A Review of Current Knowledge

Demystifying Natural Water Retention Measures (NWRM)

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This review is one of a series of Reviews Of Current Knowledge (ROCKs) produced by FWR. They focus on topics related to water supply, wastewater disposal and water environments, which may be the subject of debate and inquiry. The objective of each review is to produce concise, independent scientific and technical information on the subject to facilitate a wider understanding of the issues involved and to promote informed opinion about them.

Demystifying Natural Water Retention Measures (NWRM)

Eddlestone Water remeandering
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CONTENTS

		Page
1.	**Introduction**	**3**
2.	**Water and Climate Change Policy**	**3**
3.	**Background to Water Supply and Demand Side Measures for Management**	**5**
4.	**Defining Natural Water Retention Measures**	**6**
	4.1 Overlapping Definitions	8
	4.2 Overlapping Policies	10
5.	**Evaluating Natural Water Retention Measures**	**14**
6.	**Comparing Benefits and Costs**	**15**
7.	**Data Gaps and Key Uncertainties in Measures Evaluation**	**16**
8.	**Research Priorities**	**17**
9.	**Conclusion**	**17**
10.	**References**	**23**

TABLES

Table 1	**Classification of Natural Water Retention Measures**	**7**
Table 2	**Potential contribution of SuDS to improve water quantity and quality**	**9**

FIGURES

Figure 1	**CCRA impact summary**	**5**
Figure 2	**EU policy instruments that mainstream flood and drought risk management**	**11**
Annex	**Further information on Natural Water Retention Measures Categories**	**18**

1. Introduction

Natural Water Retention Measures (NWRM) can be defined as measures that aim to safeguard natural storage capacities by restoring or enhancing natural features and characteristics of wetlands, rivers and floodplains, and by increasing soil and landscape water retention and groundwater recharge. They can be implemented singly, or in combination, in a broad range of land-uses including agricultural and urban lands. There is some debate as to what measures can be classed as NWRM since the concept overlaps with a broader terminology used to describe green infrastructures. A narrower focus is on measures that either change land use practices, or those that directly restore or adapt water bodies. This definition is approximately in accordance with the one adopted (although not officially) by the European Commission that defines NWRM as "measures aimed to safeguard and enhance the water storage potential of landscape, soils and aquifers, by restoring and maintaining ecosystems, natural features and characteristics of water courses and by using natural processes".

This ROCK report aims to clarify the competing definitions of NWRM and to scope where these measures fit in the context of the Water Framework Directive, other related policies and regulations, and climate change policy. It will outline what the key measures are and will provide some understanding of their evaluation for assessing the technical and economic potential of NWRM in the UK and elsewhere in the EU.

2. Water and Climate Change Policy

The existence and nature of climate change is now a scientific fact and one that is central to policy design or business practice in most sectors of the UK economy. Water is likely to be the key limiting factor on economic activity, and the UK is projected to be warmer and wetter in some parts, but significantly drier by the 2080s. For the medium and high greenhouse gas emissions scenarios, the 2080s are projected to be drier than 1921, the driest year in parts of south-east England since 1766. By the 2080s, reductions in summer river flows may be significant across the UK, with the largest decreases in southern and eastern England. Some headwaters may dry up completely in summer and there may be major changes to a number of iconic river systems (e.g. upland streams and lakes in northern England, Wales, Scotland and Northern Ireland). The predictions are somewhat less clear on the nature and timing of seasonal variability and the frequency of extreme events including pluvial and fluvial flooding. Yet, experience of the recent winter storms[1] of 2013-14 leads to a suspicion that for parts of the UK the "warmer but wetter prognosis" may engender localized impacts in terms of inundation and the need for better flood water management.

Notwithstanding some large and acknowledged uncertainties about the likely extremes, the risk and potential impacts associated with these projections have been outlined in a National Climate Change Risk Assessment (CCRA); a provision under The Climate Change Act (2008). The CCRA is a periodic updating of our understanding of key vulnerabilities (Figure 1). The CCRA has completed an assessment of a range of impacts for which the water sector may need to prepare. In essence and given the factors noted above, a changing climate is expected to influence both water supply and demand, with spatially distinct impacts to the quantity and quality of water. Threats identified in the CCRA focus predominantly on the emerging challenges related to a supply-demand imbalance. But recent experience in the UK suggests a need to cover impacts related to flood risks. This variability therefore calls for a variety of adaptation responses that target these different impacts.

Adaptation responses could entail both hard engineering solutions, but also preferably the use of natural processes and ecosystem services, including the use of cost-effective 'natural' adaptation interventions, so-called NWRM. In essence, NWRM fall into a category of potential 'robust' adaptation measures. These measures are typically more cost-effective investment approaches that are either flexible/reversible, no- or low-regrets, have built-in safety margins, reduced decision time horizons, or a combination of the above. This definition of robust therefore places less emphasis on fixed or relatively irreversible engineering solutions. The measures should also seek to yield net benefits irrespective of the climate out-turn. This means that they can be low or no-cost or otherwise be privately profitable, or, more likely, provide benefits in the current climate as well as under possible future climates. If some actions are worthwhile irrespective of the climate out-turn and across a range of impact scenarios, then, it is argued, part of the scientific ambiguity associated with climate change impacts is obviated in the context of economic appraisal of adaptation options.

As will be seen later the definition NWRM in relation to climate change adaptation measures is only part of the benefits. In fact the mitigation (i.e. the reduction of emissions) may be a significant co-benefit of some measures and should be taken into account when considering the cost-effectiveness of measures.

[1] The Met Office and CEH (2014)The Recent Storms and Floods in the UK
http://www.metoffice.gov.uk/media/pdf/1/2/Recent_Storms_Briefing_Final_SLR_20140211.pdf

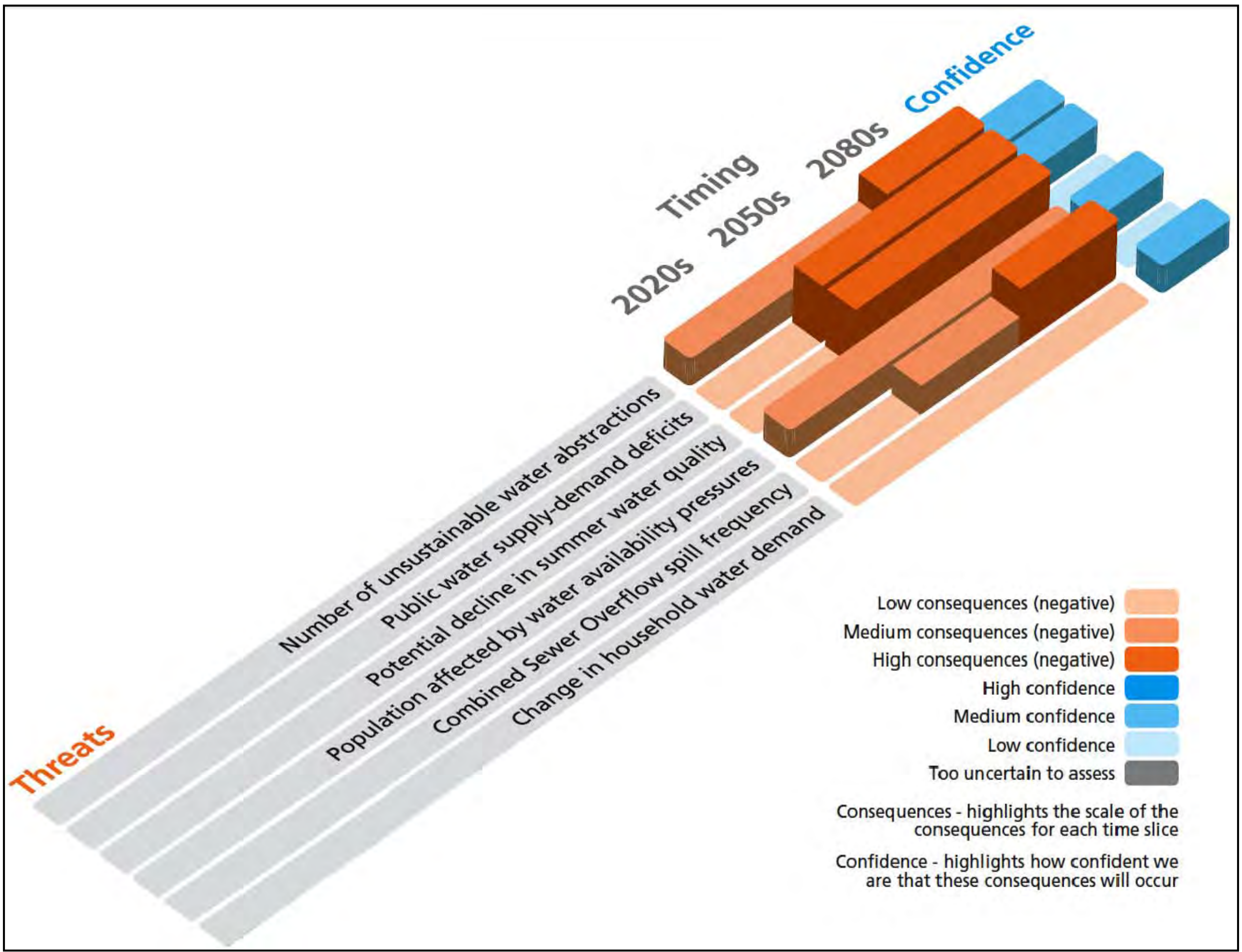

Figure 1 CCRA impact summary

3. Background to Water Supply and Demand Side Measures for Management

In addition to climate impacts, demographic factors mean that population growth and land use change are going to increase pressure on water use and reuse. In the UK, around 18 billion litres of water are collected, treated and supplied to customers every day, with over 16 billion litres of wastewater also collected and treated. In addition, many industrial and agricultural enterprises abstract their own supplies from rivers or groundwater. Although the water industry has a high level of awareness of potential climate change impacts on the sector, these will be intensified by interdependencies with other sectors (e.g. agriculture, energy, and business, industry and services) that have a responsibility for water storage, run-off and ultimately the recharge of surface and ground waters. This suggests that there is a wider variety of water management practices influencing both supply and demand and that the definition of supply and demand side management must extend beyond the focus on consumers to include other actors in water catchments.

This broader focus creates a number of institutional challenges to maximise the potential of some measures including NWRM.

4. Defining NWRMs

European Commission (2012) and Vaughn *et al*. (2010) define NWRMs as intervention techniques over water related ecosystems that are designed to replicate nature's capacity of adaptation. Their principal objective in terms of water management is to regulate water flow so that hydrologic extremes such as floods, droughts or desertification can be mitigated as well as achieving better water storage. NWRMs can be categorized broadly under 2 key headings: 1) restoration measures (e.g. rivers and wetlands); 2) changing land use practices (e.g. agricultural and forestry practices) including a range of agronomic practices to slow down the rate of water flow from arable cropping areas. Hence measures can be seen as relevant to both supply and demand side management. On the one hand the retention of flows and control of diffuse pollution are services regulating the quantity and quality of water supply. On the other, retention (e.g. within fields) and water storage methods can also be viewed as relevant to demand management.

As an evolving concept, NWRM still lacks a consistent definition, with notable overlaps and gaps between measures. To clarify the range of current measures currently grouped in NWRM literature Table 1 lists current practices according to the information available in a range of published and unpublished sources, including sources from the European Commission (European Commission, 2012; JRC, 2012). The table also provides information on relevant case studies in the UK or across the EU. The Annex provides further definition of each of the measures.

Table 1 Classification of NWRMs

Name of NWRM	Measures Restoration as Direct Interventions	Changes or Adaptation in Land Use Practices	Related European Case Study
Continuous Cover Forestry (CCF)		•	3 National Network sites in North and West Cumbria, around Bassenthwaite lake in the forests of Wythop and Dodd wood and near Gosforth at Blengdale forest in West Cumbria, UK (Mason *et al*., 1999, North West England Forestry Commission,2009)
Riparian Forests		•	The Caledonian forest in Scotland, UK (Trees for Life, 2014)
Afforestation of hilly and mountainous areas reservoir catchments targeted planting in Mediterranean region	•	•	Afforestation in Sierra Espuña and experimental restoration of “El Picarcho” forest Murcia in Spain (Rojo *et al*.,date not stated).
Buffer Strips		•	Venice lagoon water shed and Riparian buffer in Italy (Gumiero *et al*., 2013).
Crop Practices		•	Favoring deep root plants and trees, crop rotation, strip cropping, inter-cropping, early sowing, green cover
Grasslands		•	Durham grasslands, Carmel Nature Reserve, Weald meadows project, DoGG Project - Eastleigh (Grasslands Trust, 2012)
Traditional Terracing		•	Drier-climate terrace farming is common throughout the Mediterranean Basin, e.g., in Cadaques,, Spain where it is in use in vineyards, olive tree plantations, cork oak, etc., on Mallorco, or in Cinque Terre, Italy or in Madeira, Portugal (Gumiero *et al*., 2013)
Grassed Waterways (GWWs)		•	Experimental farm located about 40 km north of Munich in the Tertiary hills, an important agricultural landscape in Central Europe (Fiener and Auerswald, 2006).
No Tillage or Reduced Conservation Tillage		•	Several Northern Regions of China listed in SAI Platform (2010).
Hedgerows and Beetle Banks		•	Beetle bank application case studies in Europe (Thomas, 2010) and hedgerow examples from

			hedgelink.org
Sustainable(Urban) Drainage Systems (SUDs)		•	Examples of different SUDs are available in susDrain database (2012).
Wetlands	•	•	Neusiedlersee in Austria, Fertó in Hungary, The Teici Reserve, Latvia The Ebro Delta, Spain (Gumiero *et al*,. 2013). Norfolk and Suffolk Broads, UK (Halls, 1997).
Flood Plains	•		The Forth catchment in Scotland, the Fens in Eastern England, the Somerset Levels and Moors in the West of England, the Val de Charente in South West France the international Erne catchment between Northern Ireland and the Republic of Ireland (Wise Use of Flood Plains, 2013).
Peatlands	•		Humberhead Peatlands in UK (Natural England, 2012).
Basins and ponds in headwater catchment area	• (natural)	• (artificial)	The Kaiserstuhl case study (Scholz, 2008)
Re-meandering, Restoration Flows of Temporary Tributaries and Riverbeds, Revitalization of Flowing Waters, Reconnection of Hydraulic Annexes	•		Re-meandering the Mardereau stream at Sorigny, France (Riverwiki, 2013), Bear Brook and River Cole in the United Kingdom (Gumiero *et al*,. 2013).
Polders	•		Traeth Mawr and Sunk Island, UK (Polders-Wikipedia, 2013).
Natural Bank Stabilization	•		Ebro River in Spain, Danube River in Austria, Piave River in Italy (Gumiero *et al*., 2013)[2].

4.1 Overlapping definitions

Measures grouped under the NWRM heading are obviously not new and some overlap with pre-existing water and flood management terminology. For example, the more generic and perhaps all-inclusive terminology of green infrastructures[3] that have been advocated as environmental measures to maintain ecosystem services in both urban and rural environments. These include but are not restricted to water retention or quality objectives. The NWRM definition is also akin to measures included under the terminology of Sustainable Urban Drainage measures

[2] http://en.wikipedia.org/wiki/Polder
[3] http://ec.europa.eu/environment/nature/ecosystems/; see also ROCK FR/R0014 May 2011

(SuDs)[4], (see Table 2) and more specifically their extension to rural contexts (Environment Agency 2012).

Table 2 Potential contribution of SuDS to improve water quantity and quality

SuDS technique	Brief description	Water quantity	Water quality
Permeable paving	Infiltration through the surface into underlying layer	●	●
Filter drains	Drain filled with permeable material with a perforated pipe along the base	●	●
Infiltration trenches	Similar to filter drains but allows infiltration through sides and base	●	●
Soakaways	Underground structure used for store and infiltration	●	●
Detention basins	Dry depressions outside of storm periods, provides temporary attenuation, treatment and possibly infiltration	●	●
Retention ponds	Designed to accommodate water at all times, provides attenuation, treatment and enhances site amenity value	●	●
Wetlands	Similar to ponds, but are designed to provide continuous flow through vegetation	●	●
Rainwater harvesting	Capturing and reusing rainwater for domestic or irrigation uses	●	○
Green roofs	Layer of vegetation or gravel on roof areas providing absorption and storage	●	●

Source Defra, General SuDS Guidance

Rural SuDs (RSuDS) are measures for collection, storage and cleaning processes before allowing water to be released slowly back into the environment. They are intended to mimic natural hydrological regimes to minimise the impact of human activity on surface water drainage discharges, reducing flooding and pollution of waterways and groundwater (hence diffuse pollution). RSuDS would be mainly associated with land uses such as farming and forestry. As such, they extend definitions commonly known as Best Management Practices for diffuse pollution, which have been widely documented by relevant agencies ((Defra Good agricultural practice guidance, EA Best Farming Practices booklet, SEPA BMPs, Defra Inventory of DWPA measures) make reference to measures that fall within the definition of SuDS and are applicable in the rural environment. Finally, and more specific to flooding, there is a subset of measures sometimes described collectively as natural flood management, which are commonly defined in

[4] See http://www.susdrain.org/

counterpoint to hard engineering solutions for flood prevention and typically include forestry.

The distinctions here are quite nuanced but may imply different objectives. RSuDs for example apparently target diffuse pollution from arable agriculture with the objective of maintaining water quality. But they can also slow down water run-off and therefore be counted as a flood management technique. In parts the difference appears to be in the use of physical structures to mimic natural processes for management of water run-off. Specifically, the harnessing of natural ecosystem processes and the inclusion or exclusion of semi-permanent physical structures, which differentiate RSuDS from other best management practices such as cover crops or soil management. In contrast NWRM includes crop and soil measures (i.e. seasonal measures) and therefore appears to be a more inclusive list of measures. While this may be a semantic debate, it is possible that the definition can have some bearing on policies targeting measures (specifically cost and compensation by income foregone) - see below. Thus it may be that NWRM is a more collective definition covering a broader category of impacts likely to arise due to climate change.

4.2 Overlapping policies

Given the previous definitions, NWRMs inevitably cut across several EU and national policy and legislative domains. Figure 2 for example shows how flood and drought risk measures including NWRMs can be mapped onto existing EU policies.

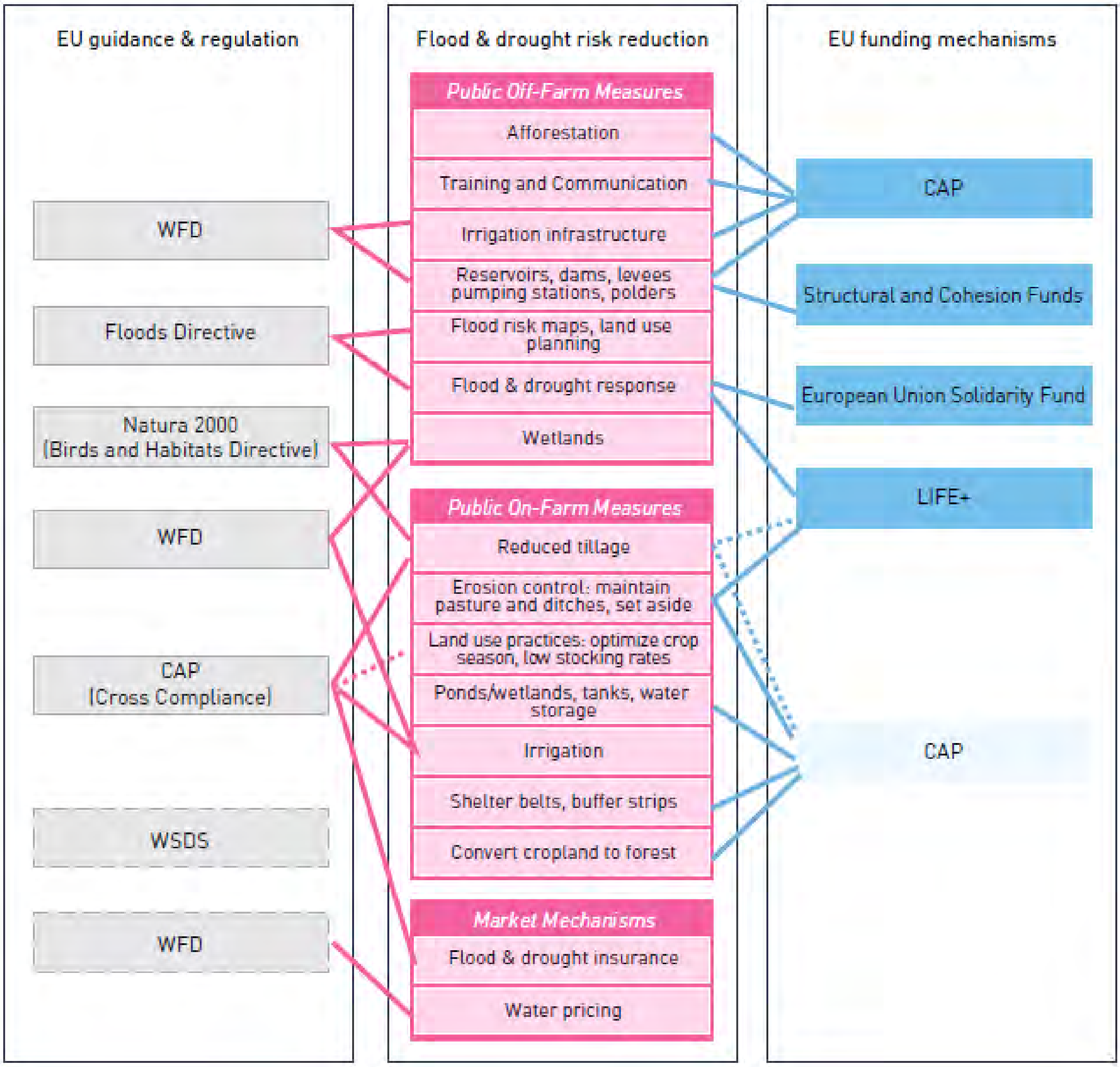

Figure 2 EU Policy instruments that mainstram flood and drought risk management
(Linnerooth-Bayer *et al*., 2013)

The Water Framework Directive (WFD) provides a major legislative driver for maintaining and improving surface and groundwater quality across Europe. Within the original timetable for implementation, there is a commitment for a Programme of Measures (PoM) to be operational by 2012 to tackle failures in achieving Good Ecological Status within river basin management plans (RBMP), which will be reviewed on a six yearly basis and which set out the actions required within each river basin to achieve set environmental quality objectives. The Directive required that the PoM associated with each river basin district is in place by December 2009 at the latest and that all the measures therein are made operational by December

2012 at the latest. The WFD allows for certain derogations on cost, but it is clear that NWRM are part of the RBMP cost-effective tool kit. Each PoM is to be updated by December 2015 and every six years thereafter with any new or revised measures being made operational within three years of their establishment.

The second key piece of legislation is the Common Agricultural Policy (CAP). Many measures outlined in Table 1 are implemented predominantly though not exclusively on agricultural land. This suggests that domestic rural policy and particularly the EU CAP may play a significant role in the way measures are implemented and compensated. The CAP targets agri-environmental objectives using alternative tiered payments that can in part be interpreted differently across member states. In the UK as in other EU states funding is delivered under 2 pillars covering production support pending some mandatory cross-compliance with some basic environmental measures (Pillar 1), plus further optional agri-environmental measures (Pillar 2). The latter is delivered according to stipulations developed under country-specific Rural Development Regulations (RDP). The RDP allow countries to define environmentally friendly farming practices that can be supported for going beyond basic good practice In England[5] specific measures relevant to NWRMs included under the Environmental Stewardship Scheme[6] include Catchment Sensitive Farming (CSF)[7] in target catchments.

The CAP is currently in a transition to the next Rural Development Programme beyond 2014 [8] with considerable emphasis on the amount of money that might be moved from pillar one to pillar two for so-called “greening” measures. This process is politically charged and there is already a congested agenda of issues competing for attention under possible alternative definitions for the RDP. For example, many commentators are suggesting that greening measures need to be more explicitly targeted on climate change (adaptation and mitigation) objectives, while others suggest that much more needs to be done to target diffuse pollution to waters. In both cases there is a potential role for supported NWRMs.

Beyond WFD and CAP, the Floods Directive (2007/60/EC) on the assessment and management of flood risks is also relevant. This Directive requires Member States to assess if all water courses and coastlines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. Its aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and

[5] Note that devolved administrations operate under separate RDPs
[6] http://ec.europa.eu/agriculture/rurdev/countries/uk/mte-rep-uk-england_en.pdf
[7] See Working Towards Catchment Sensitive Farming http://publications.naturalengland.org.uk/publication/32034
[8] See www.capreform.eu

economic activity. The Directive required Member States to first carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive also reinforces the rights of the public to access this information and to have a say in the planning process. The Directive applies to inland waters as well as all coastal waters across the whole territory of the EU. There is considerable overlap to the use of NWRM. Reducing soil sealing is another measure that can diminish flood risks. These measures should be included in both RBMPs and FRMPs (Flood Risk Management Plans).

Notable other policy overlaps exist with policy for tackling climate change. As previously noted, NWRMs are pursuant to adaptation objectives, which are in turn addressing risks identified by the CCRA. The CCRA forms part of the provisions of the Climate Change Act 2008, which creates a framework for a series of assessments of the risks posed to the UK by climate change, both current and for future generations. This must be updated every five years. The second CCRA is now being planned. The Climate Change Act also provides a legally binding, long-term framework to cut carbon emissions and it is also becoming clear that some adaptation options (e.g. afforestation, minimum tillage and peatland management) also offer significant and cost-effective emissions mitigation potential. Interestingly this mitigation potential has potential market value that might be compensated under emerging schemes on Payments for Ecosystem Services (PES) (see below).

Other stated, though sometimes informal, policy objectives include biodiversity conservation, specifically the UK's commitment under the UN Convention on Biodiversity and associated National Biodiversity Action Plan[9]. This objective is closely related to aspirations to mainstream an Ecosystems Approach in policy and planning decision as advocated by the Millennium Ecosystem Assessment MEA (2003), and the UK National Ecosystems Assessment (2011). Both reports emphasized the national contribution of many ecosystem services and the role of green infrastructures.

At subnational level one route for mainstreaming is through the planning process[10]. For example there is increasing policy support for green infrastructure in the government's National Planning Policy Framework and Natural Environment White Paper, the second National Planning Framework in Scotland and Planning

[9] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69203/pb12772-conbiouk-071004.pdf
[10] http://www.landscapeinstitute.co.uk/PDF/Contribute/2013GreenInfrastructureLIPositionStatement.pdf

Policy Wales. In support of this, The National Ecosystem Assessment has provided an evidence base for the multiple benefits that green infrastructure can deliver.

5. Evaluating NWRMs

While being aligned with numerous policy objectives a key question is how to evaluate NWRMs ex ante or ex post. A number of criteria may be used to evaluate NWRMs. EA (2012) suggest that rural RSuDs might be evaluated on whether they require low energy input; that they should occasion zero, or only positive environmental impacts; that they should have low capital and running costs, and provide additional benefits (habitat and amenity). Most of these criteria are recommended to define low or no-regret climate change adaptation measures.

A more fundamental question is whether NWRMs are technically effective and economically efficient (i.e. their benefits outweighing implementation costs). Effectiveness depends on a variety of factors including the climate zone they are implemented in; land-use; location; soil permeability; soil depth; topography; and geographical relevance. Efficiency requires a comparison of costs and benefits. Examining NWRM costs reveals a range of estimates depending on land requirements, construction and rehabilitation (investment, design and contingency) operation and maintenance, administrative costs; and other costs. Existing cost studies present a rather inconsistent picture, but do offer a hierarchy of total costs. Grassland and wetland scenarios appear to be the least expensive, while urban green scenario appears to be the most expensive, primarily due to very high unit investment, operation and maintenance costs. Crop practice scenarios are the second most expensive, primarily because of a potentially large surface area applicability.

Because measures are highly context-specific and the evidence base on what works shows a range of direct and co-benefits. Direct benefits include: soil moisture; water temperature; evapotranspiration (ETP); run-off control; groundwater replenishment; land-use change; erosion control; and storage capacity. The impacts of many measures are confirmed by definition (e.g., the storage capacity measures). Others have well-documented impacts on certain issues: e.g., the positive impact of the urban measures on run-off control. Again, however, in general the available information varies considerably in quality and quantity, and from measure to measure.

Defining co-benefits depends on what we define as the principal objectives of each NWRM. Assuming this is the retention function, then significant co-benefits include flood hazard reduction, soil quality improvement, maintenance of ambient air temperature, provision of food, fibre and/or fuel, water quality regulation, water availability/quantity, air quality, climate regulation, cultural services, and provision of habitat. Some of these benefits can be globally significant (e.g. see peatlands case study box).

6 Comparing Benefits and Costs

The efficiency criterion is more complex: since this addresses the issue of whether measures are cost-effective relative to other approaches (e.g. hard engineering) or even doing nothing. This is a question that can be asked from both private and public perspectives, with a divergence between the two; i.e. it may not be privately profitable to implement measures that are nevertheless good for wider society. Indeed, while costs can be tangible and privately incurred, many benefits are more intangible, diffuse and accrue to wider society as so-called public goods. As previously noted, this fact is recognized by public payment schemes under the CAP, which provide an incentive to implement some measures. In other cases, the requirement for mandatory action places emphasis on private land-owners to safeguard public wellbeing.

While measure costs are generally observable, the question of identifying and quantifying benefits is complex and indeed not always possible without detailed biophysical modeling. However, a number of projects are currently focused on this task, including an EU project defining NWRM applicability.[11] These projects can draw on some existing valuation information and data on co benefits of measures and synergies.

[11] See www.nwrm.eu

Case Study Box: Peatland restoration as a NWRM with co-benefits

Peatlands have been identified as crucial ecosystems for retaining water in the uplands and regulating water flow and quality in vulnerable catchments. They are also valuable stores of carbon. Most peatland sites in the UK have already degraded to some extent and climate change is anticipated to worsen this situation. Restoration of degraded sites may be able to slow the rate of loss of ecosystem services or indeed recover service levels similar to those associated with near-natural conditions. However, restoration incurs various capital and recurrent costs that are highly variable depending on the location and baseline condition of sites. These costs need to be compared to benefits to determine the economic merits of restoration. Recent research by Moxey and Moran (2014) suggests that restoration of degraded peatlands in UK can generally be justified in economic terms on the basis of greenhouse gas emission savings alone, even in the absence of further climate change. Inclusion of non-GHG benefits (e.g. water purification) in so far as they can be quantified and valued reinforces this finding, as does consideration of worsening degradation under different climate change scenarios.

7 Data Gaps and Key Uncertainties in Measures Evaluation

In Europe, the implementation of NWRM is in its infancy with information dispersed across numerous responsible institutions and disciplines. In methodological terms demonstrating measure effectiveness and the quantification of benefits clearly requires a clearer understanding of biophysical pathways between measure implementation and the delivery of benefit endpoints; e.g. in terms of water quality, flood alleviation or any of the other direct or co-benefits previously described. Most biophysical modeling is inevitably catchment specific and there is an urgent need for existing experience to be catalogued more consistently to enable cross regional and national comparisons.

The NWRM platform will contribute to the development of a European NWRM “community of practice”. It aims to produce a practical web-based guide to support the design and implementation of NWRM in Europe. This includes a better summary of both cost and benefit metrics associated with a variety of practices in different member states.

8 Research Priorities

As previously noted there is also a challenging institutional divide between actions that are required to be taken on private land versus public outcomes. This requires specific forms of regulatory policy that can include a combination of voluntary, mandatory and market-based approaches. While mandatory approaches are sometimes warranted to guarantee compliance, basic economic theory normally leads to a government predisposition for voluntary or market-based solutions. This further suggests that both agri-environmental policy (with compensation for income foregone), or more innovative payments for ecosystem services (PES) are likely to be more prominent in developing policy on NWRM implementation. PES is the generic term for transaction arrangements allowing services providers to be compensated by service users. PES schemes are in their infancy, but there are some noteworthy exploratory applications to catchment management.[12] To date there are relatively few examples of private service providers being compensated by other private service consumers. Instead most PES arrangements still tend to involve government in some role in the transaction.

9 Conclusion

NWRM are not new practices with significant overlap between the concept and pre-existing definitions of green infrastructure and SuDs in particular. Some of NWRM measures have been incorporated into agri-environment schemes such as the England Catchment Sensitive Farming Delivery Initiative (ECSFDI), Glastir Targeted Element for Wales and the Higher Level Stewardship scheme for England. Measures can target a variety of policy objectives although there is currently only a limited level of scientific evidence to determine measure effectiveness and efficiency in all contexts. The implementation of NWRMs frequently is a case of private action (and hence cost) for predominantly public good outcomes. As such, the nature of incentive payments, principally under a reformed CAP, is likely to be instrumental in their continued implementation. The emergence of PES schemes also offers some potential for private sector involvement in measure implementation.

[12] http://www.theriverstrust.org/seminars/archive/water/WRT_WATER_PES_Guide_27-06-12_A3.pdf

Annex: Further information on NWRM categories

a) Sustainable Forestry Practices

1. Continuous Cover Forestry (CCF)

CCF is the practice of regular thinning while avoiding clear-felling. The aim is to augment re-generation and permit the renewal of forest through under planting. CCF is also a requirement of the UK Woodland Assurance Scheme (Mason *et al*., 1999). Maintenance of continuous forest canopy is a multifunctional measure as it does not only provide flood alleviation and a reliable carbon sink but also promotes a sustainable forest ecosystem and security of regular timber supply at fixed volumes (Mason *et. al*.,1999).

2. Riparian Forest

A riparian forest is a forested area next to a water body such as river, stream, pond, estuary, canal, marshland, sink or reservoir. These riparian regions, as they are periodically under regular inundation, constitute transition zones between the upland terrestrial and the aquatic environments (Molles, 2008). They contribute to stabilize stream banks and sediment, decreasing the destructive impacts of flooding.

3. Afforestation of Hilly and Mountainous Areas

Afforestation is a method of catchment management by populating a river's catchment with trees (GeographyLwc, 2014). The concept might also imply re-forestation, enhancement of the conversion to forest from pastures, arable land, permanent crops and semi-natural vegetation in areas. The aim is to increase interception and the water uptake by the soil (JRC, 2012).

b) Sustainable Agriculture Practices

1. Buffer Strips

A buffer strip is a piece of land characterized by permanent cover of vegetation, which is configured specifically to needs, thus varying from simply grass to combinations of grass, trees, and shrubs which are primarily used in agriculture. The root systems of this specific vegetation in the buffers hold soil particles together, thus they protect the soil against erosion and landslides while stabilizing stream banks (Bentrup, 2008).

2. Crop Practices

Crop rotation, favouring deep root plants and trees, strip cropping and inter-cropping can be listed as related crop practices (Gomez *et al*., 2013). A higher capacity of natural water retention through infiltration can be achieved by implementing combined methods of improved crop practices. The theory behind this measure is increasing organic matter content of the soil by applying practices such as mulching, early sowing and decreasing bulk density on arable land (JRC, 2012).

3. Grasslands

Grasslands, or permanent pastures, are areas where the vegetation is dominated by grasses, sedges or rush. Increasing such vegetative cover on fields can help manage problematic surface runoff by slowing it down, reducing erosion and preventing the leaching of nutrient to proximate watercourses (Cheviot Futures, 2013). Moreover, grass growth and livestock are more resilient against drought conditions if water retention capacity of a permanent pasture has been improved and grasslands also function as efficient carbon sinks (Cheviot Futures, 2013).

4. Traditional Terracing

Terracing is farming practice to increase water retention of the soil by constructing layers or steps into an inclined plane or a hill. The primary intention is to decrease uncontrolled water run-off and to prevent soil erosion caused by it. Traditional terracing uses less heavy machinery therefore disturbance of the terrain is estimated to be much less than modern terracing (Gomez *et al*., 2013).

5. Grassed Waterways

A grassed waterway is a constructed shallow channel covered with a grass sward designed to intercept flows of surface water. This way percolation into the soil will be increased and gullying and soil erosion as well as water pollution will be prevented (Fiener and Auerswald, 2003). They are normally used within arable fields but can also be of benefit in other environments, such as in intensive grassland.

6. Conservation Tillage

Conservation Tillage (CT) refers to reduced-tillage in agricultural systems. The concept includes no-tillage, strip tillage, mulch tillage and ridge tillage to minimise the disturbance of the soil (SAI Platform, 2010).

7. Hedgerows and Beetle Banks

Hedgerows are hedges planted across slopes. They also serve as field boundaries in most cases. Their objective is to reduce water run-off (Collentine, 2014). This way they help improve infiltration and storage of the water within the soil. Beetle banks are uncultivated strips of land lying across arable fields. Although they are managed the same way as arable margins of fields, they are not next to the field boundary (Wildlife Trust, 2010). The benefits of beetle banks can be listed as cost reduction, increased pest predator populations, indirect decrease of pesticide inputs, minimization of soil erosion, runoff and watercourse pollution as well as improvement of wildlife diversity and habitat quality.[13]

c) Urban Drainage Systems

1. Sustainable Drainage Systems

Sustainable drainage systems are a diverse set of techniques. Filter strips, green roofs, filter drains, swales, soakaways, basins and permeable surfaces are some of the methods that could be listed under this category. These systems have risen as a solution to the issue of flash flooding after sudden showers in cities as a result of extremely rapid urbanization. Therefore they were initially named as urban drainage systems. However their current application is not limited to urban areas. SuDS are classified below according to how they function (SuDs Working Group for Wales, 2014)

- source control: green roofs, infiltration basins, infiltration trenches, permeable pavements, rainwater harvesting, soakaways, retention ponds, detention basins
- permeable conveyance systems: filter (or French) drains, filter trenches, swales, rain gardens, open urban green spaces, planted landscaping (shrubs, wildflowers, etc)
- passive treatment: filter strips, detention basins, retention ponds, bio-retention areas (such as park depressions) wetlands

d) Measures for Increasing Storage in Catchment and Alongside Rivers

1. Wetlands

Wetlands are distinct ecosystems protected internationally by Ramsar Convention. Although each wetland has identical vegetation due to its unique hydric soil and climate conditions, they all are characterized by being permanently or seasonally

[13] http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX. 0HABHZ9ZERA6RVD

saturated with water. According to Ramsar's Factsheet on Wetland Ecosystem Services (Ramsar Convention of Wetlands, 2009), wetlands provide valuable and numerous ecosystem services, some of which can be listed as flood control, groundwater replenishment, shoreline stabilisation, storm protection, climate change mitigation and adaptation. According to the same report, retaining these ecosystems intact has a very big economic return as annually they provide ecosystem service of an estimated value of US$ 23.2 billion only in terms of storm protection. The same source also states that the loss of a hectare of such ecosystem service will approximately translate into US$ 33,000 (2011).

2 Floodplains

Floodplain are areas adjacent to a stream or river. They extend from the banks of its channel to the base of the enclosing valley walls. They are flooded during periods of high discharge (Goudie, 2004). Their role is crucial in reducing vulnerability to flooding. As a part of the National Flood Insurance Program, The Federal Emergency Management Agency (FEMA) produces floodplain maps to define the exact location of 100-year "regulatory" floodplains for land use purposes.[13]

3 Peatlands

Peatlands are ecosystems which consist of a layer of peat, or turf, on soil surface (Northern Ireland Environmental Agency, 2011). The peat is a type of soil rich in organic matter content, mainly dead plants which are not fully decomposed, which has accumulated through natural processes occurring over thousands of years. Peatlands have an improved capacity for percolating and retaining water.

4. Basins and Ponds in Headwater Catchment Areas

The artificial basins built in an adjacent river, stream, lake or bay to manage stromwater are called retention basins. They are also alternatively called wet ponds or wet detention basins. The design feature of retention basins that differentiates them from detention and infiltration basins is that they always keep a percentage of their water capacity. They can also provide stormwater attenuation and treatment as well as fostering aquatic vegetation along their shores. Detention basins, or dry ponds, on the other hand only temporarily detain water during and after storms for flood protection and then gradually discharge all their content to a downstream water body. Infiltration basins aim to infiltrate stormwater directly to groundwater through permeable soils. Apart from flood protection, these basins and ponds are also beneficial in terms of other ecosystem services such as water quality improvement, groundwater recharge, flood protection and aesthetic improvement.[14]

[14]http://www.susdrain.org/delivering-suds/using-suds/sud-scomponents/retention_and_detention/Detention_basins.

5. Re-meandering

Re-meandering is the practice of re-shaping the historically straightened river channels through creation of a new meandering course and reconnection of cut-off meanders (Environment Agency, 2010). The length of the river channel is increased due to re-meandering; hence the capacity for water storage is also improved; leading to reduction of hydrological response times during periodical high flows (Kronvang *et al*., 2008). The objective is to improve the conditions of navigability and construct floodplains. Re-meandering also can be considered as a mean of flood risk protection for the downstream areas, additional to its contribution to water quality and climate change adaptation in terms evening out temperature fluctuations.

6. Polders

A polder is an artificially structured hydrological entity which consists of low-lying flood plains, usually a former marshland or a strip of land which has been reclaimed from a water body such as a lake, sea or river. It is isolated from outside influences by barriers or dikes and managed manually by devices. The concept was initially created in The Netherlands centuries ago as a mitigation strategy from sea floods caused by tides (Wagret, 1972). Currently it is an internationally accepted measure of water retention against high waters and flooding and can be found in river deltas and former fenlands in addition to coastlines.

7. Natural (River)Bank Stabilization

Natural (river) bank stabilization is the practice of a stream channel restoration or maintenance of existing measures such as dike or erosion protection. The aim is to safeguard a flood plain and to protect a bank or shore from erosion. Natural bank stabilization implies usage of natural materials such as roots or gravel which allows further water filtration into the bank (Gómez *et al*., 2013).

e) Other Measures for Increasing Ground Water Recharge

Usually water is withdrawn from aquifers at a rate much greater than the natural rate of replenishment. The overuse of aquifers might lead to phenomena such as soil subsidence and salination of aquifers in coastal areas (Veolia Water, 2010). To enhance water level and quality in aquifers and prevent contamination of available water, NWRMs aims to improve the natural process of percolation and facilitate supplemental soil filtration of the run-off water to aquifers. Ground water recharge is the process of run-off water percolation down the soil and filling the pores between rocks and soil particles (European Environmental Agency, 2010). The percolating water reaches the water table, either by natural or artificial methods. Conventional artificial methods of aquifer recharge include surface spreading, infiltration pits and basins in addition to injection wells (Veolia Water, 2010).

10 References

1. Bentrup, G. (2008). Conservation buffers: design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station.
2. Cheviot Futures (2013). Grassland Management and Climate Change Resilience. Available at: http://www.cheviotfutures.co.uk/phpdocuments/Grassland_Management.pdf
3. Collentine, D. (2014). What characterizes NWRMs and how do these relate to the core of River Basin Management Plans (RBMPs)? Brussels 22/01/14. Available at: http://nwrm.eu/sites/default/files/regional-workshops/Baltic/02_NWRM_character_D.Collentine.pdf
4. Environment Agency (2010) Re-meandering straightened rivers, online. Available at: http://evidence.environment-agency.gov.uk/FCERM/en/SC060065/MeasuresList/M5/M5T2.aspx Retrieved 16/07/2010
5. Environment Agency (2012) Rural Sustainable Drainage Systems (RSuDS) http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291508/scho0612buwh-e-e.pdf
6. European Commission, DG Environment (2012). Thematic Issue: Natural water retention measures**.** Available at: http://ec.europa.eu/environment/integration/research/newsalert/pdf/32si.pdf
7. European Environmental Agency (2010**)** Groundwater. http://www.eea.europa.eu/themes/water/european-waters/groundwater
8. Fiener, P. and Auerswald, K. (2003). Concept and effects of a multi-purpose grassed waterway. *Soil Use and Management* 19, 65-72.
9. Fiener, P. and Auerswald, K., (2006). Seasonal variation of grassed waterway effectiveness in reducing runoff and sediment delivery from agricultural watersheds in temperate Europe. *Soil and Tillage Research* 87 (1), 48–58.
10. GeographyLwc, Flood Management. Last Retrieved: 28/03/2014. Available at: http://www.geographylwc.org.uk/GCSE/igcse/rivergcase/floodmanagement.html
11. Gómez, C.M. (IMDEA), with contributions from Colentine, D. (SLU); Delacámara, G., (IMDEA); Strosser, P., (ACTeon); Iacovides, A., (IACO); Kinell, G., and Söderqvist T., (ENVECO); Ungvári, G., (REKK); and Fribourg-Blanc, B., (OIEau). December 10th, 2013 – Version for the drafting group of the WFD CIS WG PoM Concept Note, Natural Water Retention Measures (NWRM) and the WFD and other daughter Directives Disambiguation, issues and open questions. Available at: http://nwrm.eu/sites/default/files/documents-docs/nwrmconceptnote_to_regional_stakeholders.pdf
12. Goudie, A. S., (2004).Encyclopedia of Geomorphology, vol. 1. Routledge, New York. ISBN 0-415-32737-7.
13. Grasslands Trust (2012), Projects. Available at: http://grasslands-trust.org/projects Accessed on 16/07/2014

14. Gumiero, B., Mantb, J., Heinc, T., Elsoe, J. and Bozf, B., (2013). Linking the restoration of rivers and riparian zones/wetlands in Europe:Sharing knowledge through case studies, *Ecological Engineering*, 56 (2013) 36– 50.
15. Halls, A.J. (ed.), (1997). Wetlands, Biodiversity and the Ramsar Convention: The Role of the Convention on Wetlands in the Conservation and Wise Use of Biodiversity. Ramsar Convention Bureau, Gland, Switzerland. Wetlands, Biodiversity and the Ramsar Convention. Available at: http://www.ramsar.org/cda/en/ramsar-pubs-books-wetlands-biodiversity-21183/main/ramsar/1-30101%5E21183_4000_0__
16. JRC (2012). A work of Joint Research Centre (JRC) of the European Commission with the support of Stella Consulting SPRL, Brussels- Evaluation of the effectiveness of Natural Water Retention Measures - Support to the EU Blueprint to Safeguard Europe's Waters. Available at: http://ec.europa.eu/environment/water/blueprint/pdf/EUR25551EN_JRC_Blueprint_NWRM.pdf
17. Kronvang, B., Thodsen, H., Kristensen, E. A., Skriver, J.1, Wiberg-Larsen, P., Baattrup-Pedersen, A., Pedersen, M. L., Friberg, N. (2008). Ecological Effects of Re-Meandering Lowland Streams and Use of Restoration in River Basin Management Plans: Experiences from Danish Case Studies, 4th ECRR Conference on River Restoration, Italy, Venice S. Servolo Island, 16-21 June 2008.
18. Linnerooth-Bayer, J.A., Dubel, A., Damurski, J., Schröter, D., Sendzimir, J. (2013). Climate Change Mainstreaming in Agriculture. Natural Water Retention Measures for Flood and Drought Risk Management, European Response to Climate Change, April 2013.
19. Mason, B., Kerr G., and Simpson, J. (1999). Information Note: What is Continuous Cover Forestry?. UK Forest Commission October 1999. Available at: http://www.forestry.gov.uk/pdf/fcin29.pdf/$FILE/fcin29.pdf
20. Millennium Ecosystem Assessment (2003). Ecosystems and human well-being: a framework for assessment. Millennium Ecosystem Assessment. Island Press, Washington Available at: www.millenniumassessment.org
21. Molles, M.C. Jr. (2008). Ecology: Concepts and Applications (4th ed.). New York: McGraw-Hill. p 291. ISBN 0-07-330976-1.
22. Moxey, A. and D. Moran (2014). UK peatland restoration: Some economic arithmetic, Science of the Total Environment 484 (2014) 114–120.
23. Natural England Technical Information Note TIN109. Arable reversion and climate change: Humberhead Peatlands case study. Natural England 2012, First edition 04 April 2012. Available at: www.naturalengland.org.uk
24. North West Forestry Commission England (2009). North West England Continuous Cover Forestry Demonstration Sites North and West Cumbria. Crown Copyright, [100025498] [2009]. Available at: http://www.forestry.gov.uk/pdf/nweccfsitesmap.pdf/$FILE/nweccfsitesmap.pdf
25. Northern Ireland Environmental Agency (2011). Petlands. Available at : http://www.doeni.gov.uk/niea/biodiversity/habitats-2/peatlands.htm
26. Ramsar Convention on Wetlands Wetland Ecosystem Services (2009). Wetland Ecosystem Services- An introduction, November 2009. Available at: http://www.ramsar.org/pdf/info/services_00_e.pdf

27. RESTORE Partnership (2013). Case study: Remeandering of the Mardereau stream at Sorigny. Available at: http://riverwiki.restorerivers.eu/wiki/index.php?title=Case_study: Remeandering_ of_the_Mardereau_stream_at_Sorigny
28. Rojo, L., Vallejo, V. R. and Valdecanto, A. (date not stated). Forest and Natural Landscape. Lucinda: Land Care in Desertication Affected Areas. Available at: http://geografia.fcsh.unl.pt/lucinda/leaflets/Leaflet%20C1%20EN.pdf
29. SAI Platform Technical Briefs: Water Conservation TB 9, July 2010. Available at: http://www.saiplatform.org/uploads/Library/Technical%20Brief%209.%20Use%20of%20a%20conservation%20tillage%20system%20as%20a%20way%20to%20reduce%20water%20the%20footprint%20of%20crops.pdf
30. Scholz, M. (2008). Classification model for Sustainable Flood Retention Basins, 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK, 2008.
31. Stella Consulting (2011) Contract 070307/2010/581332/SER/D1 Final Report Costs, benefits and climate proofing of natural water retention measures: Costs, benefits and climate proofing of natural water retention measures. Available at: http://bookshop.europa.eu/en/evaluation-of-the-effectiveness-of-natural-water-retention-measures-pbLBNA25551/downloads/LB-NA-25551-ENN/LBNA25551ENN_002.pdf?FileName=LBNA25551ENN_002.pdf&SKU=LBNA25551ENN_PDF&CatalogueNumber=LB-NA-25551-EN-N
32. Suds Working Group for Wales. (2014). SuDs Techniques, 2014 Available at: http://www.sudswales.com/types/
33. Surface Water Management and Urban Green Infrastructure - A review of potential benefits and UK and international practices FR/R0014 May 2011.
34. Thomas, S. (2010). Progress on Beetle Banks in UK Arable Farming Pesticide Outlook – April 2000, The Royal Society of Chemistry. Available online at http://pubs.rsc.org/EN/content/articlepdf/2000/%20po/b006319
35. Trees for Life, online. Available at: http://www.treesforlife.org.uk/
36. UK National Ecosystem Assessment (2011). Synthesis of key findings. Available at : http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx
37. Vaughn, K. J., Porensky, L. M., Wilkerson, M. L., Balachowski, J., Peffer, E., Riginos, C.and Young, T. P. (2010) Restoration Ecology. *Nature Education Knowledge* 3(10).
38. Veolia Water, online. Rebuilding Reserves. Available at: http://www.veoliawater.com/solutions/ aquifer-recharge/
39. Wagret, P. (1972). Polderlands. Methuen and Co. Ltd., London.
40. Wildlife Trust (2010). Biodiversity Action Plan for Birmingham and the Black Country 2000. Available at: http://www.wildlifetrust.org.uk/urban/ecorecord/bap/html/fields.htm
41. Wise Use of Floodplains: EU- Life Environment Project, online. Area Case Studies Available at: http://www.floodplains.org/area_case_studies.htm