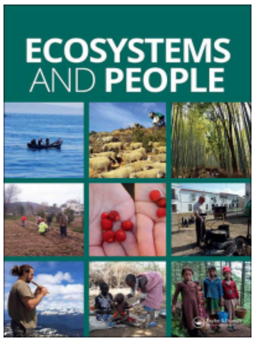


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# From local solutions to catchment-wide management: an investigation of upstream-downstream trade-offs when scaling out nature-based flood risk management

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**ABSTRACT**

Natural flood management (NFM) is a nature-based solution (NbS) widely recognised as an option to regulate flooding whilst providing multiple ecosystem services (ES) for society and the environment. To address climate change-enhanced flood risk, localised-NFM could be scaled out (expanded geographically to the catchment level). Implementing catchment-scale NFM will not only change landscape appearance but also give rise to potential ES trade-offs between the 'providers' of upstream land for flood regulation and the 'beneficiaries' of reduced flooding downstream. This paper presents a live case study of four river catchments in the UK, where a multi-agency-funded collaborative project is implementing integrated, catchment-scale NFM to work with downstream urban flood defences. Assessment of the views of upstream-downstream catchment communities is limited. Utilising five focus groups ($n = 17$ participants) we investigate the potential misalignments *or* synergies between catchment communities that will provision or benefit from NFM that could either derail *or* support scaling out initiatives. Results reveal that upstream and downstream participants hold strong affinities to contemporary rural landscape aesthetics, expressing sympathies with tasking farmers with delivering flood regulation ES when their traditional vocation is to deliver provisioning ES. Participants also exhibited resistance to landscape change caused by NFM. Nevertheless, acceptability of scaling out NFM increased when aesthetic preferences were considered, especially in provider regions, while beneficiaries prioritised more effective NFM measures over appearance. Inclusive discussion and knowledge exchange (e.g. personal stories, catchment visualisations) in the focus groups facilitated greater appreciation of whole catchment community values and understanding for scaling out NFM.

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## 1. Introduction

The most recent UN IPCC Sixth Assessment Report summarises the scale of the flood risk challenge with climate change but also the scope for ecosystem-based adaptation to reduce these risks (IPCC 2023). Natural Flood Management (NFM) is a form of ecosystem-based adaptation that is widely recognised as an option to reduce flooding whilst achieving multiple benefits throughout the catchment (Bridges et al. 2021; Iacob et al. 2014; European Environment Agency 2021). Primarily, NFM optimises the natural water retention processes within a river catchment to effectively delay or desynchronise flood peaks (Lane 2017). Measures are designed to increase interception and infiltration, slow overland and channel flows and provide additional catchment storage (Dadson et al. 2017; Metcalfe et al. 2017). Rolling out such ecosystem-based adaptations will necessitate changes in land use and land management across the river catchment.

A catchment's ability to retain storm runoff and release it slowly will depend on the scale of change in land and water management activities (Hartmann et al. 2022). Evidence of NFM effectiveness finds that land cover interventions, e.g. restoring upland woodlands and peatlands and introducing small ponds in the landscape, can reduce downstream flood peaks of smaller magnitude events (Wilkinson et al. 2019) whereas retention basins can provision larger scale flood reduction through temporary water storage (Dadson et al. 2017). Catchment management activities that deliver flood regulation are intertwined with the provision of other ES, including microclimate regulation and enhanced biodiversity (Nesshöver et al. 2017; Hartmann et al. 2022). These interactions can be positive, e.g. riparian tree planting providing a water quality buffer and carbon sequestration (Iacob et al. 2014; Huq and Stubbings 2015), or they can give rise to trade-offs in the provision of other ES (Mathieu et al. 2018), such as a reduction in agricultural land, leading

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to a loss of provisioning and cultural ES (van Der Sluis et al. 2019).

Early spatial classifications of ES determined four spatial relationships between production and benefit areas (Fisher et al. 2009), fully outlined in Supplementary material 1, in the 'ecosystem serviceshed' (Goyette et al. 2024). In the context of flood regulation, beneficiaries of NFM are situated beyond the locale of the area where the ES is produced (directional benefits), e.g. when upstream farmers adapt their land management practices reducing run-off to protect adjacent and downstream communities. In catchments where upstream areas have been altered by historical deforestation and agriculture, providing flood regulation benefits downstream will likely require permanent (e.g. tree planting) and temporary (e.g. flood water storage) changes to the visual, upstream landscape.

In an exploratory study assessing six cases of rural landscape transitions across Europe, van Der Sluis et al. (2019) find that landscape change has the largest impact on cultural services and that European Union (EU) and national land policies unintentionally and negatively affect cultural ES including landscape character (aesthetics) and cultural heritage. Other cultural ES include social relations, sense of place, inspiration and recreation (Millennium Ecosystem Assessment 2005). Different groups can exhibit equal (cultural) attachment to a landscape, but attribute different symbolic meaning to that place (Selfa et al. 2021). For example, in an agricultural landscape, van Berkel and Verburg (2014) find that users (non-locals) expressed strong aesthetic value towards landscapes which featured tree lines, forests, cultural buildings and animal habitats, while landscapes dominated by open agricultural land and modern large-scale farm businesses held lower values. Other research in a similar setting finds that long-term residents associate aesthetic beauty with controlled, intensively managed landscapes (Jacobs and Buijs 2011) and that those from farming backgrounds are less critical of large-scale agricultural landscapes (Stokstad et al. 2020).

The different values held by local and non-local groups towards agricultural and rural landscapes could ignite tension when changes to catchment management are proposed, especially when proposed nature-based solutions (NbS) provide benefits to multiple downstream stakeholders but impose costs on multiple upstream landowners (Ungvári and Collentine 2022). Therefore, it is critical to assess how NFM uptake by farmers and landowners is viewed across catchment communities. Previous research has investigated stakeholder and farmers' views on NFM (Holstead et al. 2014; Bark et al. 2021), misalignments between farmer and public preferences for NFM scheme attributes (King et al. forthcoming), and estimated payment levels necessary for farmers to participate in NFM for the benefit of a downstream community (Zandersen et al. 2021). Other studies have explored public preferences for NFM vs flood insurance (Glenk and Fischer 2010) and public Willingness to Pay (WTP) for NFM measures, e.g. Mutlu et al. (2023) use the hedonic price method to investigate the value of NFM to reduce flood risk vs investments in conventional flood risk management (FRM) in the Netherlands. Compared to the conventional option, they find a statistically significant premium of 7.8% for houses sold after NFM implementation and additional property price premiums associated with improved environmental amenities (co-benefits).

There is growing evidence that the public increasingly supports NFM and are WTP for the ES it provides (Brouwer et al. 2016; Chen et al. 2018; Mutlu et al. 2023). Furthermore, international guidelines for 'natural and nature-based features' (NNBF) for FRM have been developed led by the US Army Corps of Engineers complete with a set of key messages (USACE, Bridges et al. 2021; with river flooding covered in Chapters 15–19) and the IUCN has developed a global standard for NbS defining eight criteria[1] (IUCN, International Union for Conservation of Nature 2020). Yet, many studies continue to focus only on eliciting stakeholder values from local, in situ NFM schemes without accounting for the significant spatial dynamics and perspectives of both upstream and downstream communities. An exception is Thaler et al. (2017) who examine three catchment-based FRM strategies and the 're-scaling' processes they entail in three Austrian catchments. The authors emphasise that this new approach to flood management requires cooperation between upstream and downstream communities, imposing new power relations and necessitating multi-level stakeholder interactions, both between stakeholders at the same scale but also at different scales (e.g. local and national).

Further work by Thaler et al. (2023) explores the concept of catchment-based NFM in the context of Global South case studies, including Vietnam and Nigeria. In the Nigerian case, the authors argue that weak institutional settings, poor-coordination and limited social interactions present the most significant barriers to NFM. Supporting this, Paavola and Primmer (2019) stress that considering wider catchment dynamics to build a social consensus (e.g. between upstream and downstream stakeholders) is essential for the successful design and delivery of NFM. Additionally, Waylen et al. (2023) investigate the power of catchment partnerships to support collaborative and holistic management. Their study highlights the importance of knowledge-sharing and communication, not only between NFM partners but also between land managers and other catchment residents.

In this paper we investigate the potential misalignments *or* synergies between catchment communities in production and beneficiary areas that could either derail *or* support plans for 'scaling out' (IUCN, International Union for Conservation of Nature 2020, p. 20), i.e. implementation of NFM at the catchment-scale. Through focus groups with upstream only, downstream only, and mixed catchment participants, we address the following questions: (1) How is landscape change perceived in an upstream, rural catchment?; (2) Which ES are prioritised in a rural landscape, and how does this affect preferences for NFM delivery?; (3) How do these priorities and preferences change between upstream and downstream inhabitants?; and lastly, (4) What are the implications of ES trade-offs/synergies on the uptake of NFM at the catchment scale?

The paper proceeds with background on the case study and research approach, the results are then outlined, and implications of these findings are discussed. In the conclusion, we provide recommendations for scaling out and scaling up NFM.

## 2. Methods

### 2.1. Case study context

York is a medieval cathedral city and regional hub in North Yorkshire, UK. It is a low-lying city susceptible to large-scale flooding events, including the Boxing Day floods in 2015 when over 600 businesses and households flooded (Environment Agency 2016). In response to these damaging floods, the City of York 5-year plan was put in place, allocating £45 million to alleviate flooding in the city centre, focusing on engineered flood alleviation measures (Environment Agency 2016). A follow-up long-term (100-year) plan for managing the risk of flooding identified the provision of additional upstream storage as a significant opportunity to lower floodwater levels through York (Environment Agency 2017). The area upstream of the City of York is formed by four river catchments: the Swale, Ure and Nidd rivers drain into the upper Ouse River. Collectively, these are known as the SUNO (Figure 1). The SUNO covers an area of around 3,300 km$^2$ (330,000 hectares) and is home to approximately 240,000 households (Census 2011).

The Ousewem Project (2022–2027) funded by the UK's Department of Environment, Food and Rural Affairs (Defra) as part of the £200 million Flood &

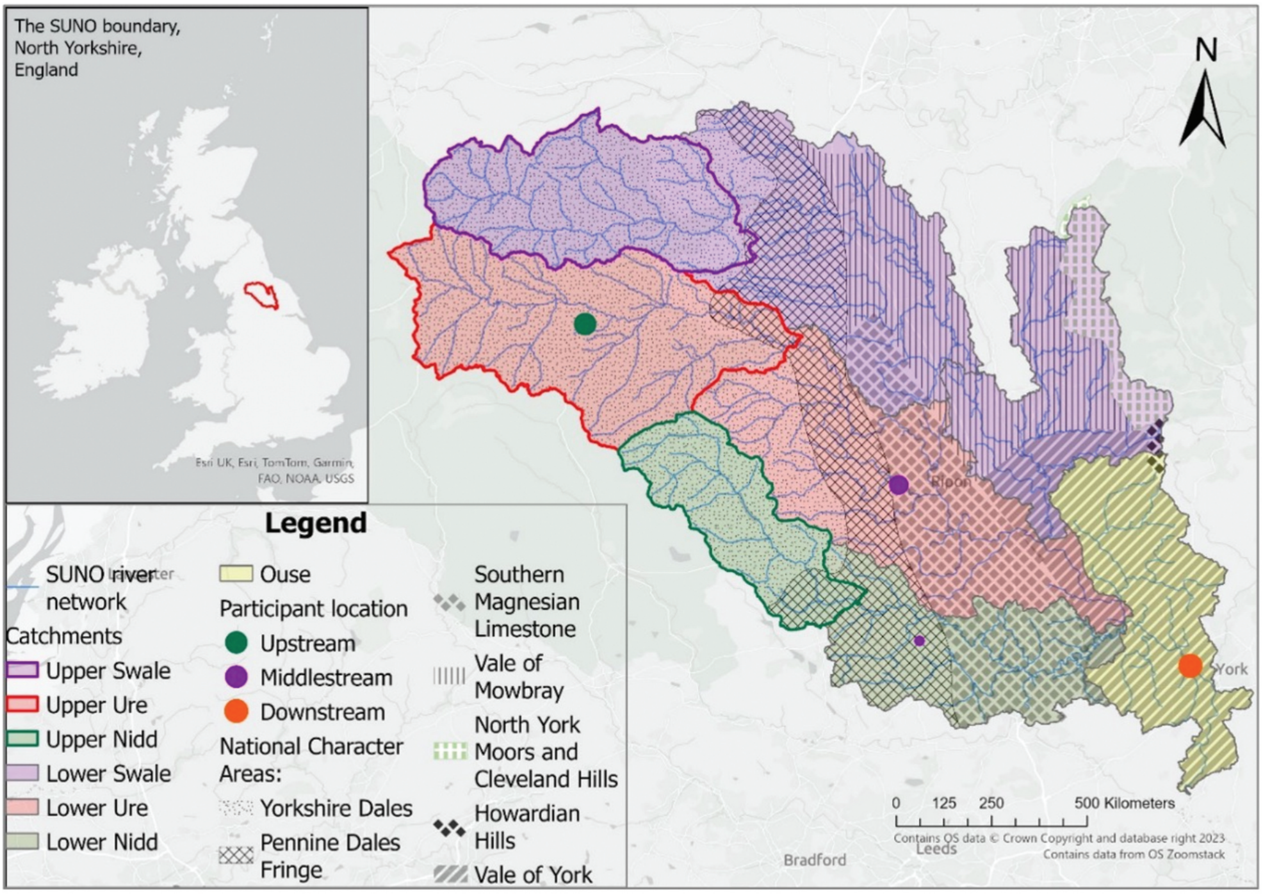


Figure 1. Outline of the case study area in the context of the UK. Classifications of natural England's National Character Area across the swale, ure, Nidd and ouse catchments. Dot placement represents the distribution of upstream, mid-stream and downstream focus groups and dot size represents number of participants (small = minority; large = majority).

Coastal Resilience Innovation Programme provides a relevant case study to test the applicability of the IUCN criteria and USACE key messages (e.g. IUCN-C1.2/USACE-KM18.6) and their correspondence (see, Supplementary Material 5 for a full assessment). Ousewem is exploring opportunities for NFM and land management changes in the upper SUNO to reduce dependence on (USACE-KM16.2) and work with engineered flood defences (IUCN-C2.2/USACE-KM18.3). It is being co-delivered by the City of York Council, Yorkshire Dales Rivers Trust, and the Environment Agency (IUCN-C5.3/USACE-KM15.7) and is taking an integrated catchment-scale (IUCN-C2.3/USACE-KM15.3), long-term approach to reduce flood risk to communities across the SUNO catchments (IUCN-C1.1/USACE-KM15.1). It will also deliver a range of benefits (IUCN-C1.2&3.4/USACE-KM15.2&18.6) across climate, ecology, and biodiversity agendas (Environment Agency 2024). As Ousewem is implemented it will provide improved understanding of the links between, and the effectiveness of, land use change/management and flood risk that can inform national and international catchment managers and policymakers and future approaches to FRM (USACE-KM19.2&19.3 and IUCN-C8.1/USACE-KM16.3).

Following Huq and Stubbings (2015), this study applied the National Character Areas (NCA) as a framework to assess opportunities for NFM as well as highlight potential synergies and trade-offs that could be associated with its delivery. In 2010, Natural England (the UK government's adviser to the natural environment in England) defined and developed NCA which characterise the presence of landscape features across England to help understand England's landscape and the influences that have helped shape it (Natural England 2014). Figure 1 displays the seven NCAs present within the SUNO catchments.

The upper catchments of the Swale, Ure and Nidd are mostly characterised by the Yorkshire Dales (YD). In these areas, are wide glaciated valleys with exposed upland moorland, dotted with stone field barns and drystone walls. The combination of steep slopes, shallow soils, and poor climate limits the growth of most arable crops. Here, the Dales landscape is dominated by pastoral farming (Gaskell and Tanner 1998). Prior to these livestock raising activities (approximately 3000BC), the landscape was covered with extensive woodland (Morris 1982). These upper catchments are located within the Yorkshire Dales National Park (YDNP), covering 2,179 $km^2$ of land. The area was designated in 1954 due to the value of its ES, notably the 'extraordinary natural beauty, the diversity of its wildlife habitats, its rich cultural heritage and its fantastic opportunities for outdoor recreation' (YDNP 2024). The harsh climate in the YD and the inability to grow arable crops mean the area could be more appealing to NFM instalment compared to further downstream in the SUNO, where land values are higher and there is a transition to urban land uses. However, the strong cultural heritage associated with the YD could present challenges to large-scale NFM options.

The lower Swale, Ure and Nidd are characterised by the Pennine Dales fringe, a more transitional landscape, where higher land supports livestock farming, and fertile lower land is used for arable agriculture. Moving down through the catchments, the Vale of York is characterised by its relatively flat, low-lying land where natural floodplain habitats and wetlands are found. Arable cultivation is the predominant land use with higher land values than upstream. The SUNO catchments present a valuable case study (USACE-KM19.2&19.3) to explore the attitudes of upstream 'providers' and downstream 'beneficiaries' and to understand the implications of implementing NFM for catchment communities (IUCN-C6.1).

## 2.2. Research design

To capture views and attitudes towards NFM in the landscape, this research takes a qualitative approach utilising five focus groups and an interview. Focus group research collects qualitative data by engaging with a small number of people in an informal group discussion, which is 'focused' around a particular topic or set of issues (Wilkinson 2004). Focus groups are not only popular for their ability to collect data from multiple individuals simultaneously, but also for providing a relaxed and informal setting, where participants enjoy sharing their ideas and perceptions (Krueger 2014). To capture the social dynamics of 'upstream' and 'downstream' communities, individual focus groups were conducted with both communities together (i.e. upstream and downstream) and independently (i.e. only upstream/downstream).

Responding to a farmer based in the Upper Ure catchment (the YD) who was unable to attend one of the focus groups, but wished to participate in the research, an interview was offered as an alternative. As farmers are considered one of the most important stakeholders in the delivery of NFM (Bark et al. 2021) the research design was adapted (and research ethics amended) to obtain in-depth data to complement the findings of the focus group research.

### 2.2.1. Data collection

Ethics approval was granted by the University of East Anglia's Science Faculty Ethics Committee (ID: ETH2122–1328 and amendments: ETH2223–0864). Five online focus groups and one in-person interview were conducted with inhabitants living within the Ure, Nidd and Ouse catchments. A non-probability sampling approach was taken, whereby participants were recruited via personal contacts of the researcher, snowballing sampling, and promotion in Facebook community groups (e.g. the Hawes and Upper Dales Community Information page). In total, 17 participants from across the SUNO took part. Prior to conducting the focus groups and interview, researchers considered their positionality. The lead-author grew up within the SUNO catchments and therefore is familiar with the landscape and values that communities hold in this area. In the context of focus groups, this can foster enhanced trust between the 'researcher' and 'participants' and thus reduce the presence of power dynamics (Jadallah 2024). Alternately, the researcher may make assumptions or misinterpret participants' perspectives based on personal views and experiences, therefore, we were mindful of this possibility when collecting and analysing data.

Table 1 presents the participants, categorised by an ID number and their location in the catchment (Upstream=US; Mid-stream=MS; Downstream=DS), e.g. P1/US is participant 1 located upstream. The sample is well distributed across the catchment categories (US = 5; MS = 6; DS = 6). All age groups except 18–25-year-olds are represented with most younger participants (25–35-year-olds) based in downstream areas (York). Female participants ($n = 10$) marginally outweigh male participants ($n = 7$). Whilst we acknowledge the relatively small number of participants as a potential limitation, our goal was not to represent the 240,000 households of the SUNO, but rather gain insight into different narratives and dynamics that exist across different spatial levels. Further work would benefit from exploring these narratives across a wider sample to assess comparisons to the wider population using quantitative methods, e.g. a survey. However, this was beyond the scope of this study.

A recent review by King et al. (forthcoming) demonstrated a misalignment of values towards NFM between farmer and public stakeholder groups. Findings revealed that the public held higher levels of acceptance for NFM, whereas farmers demonstrated scepticism towards NFM and concern over the impact of measures on their agricultural reputation and activities. Therefore, the sampling strategy aimed to include participants with and without affiliations to farming, to identify and explore any different attitudes to NFM in the landscape. Farming affiliations were assigned to participants (see Table 1) represented as high ($n = 4$), medium ($n = 3$), and low ($n = 10$).

Focus group 1 (FG1) contained a mix of upstream (Ure) and downstream (Ouse) participants. FG2 was conducted with downstream participants only (Ouse), FG3 and FG4 included mid-stream participants (lower Ure and Nidd), and FG5 was conducted with upstream participants (Ure), as was the interview (Int1), see Table 1. Mid-stream participants were included in the sample to assess whether these participants identified more with the 'providers' or 'beneficiaries' of flood regulation.

The focus groups were conducted on MS Teams and lasted between 60 and 90 minutes. Whilst we acknowledge the limitations of virtual focus groups, for example, technical issues (access to reliable internet connections, familiarity with the online platform), the focus group participants indicated a preference to meet online due to personal time constraints. Therefore, conducting them online not only accommodated participants' needs, but also resulted in a larger sample (Shelton and Jones 2022). Accessibility needs were also met during the interview, which took place in-person in the farmer's home.

**Table 1.** Description of focus group/interview participants.

| Participant ID | Age group* | Gender** | Farming affinity*** | Participation |
|---|---|---|---|---|
| P1/US | 45-55 | M | High | FG1 |
| P2/US | 35-45 | F | Medium | FG1 |
| P3/US | 45-55 | F | Medium | FG5 |
| P4/US | 65+ | M | High | Int1 |
| P5/US | 45-55 | F | High | FG5 |
| P6/MS | 65+ | M | High | FG3 |
| P7/MS | 35-45 | F | Low | FG4 |
| P8/MS | 55-65 | F | Low | FG4 |
| P9/MS | 65+ | M | Low | FG4 |
| P10/MS | 35-45 | F | Low | FG4 |
| P11/MS | 65+ | F | Low | FG3 |
| P12/DS | 25-35 | F | Low | FG2 |
| P13/DS | 25-35 | M | Low | FG2 |
| P14/DS | 55-65 | F | Low | FG2 |
| P15/DS | 55-65 | F | Low | FG2 |
| P16/DS | 25-35 | M | Medium | FG1 |
| P17/DS | 35-45 | M | Low | FG1 |

*Age group categories: 18–25 ($n = 0$); 25–35 ($n = 3$); 35–45 ($n = 4$); 45–55 ($n = 3$); 55–65 ($n = 3$); 65+ ($n = 4$).
***M* = Male; F = Female.
***High = participant is a farmer, landowner, land manager; Medium = participant comes from a farming family; Low = participant is not a farmer, nor are they directly related to one.

A guide was used to structure the focus groups/interview, which followed five parts. In Part 1, participants discussed their feelings towards the YD landscape, where images of typical scenery were used as prompts (Supplementary material 2). This section was informed by sense of place (Jacobs and Buijs 2011; Dugstad et al. 2023) and ES framings (Millennium Ecosystem Assessment 2005) to understand how and why feelings towards landscapes exist. In Part 2, the researcher introduced the concept of 'catchment flood management' and shared a 3D catchment visual (Supplementary material 3). Parts 3 and 4 specifically introduced the concept of NFM, presenting examples through animated diagrams and photos of actual schemes. Subsequently, questions were posed to determine attitudes towards different NFM types, and on scheme design and delivery in the upper catchments to reduce local and downstream flooding. These questions were informed by previous NFM literature, exploring attitudes relating to effectiveness (Bark et al. 2021; Cotton et al. 2022); barriers and drivers of NFM implementation (Wells et al. 2020; Wingfield et al. 2021), trade-offs between providers and beneficiaries (Nóblega-Carriquiry et al. 2022) and practicalities around NFM delivery, including funding/compensation (Posthumus et al. 2008), governance (Garvey and Paavola 2022) and implementation/maintenance (Waylen et al. 2018). Part 5 provided the opportunity for focus group/interview participants to reflect on the discussed topics and an assessment of knowledge gain through social interactions (informed by Pahl-Wostl 2002; Benson et al. 2016; King et al. 2023).

#### 2.2.2. Data analysis

The focus group discussions and the interview were transcribed, and qualitative thematic analysis was conducted, facilitated by the software, NVivo version 1.7.1. Firstly, pre-determined (deductive) codes, such as those relating to key concepts in the literature, e.g. sense of place, ES and social learning were considered and applied during an initial top-down approach. The remaining codes (the majority) were then identified through bottom-up inductive techniques (non-pre-determined), developing organically as more transcripts were assessed. All codes and their hierarchies can be viewed in Supplementary material 4. Following thematic coding, the analysis explored two different framings: (1) a catchment lens considered spatial differences in participant responses; and (2) participants' intensity of affiliation with farming considered if, and how, this explained views towards catchment-scale NFM. These participant attributes where then assessed for associations with specific codes that emerged during analysis using the cross-tabulation tool in NVivo (matrix query), e.g. between farming affinity and perceived 'landscape change'.

## 3. Results

Results are presented by the topics discussed in the focus groups. Quotes are provided in italics with the participant ID number and their location within the catchment (Table 1). The one participant interview is noted as P4/US/Int1. Despite the location of one mid-stream participant in a different catchment to the others (the Nidd), no clear differences in opinions were observed based on this spatial attribute, thus, we do not make a distinction to the specific catchment location of each participant.

### 3.1. Affinity with the yorkshire dales landscape: cultural identity/heritage

Whilst only five participants lived inside the YD boundary, all non-local participants had visited the YD, expressing a strong connection to the landscape and its features. Participants acknowledged the importance of cultural ES provided by the YD, with recreational activities (e.g. walking, pub lunches) being a prominent reason for visiting. In addition, a sense of place and belonging was expressed by locals and non-locals, for example, P3/US outlined the significance of the YD for their livelihood: '*this is my life here. I absolutely adore living where we live … all my friends are here, my livelihood and my future*', whilst a non-local participant expressed their place attachment through family connections and childhood memories '*It reminds me of happy days walking … dad grew up in Richmond, so this is his stomping ground. So, it's a special Dale. I visited a lot as a child*' (P11/MS).

Common landscape characteristics described by the participants were around the openness, remoteness, and beautiful appearance of the YD. For two downstream participants the lack of buildings or settlements was associated with a natural and unspoilt landscape: '*I think we're very lucky how unspoilt* [the YD] *is*' (P15/DS) and "*just the fact that there's nothing man-made that's visible*' (P17/DS). Whereas, others argue the opposite, emphasising that the YD is a man-made landscape, '*when someone said earlier that it's unspoilt, I'd say what we're looking at is kind of spoilt land because of the agricultural on it*' (P13/DS). P1/US concurs, outlining man-made features in the landscape: '*It's not natural at all … you can see coniferous woodlands … the fields are a lot greener because they're managed mostly as hayfields for winter grazing … your higher hills would generally be areas where your stock are grazed during the summer … there's nothing that isn't manmade in that picture*'. This ambiguity towards the YD landscape was particularly evident in one participant, noting how their definition of a beautiful landscape has shifted over time: '*I sort of see this landscape in two* *very different ways. I instantly see it as beautiful, but I also see it as kind of devastating all at the same time . . . I grew up with the idea that images like this were beautiful . . . but then I suppose in more recent years I kind of look at landscapes like this and feel quite depressed*' (P5/US).

### 3.2. NFM preferences: landscape aesthetics vs effectiveness

We observed that feelings towards the YD landscapes as well as expectations about its associated ES had implications for participant NFM preferences. During the focus groups, participants were introduced to different NFM measures. Whilst a range of measures were presented, the discussion focused on those that had a more visual impact on the landscape, including tree planting (conifer and broadleaf trees), and larger-scale water storage (e.g. floodplain reconnection, temporarily flooded fields, run-off storage ponds). Participants ($n$ = 7: 4 = DS, 2 = MS, 1 = US) expressed strong preferences towards measures perceived as the most visually appealing, which was strongly associated with perceived naturalness, e.g. '*I'd rather have the thing that just looks nice and feels more like natural*' (P16/DS) and '*the more natural it looks, the better*' (P17/DS).

Three participants referenced how the floodplain can hold excess water during times of peak rainfall, perceiving it as a natural phenomenon: '*The fields will naturally flood and will naturally store an amount of water anyway . . . that's happened for hundreds and hundreds of years, the farmers are used to it . . .* ' (P7/MS) and expressed preferences towards this measure due to its perceived effectiveness: '*a fully flooded field would contain presumably a large volume of water*' (P16/DS) and its benefits to wildlife: '*when we get floods here . . . it basically turns into a nature reserve on one of the fields and it lasts for ages*' (P3/US). However, this option was not universally liked. Three participants from York expressed discomfort towards the presence of water in the landscape, finding it 'intimidating', e.g. P14/DS stated: '*to me, it's far less intimidating to see four pools of water than one huge pool of water . . . it feels less manageable because it's so large. It's just that sort of sense of being slightly intimidated by it*'.

All but two participants ($n$ = 15) expressed strong preferences towards NFM schemes which included tree planting; both participants had 'high' farming affiliations (P4/US/Int1, P6/MS). Broadleaf trees were particularly preferred over conifer tree planting due to their natural appearance and benefits to wildlife. These views were shared throughout the catchment: '*we do have areas around us with the coniferous trees and they just look so harsh . . . I just much prefer the look of broadleaf trees*' (P2/US), '*I hate conifers, I think they are a blight on the landscape*' (P9/MS) and '*the broadleaf, I much prefer because they're native and I think they look much, much nicer*' (P17/DS).

However, in some cases, people were willing to trade-off the benefits of broadleaf trees (greater biodiversity, more natural appearance) for other aspects, i.e. effectiveness at managing runoff, e.g. two midstream participants stated: '*when you see a plantation of coniferous trees, it looks man-made and it looks wrong. You know, in my opinion. But if they serve . . . a purpose as a flood defence means then we've got to accept it*' (P11/MS) and '*we both like broadleaf trees . . . but if the coniferous ones are far more effective at managing the floodwaters in this situation, while looking at flood management, we swap to them*' (P6/MS). Similar views were expressed by those living downstream in York, e.g. one participant visually preferred broadleaf trees, yet perceived temporary flooded fields to be more effective, which shifted their preferences: '*I suppose visually it would be very much broadleaf . . . but . . . I'm gonna go for the more effective approach and actually needing to address a situation*' (P16/DS). Conversely, upstream participants cared deeply about the appearance of the landscape, prioritising this over the measure's effectiveness, e.g. '*I definitely prefer the broadleaf tree . . . and that will be purely because I'll be prioritising what the landscape looks visually over the impact*' (P2/US).

### 3.3. Future changes in the Yorkshire Dales landscape: ES shifts and trade-offs

When envisioning how the YD landscape may appear in the future, participants perceived a shift in ES, which in turn would change the appearance of the landscape. Nearly all participants commented on the expected increase in tree cover: '*tree planting is gonna become more of a thing that farmers probably do*' (P16/DS). Some participants were excited about the prospect of more trees, specifically recognising their regulating ES: e.g. '*I'd like to see more trees . . . it's not just flood and water absorption, it's also carbon sequestration*' (P7/MS). Whereas others felt uncomfortable with the prospect of more trees and the impact it would have on cultural services, specifically the aesthetic enjoyment of the landscape: '*I think they'll be far too many trees . . . if they're not careful, you'll come to Wensleydale and drive up with a view of trees and not see anything*' (P4/US/Int1). Other activities predicted in the landscape included provisioning ES beyond livestock farming, e.g. the expansion of renewable energy, particularly wind farms ($n$ = 4: 1=US, 3=MS) and tourism opportunities through glamping and off-grid vacations ($n$ = 2: 1 = MS, 1 = DS).

With a shift in ES, participants envisioned a reduction in traditional livestock grazing, e.g.

'*you'll get less farming and less sheep, and less landscapes like that*' (P16/DS). Those with farming affiliations cited the phase-out of EU Common Agricultural Policy subsidies (i.e. the Basic Payment Scheme, BPS, see, Rural Payments Agency 2023), post-Brexit and increasing uptake of agri-environmental scheme (AES) incentives as a key motivator for this change: '*What's going to come in are a lot of green incentives … .setting aside ground and money for tree planting on farms, creating wetland areas*' (P1/US). One participant viewed AES as an opportunity to diversify incomes in rural communities, e.g. '*This is marginalised land, and you won't get a lot of money from it, in terms of actually farming the sheep and everything, so a large proportion of the farmers' income comes from that payment*' (P16/DS). However, others were less optimistic as to how these incentives will work in practice: '*I feel very unsure about what's going to happen with the shift in the government's grant system for farming … it seems incredibly unclear, full of uncertainty*' (P5/US).

The direct impact of reduced livestock farming was discussed, with multiple participants ($n = 7$: 2=DS, 2=MS, 3=US), irrespective of their affinity with farming or catchment location, expressing concern for the future of farming communities in the YD. Small farms were perceived to be more vulnerable to future changes: '*… the more rural areas where the farms are quite small … how they will fair in the long term without the sort of meatier subsidies … it remains to be seen*' (P1/US). Furthermore, environmental schemes, particularly tree planting, raised concern for the availability of land for traditional agricultural activities, e.g. food production: '*I don't want the country covered all in trees I want to be able to eat food. I can't eat trees*' (P6/MS). Land use change on future generations of farmers was also recognised, with P5/US witnessing the impact of tree planting in the YD, commenting: '*… there were four or five farmers at one time … and it's just gone down and down. And now it's all gone to trees. Yeah, that's sort of 4 or 5 families. They're all holiday cottages now or … I think they're retired. Not got any income. No. I think that'll happen. I think the young people are getting shoved out more and more*'.

Overall, a strong sense of preserving the cultural identity of the YD landscapes was emphasised: P16/DS states, '*There's going to be change, but we don't want too much change … I think it's probably the livelihoods of people in the Yorkshire Dales that needs to be upheld as well*'. This idea of preservation was strongly associated with the YDNP, with participants (2=US, 1=MS) citing park regulations as an inhibitor of change, e.g. '*Wind farms would be a very contentious issue. People like the Yorkshire Dales National Park would object wholeheartedly to them*' (P6/MS) and '*The national park do quite a lot to protect* [the YD], *to keep it exactly the same as it is … I think it wouldn't be that much different to what it is now. Maybe a bit of planting, but nothing, you'll be able to see*' (P3/US).

### 3.4. Joining the dots: interconnected ES within catchments

The multiple ES provided by catchment-scale NFM were acknowledged across participants, with biodiversity enhancement cited the most ($n = 8$), followed by drought regulation ($n = 5$), carbon capture ($n = 4$), and water quality improvements ($n = 1$). The interconnectedness of ES was articulated by a downstream participant whose property is in a high flood risk zone: '*I'll also benefit by going and seeing perhaps a more diverse landscape up in the Dales and also actually quite excited … about what sort of new wildlife we might see in a slightly changed landscape*' (P14/DS). Furthermore, an upstream participant argued that understanding the interconnectedness of ES was essential when considering the delivery of NFM schemes: '*all these issues are interconnected … I can't think about flooding and not think about biodiversity, and I can't think of biodiversity and not think about flooding*' (P5/US).

There was recognition and a strong consensus, especially among upstream and mid-stream participants, that farmers/land managers should be compensated for delivering ES (US = 3, MS = 4), e.g. '*if it's taking away land they used for other things, they've got to be financially compensated … it's disruptive for them, but its beneficial for us*' (P11/MS). Furthermore, participants felt that without financial incentives, NFM implementation would be challenging: 'I *think people would be willing to do it if they were compensated*' (P3/US) and '*as long as they're adequately compensated and making no more money than they are from the sheep … they would probably be able to live with it*' (P6/MS). But, reservations were also expressed about NFM payments to farmers, e.g. concern over improper fund use: '*it's very well paying landowners, but what do they actually spend the money on?…if you're giving that money to those landowners, are they actually delivering the goods ultimately?*' (P8/MS) and two participants lacked confidence in the capability of farmers to deliver flood regulation, e.g. '*they might get compensated in some form, but that doesn't necessarily mean they're capable of doing it*' (P8/MS).

Mixed feelings were expressed during discussions around who was responsible for compensating farmers to install NFM on their land. Two participants believed that funds should be distributed at a very local level, exhibiting a strong sense of community and the importance of social relations and cohesion, e.g. '*It's a community thing,* *isn't it? Because those places that flood are the shops as well as homes ... you have a responsibility to contribute because it's protecting your community'* (P11/MS) and '*it would be interesting to see if there's a way you could get it so that it affected you directly, where you were able to pay the farmer's where you are ... so it was like a community kind of thing*' (P3/US). Whereas others (specifically downstream and mid-stream participants) believed it to be a national responsibility, whereby NFM is funded through a nationwide levy ($n = 6$: 4=MS, 2=DS), such as a '*climate change tax*' (P12/DS). Alternatively, two upstream participants felt that the responsibility should not all be placed on the public: '*everything's pushed on to individuals*' (P5/US), opting for a blended finance approach where different sectors contribute (e.g. environmental NGOs, water companies, local authorities): '*I would be willing to pay for something*' later adding: "*I think businesses ... , the Environment Agency, Yorkshire Water ... they need to have to pay part as well*' (P3/US).

During the focus groups, 2D and 3D maps were used to illustrate the flow of water through the SUNO catchments and diagrams/photos were presented to describe different types of NFM measures. Participants commented on the power of maps and images as a tool for understanding catchment-flow dynamics e.g. '*It's good to see it out in front of you ... especially the first one* [3D catchment image], *where you could see it all come down to York, and you're like wow, I get it now*'. (P10/MS) and '*I've found the maps and images really, really helpful. For a start, I didn't know that all of those valleys fed through to York*' (P14/DS). P14/DS further comments how learning about NFM and its interconnected ES is critical in supporting its acceptance in the landscape: '*it's* [NFM] *an essential part of a suite of measures. And I think it will only be possible with education because in an hour I feel like I've been educated*'. The power of learning is especially evident in one participant who admits a change in mind-set towards tree planting, starting the focus group stating: '*We don't necessarily want to see lots of trees in these upland areas ... going forward we still need food in this country*' and ending the focus group by saying: '*the one thing that probably has changed for me is, you know, I was a bit anti-trees in the Yorkshire Dales ... If trees are used as one of the factors for preventing flooding and then I'm more for tree planting, than I probably was before you started*' (P6/MS).

## 4. Discussion

We investigated the potential misalignments *or* synergies between catchment communities in production and beneficiary areas of the SUNO catchments, Yorkshire, UK. This NFM case study can be set in a wider international context due to its relevance to USACE key messages and IUCN criteria used for the verification, design and scaling out and scaling up of NbS (Bridges et al., 2021; IUCN, International Union for Conservation of Nature 2020). When mapping research outcomes with the IUCN NbS criteria and USACE Key Messages for riverine FRM, we find strong alignment and correspondence between them, see Supplementary material 5. Firstly, the development of this research is in response to a pressing societal challenge – flooding (IUCN-C1.1/USACE-KM15.1), where NFM is deployed to optimise human-wellbeing whilst also contributing to multiple societal and environmental benefits (IUCN-C1.2/USACE-KM18.6&15.2). This study is also informed by scale, examining the expansion of NFM from local to catchment-wide solutions. Here, we explore not only the interactions between NFM and society (from both farming and public perspectives) (IUCN-C1.1) but also mindful of any negative impacts NFM can have beyond the implementation site (IUCN-C2.3), which also closely aligns with IUCN-C6.1 (equitable balance of trade-offs) and USACE-KM15.3 (avoiding transferring risks within the catchment). For example, we find that both upstream and downstream participants hold strong affinities to contemporary aesthetics of the YD landscape with members of the public acknowledging the costs to farmers when providing regulating ES (e.g. flood regulation) when their traditional vocation is to deliver provisioning ES (e.g. food) (IUCN-C6.1). Despite these synergies, ES trade-offs were observed between upstream and downstream stakeholders, especially preferences for types of NFM based on ES priorities associated with that measure.

Many participants identified the synergies between ES delivery acknowledging that NFM benefits go beyond flood regulation. For example, a strong desire was expressed for biodiversity enhancement whilst delivering NFM (IUCN-C3.4/USACE-KM15.2&16.2). This study promotes the application of catchment visualisations and the opportunity for discussion and knowledge exchange during focus groups. This aligns with IUCN-C5.3/USACE-KM15.7 (whereby stakeholders directly and indirectly affected by NbS have the opportunity to engage and learn about its processes) as well as IUCN-C5.4 whereby accessible documentation and process mechanisms (e.g. visuals and social interactions) can be used to bridge gaps in communication across boundaries, such as upstream and downstream inhabitants. Providing this opportunity builds social processes and facilitates a greater understanding of community values, fostering upstream-to-downstream (wholescape) thinking (Maltby et al. 2018; Bark and Acreman 2020). Lastly, case studies such as Ousewem provide inspiration and evidence of the social, environmental, and FRM outcomes of out scaling NFM (USACE-KM19.2&19.3) that in turn could foster the upscaling (mainstreaming) of NFM options (IUCN-C8.1/USACE-KM16.3). The wider implications of our findings are discussed below.

### 4.1. Changing landscapes: an opportunity or threat?

Support for cultural ES in the rural landscape was strongly observed across both local (upstream) and non-local (downstream) participants. Participants expressed a sense of place towards the visual amenities of the YD, citing features described in Natural England's NCA categories, e.g. rolling hills, wide glacial valleys, stone field barns and walls, and a sense of openness and remoteness. Whilst downstream participants tended to view the value of these amenities in a recreational context (e.g. walking in the dales), local participants, and those with farming affinities highlighted the value of agriculture heritage and cultural identity associated with the YD. Similar to findings outlined in Anderson et al. (2013) and Selfa et al. (2021), we observe that different groups (e.g. local/non-local, farmer/non-farmer) can express an equal level of attachment to the same place yet attribute different symbolic meanings to that place. An outcome could be different priorities or preferences for NFM and other activities (e.g. wind turbines) deemed appropriate in the landscape.

Different values that participants place on the YD landscape partly determine the extent to which future landscape change is viewed as an opportunity for multifunctional landscapes or a threat. For example, P16/DS and P1/US noted the withdrawal of the BPS would lead to a reduction in livestock farming and an increase in activities that deliver environmental services, e.g. tree planting. In response to this change, participants commented on the opportunities, such as improvement of landscape aesthetics (cultural ES), and more diverse landscapes for wildlife (supporting ES). For provisioning ES, the opportunity for rural communities to diversify their incomes was also discussed. This is especially relevant for upland livestock grazing regions, such as the YD, which can be classified as a 'less favourable area' (LFA)[2] due to the challenging terrain and characteristics (e.g. geology, altitude, and climate). In England, most LFA farms rely on public payments with the BPS and AES together accounting for 30% of their revenue between 2021–2022 (Arnott et al. 2021; Harvey 2023). Therefore, despite holding attachments to the traditional YD landscape, there is a recognition that ways of working must adapt to maximise AES incentives to maintain incomes and preserve rural livelihoods.

Conversely, for some the shift from food production to alternative land uses was viewed as a threat to rural communities and to the future of YD farming. One farmer (P4/US/Int1), who had been farming in the YD for 55 years, commented on the increasing unavailability of land as an outcome of tree planting, for the next generation of farmers. Evidence from an Irish study on farms replacing/supplementing livestock income with afforestation income found that the majority of farmers chose not to afforest (Ryan and O'Donoghue 2016). The authors noted that farmers holding these values were mostly older and held a strong sense of traditional farming identity. Meanwhile, younger farmers were more open to diversifying their land management practices if forest incomes would exceed agricultural income. The role of agricultural identity and embedded norms associated with a rural landscape, must not be overlooked as they can underpin decision-making, and in some case override the consideration of financial incentives to align with what might be considered as 'good' farming.

The appearance of the YD was considered important when implementing NFM measures in the landscape. Both local (upstream) and non-local (downstream) participants expressed a positive relationship between features that appear more natural and those that are more visually appealing, as found in other research (Junker and Buchecker 2008; Ode et al. 2009). We observe preferences towards NFM schemes which planted broadleaf rather than coniferous trees due to an aversion towards their 'harsh' appearance which interrupted the 'natural' landscape.

These results are unsurprising as UK upland forested landscapes are dominated by coniferous plantations planted in the second half of the 20th Century (Cooper et al. 2021). The non-native Sitka Spruce became the most common species planted in the UK where it contributes approximately half of all commercial timber plantations. Public perceptions towards coniferous woodland tend to be negative, viewing them as a threat to landscape aesthetic due their monoculture appearance and association with commercial timber production (van Marwijk et al. 2012; Forestry Commission 2022). One native pine species exists (Scots Pine – *Pinus sylvestris*) which can survive in poor soils and harsh climates. Such native pinewoods are increasingly recognised for their biological, cultural and recreational values spurring replanting programmes (Salmela et al. 2010; Cooper et al. 2021). Research has found that conifers, when planted correctly, are equally, if not more effective than broadleaves at managing catchment runoff (Le

Maitre et al. 1999; Nisbet and Broadmeadow 2003; Marapara et al. 2021). Thus, it is probable that pine-woods planted to deliver a suite of ES will be an increasing feature in upland landscapes and that describing the benefits and managing opposition will be necessary (USACE-KM16.3).

To overcome this barrier to change as well as support the transition from a 'producer-only' mindset to one which integrates pro-environmental values into agricultural activities (Hyland et al. 2016), social learning networks can bring people from diverse backgrounds together, to provide opportunities for knowledge exchange and co-creation (Benson et al. 2016; Maidl and Buchecker 2021; King et al. 2023). We find that discussions between upstream and downstream participants can facilitate social learning, e.g. in FG1 we observed an upstream participant correcting a downstream participant who described the naturalness of the YD. Thus, despite landscape change being perceived as a threat to some participants who expressed the need to preserve the appearance of the YD, we can be confident that people can incorporate new understandings of place and the activities that occur within it, with the support of social learning.

### 4.2. Spatial heterogeneity in NFM preferences – ES trade-offs and synergies

The implementation of NFM and its associated ES at a catchment-scale can introduce several trade-offs and synergies between upstream and downstream participants based on the services they prioritise. Figure 2 highlights the interactions between the delivery of NFM in the YD and priorities of ES as demonstrated by participants during the interview and focus groups. Categories from Fisher et al. (2009), Figure 5) are modified to represent the spatial relationships between the providers and beneficiaries of ES in the SUNO catchment. For example, loss of traditional agricultural heritage and a reduction in local aesthetics (cultural ES) was a concern observed more strongly by those living in the YD, where providers and beneficiaries of these services are co-located. Whereas participants living further downstream (MS/DS) were willing to accept the presence of conifers in the landscape (and subsequent impact on appearance) to achieve flood attenuation, demonstrating a trade-off between cultural (landscape aesthetics) and regulating ES (ex-situ flood regulation). This is likely due to the spatial disparity between providers and beneficiaries (e.g. beneficiaries are not exposed to the YD daily, and thus are willing to trade off the aesthetic service of the YD for a service which will benefit their locality).

The impact on food provision and the resilience of the YD environment (e.g. local economy boost through alternative incomes, environmental quality) was also a priority for upstream participants, whereby the impact of NFM would mostly occur within their local setting (e.g. providers and beneficiaries/non-beneficiaries are in-situ). A more balanced priority of ES (e.g. synergies between upstream and downstream participants) were observed for sense of place, recreation (cultural ES) and biodiversity/wildlife enhancement (supporting ES). Here, the spatial relationship of providers and beneficiaries is distributed across the whole SUNO. For example, a downstream participant commented on benefitting from an increase in wildlife and biodiversity with scaled-out NFM in the YD when visiting (P14/DS, Section 3.4). Similarly, for those living within the YD, enhanced 'naturalness' and the impact this has on biodiversity was also an exciting prospect which locals would benefit from, such as storage ponds and flooded fields attracting more birdlife (P3/US, Section 3.2).

By visually assessing the spatial relationship between upstream and downstream priorities and synergies with different ES we can observe the distribution of providers and beneficiaries within the SUNO catchment. Mid-stream participants align with both upstream providers (i.e. sense of community, support for rural livelihoods) as well as downstream beneficiaries (i.e. preferences for effective flood regulation over appearance). However, overall, their proximity to the YD and experiences of rural living presented a slightly stronger alignment of values with upstream participants. This study was informed by the unknown side-effects of catchment-scale NFM and the potential trade-offs that it could ignite. However, by applying Fisher et al. (2009) categories and modifying them to the context of this study, it is now clear that synergies are present, and that aligning values between upstream and downstream participants may be more straightforward than initially believed, especially with a focus on and promotion of NFM via aligned priorities (e.g. recreation opportunities, wildlife enhancement). Furthermore, it identifies spatial heterogeneity that should be carefully considered when installing NFM (e.g. impact on agricultural heritage).

### 4.3. Facilitating landscape-scale NFM

Participants acknowledged the interconnectedness of ES that can be provided concurrently through NFM schemes, such as biodiversity enhancement, carbon capture and drought regulation. For some, ES beyond flood regulation may be prioritised, e.g. those visiting the YD to experience the 'diverse wildlife' (P15/DS). Thus, delivering NFM under an umbrella project could bolster public acceptance of large-scale schemes and funding. This aligns with EU guidance whereby NbS are


**Figure 2.** Interactions between the delivery of NFM in the Yorkshire Dales and priorities of ES expressed by participants during the interview and focus groups. The last column presents the distribution of providers (P) and beneficiaries (B) of each ES.

designed to meet multiple objectives (Martire et al. 2022). An example of this is the UK Government's Landscape Recovery scheme (LR) which supports landowners and managers working with partners to take a large-scale, long-term approach to producing environmental goods on their land (eligible on land from 500–5,000 hectares), including restoration of nature, flood attenuation, and boosting biodiversity (Department for Environment, Food and Rural Affairs 2023a). Round 1 of LR funds 22 projects and Round 2 funds 34 projects, with both schemes recommending applicants to consider blended finance mechanisms where private finance complements public funds for ES (Department for Environment, Food and Rural Affairs 2023b).

Supporting findings of Bark et al. (2021), we observed a demand for more diverse sources of funding (e.g. water company contributions) to pay for NFM to relieve strain on the public budget and generate a sense of shared responsibility. Payments from multiple sources could fund different ES in the same system, i.e. 'layering' or 'stacking' (Reed et al. 2017). For example, projects restoring degraded peatland habitats could receive funding from private companies (e.g. purchasing carbon credits), water companies (e.g. for water quality improvements), the government (e.g. for flood regulation) and environmental NGOs (e.g. public donations for wildlife enhancement). However, previous studies have noted that 'layered' payments can be restricted to ES that are easily monetised, e.g. water quality improvements, overlooking other ES such as cultural ES, leading to opposition from groups whose values have been neglected (Church et al. 2014; Reed et al. 2017). In our study, the potential disruption caused by NFM to cultural ES in the YD is a large concern. Therefore, those responsible for the design and delivery of ES on a large-scale (e.g. projects associated with the LR scheme), should consider the multiple dimensions of values that can be held by different groups across the catchment and incorporate these into a layered funding approach.

Further ways to enhance the uptake of NFM in the landscape is to acknowledge and address public preferences for NFM design. Concerns were expressed towards conifer tree planting, highlighting a need to disentangle perceptions of conifer trees from regimented plantations and to educate the public on the wider ES that (native) pinewoods can deliver, especially for those living in-situ of NFM schemes. These findings are topical given the delivery of a landscape-scale tree planting project in the YD where the Woodland Trust[3] is set to plant 291 hectares of native woodland (mixed broadleaf and Scots Pine), with the aims to boost biodiversity, reduce flooding, improve water quality, and sequester carbon (Bond 2023). Previous research has emphasised how informing the public of the ES provided through site restoration can lead to increased perceived attractiveness and thus, acceptance of new landscape features (Junker and Buchecker 2008; van Marwijk et al. 2012). Therefore, public education and engagement is essential to manage embedded views, i.e. negative views associated with pine planting, to support new projects, such as reforestation and NFM schemes.

Another example of opposition towards changes to the landscape was the discomfort of downstream participants towards expansive water storage (e.g. temporarily flooded fields next to rivers), stating it's 'intimidating' appearance, whereas upstream participants understood floodplain storage as a natural phenomenon provisioning regulating and supporting ES (e.g. habitat for wading birds and other wildlife). Notably, the three participants expressing discomfort lived in urban areas, where floods have been heavily managed using engineered infrastructure. As the primary goal of engineered flood defences is to 'keep water out', floodplain storage represents a radically different management approach which downstream, urban populations may not be familiar or comfortable with.

Our findings support the argument that society is becoming disconnected from rivers and their floodplain functions (Cohen et al. 2023), which in turn has implications for FRM preferences (Quinn et al. 2019) and potentially for NFM schemes. For example, the 2017 'York Slow the Flow' report considers the volume of water storage required upstream from York, to deliver acceptable levels of flood reduction (Environment Agency 2017). Modelling results specify over 9 million $m^3$ of storage (3,600 Olympic-sized swimming pools) is required to address the potential impacts of climate change and to maintain future water levels below York's existing flood defences. These results provide rationale for large-scale, temporary water storage in the landscape and thus, it is critical that public concerns towards expansive bodies of water are addressed. Currently, research on public attitudes towards upstream water storage is limited, therefore we recommend that future NFM schemes should: consider the potential opposition arising from at-risk communities who are accustomed to engineered flood schemes; and explore ways to overcome unease with flooded landscapes.

Thaler et al. (2023) identify four opportunities for the implementation of catchment-wide NFM: physical conditions of the catchment, social interaction, financial resources and institutional setting. Under social interaction, authors note that trust and solidarity between upstream and downstream communities are essential to mitigate potential conflicts and lack of acceptability of NFM. We find the responsibility of hosting NFM measures to deliver ES on agricultural land was considered, specifically around trust that farmers: (1) will deliver measures they are paid to do; and (2) hold the skills to deliver these measures. At the community-scale, Howgate and Kenyon (2009) find a sense of responsibility and shared community values supported cooperation of stakeholders and delivery of NFM. This social cohesion was present in our study, noted when P11/MS stated: '*you have a responsibility to contribute because it's protecting your community*'. However, beyond this scale, e.g. where benefits of NFM extend beyond the host community, social cohesions/relations between upstream farmers and downstream communities appeared weaker. Building relations with beneficiaries beyond host communities is therefore essential. Visual aids (e.g. 3D-visual of the SUNO catchments) were effective in bridging gaps between upstream-downstream communities and can support scheme developers when engaging with communities regarding landscape-wide NFM projects.

Lastly, despite most of the YD falling within the YDNP, only around 0.4% (~96 ha) of land is owned by this authority (YDNPA 2024). Specific land ownership/tenure statistics in the YD and SUNO catchments are not publicly available, however, national statistics identify that in England, 38% of land is privately owned, 14% is solely rented, 19% is mixed-majority rented, and 28% is mixed-majority owned (Department for Environment, Food and Rural Affairs 2024). Therefore, delivering flood attenuation through NFM will necessitate working with private landowners (Hartmann et al. 2018) that may hold different socio-economic priorities and concerns (Short Gianotti et al. 2018). In this study, the threat to agricultural heritage (cultural) and to food production (provisioning) raises concerns for implementation of catchment-scale NFM (regulating). Tailoring land use and nature recovery policy and funding mechanisms, including conservation covenants, AES, LR, and nature markets to deliver NFM will necessarily require wide stakeholder involvement (Morris et al. 2016).

### *4.4. Limitations and future research*

In Section 2.2.1 we noted that although the sample captures views throughout the SUNO, it is relatively small. Whilst an in-depth qualitative assessment is helpful, future work could complement these findings by conducting a survey across the SUNO. This survey could be used to quantify preferences for NFM and elicit WTP values for its services. Future research on potential trade-offs and synergies that may arise through catchment-scale NFM investigation could explore whether a statistically significant relationship exists between the distribution of participants (upstream versus downstream) and preferences for the design and delivery of NFM.

We also consider potential bias when discussing attitudes towards tree planting. Many of the participants, especially those living in or near the YD, were aware of the large-scale tree planting project (Snaizeholme) which is currently planting 291 ha of trees in the upper Ure catchment. It is possible that perceptions of tree planting may have been associated with the planting of large expanses of woodland, and the perceived threat to agriculture. Conversely, trees can be planted in ways which limit impact on agricultural practices, such as agroforestry, where trees are planted on field boundaries. This option can provide several ES, including improved agricultural productivity (Jose and Bardhan 2012; Waldron et al. 2017). In this study, the researchers cannot disentangle preferences for different planting scenarios (e.g. field boundaries versus large expanses of woodland) as discussions focused more on type of species planted. Future work could use a well-designed survey with visuals of tree planting scenarios (both tree species and method of planting) to capture these views.

## 5. Conclusion

To address the threat of increasing flood risk posed by climate change, scaling out NFM from localised solutions to catchment-wide management is required. Outscaling NFM has implications for both providers of upstream rural land, and the beneficiaries of reduced flood risk downstream. To date, little research has investigated the potential misalignments *or* synergies between catchment communities in production and beneficiary areas that could either derail *or* support plans for large-scale NFM adoption. We address this gap using a case study of four river catchments in the UK, where opportunities for catchment-wide management to supplement and complement downstream, engineered infrastructure are emerging. We conclude that NFM schemes proposed in upstream rural areas where traditional agriculture activities dominate the landscape could be perceived as a threat by those with affiliations to farming and those with attachment to rural landscape features. Therefore, when considering the outscaling of NFM, it is important not to underestimate the significance of interconnected cultural ES (heritage, aesthetics, recreation) provided in these landscapes for both locals *and* non-locals. Nevertheless, participants did acknowledge the financial opportunities of NFM and wider environmental schemes that could sustain rural livelihoods, exhibiting a transition away from a production-only mindset towards acceptance of multifunctional landscapes.

Preferences for NFM can differ depending on their prioritisation of ES. This must be considered when designing NFM schemes, e.g. installing effective measures which are deemed more attractive. When this is not feasible and NFM measures entail more opposition, such as conifer tree planting, the wider benefits of these measures could be promoted to support their uptake in the landscape. Additionally, integrating NFM schemes into wider 'umbrella' projects would not only support wider provision of ES, but also attract funding from multiple sources at a time of tight government budgets. However, care must be taken to ensure cultural ES are not omitted during the development of these large-scale projects. Furthermore, an important component of outscaling NFM to the landscape level is strong social cohesion between upstream providers and downstream beneficiaries. In circumstances where solidarity and trust are strained, catchment managers must proactively facilitate this relationship by providing opportunities to build social cohesion, e.g. through informal learning networks. During discussions, visuals, such as 3D-catchment visualisations, can be helpful in supporting the understanding of upstream-downstream dynamics and implications of catchment-wide NFM.

Lastly, we extended the conceptualisation of the IUCN NbS global standard and international USACE NNBF guidelines from a framework for NbS/NNBF design and delivery, where practitioners working to outscale NFM at the catchment level can map their scheme to the standard/guidelines (addressing any shortcomings) and align NFM interventions with international best practice.

## Notes

1. The IUCN Global Standard for Nature-based Solutions is a user-friendly framework for the verification, design and scaling up of NbS. The framework is made up of 8 criterion, found here: https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf.
2. A European Union designation to provide special measures to support farming in areas where production is difficult.
3. The Woodland Trust is the largest woodland conservation charity in the UK. https://www.woodlandtrust.org.uk/press-centre/2023/04/snaizeholme-yorkshire-dales-native-woodland-nature-boost/.

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## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Data availability statement

The data that supports the concepts, methods and findings of this study can be found in the supplementary materials (1–5).

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