Working with Natural Processes to reduce flood risk

The evidence behind Natural Flood Management

Introduction

What is it?

Working with Natural Processes (WWNP) to reduce flood and coastal erosion risk (FCRM) involves implementing measures that help to protect, restore and emulate the natural functions of catchments, floodplains, rivers and the coast. WWNP takes many different forms and can be applied in urban and rural areas, and on rivers, estuaries and coasts. It is also referred to as Natural Flood Management (NFM).

What did we do?

There has been much research on WWNP, but it has never been synthesised into one location. This has meant that it has been hard for flood risk managers to access up-to-date information on WWNP measures and to understand their potential benefits.

We have developed a WWNP Evidence Directory which looks in detail at the effectiveness of different measures at reducing flood risk. This is supported by maps which help practitioners think about the types of measure that may work in a catchment.

These 1 page summaries provide a high level summary of key findings from the Evidence Directory and point you to where you can find more information.

What did we find?

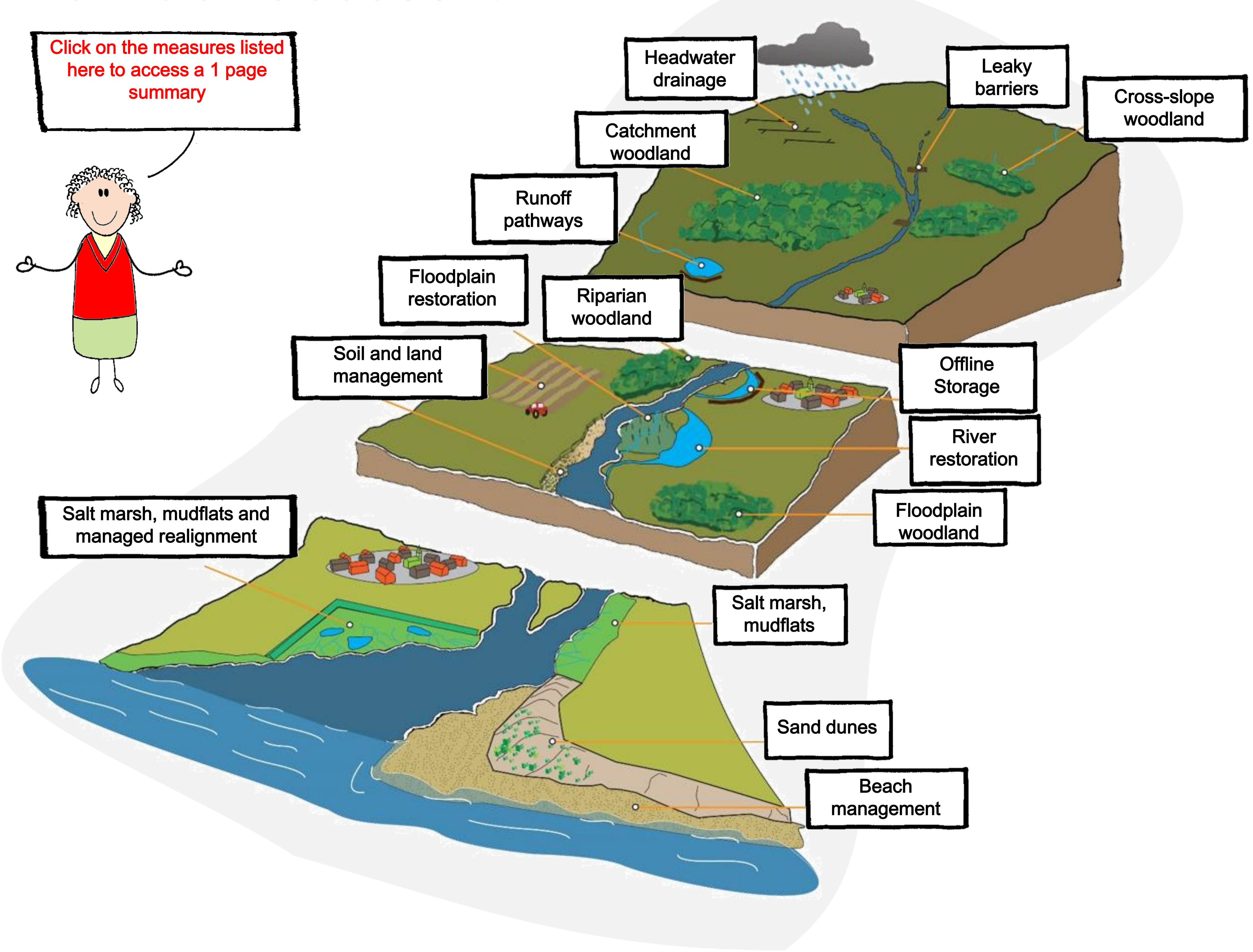
We found that WWNP…

- ✓ Is not new, there are many examples of its application across the UK.
- ✓ It works. It can reduce flood risk, by slowing, storing and filtering water.
- ✓ It complements rather than replaces traditional engineering.
- ✓ Typically reduces flood risk for smaller magnitude floods, across small to medium catchment scales.
- ✓ Almost always achieves multiple environmental benefits.
- ✓ Is currently reliant on modelled data, more observed data is needed to help validate model findings.

But we still need to understand …

- × The effectiveness of WWNP measures across different catchment scales for a range of return period events (observed and modelled data).
- × How to design and construct different measures so they perform as designed (this includes engineering design standard).
- × How different measures function in different catchment types and different geologies.
- × The role WWNP could play in making catchments more adaptable/resilient to climate change.
- × More fully the ecosystem service benefits of different measures.

How do I access it?



Are there any top tips?

Top tips

- ✓ *Take a catchment-based approach*
- ✓ *Choose the right tool(s) for the job*
- ✓ *Think about timescales – it's a marathon rather than a sprint*
- ✓ *Achieve multiple environmental benefits*
- ✓ *Work with others*
- ✓ *Learn through doing*

IMPORTANT! - The science of NFM is still evolving and developing. Many of the measures covered in these 1 page summaries have yet to be fully tested during extreme flood events. This means that we are still learning how to design and construct them.

When selecting the types of measures to use and the locations in which to place them care is needed to ensure they do not synchronise flood peaks and inadvertently increase flood risk downstream, or inadvertently create a backwater effect and increase flood risk upstream. As with all FCRM schemes it is incumbent on those who design and construct them to ensure that they are robust and do not pose a public safety risk to downstream communities.

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River Restoration

Introduction

What is it?

River restoration reintroduces meanders to rivers and restores physical process.

Making a river more sinuous can reduce flood peaks, water velocities and attenuate flow by slowing and storing flood water.

The extent of this flood risk effect depends on the length of river restored relative to the overall size of the river catchment.

Examples

On the **River Cherwell**, a flood model showed that restoring 5km of the river's channel could reduce peak flow by 10-15% (Acreman et al., 2003).

In a 25 km^2 catchment in the **New Forest** the results of a monitoring study found river restoration led to a 21% reduction in flood peak and a 33% increase in peak travel for 2year recurrence event (Sear et al, 2006).

Mayes Brook river floodplain restoration post-construction (source: Environment Agency)

What did we find?

We found that

We have a **Medium** level of confidence in the flood risk benefits of river restoration because our evidence is mainly from flood models.

We still need

- More observational data to verify model findings.
- To understand standards of flood protection that could be provided by river restoration.
- Information on the flood risk benefits of different types of river restoration measures across a variety of spatial scales.
- To understand the conveyance capacity and water storage effects of restored rivers.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Small	Large	Modelled	Restoration reduced water velocities for a 1 in 100 year flood by 41% (Keesstra et al., 2012).
Local/ Small	Not provided	Modelled	Restoring reaches of 5-10km can provide tangible attenuation of peak flows (Sholtes and Doyle, 2011).
Medium	Medium	Modelled	Restoring meanders in a 1km reach in a 17 km^2 catchment, reduced flood peaks by less than 1% for 2 to 50 year return period (Sholtes and Doyle, 2011).
Large	Not provided	Modelled	River restoration in headwaters of 400 km^2 catchment, reduced peak flow by 14% (Liu et al., 2004).

Multiple benefits

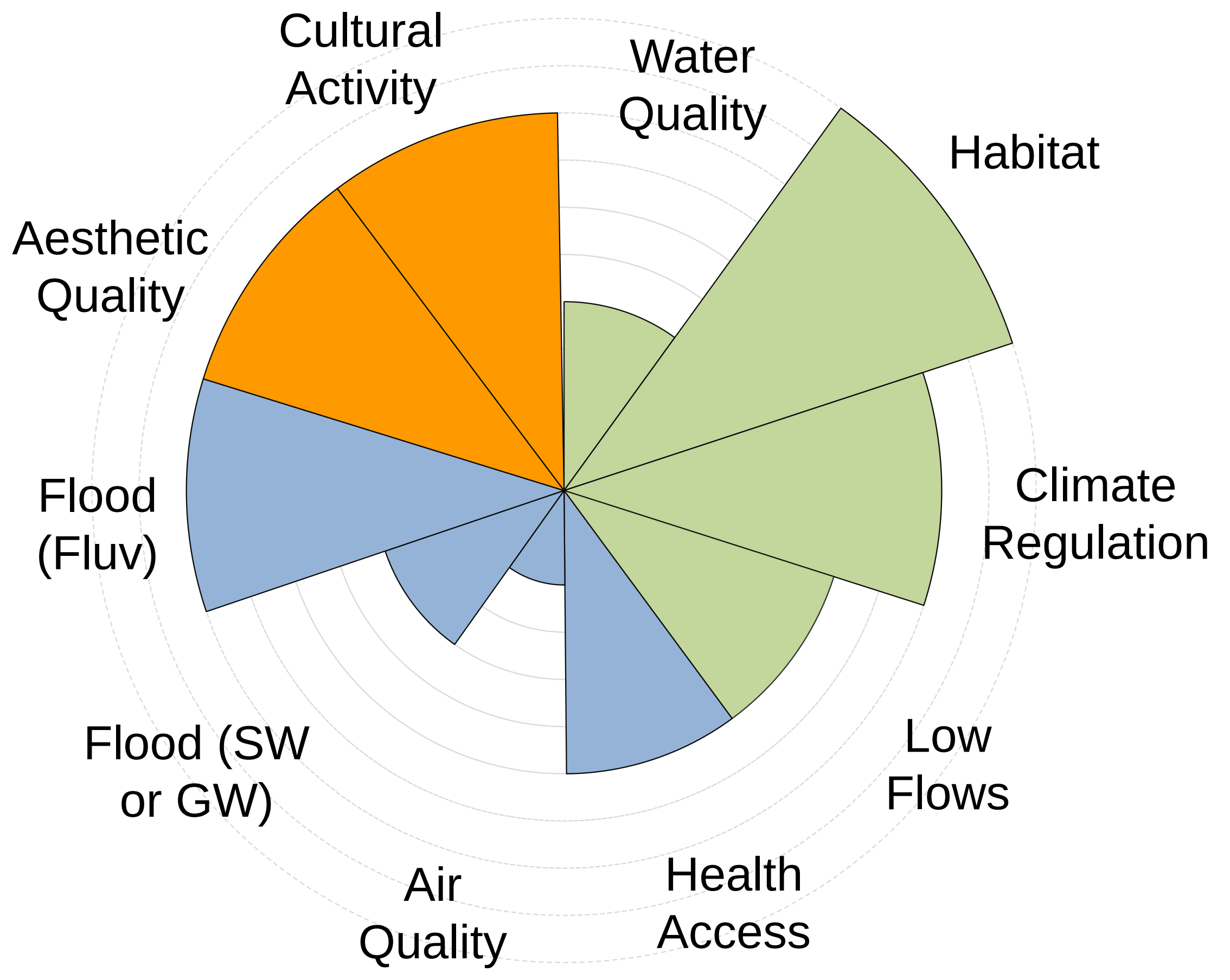
Benefits summary

River restoration can provide a wide range of benefits across most ecosystem services (see benefits wheel).

Examples

- Regeneration benefits of improving the river and surrounding park at Mayes Brook was valued at £7.8 million over 100 years, based on the uplift to property prices (Everard et al., 2011). This study showed that post restoration the need for maintenance could be reduced by approximately 50%, leading to annual savings of £5,000.
- On the River Frome (Dorset) river restoration is expected to also help manage diffuse pollution, accumulating silt on the floodplain.
- River restoration benefits recreation and tourism, the estimated per person per trip value provided by rivers and floodplains is £3.35 (Sen et al., 2012).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Green approaches in river engineering
- Manual of River Restoration Techniques
- River restoration and biodiversity

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- River Avon
- Dorset Frome
- Mayes Brook
- New Forest

Maps:

- Wetland vision
- Mapping the potential for Working with Natural Processes (England)
- NFM Opportunity Maps (Scotland)

Click **here** to download all River and Floodplain Case Studies

Terms of reference

Terminology

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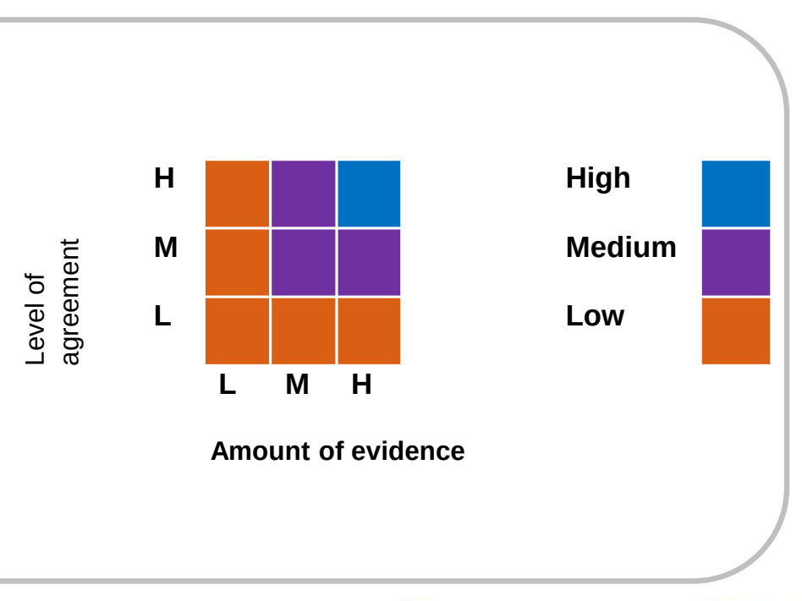
Benefits wheels

For each measure we have summarised the multiple benefits which they could provide using a wheel which covers 10 benefit indicators that have been ranked on a scale from 1 to 5 to give an indication of the relative contribution the measure can make to the provision of a certain benefit.

Key:	Benefit Type:
🟩	Environmental
🟦	Social
🟨	Cultural

Scientific confidence

For each topic, the level of confidence in the science that underpins the individual measures is defined using the approach shown in the figure below, which attaches a confidence level (high, medium or low) based on the potential effectiveness of each measure at reducing flood risk. This confidence level, assigned by scientific experts, reflects both the degree of agreement of scientific studies and the amount of information available.



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Floodplain Restoration

Introduction

What is it?

River floodplain restoration restores the hydrological connectivity between the river and floodplain, which encourages more regular floodplain inundation and flood water storage.

This can decreases the magnitude of the flood peak and reduce downstream flood depths especially for high frequency, low return period floods.

The extent of this flood risk effect depends on the length of river restored relative to the overall size of the river catchment.

The Twiggeries, Padgate Brook river floodplain restoration post-construction in 2016 (source: Environment Agency)

Examples

On the **River Glaven**, modelled and observed data showed that embankment removal led to floodplain inundation at high flows, with up to a 5% peak reduction in flood peak (Clilverd et al., 2013 and 2015).

At **Eddleston Water** modelling indicated that increasing floodplain roughness could be the most effective means of flood management, with peak flows reduced by up to 23%.

What did we find?

We found that

We have a **Medium**/**Low** level of confidence in the flood risk benefits of floodplain restoration, because we would benefit from more observational data to verify model findings. We also need to better understand where floodplain restoration could have its greatest impact and locations where it could have a neutral or negative impact on flood risk across (across different watercourse types and at different spatial scales).

We still need

- To understand the hydraulic performance of restored floodplains and their impacts on channel conveyance and d/s receptors.
- More floodplain roughness data to calibrate flood models.
- To understand the role of groundwater in floodplain restoration.

Other examples

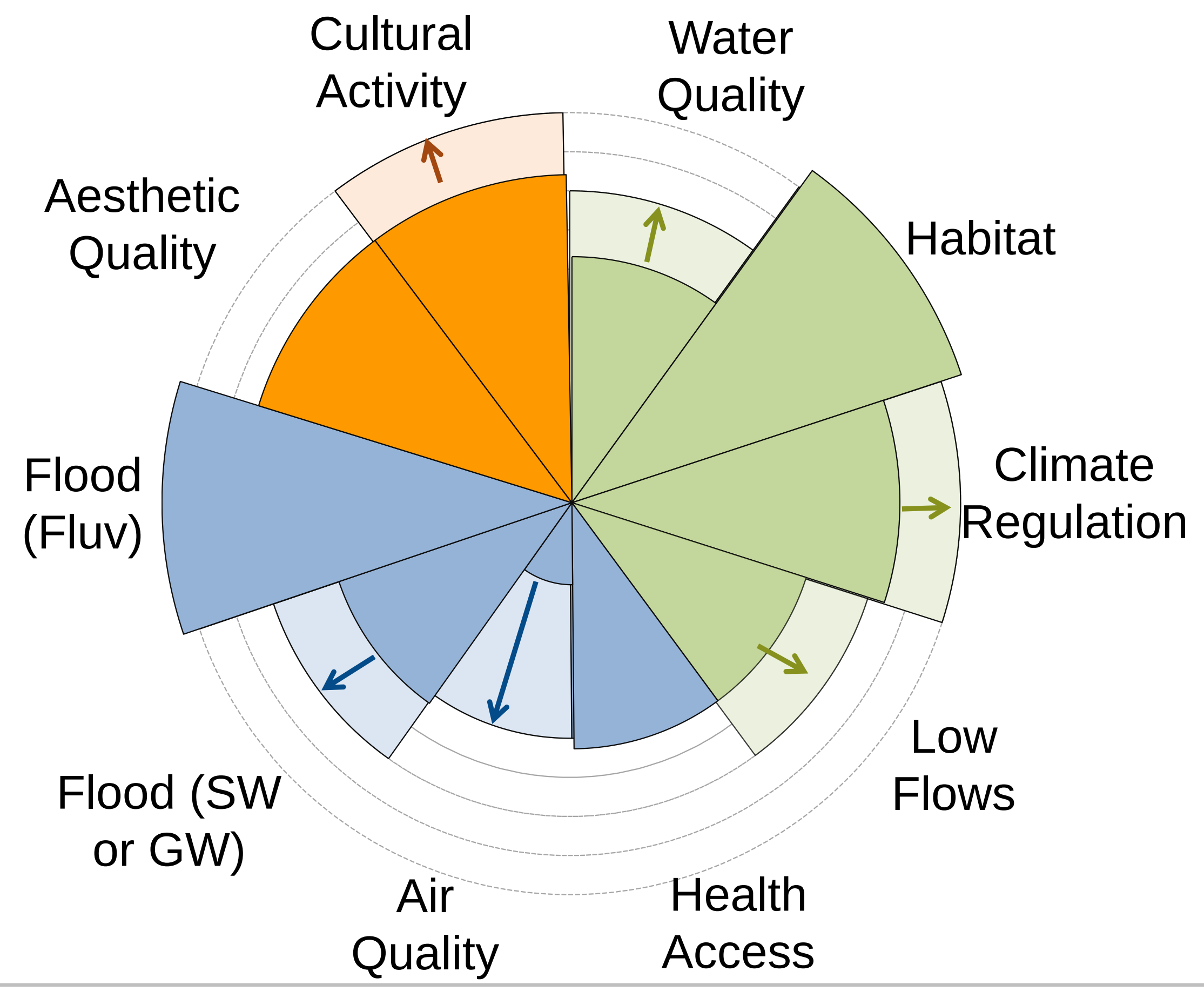
Catchment size	Flood magnitude	Modelled or observed?	Description
Small	Not provided	Observed	In **North Carolina** floodplain restoration increased the amount of times the floodplain was inundated decreasing flood peaks
Small	Medium	Modelled	The **River Chelmer** floodplain restoration was found to potentially reduce flood depths up to 0.3m in a 10% AEP event and by 0.15m (some locations) in a 1% AEP.
Medium	Not provided	Modelled	Restoring 5km of the river **Cherwell** reduced peak flow by 10-15% and increases peak floodplain water levels by 0.5-1.6m (Acreman et al., 2003).
Large	Not provided	Modelled	Kreis et al (2005) found restoring the floodplain of the **River Thur** (France) did not reduce flood peaks.

Multiple benefits

Benefits summary

Floodplain restoration can provide a wide range of benefits across most ecosystem services (see benefits wheel), most of these benefits increase substantially if floodplain wetland habitat is restored (see arrows and shading on the benefits wheel).

Benefits wheel



Examples

- 1ha of restored floodplain provides £52 per tonne of carbon sequestration benefits
- Creating an extra 50ha of floodplain (Norfolk Broads) provides £1m of carbon sequestration benefits and £27m of recreational value over 100 years (Tinch et al., 2012).
- Freshwater wetlands have been valued at £1300 per ha per year (2008 prices) (eftec, 2010)
- 1% increase in area of freshwater within 1km of a development attracts a premium of 0.36% or £694 (Gibbons et al., 2014).
- Morris and Camino (2011) found the marginal value associated with floodplain/wetland provision (per ha per year) is for : flood risk management £407; increased biodiversity £304; water quality improvements £292; aesthetics and amenity £227; and non-consumptive recreation £82.

Further reading, case studies and maps

Further reading:

- How To Use Floodplains for Flood Risk Reduction
- Floodplain Meadows: Beauty and utility. Technical handbook
- SEPA's Natural Flood Management Handbook

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Chelmer
- Eddleston
- Glaven
- Low Stanger
- Mayes Brook
- Mill Brook
- Padgate Brook
- St Austell

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Maps:

- Wetland vision
- Mapping the potential for Working with Natural Processes (England)
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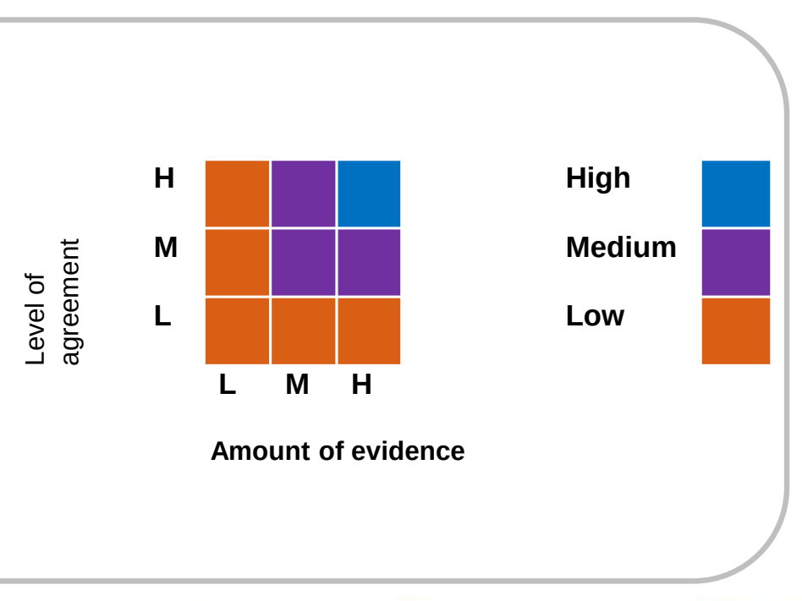

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Leaky Barriers

Introduction

What is it?

Leaky barriers are usually formed of wood and they are either formed naturally or are installed across watercourses and floodplains.

They reduce flood risk by intercepting the flow of water in a river, this can can help restore river-floodplain connectivity which can reduce flood peaks, slow water velocities and attenuate flow by storing water on the floodplain.

Examples

Observed data collected during the Boxing Day floods (2015) in **Pickering** found the flood risk scheme reduced flood peaks by approx. 15-20%. Half this reduction was due to upstream NFM measures and the other half the engineered storage area in the town.

Modelling by Odoni and Lane (2010) found installing 100 leaky barriers could reduce flood flows by 7.5% (from 29.5m^3/s to 27.3m^3/s).

Stroud valley leaky barrier (source: Chris Uttley)

Important! There is limited evidence of how these measures perform during extreme flood events. Caution is needed when installing leaky barriers to ensure they do not become detached, cause a downstream blockage with consequent impacts on public safety.

What did we find?

We found that

We have a **Mixed** level of confidence in the flood risk benefits of leaky dams. Observed and modelled evidence shows they are effective at reducing flood risk at a local scale for small flood events (**Med** confidence). We have a **High** level of understanding of their effect on sediment and geomorphology. However, there is limited evidence of their flood risk effect for large events at greater catchment scales (**Low** confidence).

We still need

- To understand their effectiveness at mitigating flood peaks at larger catchment scales for larger flood events.
- More floodplain roughness data to calibrate flood models.
- Guidance on how to design and construct them.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Not provided	Small	Observed	Wenzel et al (2014) found a delay in flood wave propagation over the local reach due to increased channel roughness and a decrease in peak discharge (2.2%) for a 3.5 year return period event
Medium	Small	Modelled	Kitts (2010) found that leaky barriers in ~12 km^2 wooded catchments can slow small flood peak by up to 33%.
Small	Medium	Modelled	Thomas and Nisbet (2012) found that installing 5 leaky barriers reduced flow velocities by 2.1m/s, delaying the flood peak by 15 min over a 0.5 km reach for 1 in 100 year event.

Multiple benefits

Benefits summary

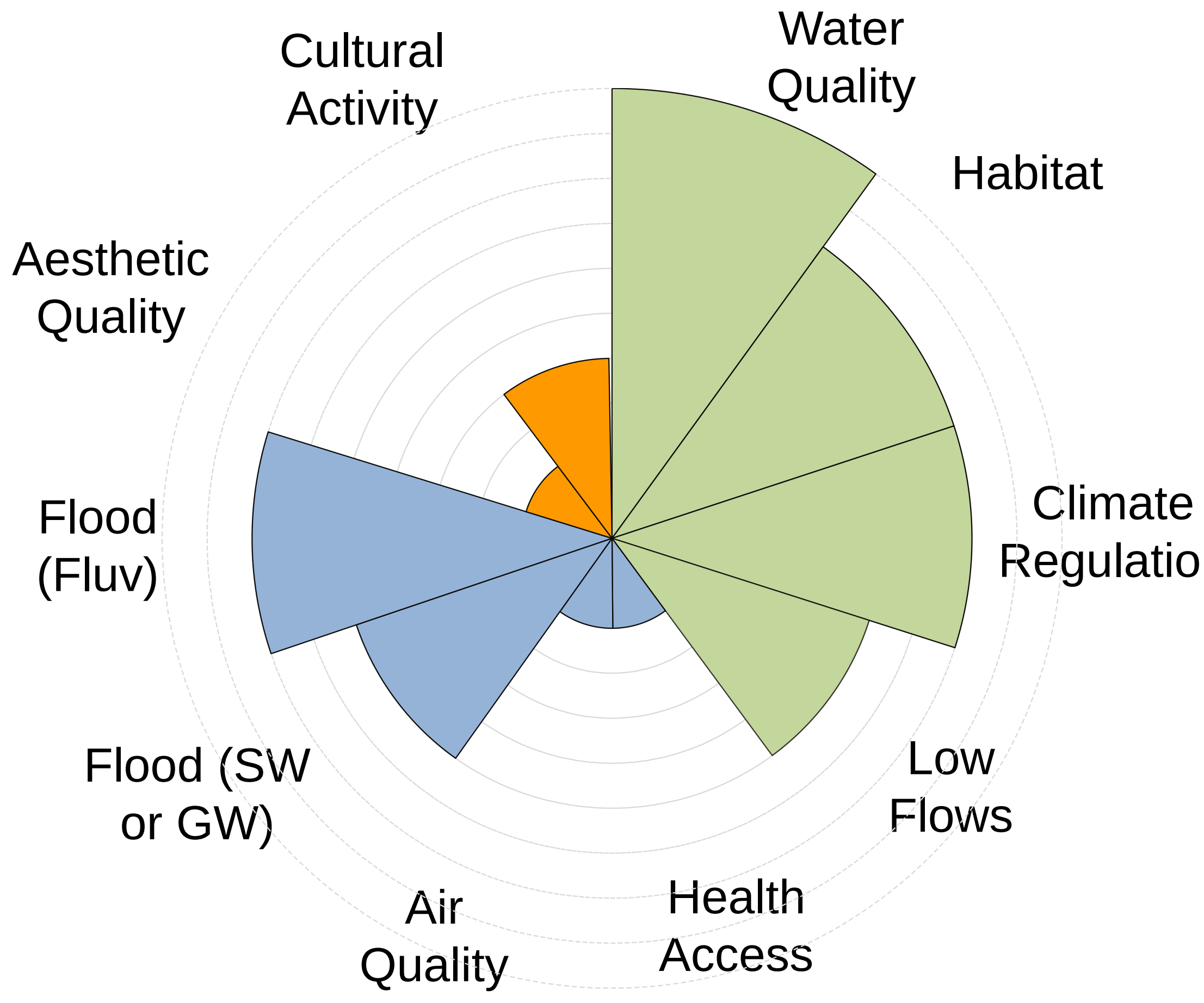
Leaky barriers provide greatest benefits to the environmental services shown in the benefits wheel.

There are limited studies to show cultural, aesthetic, air quality or health access benefits.

Examples

- One study valued the ecosystem services provided by wood placement projects from 1·08 to 1·81 € m^{-1} year, with the largest economic value for recreational opportunities (Acuña et al., 2013).
- On the Blackbrook 4 engineered log jams have reduced average phosphate concentration by 3.6mg per litre. Nitrate is also reduced. By 2035, it is predicted that 792m^3 of sediment will be stored in 3 ponds retained by the jams.
- Wood dams provide increased resilience to climate change by regulating temperature and water level (Wild Trout Trust, undated).

Benefits wheel



Further reading, case studies and maps

Further reading:

- [Fish live in trees too]
- [Woody dams, deflectors and diverters]
- [Stroud RSudS project film]
- [Evaluation of Large Woody Debris in Watercourses]

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Belford
- Blackbrook
- Bowmont
- Devon Beavers
- New Forest
- Pickering
- Stroud
- Tutta Beck

Click here to download all River and Floodplain Case Studies

Maps:

- Mapping the potential for Working with Natural Processes (England)
- NFM Opportunity Maps (Scotland)

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Benefits wheels

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🟩 Environmental
🟦 Social
🟨 Cultural

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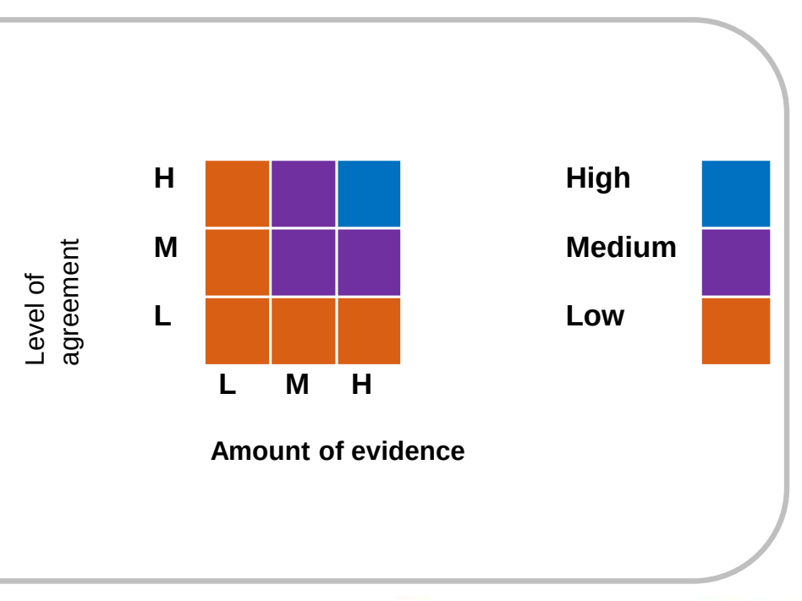

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Flood and Coastal Erosion Risk Management R&D

Offline Storage Areas

Introduction

What is it?

Offline storage areas, are areas of floodplain which have been adapted (with a containment bund, inlet, outlet and spillway) to store and then release flood waters in a controlled manner. They provide temporary flood storage which can reduce peak flow.

The extent of their flood risk effect depends on the number of storage areas provided throughout a catchment and their total storage volume.

Examples

In the **Holnicote** catchment, modelled and observed data showed that 25,000m3 of storage decreased peak flow by 10% during the December 2013 floods (National Trust, 2015). In a 1 in 5 year event, this storage could lead to a 25% reduction in peak flow.

On the **Lustrum Beck**, modelling showed that providing 100,000m^3 of storage in the upstream catchment could reduce discharge from a 1 in 100 year event by 11.5%

Holnicote storage area (source: National Trust)

Important! There is limited evidence of how these measures perform during extreme flood events. A great deal of caution is needed when designing them to ensure that any associated infrastructure are robustly designed and do not impact public safety.

What did we find?

We found that

We have a **Medium** level of confidence in the flood risk benefits of offline storage areas. More research is needed to understand the flood risk benefits of installing a network of small-scale storage areas throughout a catchment, and their impacts on peak synchronisation during a series of flood events.

We still need

- To understand how effective they are in different watercourse types and in groundwater fed catchments.
- To understand how quickly storage will fill with sediments and require maintenance.
- Guidance on how to design and construct them.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Medium	Small	Modelled	In the **Tarland** catchment: 27,000m^3 storage area attenuates a 1 in 2 year event by ~9%; multiple storage ponds providing 23,000m^3 of storage would attenuate the same event ~5% (Ghmire et al, 2014)
Small	Small	Both	In **Belford** 35 storage areas could reduce peak flow 15-30%, when ~10,000m^3 of storage was added, the peak of the largest event was reduced by ~5%
Medium	Medium	Modelled	On the **Beam** washlands, increasing the storage capacity of the existing washlands from 433,000m^3 to 458,660m^3 provides a 1 in 25 year SOP.
Medium	Medium/ Large	Modelled	In **Guisborough**, installing 15,000m^3 of storage in the catchment could reduce the 100-year peak flow by 10.9% (2 m^3/s)

Multiple benefits

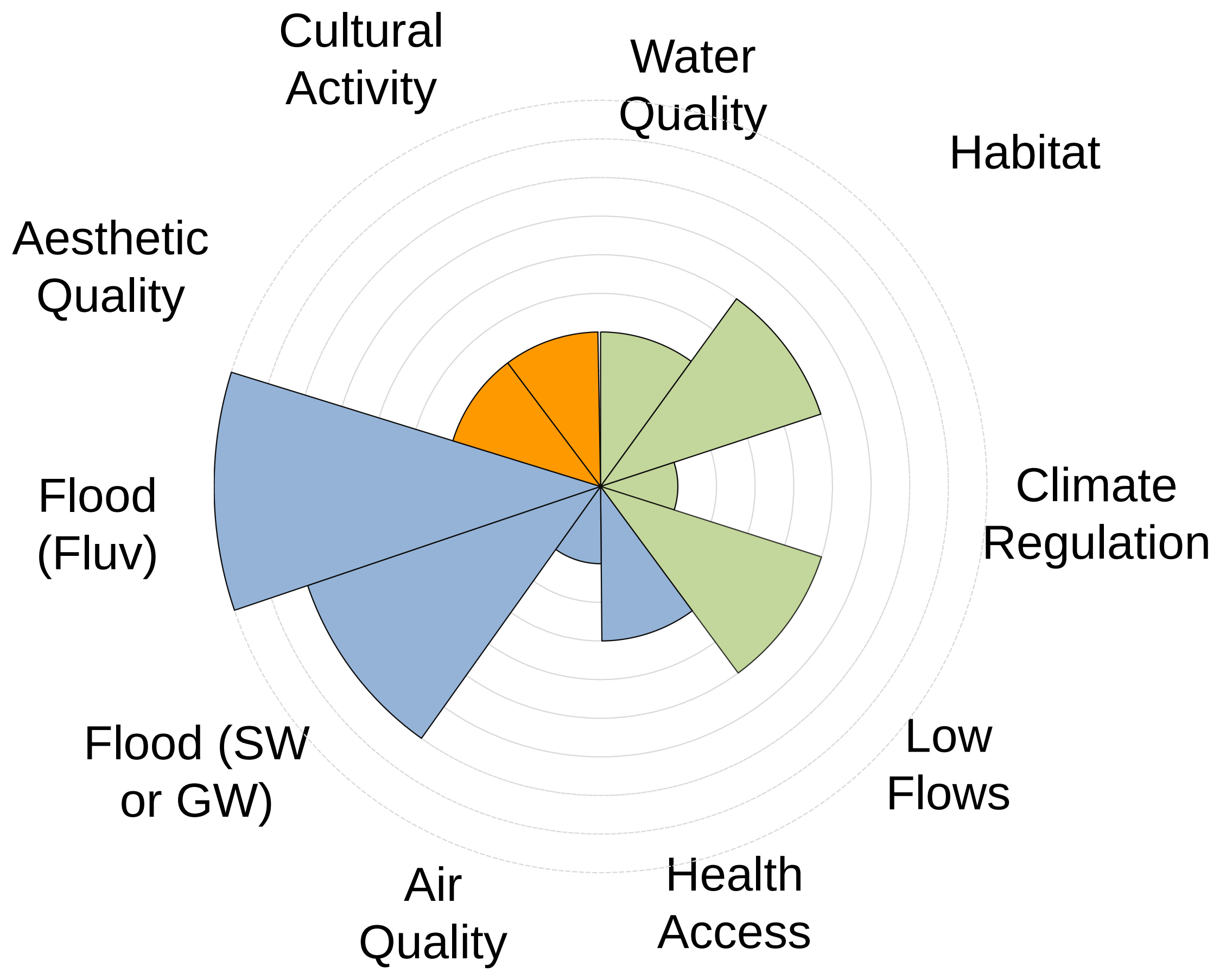
Benefits summary

Offline storage areas have greatest benefits to flood risk management and the regulation of low flows (see benefits wheel).

Examples

- In 1999, the landscape value of maintaining higher water levels was estimated at £175/ha/year (Hickman et al., 2001).
- The amenity value of Beam Parklands, based on a projected 3% uplift to property values, was found to be £26 million over 99 years (eftec, 2015).
- Well-managed washlands can generate tourism and recreational benefits, a non-market valuation of urban washlands demonstrated that the recreation services they provide are highly valued (Boyer and Polasky 2004).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Achieving More: Operational Flood Storage Areas and Biodiversity
- Flood Planner - A Manual for the Natural Management of River Floods
- Sustainable Flood Defence - The Case for Washlands

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Beam Washlands
- Belford
- Guisborough
- Holnicote
- Lustrum Beck
- Swindale Valley

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Flood and Coastal Erosion Risk Management R&D

Catchment Woodland

Introduction

What is it?

Catchment woodland can intercept, slow, store and filter water. This can help reduce flood peaks, flood flows (from 3 to 70%) and flood frequency.

Largest reductions in flood risk have been seen for small events in small catchments, the extent of this reduction decreases as flood magnitude increases.

Examples

In the **Coalburne** catchment, modelled and observed data showed that if 90% of a catchment is planted with conifers it could lead to a 5-20% reduction in peak flows and reduced flood frequency by ~50% across all events (Birkinshaw et al., 2014).

In **Brackenhurst** a model-based study showed an 18% increase in catchment woodland cover could protect 9 properties from flooding during a 4% AEP event and 14 properties for a 2% AEP event.

The restored river Black Water in the New Forest (source: River Management Blog, Simon Dixon)

What did we find?

We found that

We have **High** to **Medium** confidence in the flood risk benefits of catchment woodland, because we have a strong process understanding of the ways that woodlands reduce flood risk. 16 out of 50 studies of catchment scale felling showed increases in peak flow between 20 to 172%. More research is needed to better understand their impact during larger flood events.

We still need

- To understand how the type of woodland, its placement in the catchment and the catchment's size affect its flood risk impact.
- More model parameter ranges to represent woodland hydrological processes, properly assess flood risk impacts and to test the up-scaling of these to the catchment level.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Not provided	Not provided	Modelled	A study in **New Zealand** demonstrated that 67% catchment afforestation reduced mean flood peaks 55-65% across three different flood peaks (Fahey & Jackson, 1997).
Not provided	Medium	Not provided	In **Chiemsee** (Germany) conifer planting in two farmland catchments reduced average peak flows by approx. 100% after 20yrs (Robinson et al. (2003).
Medium/ Large	Not provides	Modelled	A **Europe-wide** assessment of the water retention potential of forests in 287 catchments found to be 25% higher in catchments with 30% cover and 50% higher in those with 70% cover (EEA, 2015).

Multiple benefits

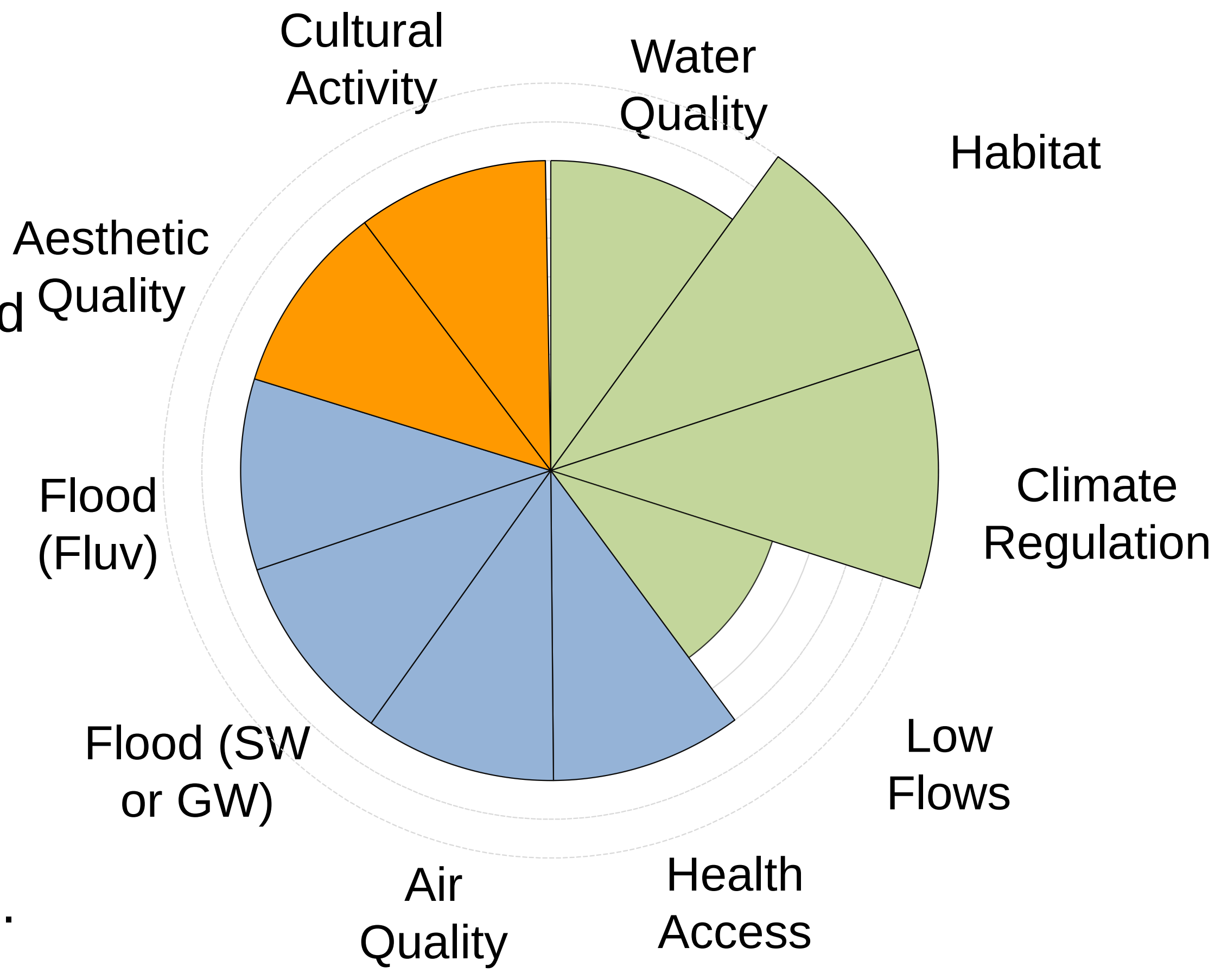
Benefits summary

Catchment woodlands provides benefits across most ecosystem services (see benefits wheel). They can take time to establish so potential benefits are not realised immediately.

Examples

- Marginal benefits of woodland were estimated to be 35p per household/year due to enhanced biodiversity in 12,000 ha (1%) of conifer forest. This increased to 84p for broadleaved native forest and £1.13 for ancient semi-natural woodland (Willis et al., 2003).
- Carbon regulation has been valued at £6.67 per tonne of carbon sequestered (Willis et al., 2003).
- Planting a 100ha forest within a 10 minutes driving distance results in an average individual welfare gain of £3.02 per year (Bateman and Day, 2014).
- Willis et al (2003) valued air pollution health benefits as £124,998 per annum for each death avoided and £602 for 11 day hospital stay avoided.
- A single recreational visit to a woodland has been valued at £1.66 - £2.75 (Willis et al., 2003).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Catching the Flood
- Woodland for Water: Woodland measures for meeting Water Framework Directive objectives

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Brackenhurst
- Coalburne
- Torne

Maps:

- Wetland vision
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Click here to download all Woodland Case Studies

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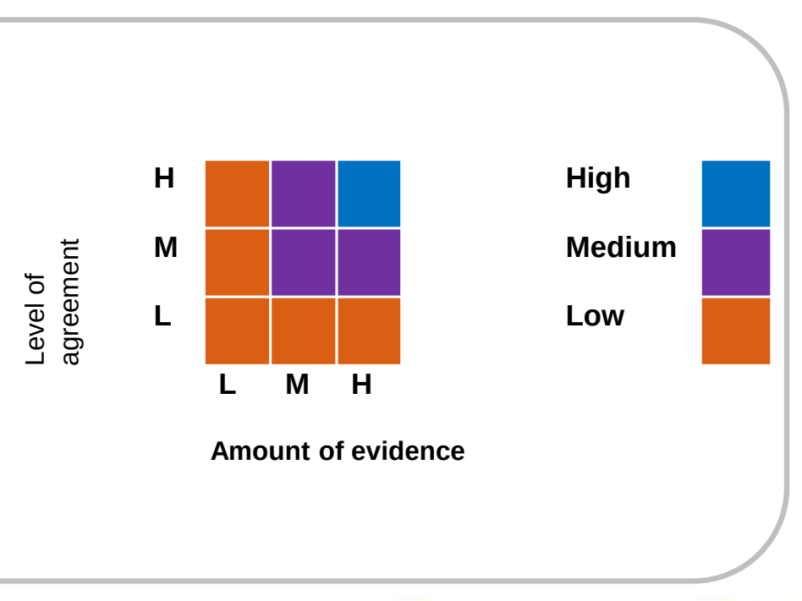
For each topic, the level of confidence in the science that underpins the individual measures is defined using the approach shown in the figure below, which attaches a confidence level (high, medium or low) based on the potential effectiveness of each measure at reducing flood risk. This confidence level, assigned by scientific experts, reflects both the degree of agreement of scientific studies and the amount of information available.



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Cross-slope Woodland

Introduction

What is it?

A cross-slope woodland is a woodland which is planted across a hill slopes. It intercepts the flow of water as it runs down the hill reducing rapid runoff and encouraging infiltration and storage of water in the soil.

There is an absence of measured data to show the flood risk impact of cross-slope woodland at the catchment scale.

Examples

In the **Pontbren** catchment observed data showed that soil infiltration rates were 67 times higher within woodland plots and shelterbelts planted on improved grassland compared with grazed pasture, which reduced run-off volumes by an average of 78% compared to control sites (Marshall et al. 2014).

Modelling of woodland planting across 19-37% of the **River Tone** catchment was predicted to have little effect on the largest peak flow event in January 2002 (McIntyre & Thorne, 2013 and Park et al, 2009).

A farm in the Pontbren catchment (source: Forest Research

What did we find?

We found that

We have **Medium** to **Low** confidence in the flood risk benefits of cross-slope woodlands because there is limited field-based evidence available to demonstrate its flood risk benefit. It is also unclear how widely we can transfer the results from Pontbren elsewhere.

We still need

- To understand the effect of a targeted and integrated network of cross-slope woodland across a range of catchment sizes for a range of flood events.
- To understand the impact of cross-slope planting during a sequence of storm events.
- To understand how the type of woodland, its placement in the catchment and the catchment's size affect its flood risk impact.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Small	Small	Modelled	A modelling study predicted that planting tree strips across 7% of a 12 km^2 headwater catchment could reduce a severe flood event (0.5% AEP) by an average of 5%.
Medium	Not provided	Modelled	Planting of conifer woodland over 29% of the 25 km^2 sub-catchment of the **River Hodder** was predicted to reduce peak flows by an average of 7%, compared to a 4% for broadleaved woodland (Ballard, 2011).

Multiple benefits

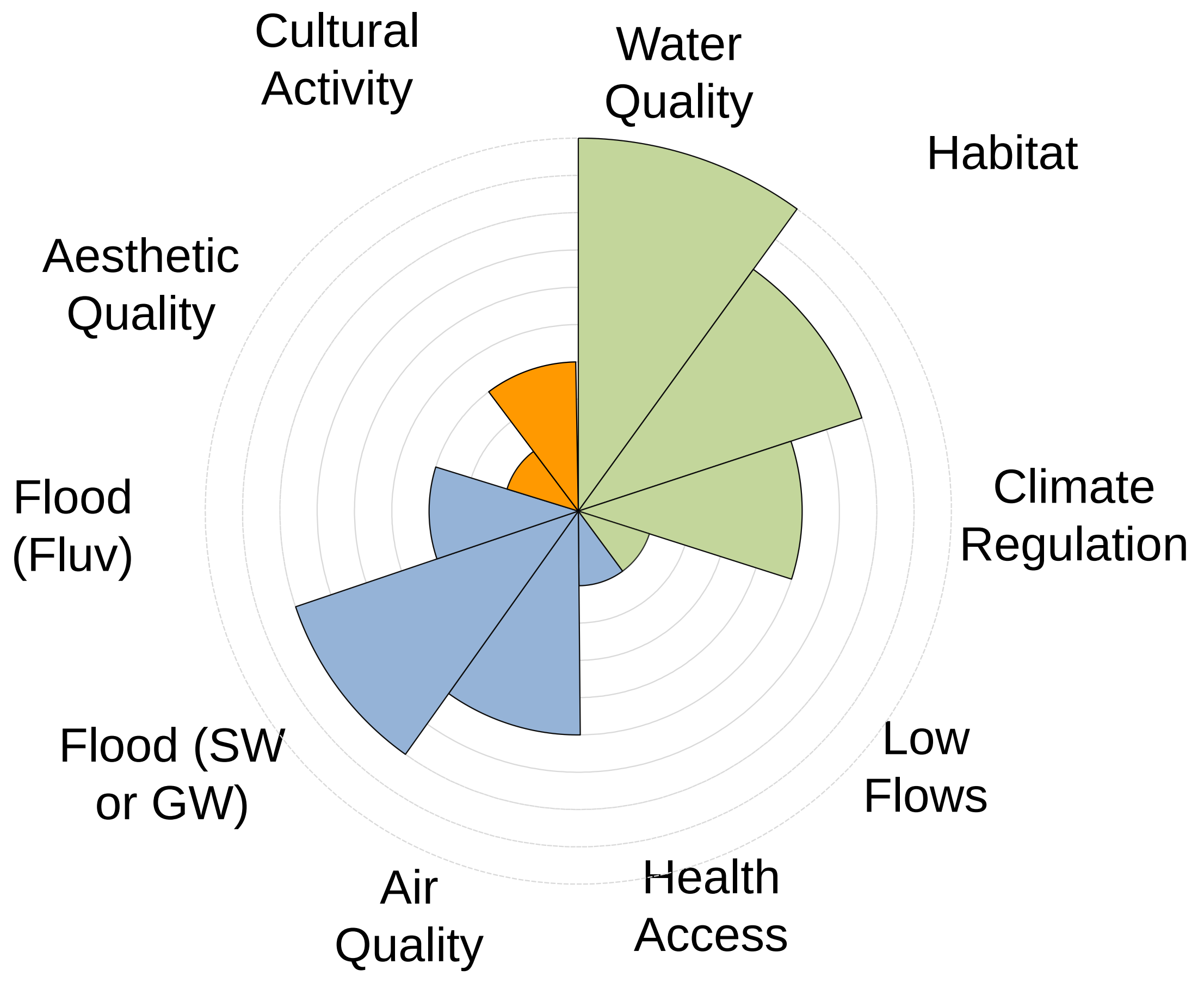
Benefits summary

Cross-slope woodlands provides benefits across certain ecosystem services (see benefits wheel). Limited literature is available covering the wider benefits of cross-slope woodlands, that which was available showed greatest benefits to flood risk and water quality.

Examples

- Cross-slope woodland is beneficial for water quality as it reduces sediment and nutrient loading from upslope land (Nisbet et al. 2011a).
- A study in Poland found that concentrations of nitrate in groundwater within shelterbelts adjacent to cultivated fields were reduced by 76–98% of the input (Ryszkowski and Kędziora 2007).
- Ghyll woodlands found in the valleys of south-east England are species-rich and support distinctive assemblages of plants (Burnside et al. 2006).
- The use of shelterbelts can achieve reductions in agricultural spray drift of between 60% and 90% (Ucar and Hall 2001, Lazzaro et al. 2008).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Catching the Flood
- Woodland for Water: Woodland measures for meeting Water Framework Directive objectives

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Pontbren

Maps:

- Mapping the potential for Working with Natural Processes (England)
- NFM Opportunity Maps (Scotland)

Click **here** to download all Woodland Case Studies

Terms of reference

Terminology

Term used:	Meaning
Small catchment	~ 10km^2
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Local scale impact	Impact not catchment wide, it is localised to where the measure has been implemented
Small flood	<10 year return period events
Medium flood	From 10 year to 100 year return period events
Large flood	>100 year return period events

Benefits wheels

For each measure we have summarised the multiple benefits which they could provide using a wheel which covers 10 benefit indicators that have been ranked on a scale from 1 to 5 to give an indication of the relative contribution the measure can make to the provision of a certain benefit.

Key: **Benefit Type:**
🟩 Environmental
🟦 Social
🟨 Cultural

Scientific confidence

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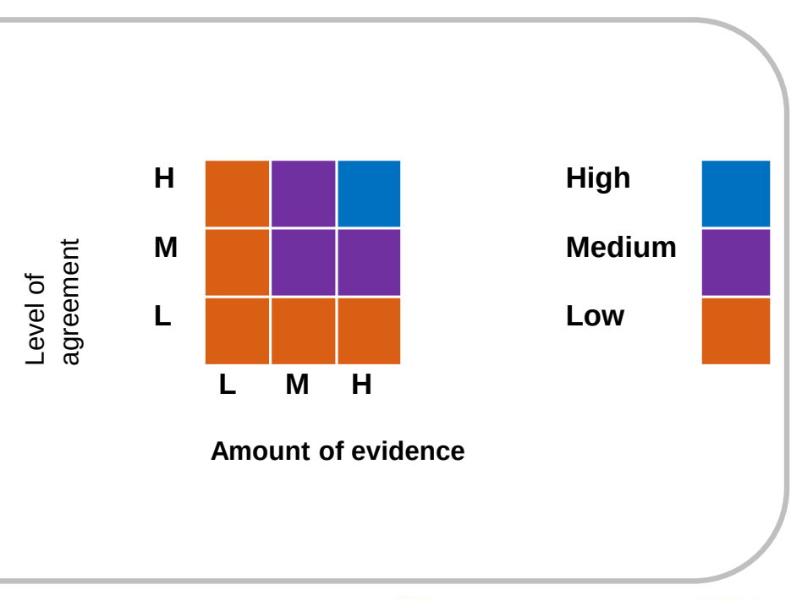

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Floodplain Woodland

Introduction

What is it?

Woodlands in floodplains can slow floodwaters and increase water depth on the floodplain. This can help reduce flood peaks (0-6%), delay peak timing (2 hours or more), desynchronise flood peak and reduce peak height. It can also enhance sediment deposition on the floodplain.

Floodplain woodlands have greatest flood risk effect in the middle and lower river reaches of medium to large catchments.

Examples

Dixon et al. (2016) predicted that the restoration of floodplain woodland within 10-15% of sub-catchments of the **Lymington River** would reduce the 3% AEP flood by 6% 25 years following planting.

Planting <1% of **River Laver** catchment (40ha) with floodplain woodland could delay the progression of the 1% AEP flood by 1hr and reduce the d/s flood peak by 1-2% (JBA, 2007).

River Chelmer, Chelmer Valley Local Nature Reserve (source: Chelmsford City Council)

What did we find?

We found that

We have a **Mixed** level of confidence in the flood risk benefits of floodplain woodlands because our evidence is mainly from flood models, we now need more observational data to verify their findings. More research is needed to better understand their impact during larger flood events across a range of spatial scales (**Medium**/**Low** confidence).

We still need

- To improve how models represent floodplain woodland processes.
- Understand the effect of floodplain woodland on low flows/droughts.
- To understand how combine the use of floodplain woodlands and leaky barriers to avoid peak synchronisation.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Local scale	Small	Modelled	Planting floodplain woodland at 3 sites in the **Mawddach** catchment was predicted to increase water depths by 0.5-1.2m, and delay peak by >30 minutes (O'Connel, 2008).
Local scale	Medium	Modelled	Rose and Rosolova (2015) found planting short rotation willow across the floodplain could for a 1% AEP flood increase floodplain flood depth >20cm and velocities by >40%.
Not provided	Small	Modelled	Johnson (2006) predicted large-scale planting on the floodplain of the **River Enrick** could reduce a 0.5% AEP flood by 0.8% and delay flood peak by one hour.

Multiple benefits

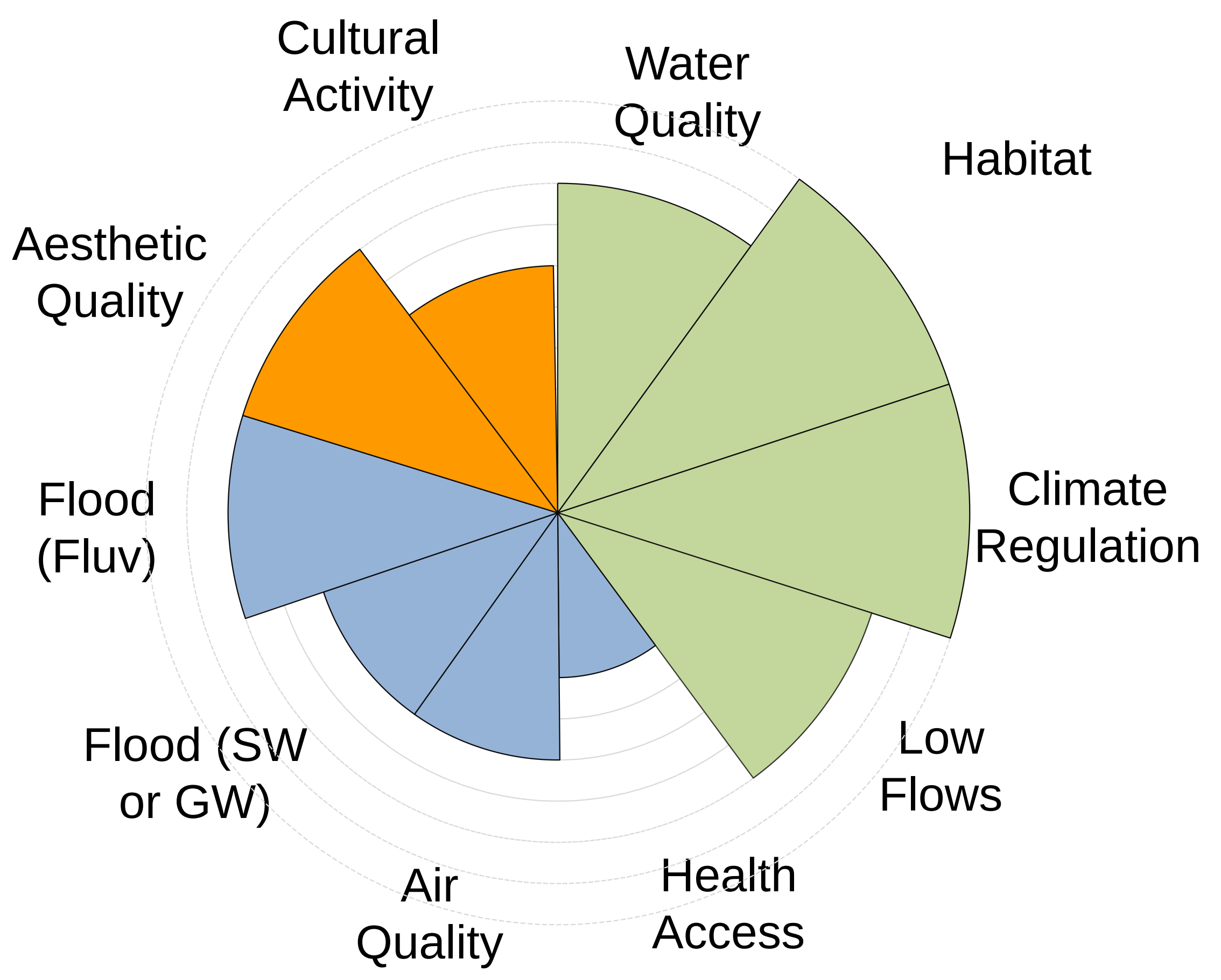
Benefits summary

Floodplain woodlands provide benefits across most ecosystem services (see benefits wheel), the greatest benefits seen in the habitat and climate regulation categories.

Examples

- Floodplain woodland reduces diffuse pollution by enhancing sediment deposition (Jeffries et al. 2003).
- Floodplain forests have high biologically diversity, high productivity and high habitat dynamism (Girel et al. 2003).
- Increased canopy shading prevents lethal water temperatures and restricts weed growth, protecting fish and other organisms (Broadmeadow et al. 2010).
- Low river flows can be boosted by the slow release of water stored in pools, side channels and floodplain soils (McGlothlin et al. 1988).
- Mature hardwood and cottonwood forests have the highest total carbon stocks (474 and 403 tonnes per ha respectively), followed by softwood forests (356 tonnes per ha) and young reforestations (217 tonnes per ha) (Cierjacks et al. 2010).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Floodplain woodland hydrodynamics
- Restoring floodplain woodland for flood alleviation

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Cary
- Great Triley
- Sussex Flow Initiative

Click here to download all Woodland Case Studies

Maps:

- Wetland vision
- Mapping the potential for Working with Natural Processes (England)
- NFM Opportunity Maps (Scotland)

Terms of reference

Terminology

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Benefits wheels

For each measure we have summarised the multiple benefits which they could provide using a wheel which covers 10 benefit indicators that have been ranked on a scale from 1 to 5 to give an indication of the relative contribution the measure can make to the provision of a certain benefit.

Key:	Benefit Type:
🟩	Environmental
🟦	Social
🟨	Cultural

Scientific confidence

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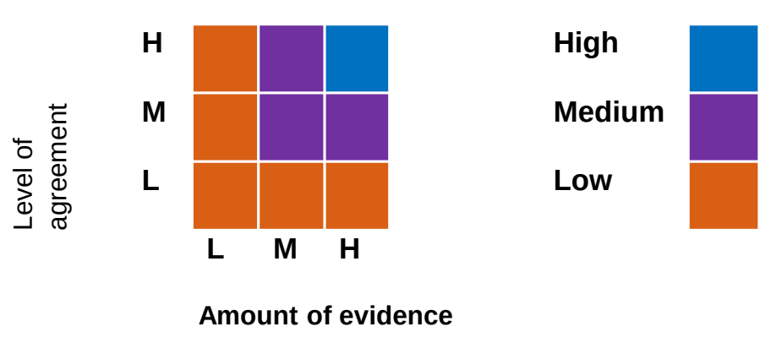

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Flood and Coastal Erosion Risk Management R&D

Riparian Woodland

Introduction

What is it?

Riparian woodlands are planted on land immediately adjoining a watercourse, they can slow flood flows and can help reduce sediment delivery to the watercourse and reduce bankside erosion. They also have high evaporation losses and can create below ground water storage.

Largest reductions in flood risk have been seen at the reach scale, in middle and upper catchments

Examples

The effects of planting deciduous riparian woodland on 9% of the 25 km^2 **Hodder** catchment was modelled to show it could reduce peak flows by 2% (McIntyre & Thorne, 2013).

A similar study by the same authors on the **River Tone** showed no significant effect on peak flows (McIntyre & Thorne, 2013).

Woody dams and riparian woodland upstream of Pickering (source: Forest Research)

What did we find?

We found that

We have a **Mixed** level of confidence in the flood risk benefits of riparian planting because our evidence is mainly from flood models, we now need more observational data to verify their findings. Whilst we understand the flood risk benefits at the reach scale, more research is needed to understand flood risk benefits across a range of spatial scales (Medium/Low confidence).

We still need

- To understand how the type of woodland, its placement in the catchment and the catchment's size affect its flood risk impact.
- More model parameter ranges to represent woodland hydrological processes, properly assess flood risk impacts and to test the up-scaling of these to the catchment level.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Medium	Small/ Medium	Modelled	Planting 50ha (0.7% of catchment) of riparian woodland and installing 100 leaky barriers on the **Pickering Beck** was predicted to reduce a 4% AEP flood by 4% and a 1% AEP flood by 8% (Odoni & Lane, 2010).
Not provided	Not provided	Modelled	Ghavasieh et al. (2006) found riparian woodland strips along a 20 km reach could reduce flood peak by 3.8%
Medium	Small/ Medium	Modelled	Modelling of the 98 km^2 **Lymington River** catchment showed restoration of riparian woodland across 20-40% of the catchment may reduce peak flows by up to 19% for a 3% AEP flood (Dixon et al., 2016).

Multiple benefits

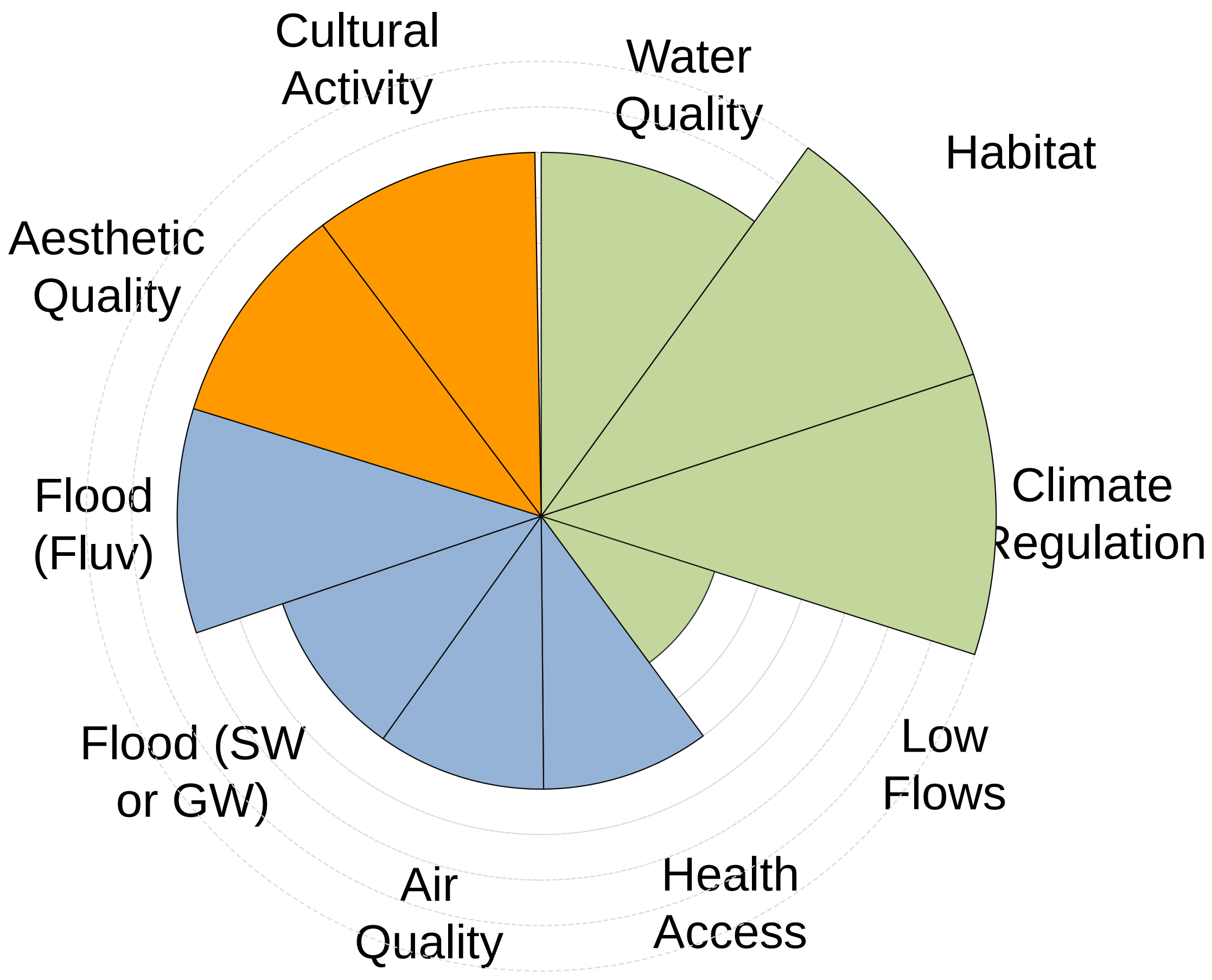
Benefits summary

Riparian woodlands provide benefits across most ecosystem services (see benefits wheel).

Examples

- The value of a woodland landscape view on the urban fringe has been estimated at £269 /household/year (Willis et al., 2003).
- Planting over 150ha of riparian woodland across the Tweed catchment combined with improving recreational facilities resulted in additional visitor spend of approximately £3 million per year (Jura Consultants, 2007).
- One study found that riparian vegetation removed more than 20% of nitrates than the channelised river section (Peter et al. 2012).
- Shade provided by trees in the New Forest reduced water temperature by up to 5.5°C on hot summer days compared with open grassland sections, preventing it from rising above the lethal limit for brown trout (Broadmeadow et al. 2010).

Benefits wheel



Further reading, case studies and maps

Further reading:

- [Restoring and Managing Riparian Woodlands]
- [The effects of riparian forest management on the freshwater environment]

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Eddleston
- Pickering

Click here to download all Woodland Case Studies

Maps:

- Wetland vision
- Mapping the potential for Working with Natural Processes (England)
- NFM Opportunity Maps (Scotland)

Terms of reference

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Benefits wheels

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🟨	Cultural

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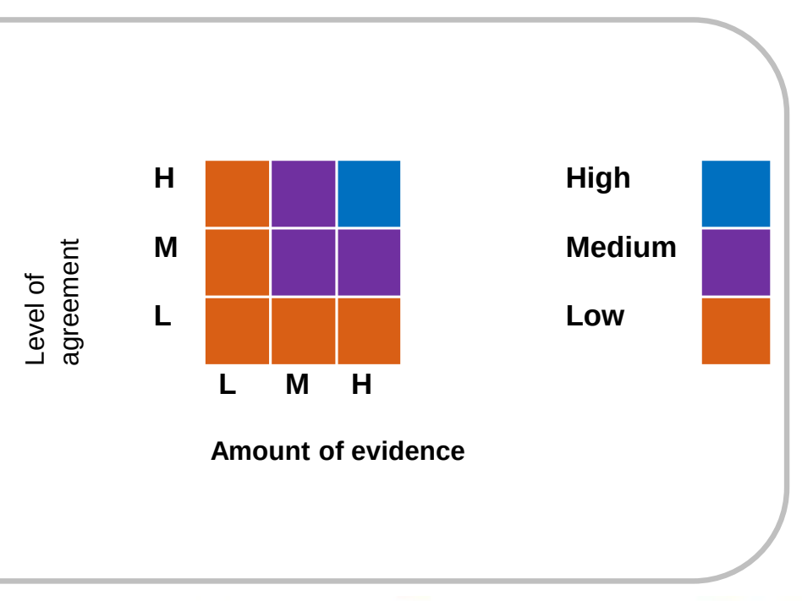

Level of agreement	L	M	H
H	🟧	🟪	🟦
M	🟧	🟪	🟪
L	🟧	🟧	🟧
	Amount of evidence		

High	🟦
Medium	🟪
Low	🟧

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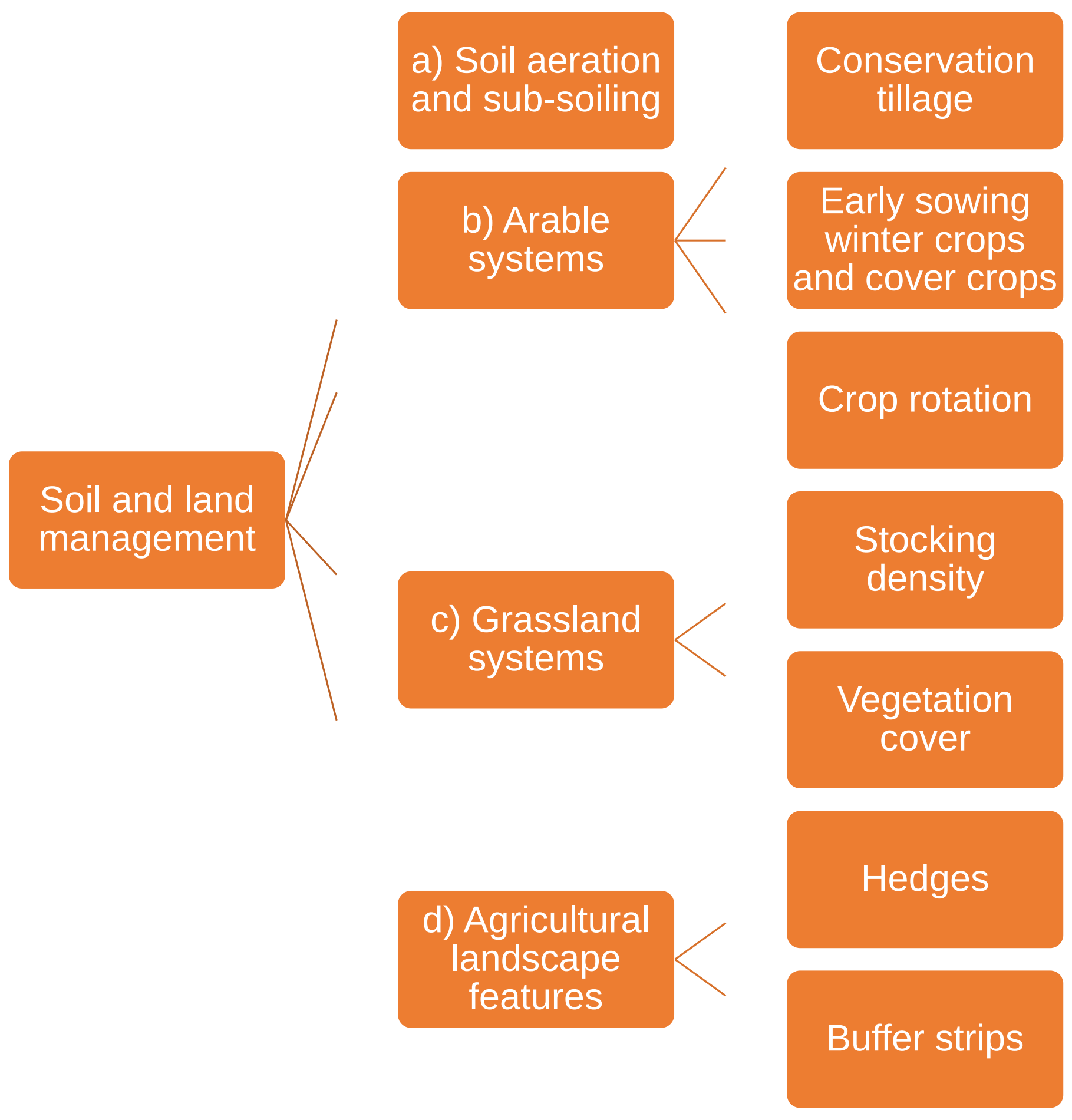
Soil and Land Management

Introduction

What is it?

Soil and land management techniques can reduce peak flow by slowing and storing surface water runoff and encouraging infiltration with the soil. They can include a wide range of different measures as shown in the following flow chart.



- Soil and land management
  - a) Soil aeration and sub-soiling
  - b) Arable systems
    - Conservation tillage
    - Early sowing winter crops and cover crops
    - Crop rotation
  - c) Grassland systems
    - Stocking density
    - Vegetation cover
  - d) Agricultural landscape features
    - Hedges
    - Buffer strips

Examples

Modelling from the **Hills to Levels** project suggests that soil and land management measures coupled with other types of NFM could reduce peak flow by up to 10% (1 in 30 year event) in steep sub-catchments, and up to 40% in flatter sub-catchments.

In **Devon**, Puttock and Brazier (2014) found Culm grassland stores more water than intensively managed grasslands (approx 241 l m^{-2} compared to 62 l m^{-2}), scrub and woodland.

Semi-permeable dam in the Eye Brook catchment (source: Water Friendly Farming Project)

What did we find?

We found that

These measures have been found to slow, store and filter water, reducing flood risk locally for small events.

However, the science which underpins these types of measures has not tended to focus on the potential flood risk benefits of the measures. Whilst the evidence that does exist shows that land management measures can reduce runoff locally, there is limited field based evidence which show a significant flood risk impact at a catchment scale (Fowler, 2005). As a result we have **Low** confidence in the flood risk benefits of soil and land management techniques.

Additionally, for some of the land management measures covered the evidence that does exist is conflicting.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Small	Not provided	Observed	In **Pontbren** (Wales), Marshall et al. (2014) found that the grazed plot had the shortest time to peak and the largest surface runoff volume and the ungrazed plot had a shallower rising limb, smaller peak and runoff volume.

We still need

- More research to determine the effect of soil and land use management measures on flood risk.

Multiple benefits

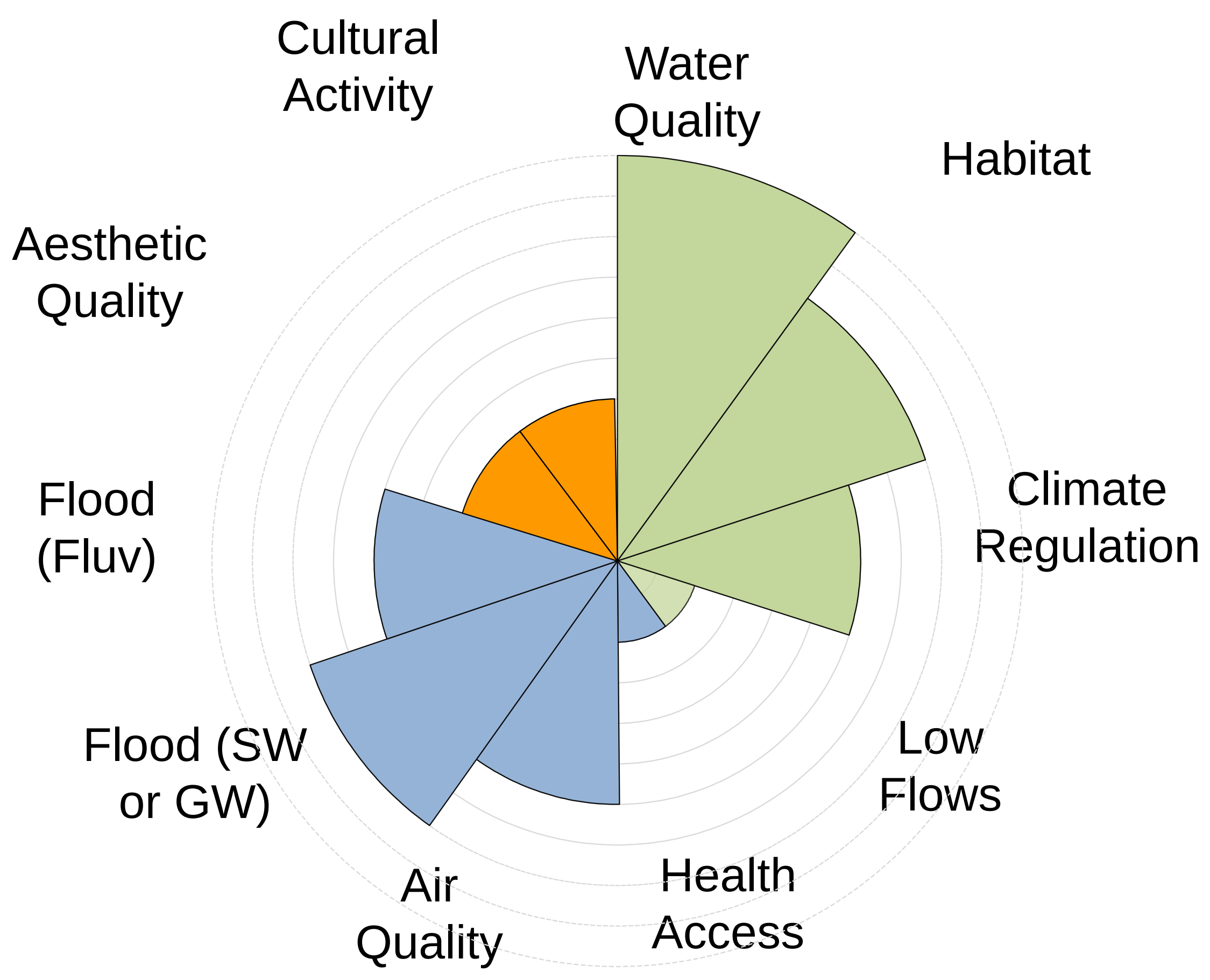
Benefits summary

Soil and land management measures can provide a wide range of benefits (see benefits wheel), especially with regards to water quality and surface water flood risk.

Examples

- Improving land and soil management practices can have a significant impact on diffuse pollution from agricultural land.
- Soil retention and land use diversity are generally beneficial for habitats. Buffer strips managed for biodiversity can increase plant diversity and provide wildlife corridors and habitat connectivity (Constanza et al., 1997 and Boutin et al., 2003).
- Land management practices including set-aside and the conversion of arable land to grassland have had a significant impact on increasing UK soil carbon storage (Bell et al., 2011).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Countryside hedgerows: protection and management
- Crop rotation and Integrated Crop Management
- Thinksoils Manual

References:

- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:

- Hills to Levels
- Pontbren
- Roe and Ive
- Water Friendly Farming

Click here to download all Runoff Case Studies

Maps:

- Wetland vision
- Mapping the potential for Working with Natural Processes (England)
- NFM Opportunity Maps (Scotland)

Terms of reference

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Benefits wheels

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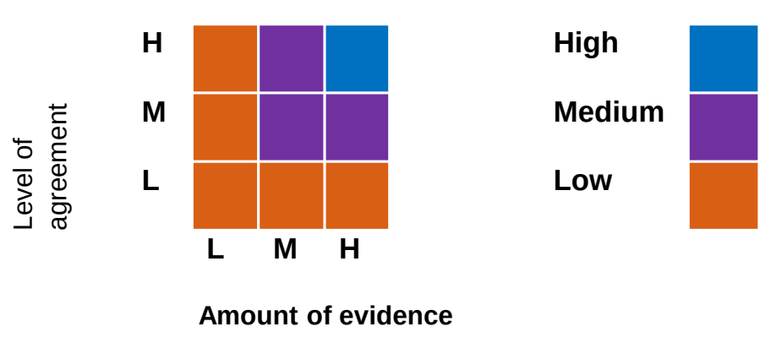

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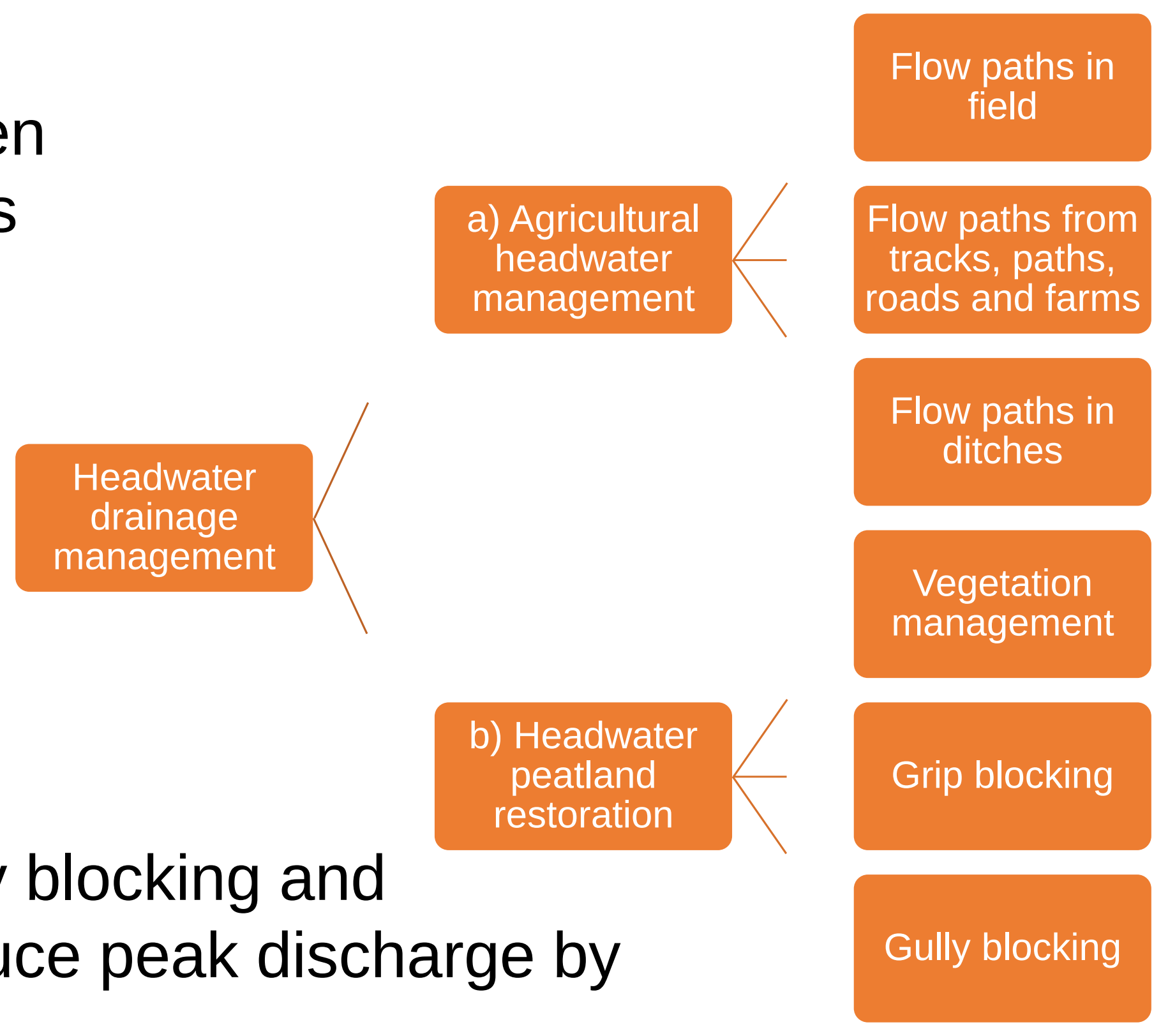
Headwater Management

Introduction

What is it?

Headwater drainage management techniques can delay and flatten the hydrograph and reduce peak flow locally for small flood events by intercepting, slowing and filtering surface water runoff and encouraging attenuation and infiltration with the soil.

They can include a wide range of different measures as shown in the following flow chart. They usually work best as a cluster of features working as a network throughout the landscape.


Headwater drainage management
- a) Agricultural headwater management
  - Flow paths in field
  - Flow paths from tracks, paths, roads and farms
  - Flow paths in ditches
  - Vegetation management
- b) Headwater peatland restoration
  - Grip blocking
  - Gully blocking


Exmoor Mire - Restored ditch showing pools formed behind peat blocks and wet areas downslope (source: Environment Agency)

Examples

Modelling and observed data from **Kinder Scout** shows that gully blocking and vegetation restoration of 12% of the catchment (9 km^2) could reduce peak discharge by 5% (Pilkington et al., 2015)

The **Exmoor Mires** project, has shown a 33% reduction in peak flow from restored sites.

Important! There is limited evidence of how these measures perform during extreme flood events. Caution is needed when installing in-channel barriers to ensure they do not become detached, cause a downstream blockage with consequent impacts on public safety.

What did we find?

We found that

We have **Medium** to **Low** confidence in the flood risk benefits of headwater drainage techniques.

Agricultural headwater management measures can be used to disrupt flow and reduce flood risk, by slowing and storing water (**Medium** to **Low** confidence). Restoring peatland slows storm water as it moves through the catchments, attenuating flow and altering storm-hydrograph, with potential flood risk benefits downstream (**Medium** confidence).

Whilst these measures have been found to slow, store and filter water, reducing flood risk locally for small events, there is limited evidence to demonstrate their benefits for bigger flood events at larger catchment scales.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Local scale	Medium	Modelled	At **Nafferton Farm** the effect of widening and flattening in-ditch features and roughening the vegetation, delayed and flattening the flood hydrographs for 1:20 to 1:25 year return period events (Kutija and Murray, 2007).

We still need

- To understand the effectiveness of these measures in different catchment types and geologies.
- To understand how to model clusters of these features throughout a catchment.
- To know how these measure affect flood flows once full.

Multiple benefits

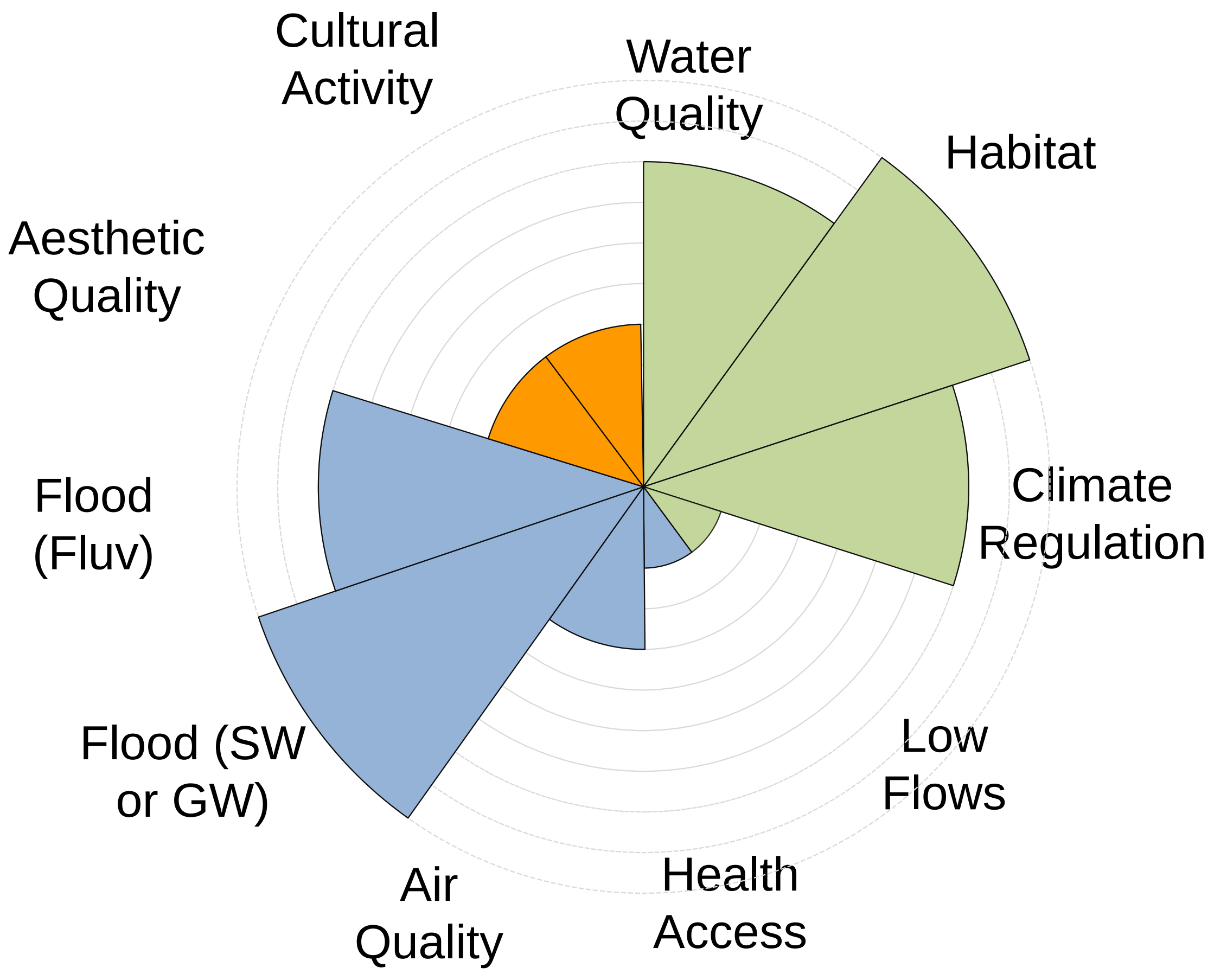
Benefits summary

Headwater drainage management can provide a wide range of benefits (see benefits wheel).

Examples

- At a carbon price of £20 per tonne CO2e, restoring severely degraded peatland to a moderately degraded state could provide a carbon revenue of around £600 per ha per year (Quick et al. 2013).
- Peat bog has been valued at approximately £300 per ha per year (2008 values) for its contribution to water quality improvement, recreation, biodiversity and aesthetic amenity (eftec, 2010).
- The per person per trip value for moors has been estimated at £9.19 (Sen et al., 2012).

Benefits wheel



Further reading, case studies and maps

Further reading:
- An appraisal of the Defra Multi-Objective Flood Management Projects
- Land use management effects on flood flows and sediment
- Restoration of blanket bog (NEER003)

References:
- Working with Natural Processes - The Evidence Directory
- Using the Evidence base to make the case for Natural Flood Management

Case studies:
- Dunruchan Farm
- Eycott Hill
- Exmoor Mires
- Hills to Levels
- Moors for the Future
- Pumlumon
- River Ray

Click **here** to download all Runoff Case Studies

Maps:
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- NFM Opportunity Maps (Scotland)

Terms of reference

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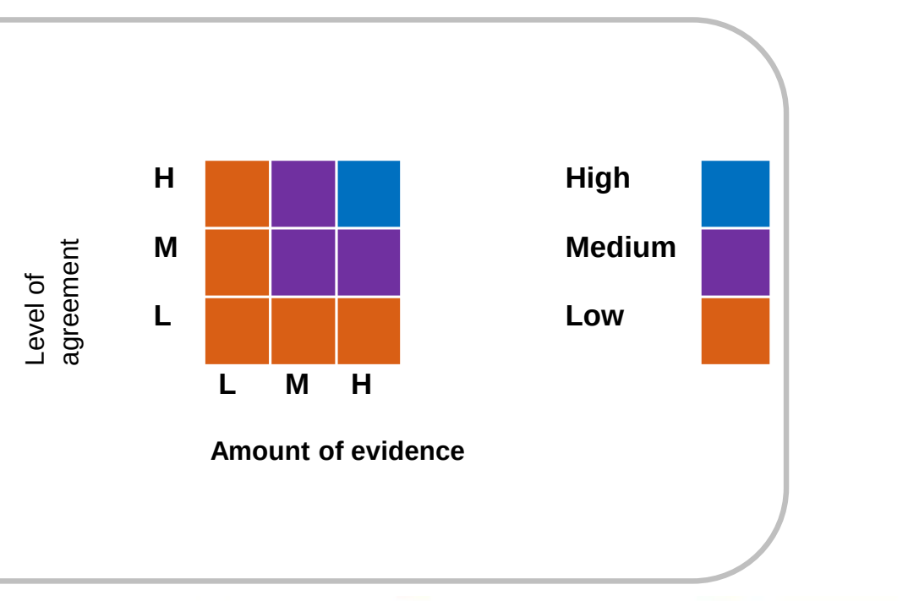

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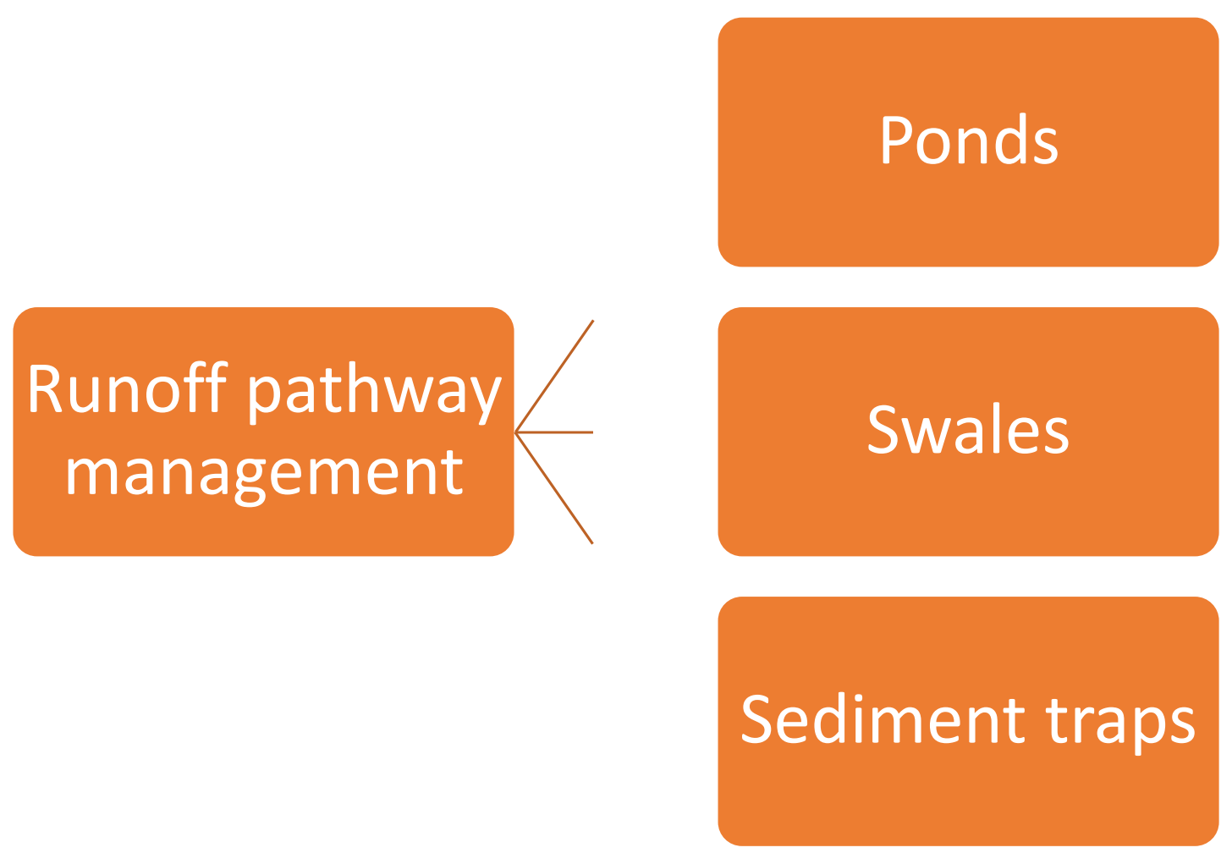
Runoff Management

Introduction

What is it?

Run-off pathway management techniques can delay and flatten the hydrograph and reduce peak flow locally for small flood events by intercepting, slowing and filtering surface water runoff.

They can include a wide range of different measures as shown in the following flow chart. They usually work best as a cluster of features working as a network throughout the landscape.


Runoff pathway management

- Ponds
- Swales
- Sediment traps


Runoff attenuation feature, Belford (source: Newcastle University)

Examples

The **Water Friendly Farming** project has installed approx. 30,000m3 of storage, modelling indicates that this could reduce the 1:100 year flood peak by 20%.

In **Debenham**, modelling has shown installing 10 NFM features could provide 34,250m3 of storage in 3 sub-catchments reducing annual average damages to properties and farmland by 31%.

Important! There is limited evidence of how these measures perform during extreme flood events. A great deal of caution is needed when designing them to ensure that any associated infrastructure are robustly designed and do not impact public safety.

What did we find?

We found that

We have a **Medium** level of confidence in the flood risk benefits of runoff pathway techniques because our evidence is mainly from flood models, we now need more observational data to verify their findings. We also need to better understand their flood risk effects across a range of spatial scales for bigger flood events.

We still need

- To understand the effectiveness of these measures in different catchment types and geologies.
- To understand how to model clusters of these features throughout a catchment.
- To know how these measure affect flood flows once full.
- To know how they function during storms to optimise their design.

Other examples

Catchment size	Flood magnitude	Modelled or observed?	Description
Local scale/ Small	Small/ Medium	Both	At **Belford,** runoff attenuation features increased peak travel time 20-35 minutes, and reduced peak overland flow (>50%). During storm events, flow diverted into the runoff attenuation features can be up to 15% (Nicholson, 2014), it can be attenuated for approx. 8hrs (Wilkinson et al., 2010).
Medium	Small	Modelled	Modelling from the **Eddleston Water** study suggests a series of larger floodplain ponds could reduce peak discharge 19-20% and delay peak flow up to 6 hours for a 1.5-year flood event.
Large	Medium	Modelled	In the **Afon Clywd** catchment modelling shows peak flow reduction of 6% for the 5yr design event, 1% for the 200yr design event.

Multiple benefits

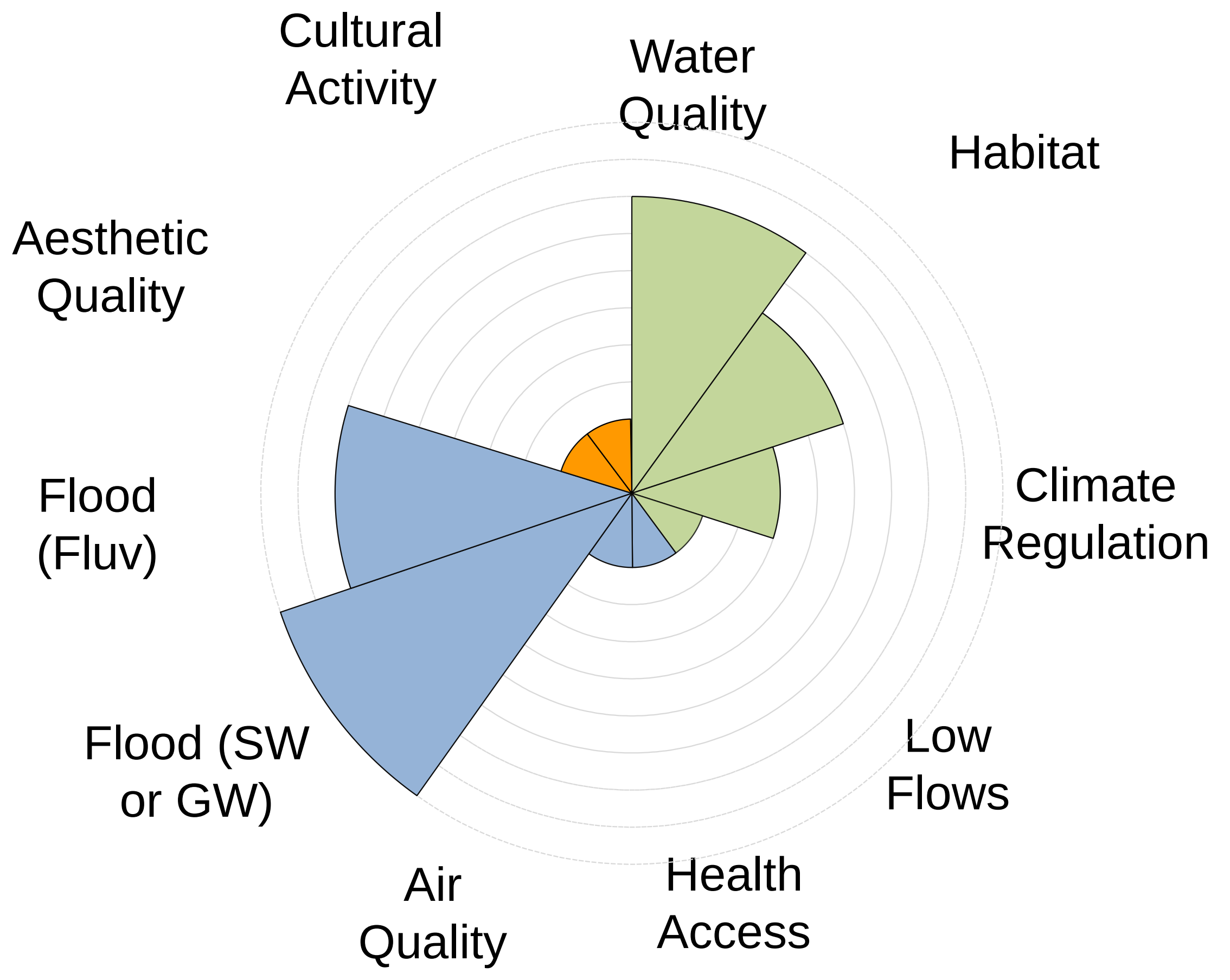
Benefits summary

Runoff pathway management can provide a wide range of benefits (see benefits wheel), but with greatest impact on flood risk and water quality.

Examples

- Run-off attenuation features benefit water quality by retaining sediment and pollutants. They effectively minimise the ability of faecal bacteria, fertilisers and heavy metals reaching watercourses through run-off (Scholes et al. 1999, Aitken 2003).
- A study of temporary ponds found that 75% supported at least one uncommon species (Nicolet et al. 2004). Ponds provide habitats for a range of aquatic mammals, amphibians and invertebrates, as well as farmland birds (Sayer et al. 2012, Davies et al. 2016).
- Deposition of organic material in ponds is an important part of the carbon budget (van der Wal 2011).

Benefits wheel



Further reading, case studies and maps

Further reading:

- [Rural Sustainable Drainage Systems]
- [Runoff Attenuation Features: A guide for all those working in catchment management]
- [Rural Sustainable Drainage Systems: a practical design and build guide for Scotland's farmers and landowner]

References:

- [Working with Natural Processes - The Evidence Directory]
- [Using the Evidence base to make the case for Natural Flood Management]

Case studies:

- Afon Clywd
- Belford
- Debenham
- Eddleston
- Evenlode
- Haltwhistle
- Nant Barrog
- Trawden
- Water Friendly Farming

Click here to download all Runoff Case Studies

Maps:

- Mapping the potential for Working with Natural Processes (England)
- NFM Opportunity Maps (Scotland)

Terms of reference

Terminology

Term used:	Meaning
Small catchment	~ 10km^2
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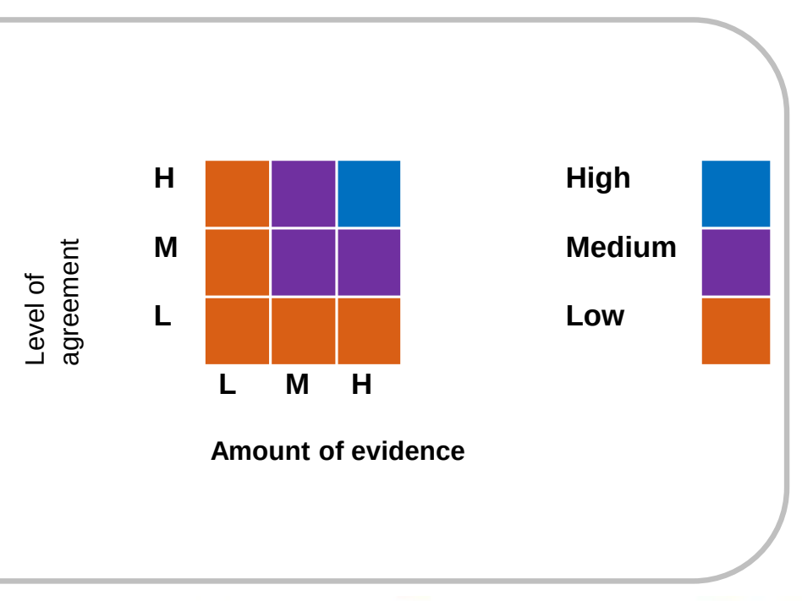
Benefits wheels

For each measure we have summarised the multiple benefits which they could provide using a wheel which covers 10 benefit indicators that have been ranked on a scale from 1 to 5 to give an indication of the relative contribution the measure can make to the provision of a certain benefit.

Key: **Benefit Type:**
🟩 Environmental
🟦 Social
🟨 Cultural

Scientific confidence

For each topic, the level of confidence in the science that underpins the individual measures is defined using the approach shown in the figure below, which attaches a confidence level (high, medium or low) based on the potential effectiveness of each measure at reducing flood risk. This confidence level, assigned by scientific experts, reflects both the degree of agreement of scientific studies and the amount of information available.



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Flood and Coastal Erosion Risk Management R&D

Saltmarsh and Mudflats

Introduction

What is it?

Saltmarsh and mudflats reduce and dissipate wave and tidal energy in front of flood defences and can extend their design life.

They can reduce the forces impacting on flood defences, and also reduce tidal surge propagation and lead to slightly lower water levels at defences.

Examples

At **Hesketh Outmarsh** managed realignment, 322ha of priority saltmarsh habitat will help to provide a more robust flood defence system, providing a 1 in 200 year standard of flood protection to 143 residential properties, 3 commercial buildings and 300ha of farm land.

Over 600 properties were identified as having a reduced risk of tidal flooding due to the provision of the **Alkborough** flood storage facilities.

Medmerry managed coastal realignment site, 10 October 2013 (source: Environment Agency and John Akerman ABPmer)

What did we find?

We found that

We have **High** to **Medium** confidence in the flood risk benefits of saltmarsh, mudflat and managed realignment. We have good modelled and observed data which help us understand their flood risk benefits. Most aspects of managed realignment are now relatively well understood.

Other examples

Flood magnitude	Modelled or observed?	Description
Large	Both	**Medmerry** is the largest managed realignment project on the open coast undertaken in Europe. The project has provided flood risk management to 348 residential and commercial properties, a more sustainable shoreline, 183 ha of intertidal habitat and an enhanced environment for recreation and access.

We still need

- Further studies to develop financial values for the various ecosystem services provide by mudflat and saltmarshes for UK settings.
- To understand whether flood storage areas in estuaries could be more widely applied across the UK.
- Improved models for siltation and vegetation development to better understand the progression of mudflat to saltmarsh.
- To understand the potential role of ‘nature based defences’ (e.g. coir logs or artificially oyster reefs) to reduce wave energy at shorelines and enhance existing saltmarshes.

Multiple benefits

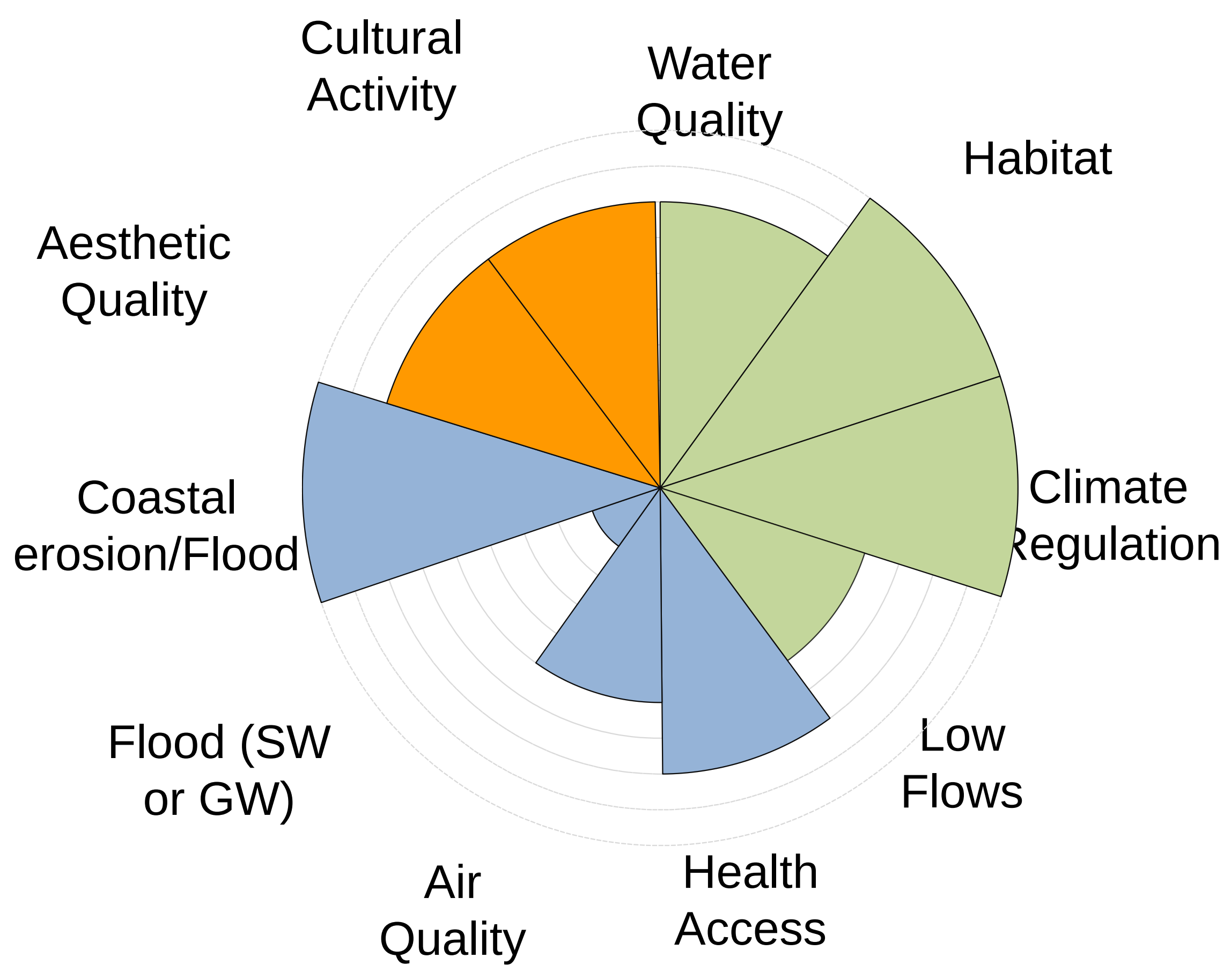
Benefits summary

Saltmarshes and mudflats provide a wide range of benefits across most of the ecosystem services (see benefits wheel). The greatest ecosystem service benefit associated with this measure its value is a habitat, climate regulations and flood and coastal risk management.

Examples

- Saltmarsh is valued at approx. £1400 per ha per year (2008 prices) for benefits to water quality improvement, recreation, biodiversity and aesthetic amenity, while intertidal mudflat is valued at approximately £1300 (eftec, 2010).
- An 80m width of saltmarsh in front of a flood defence structure could potentially save about £4,600 per metre in additional wall protection (Empson et al, 1997).
- Coastal wetland has a value of £1,793 ha/year for water quality (Morris and Camino, 2011).
- Saltmarshes sequester 2.35 – 8.04 tCO^2 per ha/year, with a value of £34.56 – £118.26 per ha/ear.
- Aesthetic and amenity value of coastal wetlands have a marginal value of £1394 ha/year (Morris and Camino, 2011).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Coastal and estuarine managed realignment - design issues
- Greening the Grey: a framework for integrated green grey infrastructure (IGGI)
- Saltmarsh management manual. R&D Technical Report SC030220
- The cost of undertaking managed realignment schemes in the UK
- Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience

References:

- Working with Natural Processes - The Evidence Directory

Case studies:

- Alkborough
- Fingringhoe
- Hesketh
- Humber
- Levington
- Medmerry
- Nigg Bay
- North Norfolk
- Rhymney
- Rye Harbour
- Sandwich
- Waldringfield

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Maps:

- NFM Opportunity Maps (Scotland)

Terms of reference

Terminology

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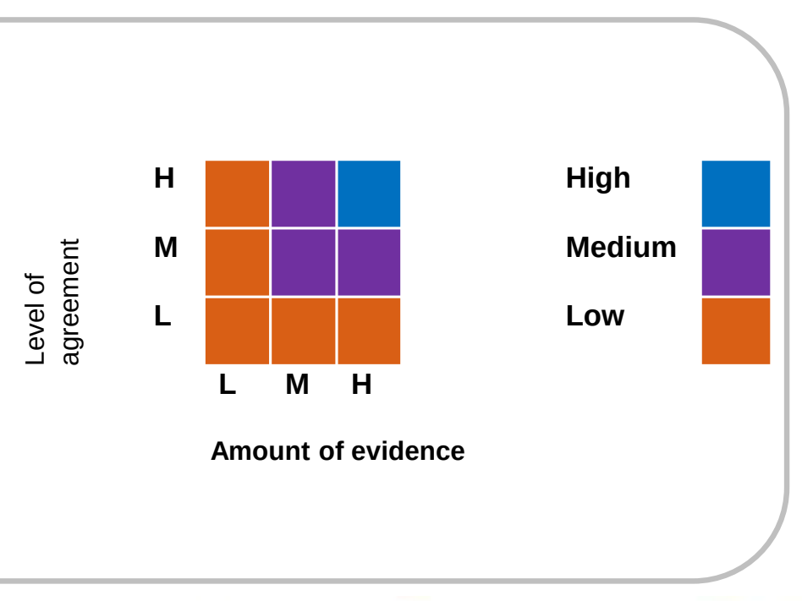
Benefits wheels

For each measure we have summarised the multiple benefits which they could provide using a wheel which covers 10 benefit indicators that have been ranked on a scale from 1 to 5 to give an indication of the relative contribution the measure can make to the provision of a certain benefit.

Key:	Benefit Type:
🟩	Environmental
🟦	Social
🟨	Cultural

Scientific confidence

For each topic, the level of confidence in the science that underpins the individual measures is defined using the approach shown in the figure below, which attaches a confidence level (high, medium or low) based on the potential effectiveness of each measure at reducing flood risk. This confidence level, assigned by scientific experts, reflects both the degree of agreement of scientific studies and the amount of information available.



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Sand Dunes

Introduction

What is it?

Beach-dune systems form a natural barrier that reduce the risk of tidal inundation landward of the dune, they also act as reservoirs of sand to nourish beaches during storms.

They act as a buffer protecting flood defence structures or cliffs behind from direct wave attack and erosion, this in turn enhances the design-life of other flood risk management infrastructure.

They can also protect estuaries and lagoons through restricting the passage of storm surges and waves (Pye *et al.,* 2007).

Examples

At **Hightown** works were undertaken to reinstate dunes to the same position they were in 30 years ago, increasing the dune volume by 28,000 cubic metres has ‘bought’ the frontage 28 years of time. Prior to the project this section of coast was losing, on average, 1000 cubic metres of sand per year.

Hightown Sand Dunes (source: Sefton Council)

What did we find?

We found that

We have **High** to **Medium** confidence in the flood risk benefits of sand dunes. More observed data is need to better understand how dunes respond to a storm or series of storms.

We still need

- Design guidance on the best ways to implement different dune management measures.
- Further observed studies to examine how dunes respond to a storm or series of storms.
- Information to help us understand and predict the future evolution of dune systems so we can implement effective dune management measures.

Multiple benefits

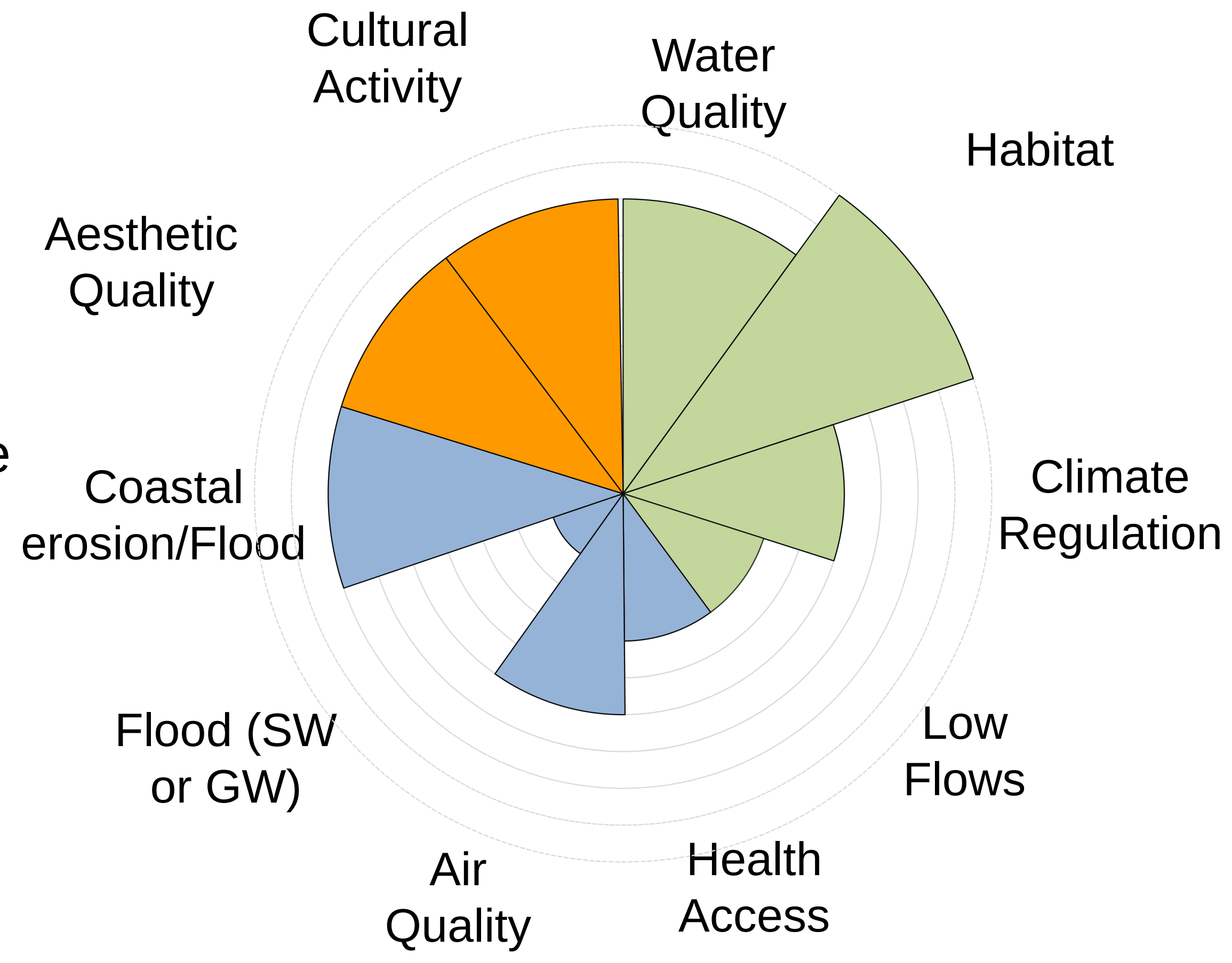
Benefits summary

Sand dunes provide a wide range of benefits across most of the ecosystem services (see benefits wheel). The greatest ecosystem service benefit associated with this measure its value is a habitat.

Examples

- The sea defence value of dunes is estimated at £1,734 per metre dune (Connors, 2016).
- Dunes are a major reason for visiting the coast, on the Sefton Coast (Merseyside) there are 4.5 million visits per year, generating £62.7 million towards the economy (Jones, 2011).
- Willingness to pay estimations for SSSI conservation activities related to sand dunes include £1377/ha/yr for a ‘maintain funding’ scenario, the highest of any habitat measured. The willingness to pay for increasing funding is £860/ha/yr (Christie and Rayment, 2012).
- As dunes are an early successional habitat, carbon accumulation rates are high, approximately 2.16 ± 0.91 tCO_2 per ha (Jones *et al.,* 2008). This equates to £18.36 – £45.9 per ha per year (Connors, 2016).

Benefits wheel



Further reading, case studies and maps

Further reading:

- [A guide to managing coastal erosion in beach/ dune systems]
- [Beach Management Manual (Second Edition)]
- [Sand dune processes and management for flood and coastal defence]

References:

- [Working with Natural Processes - The Evidence Directory]

Case studies:

- Hightown
- South Milton Sands

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Maps:

- [NFM Opportunity Maps (Scotland)]

Terms of reference

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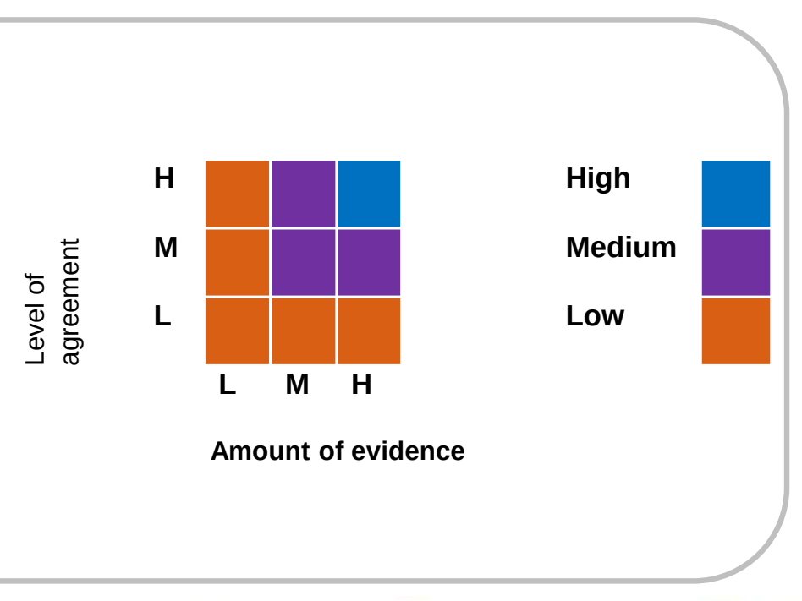

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Beach Nourishment

Introduction

What is it?

Beaches provide an effective form of coastal defence, but only if they are of sufficient width and level. Where beach systems become depleted this affects their flood risk management value.

Beach nourishment is the process of adding material to the shoreline. It is undertaken to improve or restore beach and their coastal defence function, it helps retain the standard of flood protection to the section of coast where implemented. to be effective it is a long-term maintenance activity usually repeated annually.

Pagham Beach Recharge (source: Uwe Dornbusch)

Examples

The **Pevensey** sea defences reduces the risk of flooding to between 7,000 and 10,000 properties who's standard or protection has been improved from a 1 in 20 year event to a 1 in 400 year event through beach nourishment and bypassing.

The **Dutch Sand Engine** is a nourishment of 21.5 million m^3, intended to last for 20 to 30 years.

What did we find?

We found that

We have **High** confidence in the flood risk benefits of beach nourishment.

Observed and modelled data indicates that it can be an effective tool in helping retain the stand of protection of landward defences.

We still need

- Process-based models for open coastlines to predict system behaviour over the meso-scale change (>10 km and >10 years).
- More observed data is need to understand the potential in the UK for shoreface nourishment which is currently more commonly undertaken in the Netherlands.

Other examples

Flood magnitude	Modelled or observed	Description
Large	Both	At **Pagham harbour** the loss of beach was increasing the risk of erosion for 76 residential and commercial properties. Prior to the scheme the risk had dropped from a target 1:200 to about 1:150 to 1:180. By-passing of shingle beach material addresses the loss of beach sediment and restores the target standard of protection.
Not provided	Observed	The harbour arms at the seaward entrance of **Shoreham** obstructs littoral drift along the Sussex coast. Shingle transfer operations are undertaken annually to prevent the collapse of coastal structures in areas of depletion.

Multiple benefits

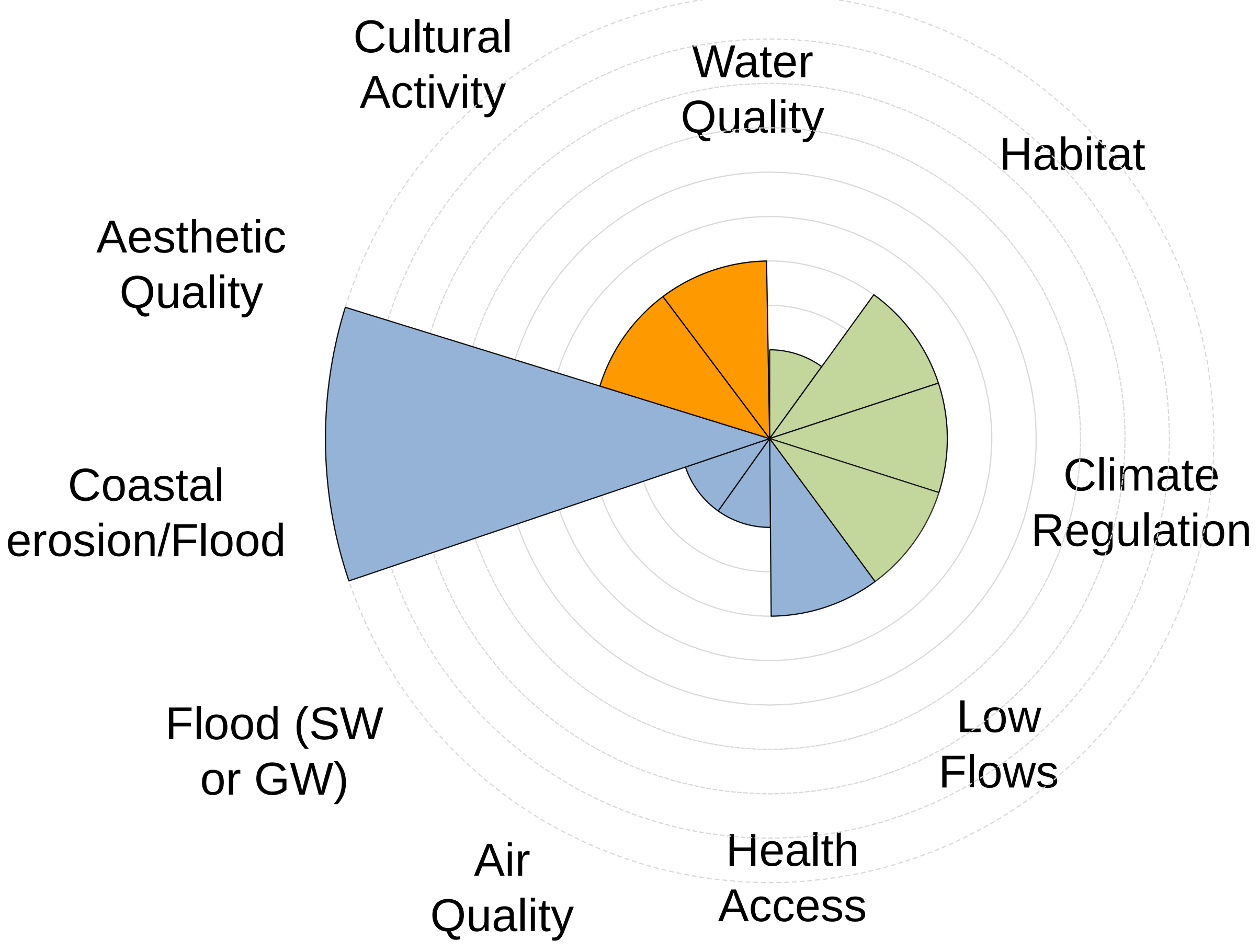
Benefits summary

There is little literature which specifically explores the wider benefits of beach nourishment, that which is available points to this measure having mainly a flood and coastal erosion risk management benefit (see benefits wheel).

Examples

- There are approx. 200 million visits to seaside resorts in the UK every year (Natural England, 2015), with seaside tourism valued at £17 billion (Jones, 2011).
- For large scale beach nourishment, a feasibility study of the Sand Engine approach in North Norfolk concluded that increasing the beach width over a 3km frontage would create 30ha of new intertidal habitat with a value of £1.5million (Crown Estate, 2015).

Benefits wheel



Further reading, case studies and maps

Further reading:

- Beach Management Manual (Second Edition)
- Eco-engineering in the Netherlands. Soft measures with a solid impact
- Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience

References:

- Working with Natural Processes - The Evidence Directory

Case studies:

- Pagham
- Pevensey
- Poole Harbour
- Sandscaping
- Shoreham

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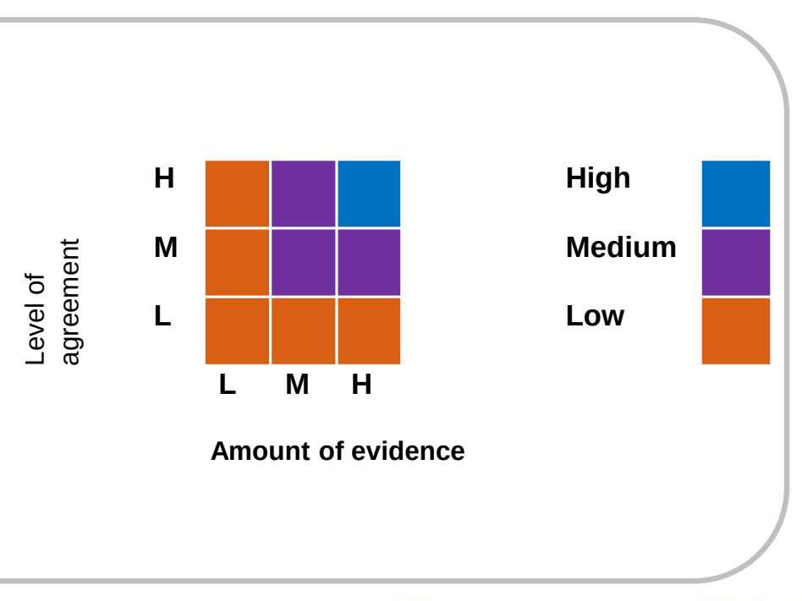

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