# 4 Services provided by nature

4.1 This section provides evidence about the different services provided by nature. Specific services may be of interest to different policy makers and practitioners, so you may choose to focus just on those. Alternatively, you may be interested in overarching themes such as economic competitiveness, so **Chapter 2** and **Chapter 3** may be useful in identifying how the environment contributes to those themes.

4.2 It is important to note that not all services provided by nature are included here. The ones chosen are the ones which on the basis of current evidence are most important in the context of environmental projects. The ones selected are also those for which we have available scientific and economic evidence.

## 4d Freshwater flood risk management

*There is strong evidence that natural features such as forests can contribute to reductions in water runoff and velocity. This is heavily dependent on the individual catchment context, including slope, vegetation type, soil condition and broader catchment hydrology.*

### Introduction

4.17 This section reviews the benefits the natural environment can offer in reducing flooding from rainwater. Many of the interventions that will reduce flood risk also have the potential to support water quality through reducing diffuse pollution - see Section 4m **Water quality** for more detail.

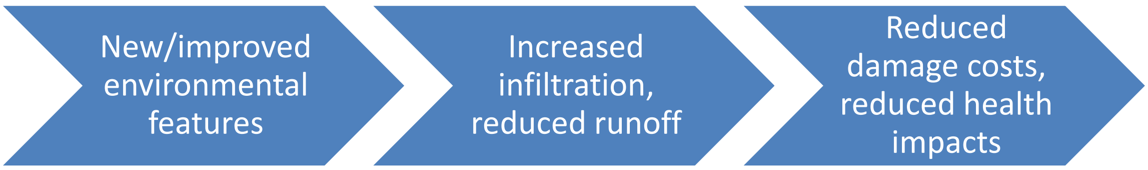
4.18 Around 5.2 million houses in the UK are at risk of flooding. The average annual cost of flooding in England is estimated at over £1 billion. Analysis by the Environment Agency suggests that if investment in flood protection is maintained at present levels of £800 million per year, by 2035 there will be an additional 350,000 properties in England at significant risk of flooding (Environment Agency 2009).

4.19 Improved flood control leads to reduced costs of flooding and can by extension lead to reduced insurance premiums and increased property values[57]. Additionally, being flooded significantly increases the risk of both physical illnesses such as gastroenteritis and mental ill health (Tunstall, Tapsell et al. 2006). Reacher (2004) found that adults who had suffered from flooding had four times the background level of psychological distress.

4.20 There have been significant problems in recent years with intra-urban flooding – in which the drainage systems within the urban area are overwhelmed by rainstorms (Parliamentary office of Science and Technology 2007). These flood events have been made worse by changes to the urban realm such as increased hard landscaping and the paving of driveways (Parliamentary office of Science and Technology 2007).

4.21 Intensification of farming since the Second World War has led to a number of changes to the farmed environment which increase the rate of run-off. These include loss of hedgerows, overgrazing, channelized rivers, and winter crops leading to bare and compacted soil (O'Connell, Beven et al. 2005). It is estimated that agriculture makes flooding worse by £234 million annually (Jacobs 2008)[58].

### Theory of change




[57] See the section on house prices to put this in economic context.

[58] This assessment is based on an Environment Agency judgement based on their record that 14% of flood damage is attributable to agriculture – this will almost certainly be an understatement because it is based only on hill-slope flooding. On this basis 14% of the damage caused by flood and the money spent to prevent floods is attributed to agriculture.

### Can the benefit be quantified?

4.22 In principle the relationships could be quantified, but the number of contextual factors means that there is currently, and is likely to remain, significant uncertainty around quantification. Three factors are particularly influential – scale, catchment unique characteristics, and natural climate variability (Pattison and Lane 2011).

### How strong is the evidence?

4.23 Evidence about flooding is inherently complex and contextual and therefore strongly generic statements and formulas are not available. However, a review of the evidence shows that there can be important flood mitigation benefits.

4.24 Parrott, Brooks et al. (2009) note that this benefit can occur in two ways: by reducing the quantity of water runoff (flood generation) or by slowing the movement of water through the watercourse (flood propagation). Slowing the movement of water can increase flood warning times and allow people time to take action to reduce damages. It should be recognised however, that flood events are unlikely to be prevented by changes to the natural environment, due to the relatively small effects these are expected to have on overall flood scale.

### Evidence

**Agriculture**

- There is some evidence which supports a correlation between upstream soil damage and large floods. (Holman et al. 2003) found significant soil degradation in the catchments which flooded in 2000 and suggest that flooding may be caused by a combination of soil degradation and prolonged wet weather. Additionally (O'Connell, Beven et al. 2005) report that (Boardman et al. 2003) found a statistically significant relationship between autumn sown cereals and local muddy floods.
- There are good opportunities to reduce run-off from farms through measures such as grass buffers, temporary ponds, appropriate ditching and decanalisation. Although there is no proven rule that organic and other less intensive forms of farming will always reduce flood risk, in general terms less intensive farms have less of the factors which support faster run off. The few UK studies and those from abroad support the view that less intensive farming leads to reduced flood risk due to greater presence of the features above and healthier soil (O'Connell, Beven et al. 2005)[59].
- Many blanket bogs have been drained through the cutting of drainage 'grips'. Reblocking these grips on a blanket bog in Wales was found to result in lower peak flow rates during storms. The water table rose and water flows from the bog became more stable (Wilson, Wilson et al. 2011).

**Trees**

- There are different ways in which trees may contribute to flood control. Conifers, for instance, use a great deal of water and increase the capacity of the soil to absorb water (Nisbet, Silgram et al. 2011). By increasing infiltration rates in forest soils, trees can have significant impacts on flooding - modelling since the O'Connell review in Pontebren in Wales suggest that **in this context**, a shelterbelt at right angles to the slope could reduce field scale flood peaks by 40% (Jackson, Wheater et al. 2008)[60].

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[59] Although the literature is insistent that application must consider the context in every case.

[60] The context is hillsides in Wales which are heavily stocked with sheep, have heavy clay soils and significant artificial drainage. The results are for a significant row of trees (80m x 15m). These results are based on a comparison between modeled data and field results.

- Urban forests intercept rain water and reduce peak run off. This is most effective for smaller storms but the effect is reduced for larger storms in which canopies become saturated. The effectiveness will vary according to local climate, tree species and time of year (broadleaved trees have no leaves during winter storms) (Xiao, McPherson et al. 1998).
- Test plots in Manchester demonstrated that over a year, the addition of a street tree could reduce stormwater runoff by between 50 and 62 percent in a 9 square metre area, compared with asphalt alone (Armson, Stringer et al. 2013)[61].
- Trees can contribute to greater hydraulic roughness of floodplains, slowing water flow. Modelling around the River Parrett in South West England found that floodplain woodland could slow water velocity within the woodland, increasing the water level by up to 270 mm and increasing flood storage by 71%. For the two areas modeled flood peak was slowed significantly – the water's travel time was increased by 30 and 140 minutes (Thomas and Nisbet 2007)[62].
- Research in the Scottish Borders, UK, found that the soil permeability of aged broadleaf forest was between 5 and 8 times greater than the neighbouring grassland. This gives it a much greater capacity to infiltrate high intensity rainfall (Archer, Bonell et al. 2013)[63].
- In the River Laver catchment, modelling suggested that the creation of 40 hectares of woodland across 4 sites could delay the progression of a 1 percent annual probability flood by almost 1 hour. This would desynchronise flood flows from a tributary and reduce flood peak height by 1-2% (Nisbet and Thomas 2008).
- A comparison between the Wye and Severn catchments in Wales found that the Wye (moorland pasture) had consistently more pulse events[64] than the Severn (48-67% afforested), and also had higher maximum pulse heights. Pulse events on the Severn tended to be less extreme but longer duration (Archer 2007)[65].
- Although it is logical that increased farm runoff and local flooding would feed into larger flood events there is as yet little direct evidence for it. This is because dealing with larger floods is made more complex because the key issue is the extent to which water from tributaries arrives at the vulnerable site at the same time, meaning that action which reduces local flooding could make a larger flood event worse (O'Connell, Beven et al. 2005). This means that some areas which shed water rapidly may be necessary to ensure flood waters reach the critical region out of phase.
- An Environment Agency whole catchment modelling project for the River Parret in Somerset concluded that, although other measures could be beneficial, major rainstorm events would require significant detention of water at upstream locations (Park and Cluckie 2006). This would require new infrastructure which could be green, grey or a mixture, but positive impact on flood risk would require a catchment wide approach.

[61] This test was conducted using three test plots, each 9 square metres. They contained either asphalt, asphalt and one street tree, or grass. The authors note that the year of test was drier than average.

[62] This study is based on small scale modeling and concludes that significant benefits could be available if the approach was scaled up. This brings it into tension with a whole catchment modeling project for the same river which found that new forestry could make a difference but that very significant areas would be need to be given over to woodland to make an impact: Park, J. and I. Cluckie (2006). Whole catchment modelling project. Technical Report to the Environment Agency.

[63] Hill gradients varied between 1% and 22%, and included part of the floodplain of the Eddleston Water, a tributary of the River Tweed.

[64] A pulse event refers to a rise above a threshold flow. For this project they examined pulse events above multiples of the median flow, for instance pulse events above 5 times the median flow.

[65] The author notes that the success of this analysis depends on the two paired catchments having a very similar hydrological response. This is difficult to prove.

## Sustainable Urban Drainage Systems

- Sustainable Urban Drainage Systems (SUDS) cover a mixture of approaches which filter or retain water near where it lands offering flood protection and biodiversity benefit. Reviews have found these to be cost-effective flood control mechanisms (Duffy, Jefferies et al. 2008).
- Research in Scotland found sustainable urban drainage systems (SUDS) were a cost-effective method of delivering drainage which met the requirements of current environmental legislation. The term SUDS covers a mixture of interventions but normally include detaining water above ground close to where it fell, as in this case. In particular capital costs of traditional drainage are more than double the capital costs of SUDS, annual maintenance costs are 20 – 25% cheaper for SUDS and SUDS is around half the cost over a 60 year life span (Duffy, Jefferies et al. 2008)[66].
- A study in Cambridgeshire found that SUDS measures in a residential suburb reduced both the flow and volume of stormwater entering the drainage system. This was achieved at a lower cost and with reduced maintenance effort than a traditional stormwater system (Royal Haskoning 2012).
- A monitored rain garden in the USA with a 0.49 hectare catchment was found to remove 973 cubic metres of stormwater runoff per year (Flynn and Traver 2013)[67].

## Green roofs

- Green roofs intercept rain water and reduce peak run off. This is most effective for smaller storms but the effect is reduced for larger storms in which roofs become saturated. The effectiveness will vary according to type of roof and local climatic conditions (Mentens, Raes et al. 2006).
- Modelling conducted on Manchester found that adding green roofs to all buildings in town centres, retail and high-density residential areas could reduce run off by 17.0 – 19.9% (Gill, Handley et al. 2007).
- Over 27 months, a green roof test bed in Sheffield was found to retain 50% of total runoff. For significant storm events with a likelihood of occurring less than once per year, the green roof retained 43% percent of all rainfall on average, although this was highly variable (Stovin, Vesuviano et al. 2012)[68].
- A 43 year old intensive green roof in Manchester was found to retain 51.2 percent of all rainfall. Organic content in the soil had accumulated over time, which improved water retention (Speak, Rothwell et al. 2013)[69].

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[66] The study methodology is robust and conservative and the figures inputted are based on real costs. The major cost omitted from the study is the cost of the (surface) land taken up by SUDS, but this is clearly flagged. On the other side of the balance sheet however, the traditional engineering system which serves as a cost comparison would require additional treatment to meet regulatory standards and this cost was not included. Neither were the aesthetic and biodiversity benefits of the SUDS system. A full blown cost-benefit analysis which included these would be useful, but this study is a useful comparison of engineering and maintenance costs. The study does not appear to use Green Book standard discount rate because it applies the standard 3.5 per cent for the full 60 years of its life time costs analysis, and this should drop to 3 per cent for the second 30 years, but this will not significantly alter the findings. The study was paid for by the developers of the site (Taylor Wimpey Developments Ltd), but this is clearly marked.

[67] This particular rain garden was 405 square metres in area. It should be noted that the rate of pollutant removal would be expected to reduce over time due to sedimentation, if this was not removed.

[68] The authors found that it was not possible to develop a robust predictive model using the data obtained, as the relationships between the soil substrate, previous weather conditions, rainfall intensity and runoff were complex.

[69] Intensive green roofs generally have a deeper substrate layer, greater than 15 cm. The authors note that the research was conducted in an unusually wet year – this may lead to underestimation of retention rates.

### Link with climate change

- The problem of rain water floods is likely to have already been exacerbated by climate change because all regions of the UK have experienced an increase in the amount of winter rain that falls in heavy downpours. For all regions an increase in winter rainfall and a decrease in summer rainfall is projected by the 2040s. Winter rainfall in the Northwest of England is projected to increase by 6% in the 2020s, 10% in 2040s, and 16% in the 2080s increasing flood risk (Department for Environment Food and Rural Affairs 2009)[70].
- Climate change may also lead to reduced soil organic content (Jenkinson, Adams et al. 1991), which would exacerbate flood risk.

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