Integrated Catchment Solutions Programme

Natural Flood Management: Nidderdale AONB

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Non-Technical Summary

Yorkshire's Integrated Catchment Solutions Programme (iCASP) is a 5 year Natural Environment Research Council (NERC) - funded programme with the mandate to rapidly deploy the UK's existing environmental research and expertise to solve problems in the Yorkshire region. The Nidderdale Area of Outstanding Natural Beauty are currently participating in a Defra funded Test and Trial related to the Environmental Land Management Scheme (ELMs). As part of the trial, natural flood management (NFM) is being incorporated into farm plans. This report details the process of mapping options for farm holdings related to NFM, the time and technical requirements needed to produce maps and lessons learnt.

The main lessons learnt from this project are as follows:

- Mapping offers a vital first step in distinguishing risk areas within land holdings that could be targeted to reduce flood and diffuse pollution risk by installing interventions.
- Mapping can help reduce field work time by distinguishing the main areas of interest on the land holdings.
- Support is required to help feed in local knowledge of the area and farming style, complete ground truthing and engage with the landowner – without the landowner being on board with the interventions, the desired outcomes will not be achieved.

The following interventions have been proposed for the land holdings in this study to help reduce fine grained sediment run off and decrease flood risk: leaky woody dams, hedgerows, buffer strips, tree planting and offline ponds. It's important to note, that soil management techniques such as reducing compaction can also offer large benefits and should also be considered during the ground truthing stage, but have not been mapped as opportunities.

Time should be costed in for mapping a s it offers a quick and repeatable method to highlight risk areas and opportunities for further investigation. Mapping for this work has taken between 1 and 2 weeks. Previous technical knowledge on mapping, NFM and using Geographic Information System (GIS) and SCIMAP software has been utilised in this project.

Contents

1. Introduction

Yorkshire's Integrated Catchment Solutions Programme (iCASP) is a 5 year Natural Environment Research Council (NERC) funded programme with the mandate to rapidly deploy the UK's existing environmental research and expertise to solve problems in the Yorkshire region. The Nidderdale Area of Outstanding Natural Beauty (AONB) are currently testing the role of Land Management Plans as the foundations for supporting high natural value farming and land management that is resilient, profitable and environmentally sustainable. As part of this, natural flood management is being explored. Natural flood management (NFM) is a technique that aims to work with natural catchment processes such as planting trees and the addition of large woody dams. Flood risk and environmental benefits include, but are not limited to: slowing flood peaks, reducing the depth and duration of flooding, reducing soil erosion and sediment risk, increasing carbon storage, improving water quality and increasing habitat connectivity. Natural flood management is increasingly being used for catchment management in the UK, as catchment-wide approaches have been championed, further, NFM offers sustainability benefits and can provide additional protection against climate change.

In order to understand where to place NFM for maximum benefits, a hotspot mapping approach is undertaken to understand where the greatest risk or potential is. Opportunity mapping then uses hotspot maps, associated data and catchment knowledge to produce a targeted map of key locations within a catchment where interventions should be placed for maximum benefits. The aim of this report is to showcase the process of producing maps, the limitations, technical requirements and time taken. Finally, lessons learnt are reported which could be used to inform the future direction of NFM in the context of the Environmental Land Management Scheme (ELMs). The report draws on lessons learnt through several iCASP projects and associated academic expertise including: The River Don Hidden Heritage Secret

Streams[1], Natural Flood Management[2]; National Trust Payment by Results[3] and Skell[4] projects.

1.1 Study area

The Nidderdale AONB, in north Yorkshire covers an area of 600 km, the only town in the designated area is Pately Bridge. However, nearby to the borders are the towns of Otley, Ilkey, Masham and Ripon. The farm holdings in this study are located across the designated landscape, and are part of the following main river catchments: River Washburn, River Nidd, River Laver and River Ure. Figure 1.1 shows the farm holdings analysed during this project.

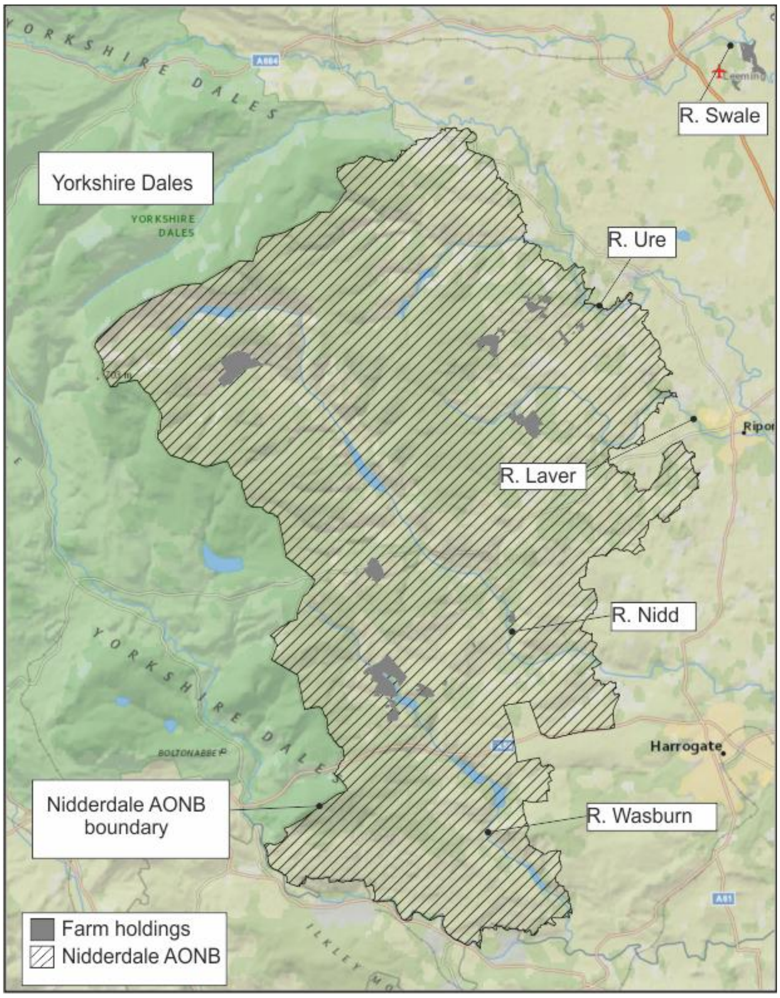

***Figure 1.1** – Location map. (Source of basemap – National Geographic ESRI).*

[1] Website link to Don HHSS iCASP project
[2] Website link to NFM iCASP project
[3] Website link to NT Payment For Outcomes iCASP project
[4] Website link to Skell iCASP project

2. Processes of natural flood management mapping

Mapping has been undertaken using SCIMAP. SCIMAP is an open source software that investigates diffuse pollution risk in catchments, the output produces a relative look at risk (i.e. the likelihood of erosion occurring) based on underlying physical parameters related to slope, land use and rainfall. When assessing where NFM interventions should be placed the following maps are produced:

- Hotspot maps: show the risk areas for different factors such as diffuse pollution and overland flow;
- Opportunity maps: maps of the NFM options that could help reduce the risk for different factors such as overland flow and diffuse pollution.

2.1 Data required

SCIMAP requires information on the following parameters: elevation (Digital Elevation Model, DEM), rainfall and land-use. Table 3.1 shows the data required, as well as sources and costs of the data.

***Table 3.1** – Data required for SCIMAP and alternative data sources*

Data	Resolution	Source	Cost	Alternative
DEM	50 m	Website link to OS DEM.	Open access	Higher resolution DEMs can be bought from the OS (5m) or LiDAR (50cm – 2m) can be downloaded from the Environment Agency.
Rainfall	5 km	UK Met office - Website link to Met Office data.	Open access	
Land use	CORINE - 100m (25ha)	CORINE – Website link for CORINE data.	Open access (n.b. higher	Satellite imagery can be used to produce high

	CEH - 1km	CEH - Website link for CEH data.	resolution data can be bought from CEH for a fee)	resolution (10m) seasonal land use maps (see Don iCASP project output GIS methodology[5]).
Ordnance Survey Basemaps	5km	Website link for OS basemaps.	Open access	Google earth imagery, satellite imagery

For the online version of SCIMAP data on elevation (DEM), rainfall data and land use data are already pre-loaded. Users can upload higher resolution data where available.

The following data is produced:

Diffuse pollution – SCIMAP assesses relative risk within a catchment, and therefore does not produce absolute volumes of sediment produced. SCIMAP produces three output datasets of relevance to this work. The online version of SCIMAP was used for this work. Each dataset is described below:

1. Erosion Risk: this grid shows erosion risk across the catchment and ranges from 0 (lowest risk) to 100% (highest risk)[6].
2. Erosion Risk in Channel Concentration: this output shows the concentration risk of the sediment in the channel, which is a cumulative value of all the inputs upstream related to erosion risk.
3. Network Index: this grid shows the hydrological connectivity of the catchment, the data ranges from 0 (lowest connectivity) to 100% (high connectivity). This grid can be used to look at overland flow connection within the catchment.

The erosion risk data (1 and 2) can be used to understand where interventions can be placed in order to decrease diffuse pollution, in this case related to input of fine-grained sediment into the river channel.

[5] Website link to Don HHSS iCASP project

[6] Risk defined here is related to the chance of a parcel of land producing sediment, 100 indicates that erosion is high in this area and likely to produce diffuse pollution.

Overland flow - The network index[7] from SCIMAP was used to look at overland flow pathways within the study area; overland flow refers to water that flows on the land surface. This information is used to assess placement of NFM interventions that slow overland flow. Again, volumes of overland flow are not produced and this information only indicates where there is potential for overland flow.

2.2 Process

The online version of SCIMAP (my.SCIMAP) was used to produce the mapping in this report[8]. Alternatively the software can be downloaded, information on processing data on the downloaded version can be found here[9].

My.SCIMAP has the following tabs that help set up the model:

- Catchments: click on the ‘create new catchment’ button on the left hand side to bring up a UK river network map. Zoom to the river catchment of interest, name the catchment and click ‘calculate’. Save the new river catchment.
    - Make sure the river catchment of interested is highlighted in blue on the left hand side in the ‘current catchments’ menu.
    - On the catchment tab, you can also change the land cover, rainfall and DEM data to higher resolution by clicking ‘replace’.
- Parameters tab: you can use the in-built parameters showing the risk weightings for different land cover classes.
- Observations: on this tab you can input any observations from fieldwork that can help the model in distinguishing risk. If you do not have any observed data move to the build tab.
- Build: on this tab you chose the river catchment of interest, click on ‘use parameter’ set and load the in built parameters and click run scimap. If you have observed data you can click on the ‘use observations’ button and use your observations from the drop down list.
    - SCIMAP can be left running during the day and you do not need to be logged in whilst the model is running.

[7] The Network Index is a modified version of the topographic wetness index which measures the hydrological connection in the landscape. For more information see here.
[8] Website link to my.SCIMAP
[9] Website link to Don HHSS iCASP project

- Results: On this tab you can download your results either as GIS datasets or for export it to google earth, by clicking the relevant button at the bottom of the page.

The farm locations were split across four river catchments, resulting in four model runs. The model was left to run overnight. Once completed, the data output on overland flow risk and diffuse pollution risk was downloaded and processed (clipped to farm parcels and reclassified) in ArcGIS. Once processed, interventions could be distinguished and digitised using ArcGIS. A final process of exporting the maps (diffuse pollution, overland flow and opportunities) and placing them in a template was used in CorelDraw, however, this can also be done in ArcGIS.

The processing within ArcGIS relates to presenting the data in an easier way – removing areas of lower risk from the map, so that there is a focus on the areas that will have a greater benefit from NFM. In order to do this, the map layers relating to overland flow and diffuse pollution were reclassified as following:

- Low risk: <50%, white
- Medium risk: 50 – 70%, yellow (erosion risk) / light blue (overland flow)
- High risk: 70 – 90%, orange (erosion risk) / medium blue (overland flow)
- Very high risk: <90%, red (erosion risk) / dark blue (overland flow)

In ArcGIS, the map layers can be reclassified in the *properties* of the layer, using the *symbology* tab. Using the *classified* tab, the range can be manually updated to fit the bandings suggested above by clicking classify and the correct colour assigned.

The land holdings ranged in size from 0.29 km^2 to 1.92 km^2, and 16 maps were produced respectively for each output based on the individual parcels. Output maps for hotspots for overland flow and diffuse pollution and opportunity maps for each land parcel were produced.

The online version of SCIMAP was used for this work, in comparison to the downloadable version it offers the following benefits:

- Little to no experience of GIS is required to run the initial modelling.
- Pre-loaded data, which saves time to the user. Higher resolution data can be uploaded when available.

The downloadable version has the following benefits:

- Easier method to change and use high resolution data to run different scenarios.
- Quicker model runs depending on the computer used.

However, the downloadable version requires understanding of using SAGA GIS.

2.3 Time required for modelling

The mapping element of this work for the hotspot and opportunity maps took approximately the following time:

1. Setting up my.scimap for each model run – 30 mins per model run. (N.B. for the desktop version this time would be longer) – 4 x 30 mins = **2 hours**
2. Leaving my.scimap running overnight.
3. Downloading, importing and processing data in ArcGIS – 10 minutes per land parcel per hotspot data - 16 x 10 mins = **2 hours 40 mins**
4. Producing opportunities for each land parcel – investigating risk and digitising interventions – 1 to 2 hour per land parcel = **16 to 36 hours**
5. Exporting and processing maps in CorelDraw - ~30 minutes per map – 16 x 3 maps = 48 maps produced 48 x 30 mins = **24 hours**

Total time of mapping for this project: 6 – 9 working days (~1 – 2 weeks)

2.4 Technical requirements

GIS: To run my.scimap no knowledge of GIS is required, the online portal is easy to navigate and start the model running. Processing in GIS requires understanding of processes such as loading data, clipping data, reclassifying data, creating shapefiles and digitising them for opportunities and exporting maps.

Technical knowledge: An understanding of the different types of NFM, the locations where different interventions work well and what the physical outcomes of the interventions is required in order to make an informed decision of what potential interventions could work. However, this is only one side of the requirement – local knowledge of the farm is vital; this could be provided by the landowner or farm advisor (see Section 4).

2.5 Ground truthing outputs

SCIMAP offers a starting point for investigating opportunities on land holdings, however the mapping output is limited by the resolution of data used in the initial modelling, in this case open source data with a resolution of 50m was chosen. Further, as many models work on a set of equations, the output needs to be verified for the given location. For example, SCIMAP does not integrate geology, but uses land use as a proxy and therefore areas predicted as high risk may not actually be; further the equations in SCIMAP simplify the situation. Additionally the land use data does not detail the habitats present within the land parcel; this may impact the intervention chosen. Ground truthing is therefore important in: 1) to allow the map outputs to be verified and; 2) to engage with the land manager; 3) to assess what habitats are present.

Engagement with farmers: The field visit allows engagement with farmers and is the first stage of verifying mapping outputs. The ground truthing can be done by a farm advisor who could explain the process of creating the maps, and explain any limitations of the modelling. The farmers / farm advisors have invaluable local knowledge that cannot always be picked up by modelling; using their on-the-ground experience helps to speed up the ground-truthing of the maps to make sure effort is not wasted e.g., focusing on an area that does not contribute to erosion or flooding.

Verification of map outputs: This process involves walking the entirety of the land holding, preferentially focusing on high risk areas. The maps can then be updated with information on the landscape e.g., evidence of gullying and erosion and photographs can be taken to understand the setting. As modelling outputs are limited to the resolution of data used, in this case 50m, the opportunity maps offer an insight into the general area where interventions should be placed. During ground-truthing, the feasibility of placing interventions was assessed e.g., does this buffer strip work in the field? can this tributary be used to place leaky woody dams, what location is optimal?

The ground-truthing can also help determine other flow paths that may become apparent in different flow regimes, for example if a site visit occurs after intense thunderstorm / high intensity events; evidence of new pathways may become apparent.

Importance of this process: Engagement with the farmers at an early stage is invaluable, not only can the local on-the-ground knowledge be incorporated, but the farmers can help shape the opportunities discussed and the approach taken. Engaging at an early stage with a co-design focus ensures that there is buy-in, as the opportunities can work with existing business plans. This can also lay the foundations for future discussions surrounding NFM. Modelling can help prioritise areas to investigate, and by ground-truthing the output, the specific locations of NFM opportunities can be highlighted. Further the ground truthing allows analysis of local conditions and assess the practicality of the intervention e.g., gradient of river or presence of sensitive habitats such as species rich flushes or patches of species rich grassland.

2.6 Pros and cons of mapping

The hotspot and opportunity maps produced in this report are based on GIS modelling of hotspots, or problem areas in the catchment. This information can be used to prioritise the areas and interventions used that will have the biggest impacts e.g., that can slow the flow, reduce diffuse pollution. They therefore act as a time saving activity that reduce the need for extensive catchment-wide fieldwork. The modelling methods can also be used to test problem areas under different conditions and can be used to see how different interventions will perform under different climate change scenarios.

Benefits of mapping using GIS:

- Quick and repeatable methodology.
- Saves time by prioritising areas and interventions that can be used.
- Can test whether interventions can be used for multiple benefits.
- Can be used to model different scenarios to see how problem areas change (e.g., using seasonal land use maps for mapping erosion risk or different flood return periods for tributary synchronisation work).

Nonetheless, the outputs need to be ground truthed and only show the general area of where interventions should be placed due to the resolution of the data used. Further, the GIS methodology is comprised of simplified models based on a limited set of equations which simplify the complexities experienced in catchments. When placing in-stream interventions a detailed understanding of the hydrology and hydromorphology of the reach is needed.

Limitations of opportunity modelling:

- Mapping is limited by the resolution of data and simplified equations used and therefore the outputs need to be ground truthed.
    - Incorporation of local on the ground knowledge is key
- Any in-stream work requires further detailed modelling to understand the hydrology and hydromorphology of the reach.

2.7 Other modelling

This project used SCIMAP, which produces a relative assessment of risk. The following models could also be used, the list below is not exhaustive and relates to the models that have been used frequently in iCASP projects:

1. SD-TOPMODEL – A hydrological model that can be used to assess the impact of interventions on the hydrology of the catchment e.g., flood peak reduction. The model works well for land management changes such as soil management or land use change. See 'Calderdale NFM': Link to Calderdale NFM project on iCASP website
2. SWAT – An open source model that can show volumes of sediment produced by land parcels. Land management can then be modelled to see changes in the sediment budget e.g., planting trees. This can be used to ascertain potential volume reductions related to different interventions. See Skell project for more information.

3. Options

The following options have been suggested: leaky woody dams, offline ponds, tree planting, buffer strips and hedgerows. For further outcomes of interventions please refer to NFM publications by the Environment Agency (EA)[10] and Scottish Environment

[10] Burgess-Gamble, L, Ngai, R., Wilkinson, M., Nisbet, T., Pontee, N., Harvey, R., Kipling, K., Addy, S., Rose, S., Maslen, S., Jay, H., Nicholson, A., Page, T., Jonczyk, J., and Quinn, P. 2018. Working with Natural Processes – Evidence Directory. Environment Agency.

Protection Agency (SEPA)[11]. Table 4.1 documents the outcomes of the interventions chosen for this study.

Option	Impact on diffuse pollution	Impact on overland flow
Leaky woody dams	Can promote the deposition of fine grained sediment, but can also cause scour increasing sediment loads.	The introduction of woody material or boulders to a natural channel to slow the flow increase instream water levels during moderate to high flows, and thereby increase water storage on the floodplain.
Offline ponds	Trap sediment, however, the rate of sedimentation depends on how frequently the pond is inundated	Ponds and wetland scrapes can regulate flow by providing extra storage during high rainfall events, which can attenuate the flood peak; this can help reduce flood risk locally.
Tree planting	intercept overland flow, and can be used to reduce diffuse pollution due to the increase in resistance and soil infiltration	increase roughness, and slow flow down, which increases the chance of infiltration, interception and evapotranspiration
Buffer strips	Promote deposition due to increased roughness	Slow the flow by decreasing the velocity of overland flow due to increased roughness. Buffer strips can also increase infiltration.
Hedgerows	intercept overland flow, and can be used to reduce diffuse pollution due to the increase in resistance and soil infiltration	– Hedgerows are run off control features, which are very effective if planted in a natural gully or along the contour of a field. increase roughness, and slow flow down, which increases the chance of infiltration, interception and evapotranspiration

[11] Forbes, H., Ball, K., and McLay, F., 2015. Natural Flood Management Handbook. Scottish Environment Protection Agency.

It is important to note, soil management has not been mapped using the SCIMAP output. However, it is a key way to help reduce diffuse pollution and slow the flow. For further information see the NFM publications by the EA[12] and Sepa[13], or the handbook by the Yorkshire Dales National Park Authority[14].

3.1 Worked example – hotspots and opportunity mapping

Figures 3.1- 3.3 show a worked example of a land parcel in the study area, detailing why each intervention was chosen and what other interventions could be used to also reach the same aims.

Figure 3.1 shows the overland flow potential in a land parcel. Within the largest farm parcel, flow paths dominantly flow towards the main river channel that run through the land holding. Towards the southern boundary of the largest farm parcel, flow pathways also flow towards another tributary, which forms a confluence at the south-eastern boundary of the larger land parcels. Of the flow pathways towards the main river, there are several main areas of interest of very high risk, the largest extent of risk forms a dendritic pattern and mirrors the numerous small watercourses on the land parcel, and flow from one side of the land parcel to the other. Risk of overland flow is lower towards the smaller river, where there is a dominance of medium risk, however there are 3 areas of interest of high to very high risk. Figure 3.2 shows diffuse pollution erosion risk; the land parcel has numerous areas of Erosion risk extends across the largest parcels, towards the main river, mirroring the overland flow risk. The largest area of medium to very high risk forms a dendritic pattern. Towards the smaller river system there are 6 main areas of interest, ranging from very high to medium. Using both the overland flow risk (Figure 3.1) and diffuse pollution (Figure 3.2), opportunities for NFM have been proposed for the land parcel (Figure 3.3). The following opportunities have been proposed for the farm: leaky woody dams, buffer strips, offline ponds, hedgerows and tree planting. Leaky woody dams have been proposed for the numerous small

[12] Burgess-Gamble, L, Ngai, R., Wilkinson, M., Nisbet, T., Pontee, N., Harvey, R., Kipling, K., Addy, S., Rose, S., Maslen, S., Jay, H., Nicholson, A., Page, T., Jonczyk, J., and Quinn, P. 2018. Working with Natural Processes – Evidence Directory. Environment Agency.
[13] Forbes, H., Ball, K., and McLay, F., 2015. Natural Flood Management Handbook. Scottish Environment Protection Agency.
[14] Yorkshire Dales National Park Authority. 2017. Natural Flood Management Measures – a Practical guide for farmers.

becks on the property to help slow the flow and promoting storage on the floodplain. They may also help store sediment but can also cause scour. Buffer strips have been proposed to promote the deposition of fine grained sediment and slow the flow, by increasing roughness and promoting infiltration. Hedgerows have also been proposed to also achieve the same outcomes as buffer strips. Offline ponds have been proposed to help store water and reduce flood risk. Offline ponds will also help store fine grained sediment, but will have to be emptied to ensure storage potential remains the same. Trees have been suggested in a few locations, to extend nearby woodland. The tree planting will help slow the flow and promote the deposition of fine grained sediment. Tree planting may not always be the most favourable intervention, as it may not work with the farm business – alternatively a buffer strip could be used in this location.

Other interventions can also be chosen given the local conditions for example tree planting can be replaced with a buffer strip to achieve increased roughness, the promotion of infiltration and slowing the flow. It is important to note that soil management techniques e.g., reducing soil compaction, can also help reduce flood and diffuse pollution risk.

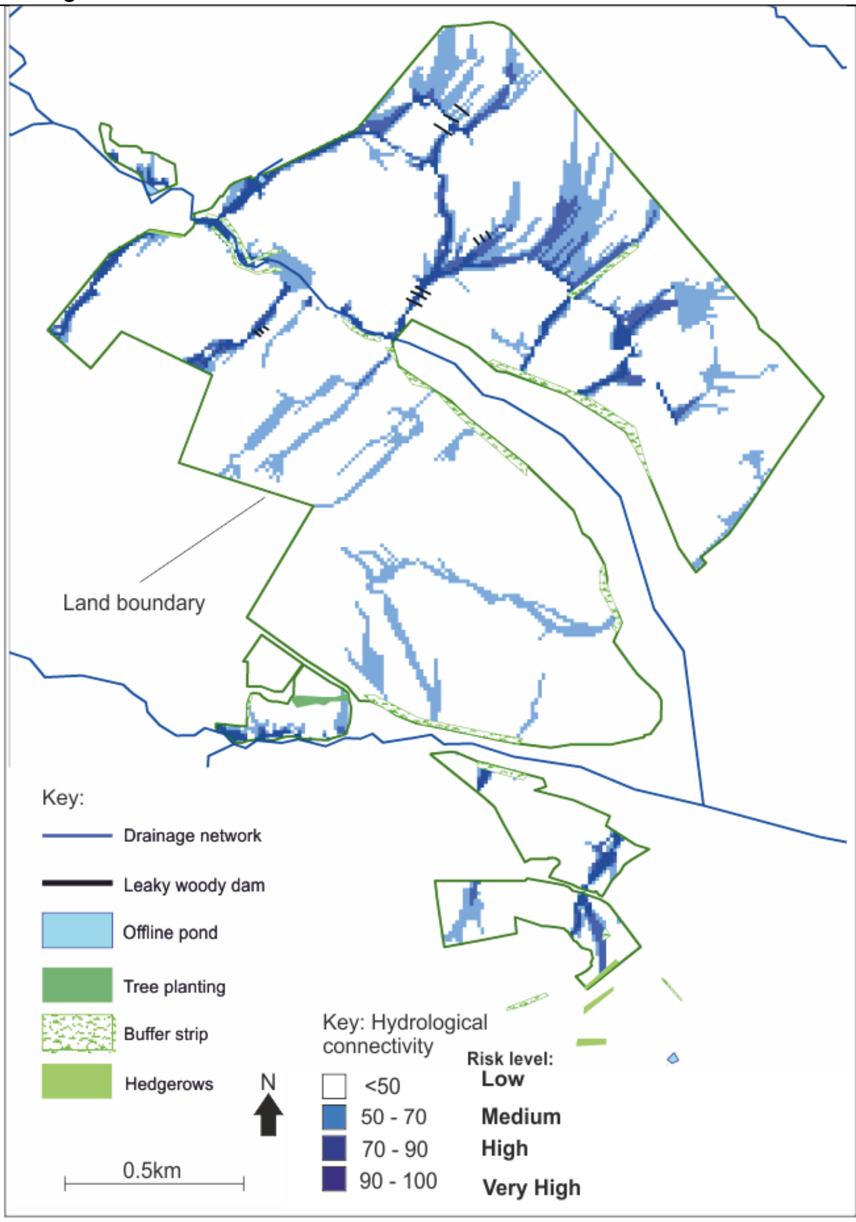

Figure 3.1 *– Example of overland flow SCIMAP output.*

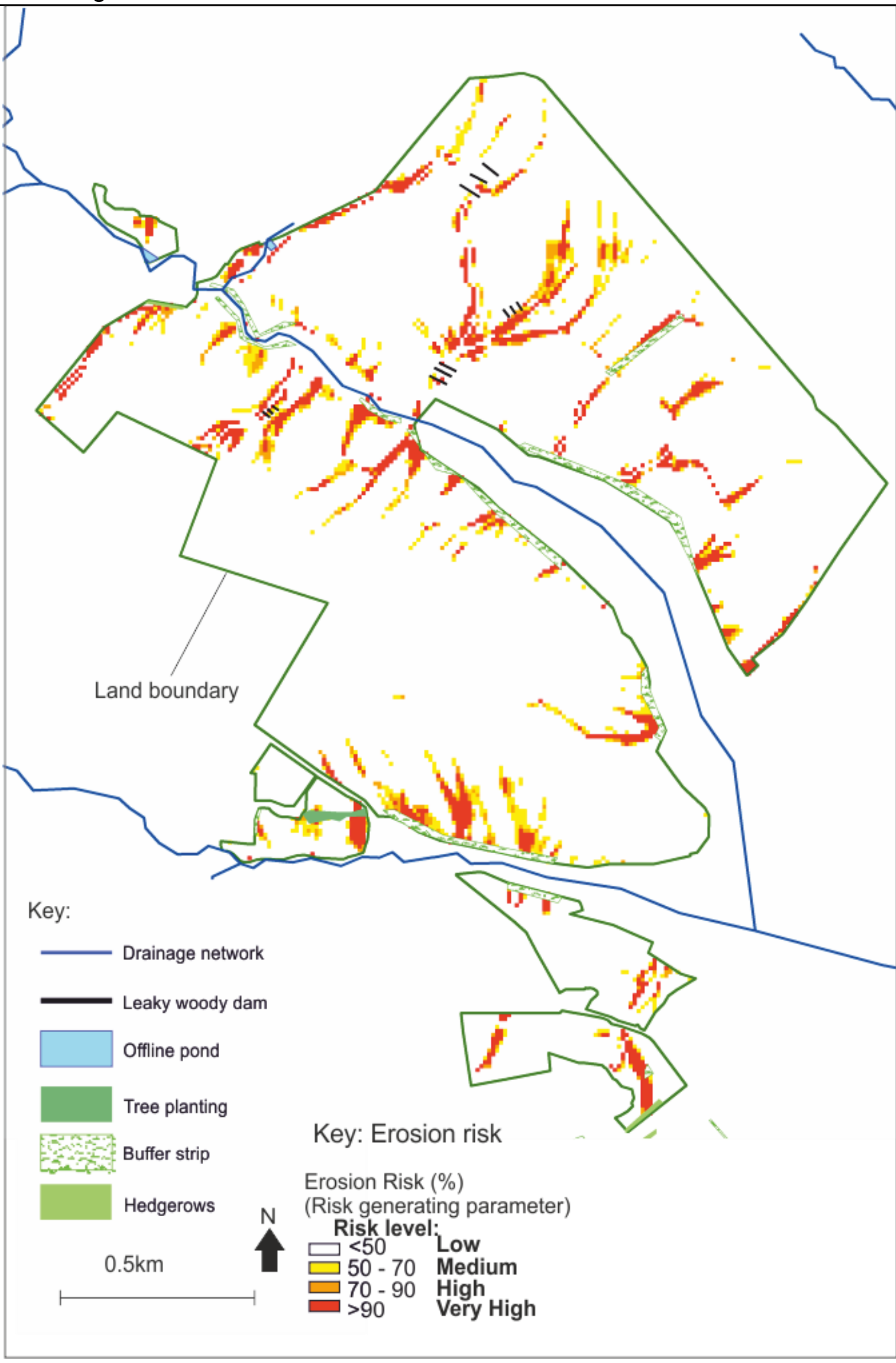

***Figure 3.2** – Example of erosion risk map output.*

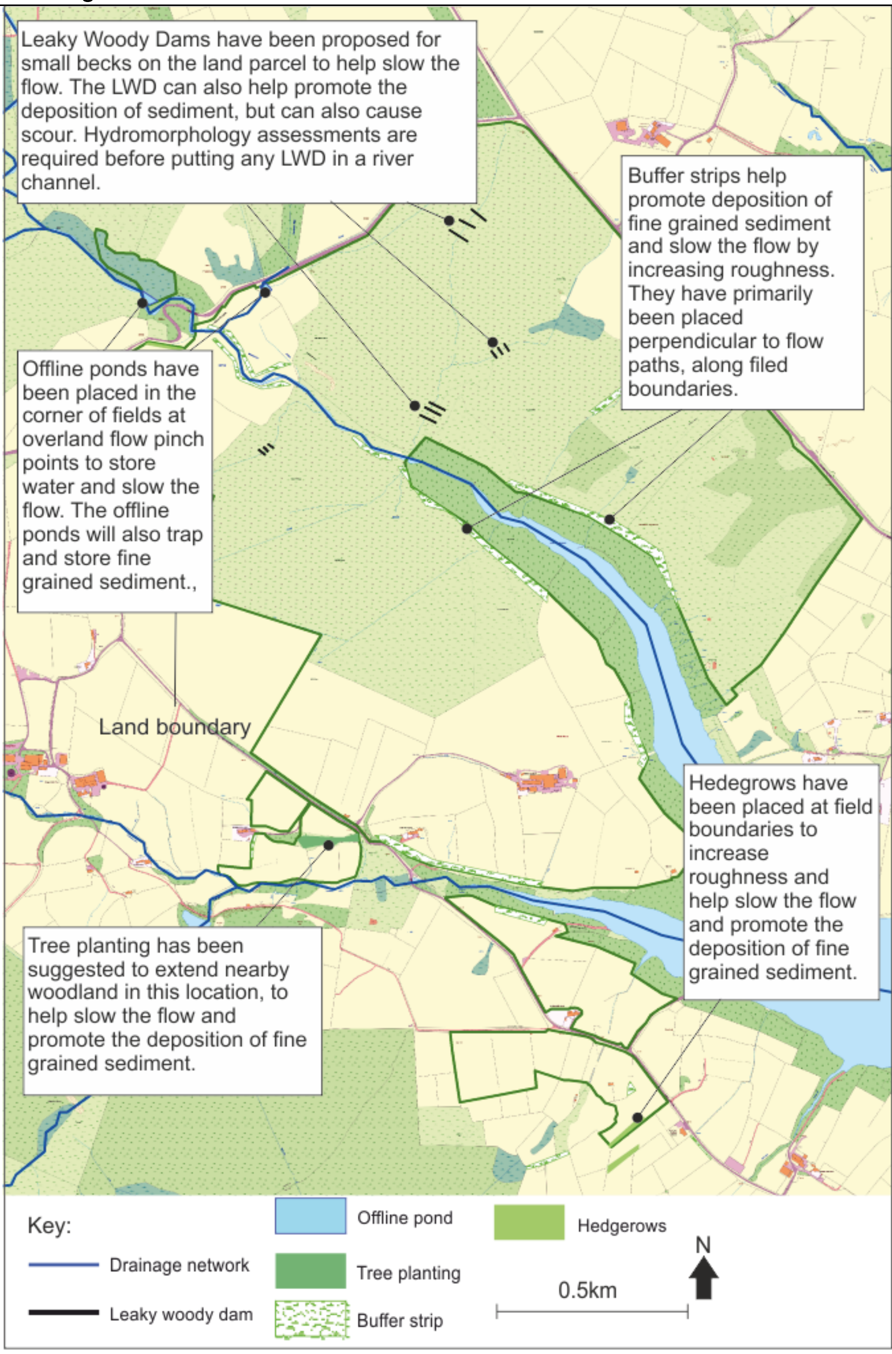

Figure 3.3 *– Example of Opportunity Map, with annotated notes of interventions chosen.*

4. Lessons learnt

Mapping

Mapping is a vital part of investigating what NFM interventions could be placed on a land parcel. It offers a first stage approach to prioritising key areas of interest without extensive fieldwork. Mapping requires underlying GIS and technical knowledge. In order to build sufficient time into projects, mapping and modelling should be given a minimum of a month, based on the size of the this project, in order to download information, run models, process the data and present the results. Some of this time will also be used to update maps once ground-truthing has occurred.

Costs may be required to buy higher resolution data where necessary. However, there are many open access options that will be able to produce first stage maps before further investigating via ground truthing or more in depth modelling (e.g., distinguishing the actual volumes of flow storage or delay to flood peak etc.).

Support needed

Desktop analysis can only do so much and acts as a first stage to direct further investigation. Therefore, a walkover survey by a farm advisor or alternative would be required. Additionally, modellers do not often have the vital on the ground local knowledge that farm advisors and farmers do about the land. Uptake of interventions will only occur when the interventions work with the farmers business, knowledge of the local conditions and business is therefore key.

5. Conclusions

This project has assessed what interventions could be used to slow the flow and reduce diffuse pollution in land holdings in the Nidderdale AONB. The main lessons learnt are that mapping and modelling offers a vital first step for assessing what NFM can be used on a land parcel. The mapping and modelling require previous technical knowledge. The mapping stage helps to identify risk areas, which in turn allows for prioritisation of areas for ground truthing. However, the vital local knowledge of the farmer and farm advisor is also crucial – without this, the interventions mapped may not work with the farmers business and there may not be any uptake helping to reduce diffuse pollution and slowing the flow. Additionally farm advisors have on the ground understanding of key habitats and aims of individual organisations, and how funding may vary with different interventions.

Integrated Catchment Solutions Programme

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