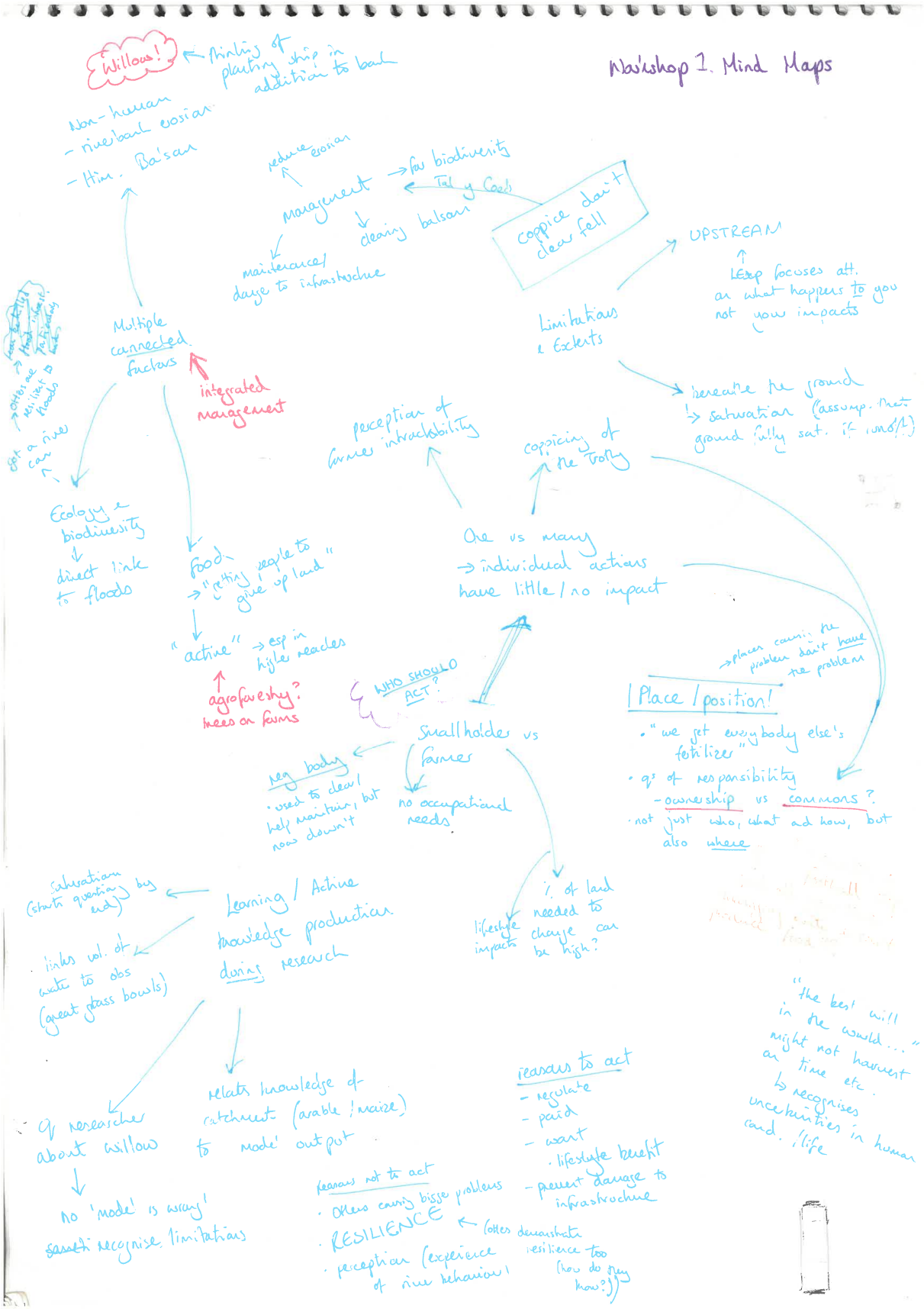
The Model Shows:

- An increase in Woodland causes a decrease in flood peak
- Wet wooded areas appear to have less overall impact (saturation may reduce impact of infiltration into soils)
- Small frequent interventions have an additive effect
- Location matters, impacts not only due to 'what' is being replaced but also 'where'
- 'Riparian' or floodplain planting may show diminishing returns at very large acreage
- There is a large increase in flood peak under circumstances of tree or ground cover loss

Provisional reflections - to be critiqued by land managers:

- Small, diverse tree planting schemes, suitable within the farmed landscape, would have a positive impact on flooding
- Planting in wet areas may have a less effective impact. Planting should be prioritized for other land management benefits (supporting riverbanks, improving biodiversity etc)
- Small areas of arable tree-crop, such as willow or hazel coppice for energy or tree-forage may show the most significant impact on flood peaks
- Woodland planting within the catchment should be expected to meet multiple benefits including reducing flood peaks
- Ensuring replacement of tree cover that may be lost due to Ash Dieback or other impacts should be considered a priority, as should choices that minimise bare ground within the catchment
- Model provides guiding information with inherent uncertainties and local variation. This suggests need for monitoring and adaptive approaches.

Appendix XIV: Workshop mind maps



Workshop 2

Silt

Circumstances and changes in circ.: land? income from land? new ownership? passing vs adopt? how affect community?

Multiple Outcomes / drivers

Heterogeneity

Suggesting Solutions
- coppice / pollard
- offsetting

Limitations & extent

applicability impacted by more than physical characteristics

single farm to dictat

conflict NVZ

can't apply generalised rules

Scale

not exact fine detail

fencing

SH make sure it doesn't break

FR trap debris so doesn't damage equip

→ different social sits / needs affect type of intervention and impact / efficacy...

→ add info: → Lived exp / Obs adds in detail (impact of diff grasses / management)

: unknowns → scale impact of Ash (not visible)

: innovation / practical management suggestions

Don't provide 'advice' provide options

→ knowledge bank?

"applicable my side isn't taken"

⇒ cooperation & offsetting

individual action (vs) community action

→ big vs small

→ my side / other side

→ all work no impact

production / offsetting

Incentives and barriers to action

grant structures / admin — particularly for small holders

production

gates swing both ways → production is a barrier to a farmer but a potential for a smallh.

upstream vs downstream knowledge

perception and generalization
↳ admin vs cost?
↳ equality vs justice?

Communication & timing

Governance

timing about grants
knowledge of grants

tiered governance split → NFUs or council?

taking control (see conflict)

- never take growers skilling
- impact of grants
- conflict over generalised regulation
- given options = gaining control

⇒ combining less knowledge types
- options / expectations / reward
- place-based application

Multiple knowledge integration
Flexibility
Control

Learning / knowledge

application to choices

adding to model info

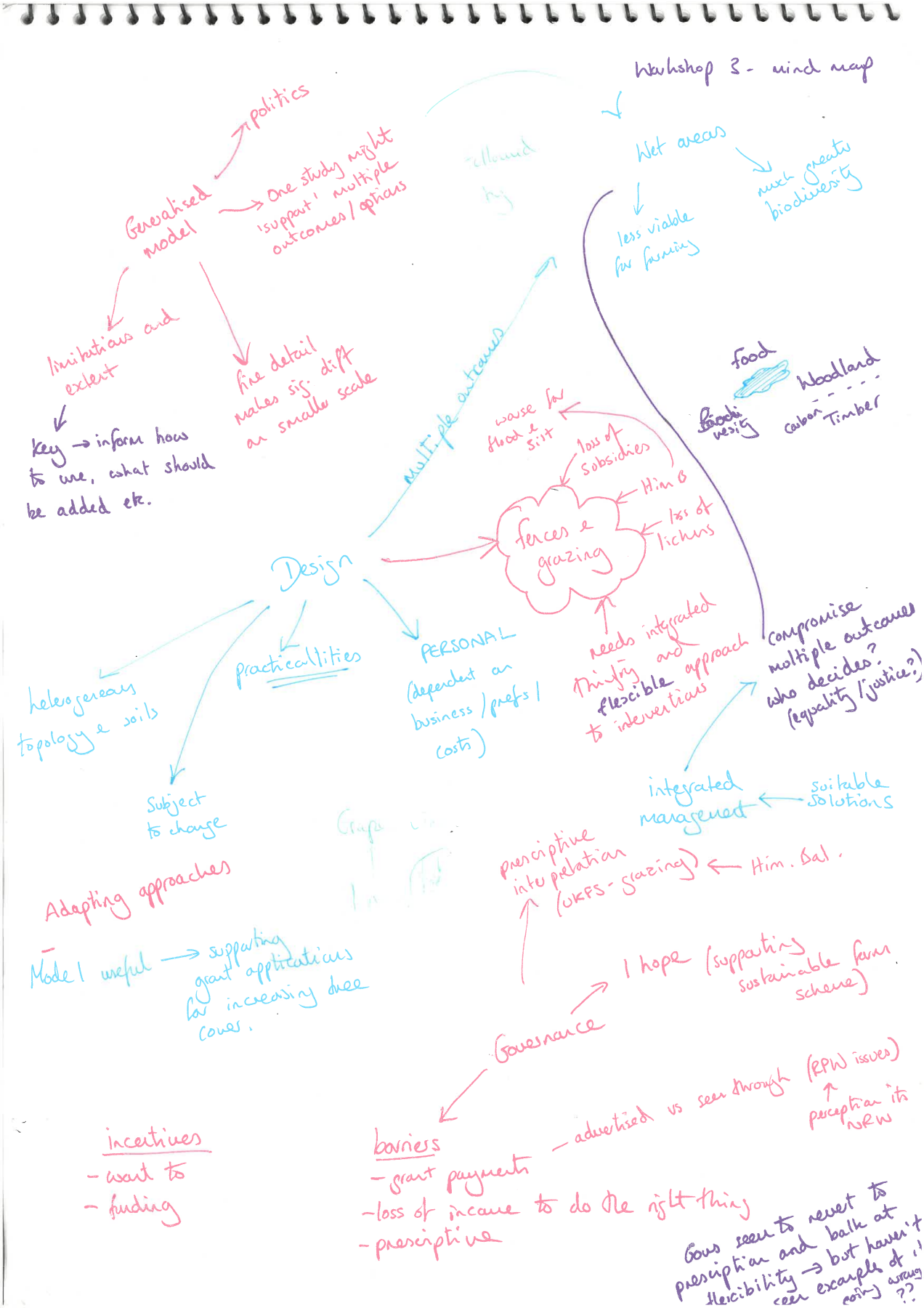
Scale

peer to peer (not accessible to small holders?)

paid advisors

Willow
↳ preventing erosion, loss of soil. Silt build up creating pools.

resilience & permanency (better than engineering)


Workshop 3 - mind map
politics
Generalised model
One study might support multiple outcomes / options
limitations and extent
key → inform how to use, what should be added etc.
fine detail makes sig. diff on smaller scale
wet areas
less viable for farming
most greatly biodiversity
food
woodland
carbon
Timber
multiple outcomes
worse for flood & silt
loss of subsidies
Him B
loss of lichens
fences & grazing
Design
needs integrated thinking and flexible approach to interventions
compromise multiple outcomes who decides? (equality / justice?)
heterogeneous topology & soils
practicalities
PERSONAL (dependent on business / prefs / costs)
Subject to change
Adapting approaches
integrated management
suitable solutions
prescriptive interpretation (UKFS - grazing)
Him. Bal.
Model useful → supporting grant applications for increasing tree cover.
I hope (supporting sustainable farm scheme)
Governance
incentives
- want to
- funding
barriers
- grant payments
- loss of income to do the right thing
- prescriptive
- advertised vs seen through (RPW issues)
perception in NRW
Govs seem to revert to prescription and balk at flexibility → but haven't seen examples of it going wrong ??

Appendix XV: Summary report for NRW South East Area team

Forest, Flood and Farming - Provisional summary for NRW

Jenny S Knight

May 20, 2022

Land manager lived experience and local expertise directly impacts and improves planning treescapes and landscape change for Nature Based Solutions.

Doctoral Research exploring the importance of farmer/land manager lived experience and expertise in landscape change through the lens of tree planting for Natural Flood Managment (NFM)

Contents

0.1 Provisional and Selected Findings . . . 1
0.2 Context . . . 2
0.3 Aims of the thesis: . . . 2
0.4 Interdisciplinary Approach . . . 3
0.5 Summary . . . 4
0.6 Participant Data Sheet - provided at evaluation workshops . . . 5
0.7 Selected Bibliography . . . 6

0.1 Provisional and Selected Findings

- The physical catchment characteristics and understandings of place will directly impact on the efficacy and suitability of interventions
- Engaging with lived experience and local expertise (for example, through long interviews, developing relationships and techniques such as participatory mapping) improves scientific practice and can directly inform policy.
- Output of hydrological model demonstrates the efficacy of increased treescapes in reducing flood peaks. However, it highlights that the suitability of interventions will be affected by the differences in physical characteristics of individual catchments.
- New treescapes and NFM interventions must enable land managers to meet a diverse range of outcomes if they are to function within working landscapes. This suggests integrated land management and adaptive approaches.
- Community engagement, monitoring and adaptive practice will be necessary in trialling, understanding and maintaining effectiveness and maintenance of any interventions.
- Priority actions should focus on working with land managers to ensure flooding doesn't get worse by identifying landscape scale interventions. This approach will also need integrating with all water management issues including drought and water quality.

This document has been collated to help inform Natural Resources Wales of findings and relevant information about the Doctoral Research conducted. It is currently in process and has not been peer reviewed so findings are provisional and not for wider circulation without approval of researcher. All references must be correctly attributed to the researcher.

0.2 Context

The paradigm shift in political support for the benefits of forested landscapes sits alongside broader changes in Flood Management since the 2007 disasters. There is increased funding for tree planting for Natural Flood Management (NFM) despite uncertain scientific evidence, with little data for efficacy in large sites or the impact of woodland management. NFM can be seen as a 'Wicked' problem and becomes an example where democratic discussion and 'extended peer communities' may be the relevant experts. However, current policy and planning is technocratic and teleological, a process which has encountered significant 'social' barriers towards implementation and support for both NFM and tree planting schemes.

0.3 Aims of the thesis:

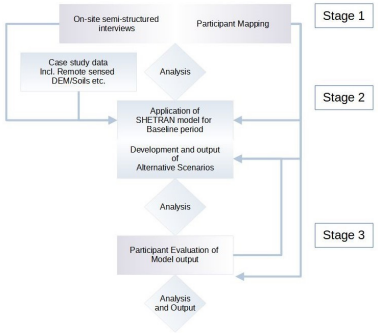
Within the context of environmental challenges and landscape change we aim to understand how farmers / land managers knowledge and expertise informs their decision making and how compatible and relevant that knowledge is with knowledges that currently inform science/policy decision making; specifically hydrological approaches including computational modelling of Trees for Natural Flood Management.

Objectives:

- Identify farmers / land managers relevant knowledge and expertise and how this impacts their decision making and political behaviour
- Explore the integration/compatibility of different knowledges for decision-making including farmer/land manager knowledge and expertise and scientific knowledge from hydrology principles in particular the use of computational modelling for evaluating landscape scale change.
- Critique current science/policy interface and decision making process alongside farmer/model knowledge integration for usefulness in enabling management interventions that i) deliver NFM and ii) are acceptable to multiple stakeholders ...

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0.4 Interdisciplinary Approach



- Stage 1A: Participatory mapping used to identify participants perception of their landscape and knowledge of the land use. This took place alongside semi-structured interviews either 'at farm table' or walking around the landscape.

  Data collected/created included the audio recordings, maps, photographs, field notes and subsequent transcripts of activities and interviews.

- Stage 1B: Data collection in regards the physical characteristics of the site (onsite and remote data), supplemented with expertise of the land owners gained in the qualitative interviews in regards flood characteristics of the site.

  Data collected/created: Photographs, GPS data for key sites, site characteristics, online remote data (e.g. DEM / land cover), hydrological and weather data

- Stage 2A: Application of SHETRAN Model to the catchment to develop a model of a known flood period – December to February 2014. Baseline model calibrated using NRW levels data for site / evaluated against levels for storm period and against historic flow data.
- Stage 2B: Development of alternative land cover scenarios for increased treescapes and other land use changes to evaluate impact on modelled catchment hydrology; building on participant data and preferences, and informed by scientific and policy context.
- Stage 3: Evaluation of model and provisional qualitative findings through conventional hydrological analysis and a series of participant workshops,. These informed a number of further model runs, and are being analysed to contextualise and fully understand model output, both in possible impacts of tree cover within catchment, but also its 'position' in regards a source of knowledge in decision making and management implications....

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0.5 Summary

The Trothy river catchment is +140km2; it is largely agricultural and is well populated. Despite a perception of being 'well-wooded' it is only at 11% contiguous woodland cover. Flooding occurs significantly at stages along the length, and at the confluence with the River Wye (near Monmouth) impacting the behaviour of the river there and below. However, it would not meet the criteria for any engineered flood management being attributed 'low-risk'; increased development in the area may impact this rating in the future (see implications for development of Trothy house and cost/benefit analysis of directing funding)

Findings from the fieldwork in 2019/2020 demonstrated the importance of knowledge exchange with participants, at both a scientific and cultural level. The importance of cultural behaviours, land management and non-human agency in landscapes was identified by both participants and researcher. As well as directly impacting the modelling process and purpose, this has key impacts for future 'evidence-based' policy and environmental governance.

Support for tree planting was positive, with 20 out of 22 sites suggesting / having plans for / or actively planting trees. This is despite 18 out of 22 sites declaring a lack of interest in new woodland or a need for trees during early stages. This outcome is key reflecting the importance of developing relationships and understanding landscapes through knowledge exchange rather than short survey, or distance based evaluation.

Page 5 shows the datasheet as shared with participants. Model findings speak to:

- the potential of treescapes of different scales, locations and arrangements to reduce flood peak heights, including the differences between strategic and random planting
- the effect of alternative land cover scenarios on delaying the arrival of the flood peak to a downstream location ("lag-time") and in moderating flood events
- The importance of potential loss of trees or other future management choices on increasing the scale of flooding

Provisional analysis with participants showed that the model reflected the behaviour of the river and floods that participants experienced. Factors such as the spatial resolution of the model leant to the model being a learning tool rather than a determining factor; in addition participants identified the importance of changing land management choices. These and other factors reinforced their preference for a range of adaptive options rather than prescriptive measures.

Both the model output and participant feedback emphasised the importance of heterogeneity both of and within the catchment. The model demonstrated that commonly held 'types' of NFM would not necessarily be suitable in this catchment due to soil depths and current behaviour. Participants recognised this and also identified the impact of land management on the efficacy of seemingly simple interventions (such as fencing off riverbanks - see Himalayan Balsam). Local experience of river behaviour has the potential to inform suitability of infrastructure and intervention in both effectiveness and maintenance implications (see major wall collapse)

Throughout the work participants were supportive of concepts of change and adaptation. Participants themselves suggested cooperative working, monitoring projects, resilience measures and 'offsetting' style projects. Negative perceptions were of 'enforced', 'external' and 'restrictive' measures, and barriers to progress included administration and knowledge exchange (both an ability to share and to access information).

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