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# Costs, benefits and climate proofing of natural water retention measures (NWRM)

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***Disclaimer***

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# LIST OF ACRONYMS

| | |
|---|---|
| AGR | Artificial Groundwater Recharge |
| BAT | Best Available Techniques |
| CAP | Common Agricultural Policy |
| CBD | Convention on Biological Diversity |
| CCF | Continuous Cover Forestry |
| CICES | Common International Classification of Ecosystem Services |
| CIS | WFD Common Implementation Strategy |
| CLC | Corine Land Cover |
| DG ENV | Directorate-General for Environment |
| EAFRD | European Agricultural Fund for Rural Development |
| EC | European Commission |
| EEA | European Environment Agency |
| ERDF | European Regional Development Fund |
| ESF | European Social Fund |
| ESS | Ecosystem Services |
| ETP | Evapotranspiration |
| EU | European Union |
| GAEC | Good Agricultural and Environmental Condition (CAP) |
| GD24 | Water Framework Directive's Guidance Document No. 24 |
| GDP | Gross Domestic Product |
| GI | Green Infrastructure |
| ILUC | Indirect land-use change |
| IPCC | UN Intergovernmental Panel on Climate Change |
| IUCN | The International Union for Conservation of Nature |
| JRC | European Commission Joint Research Centre |
| LAI | Leaf Area Index |
| LID | Low Impact Development |
| LUMP | Land Use Modelling Platform |
| MEA | Millennium Ecosystem Assessment |
| MFF | Multi-annual Financial Framework |
| MG4 | MG4 grassland: *Alopecurus pratensis* – *Sanguisorba officinalis* (Meadow foxtail – Great burnet) |
| NWRM | Natural Water Retention Measures |
| O&M | Operation and maintenance costs |
| RAF | Runoff Attenuation Features |
| RBMP | River Basin Management Plans |
| RDP | Rural Development Programme |
| SuDS | Sustainable Drainage Systems |
| SMR | Statutory Management Requirements |
| TEEB | The Economics of Ecosystems and Biodiversity |
| WFD | Water Framework Directive |

## EXECUTIVE SUMMARY

The term natural water retention measures (NWRM) refers to 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.

This study aimed to provide a solid methodological and quantitative basis for identifying the financial needs and policy implications at the EU level for NWRM, and to support the European Commission (EC) in identifying the best instruments to create synergies between the European Union (EU) policy framework and measures at a river basin level.

A study of this size and scope can only hope to scratch the surface of the vast amount of information that exists. In addition, the knowledge base available to the study is very variable in quality from one measure to another. Furthermore, the study was expected to include the results of a series of modelling exercises by the EC Joint Research Centre (JRC) which were not finally available. This meant that several of the expected results – in particular, the assessments of effectiveness and benefits of the measures - had to be curtailed.

The study identified 21 NWRM, divided into four categories:

1. **Forest measures**: Continuous Cover Forestry (CCF); Maintaining and developing riparian forests; and Afforestation of agriculture land.
2. **Urban measures**: Filter strips and swales; Permeable surfaces and filter drains; Infiltration devices; and Green roofs.
3. **Agricultural measures**: Restoring and maintaining meadows and pastures; Buffer strips; Soil conservation crop practices; No or reduced tillage; Green cover; Early sowing; and Traditional terracing.
4. **Water storage measures**: Basins and ponds; Wetland restoration and creation; Floodplain restoration; Re-meandering; Restoration of lakes; Natural bank stabilisation; and Artificial groundwater recharge (AGR).

On the basis of the available information, the **applicability** of all the measures was assessed according to their EU climate zone; land-use; location; soil permeability; soil depth; topography; and EU geographical relevance. The study confirmed the applicability of most measures in terms of their climate zone and relevance to the EU. Information on the other applicability criteria varied considerably in its quality and quantity, and from one measure to another.

The **direct impacts** of the NWRM were assessed: 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.

In addition to their direct impacts on water retention, the following **benefits and co-benefits** were assessed for all measures: flood hazard reduction; soil quality improvement; 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. The available information confirms that a number of NWRM provide a wide range of benefits and co-benefits, in addition to water retention.

The study assessed the **Costs** of all measures, according to the following criteria: land requirement; construction and rehabilitation (investment, design and contingency); construction and rehabilitation (operation and maintenance); administrative costs; and other costs. The study concludes that the annualised costs of the NWRM range from €0.85 million (€0.002 per person) for buffer ponds, to €180,460 million (€360 per person) for the urban measures. The costs of the urban measures are very high and unlikely to be offset by the benefits of these measures. Crop practices are also expensive: €8,320 million per year (€17 per person); but in this case, if the 100 year flood period was reduced by 30%, it would result in a benefit of €11,040 million, which would make the scenario cost-effective.

The measures were also assessed against the following criteria to determine whether they can be considered as **no-regret measures**: future climate change scenarios; timing; planning horizon; flexibility; risks (cost effective and beneficial measures); local and regional scale; and economic analysis. The study concludes that it is of utmost importance that NWRM are planned taking into consideration the local conditions. In particular, the contribution of forest measures to water availability and flood hazard reduction has to be evaluated on a case-by-case basis, as these depend on *in situ* conditions and the scale (e.g., catchment level or local level) of the forests.

Finally, the study analysed the most relevant EU policies and funding programmes to determine the **barriers** and the **opportunities and weaknesses** of the current EU policy framework for promoting these measures at EU level. The NWRM study concludes that the 21 measures have been widely implemented throughout the EU, but could be further promoted through the EU policy framework. In particular, this should be done by:

- More explicit reference to NWRM in legislation;
- More research on quantifying and monetising the benefits of NWRM;
- A better acknowledgement of the role of the urban environment in flood mitigation, biodiversity and nature conservation;
- The promotion of the “soft measures” approach and the concomitant acknowledgement of the services that nature can provide for avoiding, mitigating or solving environmental problems such as flooding, water scarcity, etc.; and
- The provision of guidance and training on NWRM in the wide range of funding tools and platforms already available.

# 1. SCOPE OF STUDY

*"Having to find man-made solutions to replace the services that nature offers for free is not only technically challenging, but also very expensive."*[1]

Many projects and studies on flood protection and mitigation have been carried out in the EU in recent years, especially after the devastating floods of 2002 and 2005. Many of the flood mitigation strategies developed have included a mix of NWRM with other approaches including hard-engineering works. Many of these projects have increasingly recognised that NWRM provide a wide range of benefits for both flood control and the provision of ecosystem services (ESS).

However, NWRM present various implementation challenges (legal, economic, social, and technical). The effectiveness, costs, and benefits of NWRM at the river basin scale also require further research and assessment. The challenge that faces the EU is to better understand these measures and to assess the potential of EU policy and funding instruments to provide policy recommendations for promoting these measures at EU level.

## 1.1 Objectives

*Costs, benefits and climate proofing of natural water retention measures* (NWRM), a study conducted by STELLA Consulting for DG ENV, is a first step in that direction. The aim of the NWRM study is to provide a solid methodological and quantitative basis for identifying the financial needs and policy implications at the EU level for NWRM, and to support the Commission in identifying the best instruments to create synergies between the EU policy framework and measures at a river basin level. It also aims to help disseminate and make more visible the implementation of these measures at the EU level and their potential side benefits.

The specific objectives of the study are to:

- Based on a typology of NWRM, provide estimates of their costs and benefits, and of their potential for increasing resilience to climate change; and
- Analyse the potential of EU policy and funding instruments to promote non-regret measures.

## 1.2 EU policy background

The NWRM study is placed within the framework of three main EU policy areas and aims to contribute to the implementation of related strategies:

1. The NWRM study is one of the studies feeding directly into the ***Blueprint to Safeguard Europe's Water Resources***, an initiative of the EC for a Communication to be launched in November 2012. This

[1] SURF-nature Project – INTERREG IVC (2011): Green Infrastructure – Sustainable Investments for the Benefit of Both People and Nature.

is a policy response at the European level to address the implementation issues and gaps in the current EU water policy framework to ensure a sufficient availability of good quality water for sustainable and equitable use. The Blueprint will address the implementation issues related to the current EU policy framework (e.g., the Water Framework and Floods Directives) and develop measures to tackle, in particular, water availability and quantity problems. The NWRM study supports and feeds into this Blueprint, in particular in the area of developing a positive role of land use management, and developing cost-efficient, multipurpose NWRM that reduce the vulnerability of water resources and related ecosystems to climate change and other anthropogenic pressures.

2. The NWRM study is also implemented within the context of EU climate policy, and in particular, the ***White Paper on adapting to climate change***[2]. The White Paper outlines a framework for adaptation measures and policies to improve the EU's resilience to dealing with the impacts of climate change. It suggests that "working with nature's capacity to absorb or control impacts in urban and rural areas can be a more efficient way of adapting than simply focusing on physical infrastructure".

3. The NWRM study also takes into account nature and biodiversity policy and the green infrastructure (GI) approach, in particular, the implementation of the *Biodiversity Strategy*[3] and the upcoming *Green Infrastructure Strategy*[4]. The EU Biodiversity Strategy to 2020, recently adopted by the EC, acknowledges that "Ecosystem-based approaches to climate change mitigation and adaptation can offer cost-effective alternatives to technological solutions, while delivering multiple benefits beyond biodiversity conservation". The Green Infrastructure Strategy to be published later in 2012 aims "to safeguard and restore valuable natural ecosystems at a broader landscape level so that they can deliver valuable services to mankind". The Strategy will aim to prioritise investments in nature through a more integrated approach to land use. This explicitly includes investments in protecting and restoring water retention-related ESS.

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2 COM (2009) 0147. White paper - Adapting to climate change: towards a European framework for action {SEC(2009) 386} {SEC(2009) 387} {SEC(2009) 388}.

3 COM(2011) 244 final. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. Our life insurance, our natural capital: an EU biodiversity strategy to 2020.

4 European Commission. Green Infrastructure. http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

# 2. DEFINITIONS

The following sections define a number of concepts implied in NWRM.

## 2.1 Water retention

The NWRM study takes into consideration three types of water retention / water storage:

1. Water retention in the soil;
2. Water retention in the landscape; and
3. Groundwater.

Water retention in the soil is mainly implemented in the upper catchment zones. Soils can take water in during rainfall or irrigation, and they will do so until all soil pores are filled with water. Part of this water will drain away and end up in aquifers or streams, while the rest of the water will be used by plants and other soil organisms. The pattern of water retention in the soil is complex since it depends on the organisation of the pore space and the composition and arrangement of the solid particles (Lavelle and Spain, 2001). For example, depending on the permeability of the forest soils, forests help water transfer, through tree roots, as tree roots networks provide pathways rapidly delivering water to deeper soil (Mosley, 1979; O'Loughlin and Ziemer, 1982). By contrast, impervious surfaces such as roads, roof tops and car parks, do not allow rainfall to soak into the ground.

Water can also be retained in the lower part of the catchment in the floodplain. Wetlands, including bogs, fens, marshes, swamps and mires, as well as lakes, rivers, basins and ponds retain water in the landscape and are all water reservoirs *per se*. The water stored in these features represents a significant part of the water balance in the river basins and are essential for flood water storage. The amount of water in these surface bodies is constantly changing, due to inflows (e.g., precipitation, overland run-off, groundwater seepage or tributary inflow) and outflows (e.g., evaporation, discharge to groundwater) (USGS, 2012).

Water can also be retained as groundwater in aquifers for long periods of time. Rainfall can slowly infiltrate through the soil layer and replenish groundwater. The amount of rainfall that recharges groundwater varies, depending on the slope, soil and vegetation ( Maryland's Department of the Environment, 2009). Elimination of vegetation decreases the soil's ability to hold and process water and may therefore decrease groundwater recharge.

All NWRM increase one or other of these types of water storage capacity. For example, all agricultural NWRM (e.g., crop practices, early sowing, no and reduced tillage) increase water retention in the soil, as do some of the urban measures, which facilitate the infiltration of water into the soil (e.g., permeable surfaces, infiltration devices, filter strips and swales). Other measures, such as floodplain restoration, lakes and wetland restoration, aim to restore the "natural" landscape water storage capacity of floodplains and enhance the water retention capacity of the soil. All NWRM that improve infiltration of the soil also improve groundwater replenishment.

**EXAMPLE OF A NATURAL WATER RETENTION MEASURE: RESTORING WETLANDS, BOGS AND FENS**

Wetlands, bogs and fens are considered as relatively pristine natural water bodies when they are not used for intensive farming or for peat cutting. They also constitute the best means of providing appropriate retention (of water and its constituents). Natural or close-to-natural wetlands are the key elements of the eco-hydrological approach to managing water systems, an approach that is considered as the best solution to the joint handling of ecological and water problems, and thus the impacts of climate change. Restoring wetlands, bogs and fens is therefore one of the NWRM included in this study.

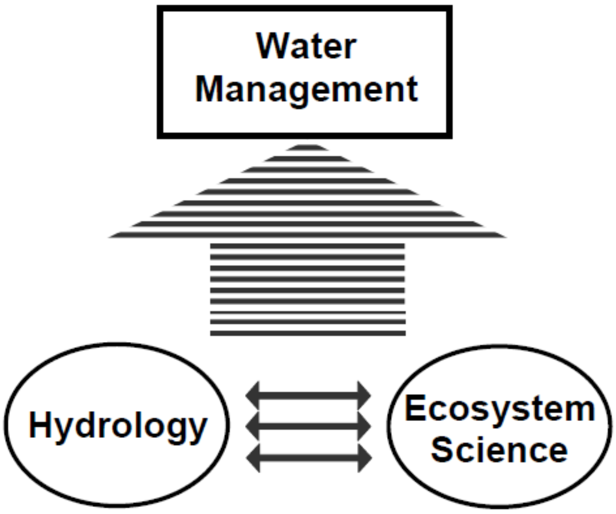
In recent decades, massive land-use changes have taken place, including meadow conversion, deforestation, urbanisation, intensification of agriculture, and changes in natural river flows. These have led to major adverse ecological effects on ESS, including the significant modification of the “original”, “natural” water retention capacity of soil, landscape and groundwater replenishment. However, various measures can restore the water retention capacity of soils, landscape and groundwater replenishment. Soft-hydraulic measures can help restore the flow of rivers to a state as close to their former natural state as possible so that they can perform their ecosystem functions. However, restoration does not restore all functions of the ecosystem before degradation and the priority is therefore to protect or maintain these services. For example, some agricultural practices can help maintain a good soil structure for retaining water.

## 2.2 Natural versus non-natural water retention measures

Clearly, a measure can never be entirely “natural”, as the implementation of a measure is always a human intervention. In the context of the NWRM study, the attribute “natural” is therefore used to refer to measures designed and implemented to re-use natural features, such as the natural storage capacity of soils or the ability of trees to intercept rainwater to mitigate surface run-off and soil erosion. NWRM therefore focus on maintaining or restoring the natural features and characteristics of water courses, wetlands and floodplains; and by increasing soil water retention and groundwater recharge. “Non-natural” water retention measures are understood as hard engineering measures or hydraulic construction / infrastructure, including large, artificially-created retention basins, dykes and - to the extent that they involve heavy-machinery, artificial materials and construction - polders.

Increasing evidence on the decline of both water quality and biodiversity shows that hard-engineering or hydro-technical measures, such as wastewater treatment plants and flood defences, are not sufficient to manage healthy water systems. The eco-hydrological approach is an alternative approach that advocates the joint handling of ecological and water problems, and thus for addressing the impacts of climate change (Jolánkai and Bíró, 2008). Nuttle, 2002 defines eco-hydrology as “the sub-discipline shared by the ecological and hydrologic sciences concerned with the effects of hydrological processes on the distribution, structure and functioning of ecosystems, and on the effects of biotic processes on elements of the water cycle” (see Figure 1). This approach is the foundation of sustainable water management, and includes natural or close-to-natural ecosystems, including all NWRM as defined by this study, as key elements.

**FIGURE 1**
**ECO-HYDROLOGY: INTEGRATION OF HYDROLOGY AND ECOSYSTEM**




The aim of NWRM is to slow down or reduce the flow of water downstream leading to a more natural flow regime within a catchment, for example, by leaving space for the river to flood areas in the floodplain. This implies, at times, using man-made structures, but adapted to natural water flows and systems as opposed to creating new ones. For example, managing forests as CCF rather than even-aged stands can be considered a NWRM, as CCF better intercepts water and also improves the soil structure (due to the roots of uneven-aged trees) and therefore increases water storage capacity and mitigates soil erosion.

By restoring degraded habitats and the natural flow regime within a catchment, these measures have the added benefit of restoring ecosystem functions and services (e.g., carbon sequestration and climate regulation, purification of water and air, provision of water). On 08.03.2011, DG ENV published a Note[5] defining NWRM as measures that result from building-up GI. According to DG ENV, these measures contribute to the "protection and restoration of e.g. floodplains and coastal ecosystems, [to the] mitigation of climate change impacts by conserving or enhancing carbon stocks or by reducing emissions caused by e.g. wetland and river ecosystem degradation and loss, [and to the] provision of cost-effective protection against some of the threats that result from climate change such as increased floods".

### 2.3 No-regret measures

Evidence shows that global warming is having and will continue to have impacts on water resources. According to the WFD's Guidance Document No. 24 (CIS GD24) "River Basin Management in a changing climate", published in 2009[6], climate change affects the following water resource variables:

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5 European Commission, 2011, Note: Towards Better Environmental Options for Flood risk management. (http://ec.europa.eu/environment/water/flood_risk/pdf/Note%20-%20Better%20environmental%20options.pdf).

6 European Commission, 2009. Guidance Document No. 24 (CGD24) "River Basin Management in a changing climate". Technical Report - 2009 – 040. p.25.

- Water availability (river flows and groundwater levels);
- Water demand (especially peak demands during periods of drought);
- Intensity and frequency of floods and droughts, and of strong stream or low flow conditions;
- Surface water quality, including temperature, and content of nutrients and other contaminants;
- Biodiversity in aquatic systems; and
- Groundwater quality.

However, the climate change models and projections used to understand potential impacts are currently largely based on assumptions. Their predictions therefore contain uncertainties regarding the impacts that climate change will have on water or on the hydrologic cycle (CIS GD24). No-regret measures are measures that are not affected by these uncertainties because they should help address current environmental problems and at the same time help build the resilience of ecosystems to adapt to climate change in the future. Measures that cannot be reversed, or only reversed at high cost, should not be implemented.

**NO-REGRET MEASURES**

No-regret measures are measures that are of benefit no matter how or if predicted climate change impacts materialise. The Intergovernmental Panel on Climate Change (IPCC) defines no-regret measures as measures whose benefits - such as improved performance or reduced emissions of local/regional pollutants, but excluding the benefits of climate change mitigation - equal or exceed their costs. They are sometimes known as "measures worth doing anyway".

Forward-looking, planned NWRM should in most cases be no-regret measures *per se*, as they enhance the natural flows and storage capacity of ecosystems and at the same time contribute to reducing the impacts of climate and enhance resilience to climate change. Therefore, they should be beneficial, no matter which impacts climate change will have. Moreover, NWRM also offer co-benefits such as the provision of habitat, water purification and water provision.

## 2.4 Green Infrastructure and Ecosystem-based Approach

NWRM contribute to the objectives of both the GI approach and the principles of the Ecosystem-based Approach.

**GREEN INFRASTRUCTURE (GI)**

According to the European Commission, GI will help maintain healthy ecosystems so that they can continue to deliver valuable services such as clean air and fresh water. In turn, GI will strengthen ecosystems and make them less vulnerable to the impacts of climate change. GI provides several benefits for biodiversity and society alike. The GI concept links the achievement of these benefits closely to an integrated approach to land management and to careful strategic planning.

GI consists of large natural areas (such as forests or grasslands), green corridors (such as buffer strips next to streams or roads), or small sized green spaces (such as green roofs). The GI approach aims to introduce, restore or maintain green spaces and, where relevant, connect them to a green continuous habitat. The GI underlying principle is that the same area of land can frequently offer multiple benefits once the right priorities are set. In short, GI performs four interdependent roles:

1. Protecting ecosystem state and biodiversity;
2. Improving ecosystem functioning and providing multiple ESS;
3. Promoting societal well-being and health; and
4. Supporting the development of a green economy, and sustainable land and water management[7].

GI can therefore contribute to increasing resilience, and reduce vulnerability. Moreover, delivering those essential services to society is generally cheaper than artificial solutions, which are not designed for providing multiple services.

NWRM are a means to achieving the GI objectives, by delivering benefits for water retention, but at the same time improving other multiple services depending on the ecosystem configuration. GI, and in particular NWRM, focus on safeguarding and enhancing the water storage potential of ecosystems and aquifers, by restoring the natural features and characteristics of water courses with direct impacts on hydrology and water retention. At the same time, they enhance ecosystems and their functional performance, resilience and resistance, thus helping to upgrade the entire river basin for all the uses of man and nature (Jolánkai, no date) and provide many other benefits, such as improved habitat connectivity, which contributes to biodiversity conservation.

**ECOSYSTEM-BASED APPROACH**

The Convention on Biological Diversity (CBD), through the Fifth Conference of Parties (COP 5), defined the ecosystem approach as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way". It also sets 12 principles of the ecosystem approach. Principle 1 aims to place society in the centre of biodiversity conservation, as it acknowledges that "the objectives of management of land, water and living resources are a matter of societal choice". Principle 4 recognises "the need to understand and manage the ecosystem in an economic context". Principle 5 acknowledges that the conservation of ecosystem structure and functioning is a priority. The ecosystem approach therefore aims to manage the ecosystems based on the principle that they provide multi-benefits for society and nature itself.

Restoring ecosystems such as watershed forests, or riparian and coastal wetlands reduces exposure of human communities to natural disasters, such as landslides, flooding, storms and wave surges. GI assists in water retention, which has a key role in mitigating the effects of extreme events like floods and seasonal water scarcity and contributes to achieving good ecological status of waters and dependent ecosystems. Planning and establishing GI during river basin management planning therefore delivers multiple benefits and at the same time reduces the cost of implementing the WFD, and offers better environmental options for flood management.

Ecosystem-based approaches use biodiversity and ESS as part of an overall adaptation strategy to help people and ecosystems to adapt to and to mitigate the adverse effects of climate change. NWRM use the ecosystem-based approach, as

[7] European Commission, 2012. The Multifunctionality of Green Infrastructure. In-depth Report. Science for Environment Policy. DG Environment News Alert Service. March 2012.

they aim to contribute simultaneously to regulate water flows and storage, increase resilience of ecosystems to climate change, conserve carbon stocks, improve biodiversity and connectivity, improve health and provide cultural and recreational services.

## 2.5 Climate change adaptation strategies

It is widely accepted that climate change alters precipitation quantity (in northern Europe) and rainfall intensity (across Europe), thus increasing run-off and erosion. The increase in run-off has two important effects (IPCC, 2007):

1. An increase in flooding risk; and
2. A decrease in the volume of water infiltrated in the soil, thus reducing groundwater recharge.

The increase in run-off decreases the base flow feeding rivers and thus low flows in the summer. The presence of NWRM could potentially slow down the flow of water, allowing it to better penetrate. The risk of flooding during the storm is thus reduced and groundwater recharge is improved.

NWRM can also support ecosystems in their adaptation to climate change by improving connectivity between natural areas and decreasing habitat fragmentation. Given that these measures work with nature by increasing the adaptive capacity of ecosystems, they can potentially be considered no-regret measures (Laaser *et al*., 2009), acting as adaptation measures and therefore helping ecosystems and society cope with climate change. The White Paper on adapting to climate change states that no-regret measures should be given priority as they generate net social and / or economic benefit, taking into account the uncertainty in future forecasts[8].

One of the objectives of this study is to investigate to what extent NWRM are no-regret measures, and should be integrated into the EU climate change adaptation strategies as proposed by the framework of the White Paper: Adapting to climate change.

[8] COM/2009/0147. White paper - Adapting to climate change: towards a European framework for action {SEC(2009) 386} {SEC(2009) 387} {SEC(2009) 388}.

# 3. OVERVIEW OF METHODOLOGY

This section outlines the methodologies for:

1. Collecting, organising and reviewing the sources of information;
2. Identifying the 21 measures;
3. Assessing the applicability of the 21 measures;
4. Assessing the effectiveness of the 21 measures;
5. Assessing the benefits and co-benefits of the 21 measures;
6. Calculating aggregated costs of the modelled measures;
7. Identifying no-regret measures; and
8. Assessing EU policy implications.

## 3.1 Information base

The information base of this study is constituted of:

1. 153 sources of information (mainly technical or scientific documents) relating directly to the applicability, direct impacts, costs, benefits and / or co-benefits of NWRM;
2. 236 other documents supporting the methodological framework of the study and the cost and benefit analyses, no-regret assessment and policy assessment; and
3. A set of land-use simulations carried out by the JRC.

The NWRM study was designed to first receive and structure information received through a Call for Evidence launched by the EC[9]. Thirty-eight sources of information were received through this Call, supplemented by a further 91 sources of information provided directly to the study by DG ENV. The information available in these 129 sources was however insufficient to carry out the initial activities of the study (i.e., to establish the typology of measures). Therefore, to fill in as many of the information gaps as possible, the following sources of information were investigated:

- Relevant projects;
- Technical journals;
- Organisations carrying out research in forest, water and land-use management; and
- Government agency websites and documents.

[9] To gather relevant information, studies and reports on the costs and benefits of NWRM from the stakeholders, DG Environment launched a “Call for Evidence” on its homepage (http://ec.europa.eu/environment/water/adaptation/ecosystemstorage.htm), in September 2010 with a closing date of 31.10.2010, which was later extended to 30.11.2010. The Commission solicited information by sending the Call to the relevant Working Groups (e.g., Floods, Agriculture) and to DG Agriculture and DG Research.

This resulted in a further 260 sources of information. Therefore, this study had a total of 389 sources of information at its disposal (see the Bibliography). The information received and gathered is composed of technical, scientific, project and policy documents (case studies, reports, studies, projects documents, websites, etc.).

Initially, these sources of information were categorised according to their relevance to the study and, in particular, according to their relevance to the 21 NWRM. One hundred and fifty three sources were therefore prioritised and used in the implementation of the first activities: the establishment of the typology of NWRM and the NWRM Database (see Annex 1). These 153 documents were then reviewed for information on the 21 NWRM and an overview of the available information was recorded in 21 Fact Sheets, one per NWRM (see Annexes 2-12). The remaining 236 sources were mainly used as support to the background or methodological approach of the study, as well as for the later assessments (cost-benefit assessments, and no-regret and policy reviews).

Despite the large number of documents and sources identified and reviewed, the information base of the study is far from comprehensive. A study of this size and scope can only hope to scratch the surface of the vast amount of information that exists. The quality or relevance of the information to the needs of the study in these 153 sources was also very variable and in many cases did not allow for firm conclusions to be drawn. An overview of the quality of the information, by measure, is presented in Annex 13.

Overall, the main gap in the information available for NWRM is the availability of quantitative data. Quantitative information on the benefits and co-benefits is very limited. It has been therefore impossible to quantify the co-benefits of these measures and thus monetise the ESS that the measures contribute to. Consequently, it has been impossible to carry out a full cost and benefit analysis as a part of the argument to make an economic case for implementing these measures is not available. Quantifying these benefits would contribute to tools such as the Payment for ESS, but also to other current initiatives mentioned throughout this study. Quantifying these benefits could also contribute to guiding policy; for example, they could be integrated in the Cohesion Fund’s indicators.

It is therefore recommended that future studies and projects place a stronger emphasis on the need to quantity and monetise ESS. Relevant actions should be highlighted through EU funding instruments such as the Framework Programme (or Horizon 2020 after 2013) and the LIFE programme. Moreover, the WFD Common Implementation Strategy (CIS) groups are the perfect forum to provide guidance and share best practices on these tools.

In particular, there is very little quantitative and qualitative information on the contribution of NWRM to ambient air temperature regulation and air quality improvement. Quantitative information on the contribution of these measures to the provision of habitat, cultural services and food/fibre/fuel is very general and would require more research in order to quantity the benefits. Many gaps which are only applicable to a specific group of measures are explained in more detail in Annex 13.

### 3.2 Identification of natural water retention measures

Using the 153 sources of information, a total of 42 NWRM were initially identified within the scope of this study, categorised under six land-use types corresponding to the Commission's policy areas (see Annex 14).

A. Forests and other wooded land;

B. Meadows and pastures;

C. Agricultural land;

D. Urban land;

E. Lakes and their wetlands; and

F. Rivers and their wetlands.

To simplify and streamline the measures, some measures were subsequently merged. In particular, the measures under "Agriculture land" were grouped into six main categories in line with the CAP / Good Agricultural and Environmental Condition (GAEC) (Cross Compliance). Measures under "Urban land" and already grouped under SuDS were divided into four distinct measures (Filter strips and swales, Permeable surfaces and drains, Infiltration devices, and Basins and ponds) since none of them is applicable exclusively to urban land. The same was done with Rivers and their wetlands: Wetland restoration and creation, Floodplain restoration, Re-meandering, Riparian forests and Natural bank stabilisation were looked at separately as they are applicable under different conditions. Not every floodplain is suited for the introduction of riparian forests, for example.

According to the definition of "natural" and "non-natural" water retention measures in Section 2 and according to the six land-use types above, this study finally identified 21 NWRM with EU relevance. Table 1 presents the 21 NWRM identified by this study, organised into four categories and with a brief description:

1. Forest measures;
2. Agricultural measures;
3. Urban measures; and
4. Water storage measures (storage in the landscape).

**TABLE 1**
**NATURAL WATER RETENTION MEASURES**

| Category | NWRM measure | | Short description |
|---|---|---|---|
| **Forest measures** | **F1** | Continuous cover forestry (CCF) | CCF maintains continuous woodland conditions, rather than periodically removing trees like clear-felling systems. CCF requires tending and thinning practices aimed at achieving a maximum stability of forests. In addition, during the regeneration phase the canopy is maintained. CCF leads to more diverse forests providing multi-purpose benefits. |
| | **F2** | Maintaining and developing riparian forests | Riparian forests are forested areas of land along water bodies such as rivers, streams, ponds and lakes. Riparian forests can contribute to flood alleviation by delaying the downstream passage of flood flows, reducing the volume of run-off, and promoting rainfall infiltration into the soil, thereby reducing the rate of run-off. |
| | **F3** | Afforestation of agriculture land | Afforesting agricultural land refers to developing a forest stand on former agricultural areas. Plants used for afforesting agricultural land are trees or tree crops (e.g., edible legumes, fruits or nuts). The objective of afforesting agricultural land is to increase ETP, slow surface run-off and increase infiltration in the catchment. Trees let rainwater infiltrate into the soil by intercepting rainfall with their canopies; this slows water run-off, rainwater can better infiltrate into the soil, thus replenishing groundwater supplies. Tree roots also lead to a better soil structure. Furthermore, their ability to remove harmful nutrients contributes to improved groundwater quality. |
| **Urban measures**[10] | **U1** | Filter strips and swales | Filter strips and swales intercept and drain water evenly off impermeable areas to slow down the flow and encourage infiltration, thereby contributing to run-off mitigation. These infiltration devices also contribute to unsealing urban areas. Filter strips and swales are SuDS. |
| | **U2** | Permeable surfaces and filter drains | Filter drains contain a volume of permeable material below ground to store surface water. Permeable surfaces and filter drains retain water by infiltrating rainwater and surface run-off directly into the soil. Run-off flows to this storage area via a permeable surface, which can consist of grass, if the area is not travelled on, gravel, porous paving blocks, continuous surfaces with an inherent system of voids, or solid paving blocks with gaps between individual blocks. Permeable surfaces and filter drains are SuDS. |
| | **U3** | Infiltration devices | Infiltration devices include soakaways, infiltration trenches and infiltration basins, as well as swales and ponds. Soakaways and infiltration trenches are completely below ground, while infiltration basins and swales for infiltration store water on the surface; they are dry except during heavy rainfall. Infiltration devices drain water directly into the ground and are generally integrated into the landscape. By storing and infiltrating water, infiltration devices contribute to water retention; they are SuDS. |

[10] Urban measures as defined by this study refer to Sustainable Drainage Systems (SuDS). However, these measures can also be applicable to other land uses.

| Category | NWRM measure | | Short description |
|---|---|---|---|
| **Urban measures** | **U4** | Green roofs | Green roofs are covers of living vegetation on top of buildings of all sizes, from small garages to large industrial structures. In addition to plants, green roofs can also include drainage or irrigation systems. Plants capture rainwater on their foliage and absorb it in their roots, encouraging ETP and preventing at least a part of storm-water from entering the run-off stream. Green roofs also create new habitats in a sealed urban environment and can help lower the air temperature. Green roofs are SuDS. |
| **Agricultural measures** | **A1** | Restoring and maintaining meadows and pastures | Meadows are areas or fields whose main vegetation is grass, or other non-woody plants, used for mowing and haying. Pastures are grassed or wooded areas, moorland or heathland, generally used for grazing. Due to their rooted soils and their permanent cover, meadows and pastures provide good conditions for the uptake and storage of water during temporary floods. They also protect water quality by trapping sediments and assimilating nutrients. |
| | **A2** | Buffer strips | Buffer strips are areas of natural vegetation cover (grass, bushes or trees) at the margins of fields, arable land, or roads. Due to their extensively used green cover, buffer strips offer good conditions for effective water infiltration and therefore promote the natural retention of water. They can also significantly reduce the amount of suspended solids, nitrates and phosphates originating from agricultural run-off. |
| | **A3** | Soil conservation crop practices | Various soil conservation crop practices (e.g., crop rotation, strip cropping, intercropping, interlayer crops) can ensure that the soil retains water by maintaining good soil characteristics. These practices minimise the alteration of the composition and structure of the soil, thereby safeguarding it against erosion and degradation, and preserving soil biodiversity. Crop rotation, for example, involves cultivating different crops in temporal succession on the same land. This enhances soil structure, improves nutrient cycles, and increases microbiological diversity. |
| | **A4** | No or reduced tillage | Tillage is a mechanical modification of the soil. Intensive tillage can disturb the soil structure, thus increasing erosion, decreasing water retention capacity, reducing soil organic matter through the compaction and transformation of pores. |
| | **A5** | Green cover | Green cover refers to crops planted in late summer or autumn, usually on arable land, to protect the soil, which would otherwise lie bare during the winter, against wind and water erosion. Green cover crops also improve the structure of the soil, diversify the cropping system, and mitigate the loss of soluble nutrients. |
| | **A6** | Early sowing | Early sowing refers to sowing up to six weeks before the normal sowing season. This allows for an earlier and quicker development of crops and of a root network that leads to soil protection. The period in which the soil lies bare is shorter and, therefore, erosion and run-off are less significant and water infiltration is improved. Early sowing can also help to mitigate the extreme ETP rates typical of Mediterranean summers. However, early sown plants are frost sensitive; therefore farmers run the risk of losing the crops because of the low temperatures. In northern countries, temperature in spring (March) can be adequate but the risk of frost is still serious until May. Therefore, early sowing requires specific tools (plastic tunnel covers, onsite green house, etc.) and cannot be applied by any farmers for any crops. |

| Category | NWRM measure | | Short description |
|---|---|---|---|
| **Agricultural measures** | **A7** | Traditional terracing | Traditional terraces consist of nearly level platforms built along contour lines of slopes, mostly sustained by stone walls, used for farming on hilly terrain. When properly built and well maintained, terraces can reduce erosion and surface run-off by slowing rainwater to a non-erosive velocity. So-called traditional terracing involves less disturbance of the terrain than modern terracing, as it does not involve significant levelling or cutting using heavy machinery. |
| **Water storage measures** | **S1** | Basins and ponds | Basins and ponds store surface run-off. Detention basins are free from water in dry weather flow conditions but ponds (e.g., retention ponds, flood storage reservoirs, shallow impoundments) contain water in dry weather, and are designed to hold more when it rains. |
| | **S2** | Wetland restoration and creation | Wetlands restoration and creation can involve: technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); technical small-scale measures such as clearing trees; as well as changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. Wetland restoration can improve the hydrological regime of degraded wetlands and generally enhance habitat quality.<br>Creating artificial or constructed wetlands in urban areas can also contribute to flood attenuation, water quality improvement and habitat and landscape enhancement. |
| | **S3** | Floodplain restoration | A floodplain is a plain bordering a river which provides space for the retention of flood and rainwater. Floodplain soils are generally very fertile and they have often been dried-out to be used as agricultural land. Nowadays, the objective is to restore them, their retention capacity and ecosystem functions. |
| | **S4** | Re-meandering | In the past, rivers have been straightened by cutting off meanders. Re-meandering is bringing a river back closer to its naturally meandering state by creating a new meandering course and by reconnecting cut-off meanders. Re-meandering slows down the flow of a river. The new form of the river channel creates new flow conditions and very often also has an impact on sedimentation. The newly created or reconnected meanders also provide habitats for a wide range of aquatic and land species of plants and animals. |
| | **S5** | Restoration of lakes | Lakes are by definition water retention facilities; they store water (for flood control) and provide water for many purposes such as water supply, irrigation, fisheries, tourism, etc. In addition, they serve as sinks for carbon storage and provide important habitats for numerous species of plants and animals, including waders. In the past, lakes have sometimes been drained to free the land for agriculture purposes, or have simply not been maintained and have silted up. Restoring lakes is re-introducing them where they have been in former times or revitalising them. |

| Category | NWRM measure | | Short description |
|---|---|---|---|
| **Water storage measures** | **S6** | Natural bank stabilisation | In the past, various activities were undertaken to straighten rivers, such as the stabilisation of river banks with concrete or other types of retention walls. Such actions limited rivers' natural movements, leading to degradation of the river, increased water flow, increased erosion and decreased biodiversity. Natural bank stabilisation reverses such activities, allowing rivers to move more freely. Where bank stabilisation is nevertheless necessary, such as in residential areas, natural materials such as roots or gravel can be used. Natural materials are preferable as they allow water to infiltrate into the bank. They also provide better living conditions for aquatic fauna. |
| | **S7** | Artificial groundwater recharge (AGR) | AGR stores large quantities of water in underground aquifers to increase the quantity of groundwater in times of shortage. It results in a lowering of run-off from surrounding land, and in an enhanced natural condition of aquifers and water availability. The natural cleaning process of water percolating through the soils when entering the AGR improves water quality. |

Annexes 2-12 describe each of the 21 measures in more detail.

The 153 relevant sources of information gathered through the Call for Evidence and subsequent literature search were reviewed for all 21 NWRM against the 30 criteria in Table 2, to identify the measures' applicability and direct impacts, as well as to identify information on potential costs and potential benefits and co-benefits. These criteria are described in more detail in the following sections. The results of the assessments per measure are presented in 21 Fact Sheets (see Annexes 2-12) and summarised in Section 4 below.

**TABLE 2**
**ASSESSMENT CRITERIA**

| Applicability | Direct Impacts | Benefits and co-benefits | Costs |
|---|---|---|---|
| Climate zone | Soil moisture | Flood hazard reduction | Land requirement |
| Land use | Water temperature | Provision of food/fibre/fuel | Construction and rehabilitation (investment, design, contingency) |
| Location | Evapotranspiration | Soil quality improvement | Construction and rehabilitation (operation and maintenance) |
| Soil permeability | Run-off control | Water quality improvement | Administrative costs |
| Soil depth | Groundwater replenishment | Water availability / quantity | Other costs |
| Topography | Land-use change | Air quality | |
| EU relevance | Erosion control | Climate regulation | |
| | Landscape storage capacity | Ambient air temperature | |
| | | Cultural services | |
| | | Provision of habitat | |

## 3.3 Assessment of the applicability of the 21 measures

Applicability refers to the spatial range in which the NWRM can be or have been implemented. In conjunction with the Commission and NWRM Steering Committee, the set of applicability criteria shown in Table 3 were established. The applicability criteria are linked to the types of river basins in Europe. The applicability criteria describe the location of the measure: where it can be implemented, in which climate zone or land use, at which location in the river basin, and on what type and depth of soil. Applicability also includes the topographical conditions of the area where the measure can be implemented and the geographical relevance to the EU territory.

The 153 sources of information were reviewed for relevant information on all of these criteria. The results are entered into Fact Sheets, one per measure (see Annexes 2-12).

**TABLE 3**
**CRITERIA TO ASSESS APPLICABILITY OF NWRM**

| Assessment criteria | Description |
|---|---|
| **1. Climate zone** | The Environmental Stratification of Europe, carried out by Metzger *et al*., 2005, identified 84 strata, grouped into 13 main zones. Each measure was assessed according to which of the 13 main zones it has been implemented. |
| **2. Land use** | The principle land-use(s) relevant to each measure have been identified. Each category of measures may have a primary land use but can be applied to others as well (or may involve a land-use change). |
| **3. Location** | This study covers NWRM at the scale of watersheds, channels and run-off routes, and floodplains in rural and urban areas. The location of NWRM in the watershed is closely related to topography. Usually, erosion-prone soils are located upstream, where the slope is steep. Therefore, natural measures affecting erosion control are more efficient upstream. Otherwise, detention and wet ponds and constructed wetlands can be implemented only in flat terrain (downstream). Accordingly, this study has used two primary locations:<br>• Upstream: area between watershed limit and the floodplain, or flat area near the river; and<br>• Downstream: area including the river floodplain and flat area near the river. |
| **4. Soil permeability** | The soil's ability to retain water is strongly related to soil texture. Soil texture affects the volume of run-off and the potential for infiltration. Water percolates quickly into rough textured, highly porous soils. Soil texture is determined by the proportion of sand, silt and clay particles in the soil. Clay soil tends to produce a greater volume of run-off because of its relatively poor permeability. Finely textured silt and clay soils allow almost no infiltration, generating large volumes of run-off. Soil infiltration capacity largely determines the effectiveness of the NWRM. Accordingly, this study has used three levels of soil permeability:<br>1. Low: < 7.10-6 m/s (e.g., silty clay soil);<br>2. Medium: 7.10-6 m/s – 8.10-5 m/s (e.g., sandy clay soil); and<br>**3.** High: > 8.10-5 m/s (e.g., sand, gravel). |
| **5. Soil depth** | Soil depth plays an important role in the infiltration of water into the soil. Shallow soil lets less water infiltrate before it is saturated. Deep soil can store a greater volume of water. Accordingly, this study has used five categories of soil depths:<br>1. Very shallow: < 25 cm;<br>2. Shallow: 25 - 50 cm;<br>3. Moderately deep: 50-90 cm;<br>4. Deep: 90-150 cm; and<br>5. Very deep: 150 cm. |
| **6. Topography** | Topography is a crucial factor to be considered in implementing water retention measures. Steep slopes in particular can reduce the effectiveness of some measures and increase the effectiveness of others. Moreover, the potential for erosion increases exponentially with increasing slope lengths and gradient. Accordingly, this study has used three categories for topography:<br>1. Sloping: critical sloping topography (slopes > 10%); steep sloping topography (slopes between 5 and 10%); and mild topography (slopes between 0% and 5%);<br>2. Floodplain; and<br>**3.** Channel. |

| Assessment criteria | Description |
|---|---|
| **7. EU relevance** | This criterion refers to the geographical relevance of the measures, taking into account the study's goal to determine a measure or a combination of measures that are applicable, effective, and efficient at EU level, and to provide policy recommendations for promoting the uptake of NWRM at EU level. |

### 3.4 Assessment of the effectiveness of the 21 measures

The **effectiveness** of a measure is its capability to achieve its desired water retention objectives. These objectives are measured through the direct impacts of the measures on the landscape and on soil and water systems. For example, NWRM aim to increase soil moisture, control run-off, increase groundwater recharge, control erosion, and store water in the landscape or in different layers of the soil. Sustainable agricultural practices, for example, are generally designed to reduce erosion and retain moisture in the soil. Wetland restoration (in floodplains) projects generally slow down run-off in the floodplain (see Table 4).

In conjunction with the Commission and NWRM Steering Committee, the following set of effectiveness criteria were established. The 153 sources of information were reviewed for relevant information on all of these criteria. The results are entered into Fact Sheets, one per measure (see Annexes 2-12).

**TABLE 4**
**CRITERIA TO ASSESS THE EFFECTIVENESS OF NWRM**

| Assessment criteria | Description |
|---|---|
| **8. Soil moisture (soil storage capacity)** | Soil moisture is generally defined as the water held in the spaces between soil particles. It is a measure of the water storage capacity of the soil, which refers to the amount of water that the soil can store in its layers. Water is only stored in the upper soil layer; therefore soil moisture is a very important parameter for flood forecasting and water resources management[11]. According to the FAO, 2005, the capacity of soil to retain and release water depends on various factors including: texture; depth; physical structure including pores; content of organic matter; and biological activity. The water available in the soil is very important for the biological activity in the soil, and therefore for soil biodiversity; the quantity and quality of plant-available water has a significant impact on plant growth. Moreover, it indicates the hydro-dynamic characteristic of the soil, an important factor in agricultural production. |
| **9. Water temperature** | Stream temperature varies naturally with seasonal variations and other physical characteristics of water courses and bodies, such as the temperature of run-off and the shade given by trees and other riparian plants. Water temperature has important impacts on the oxygen content of freshwater and therefore on the primary production of organic compounds from carbon dioxide, crucial for life. It can also affect the metabolism of species with increases in temperature often leading to negative impacts on the aquatic life in streams. |
| **10. Evapotranspiration (ETP)** | ETP refers to the transpiration from vegetation and evaporation from bare surfaces without vegetation. Transpiration increases with plant growth. The evaporation of bare soil decreases with time to stop after the first few |

[11] http://www.ipf.tuwien.ac.at/insitu/.

| Assessment criteria | Description |
|---|---|
| | centimetres of soil are dry.<br><br>Water leaves basins through ETP. However, the actual ETP depends on the types of vegetation and land-use in the basins: ETP is optimal when the soil is well supplied with water and completely covered by vegetation. Full coverage, such as a forest, will consume water rapidly from the soil, creating a greater capacity for storing water. Generally, GI also maintains water in ponds, wetlands or vegetation for a longer period with a consequent increase in ETP. In wet climates, the consequent increase in soil water storage capacity potentially reducing flooding. In semi-arid catchments and dry climates, forests will also increase ETP (again, with positive potential impacts for flood hazard reduction), but it will also decrease the global water budget with a lower long-term groundwater recharge. This can be critical in locations where water availability is a priority.<br><br>Furthermore, ETP is an important mechanism within the hydrological cycle. Its promotion by unsealing soils or replanting trees is therefore essential. |
| **11. Run-off control** | Run-off control consists of reducing the peak flow to a level below flooding (levelling-off of peak flow). Run-off, especially from roads or intensively-used agricultural land, also leads to the pollution and eutrophication of rivers. NWRM aim to reduce peak flow run-off by: enhancing infiltration; slowing the flow; or creating buffers for storing run-off water gradually released after rainfall.<br><br>Run-off and mudflow can also be limited by increasing infiltration, thus increasing soil water content. The infiltration rate depends on soil texture, land use, soil fertility, etc. When the rain exceeds the infiltration rate, water remains on the ground where it is stored in pools and sinks or is channelled downhill (Emery, no date). The excess water run-off increases the risk of flooding with sediment transport leading to mudflows. |
| **12. Groundwater replenishment (aquifer storage)** | The slow infiltration of rainfall through the soil is essential for replenishing groundwater. The amount of rainfall that recharges groundwater varies, depending on the slope, soil and vegetation. Elimination of vegetation decreases the soil's ability to hold and process water and may therefore decrease groundwater recharge. All measures that improve infiltration of the soil also improve groundwater replenishment. |
| **13. Land-use change** | The current land-use used affects the water-holding capacity of the soil. Some kinds of land-use can impede the infiltration of water into the soil (e.g., soil sealing in urban areas). Other land uses decrease the quality of the soil (e.g., intensive agriculture with pesticides or soil compaction). Moreover, agricultural land-use and land-take for urban settlements produce a high pressure on the availability of land for NWRM. Vegetative groundcover, on the other hand, offers a number of important advantages, including reducing raindrop impact, slowing run-off velocity, reducing erosion, helping to absorb water, and holding soil in place. Planned, integrated land-use is therefore of utmost importance for water management. |
| **14. Erosion control** | In general, soil erosion is caused by rainfall. The impact of rainfall causes particles of soil to be detached, and they can then be washed away by surface run-off. Surface run-off begins when the soil is saturated and can no longer absorb the falling rain. Scouring of the exposed soil by run-off can cause further erosion. The selection of the appropriate NWRM for soil conservation should be based on protecting soil from rainfall, slowing run-off, improving infiltration in the soil and sediment control by spreading, ponding or filtering. Some of the erosion and sediment control measures are temporary (crop practices, tillage, early sowing) while others are permanent. |

| Assessment criteria | Description |
|---|---|
| **15. Landscape storage capacity** | The landscape water storage capacity refers to the water available in the floodplain's landscape features. Especially during floods, the landscape can store large volumes of water in wetlands or floodplains. Other landscape features that can store water - permanently or not, depending on their outflow rate - include basins and ponds, lakes and wetlands. Rivers and streams also store water, but they discharge this water constantly and faster than more static landscape water features. |

## 3.5 Assessment of the benefits and co-benefits of the 21 measures

The costs, benefits and co-benefits that NWRM cause or provide indicate the efficiency and utility of the measures to society and nature. Some NWRM can represent a significant cost to communities; however, these costs should be weighed against the various benefits that they also provide.

To carry out a cost-benefit analysis, aggregated costs and benefits must be determined. Central to this are the estimates of the total benefits and full costs to society; all relevant costs and benefits must be expressed in monetary terms. Determination of costs is normally relatively easy since market prices do exist or could be extracted from comparative projects. For benefits, however, the task is more complicated. It is difficult to estimate in monetary terms the cost-effectiveness - or efficiency - of these measures. There are many methodological and data challenges to assess and value these benefits.

### 3.5.1 Identification of benefit and co-benefit assessment criteria

The main goal of implementing appropriate NWRM is to reduce surface run-off after rainfall events in order to reduce flood risk. The related advantages are numerous, and include reduced erosion and leaching, as well as increased groundwater recharge and climate regulation (Pichler *et al*.,, 2009; Forest Research, 2010).

The Millennium Ecosystem Assessment (MEA) framework is a widely accepted method of categorising ESS (TEEB, 2010); other studies on ESS valuation, such as The Economics of Ecosystems and Biodiversity (TEEB) have adapted this framework. The MEA framework captures the full range of environmental impacts and highlights the value of environmental services instead of focusing on the value of environmental damage. It recognises four categories of services: supporting (e.g., nutrient cycling, soil formation and primary production); provisioning (e.g., food, fresh water, wood, and fibre and fuel); regulating (e.g., climate regulation, flood and disease regulation, and water purification); and cultural (aesthetic, spiritual, educational and recreational). While the MEA considers all benefits as "ecosystem services", the TEEB distinguishes between a 'good' and a 'service' (Haines-Young, and Potschin, 2010), and acknowledges "the direct and indirect contribution of ecosystems to human well-being". Table 5
shows the typology of goods and services proposed by the TEEB.

**TABLE 5**
**TEEB TYPOLOGY OF ESS**[12]

| | |
|---|---|
| **PROVISIONING SERVICES** | |
| 1 | Food (e.g., fish, game, fruit) |
| 2 | Water (e.g., for drinking, irrigation and cooling) |
| 3 | Raw materials (e.g., fibre, timber, fuel wood, fodder, fertilizer) |
| 4 | Genetic resources (e.g., for crop-improvement and medicinal purposes) |
| 5 | Medicinal resources (e.g., biochemical products, models and test-organisms) |
| 6 | Ornamental resources (e.g., artisan work, decorative plants, pet animals, fashion) |
| **REGULATING SERVICES** | |
| 7 | Air quality regulation (e.g., capturing (fine) dust, chemicals, etc.) |
| 8 | Climate regulation (incl. C-sequestration, influence of vegetation on rainfall, etc.) |
| 9 | Moderation of extreme flows (storm protection and flood prevention) |
| 10 | Regulation of water flows (e.g., natural drainage, irrigation and drought prevention) |
| 11 | Waste treatment (especially water purification) |
| 12 | Erosion prevention |
| 13 | Maintenance of soil fertility (incl. soil formation) |
| 14 | Pollination |
| 15 | Biological control (e.g., seed dispersal, pest and disease control) |
| **HABITAT SERVICES** | |
| 16 | Maintenance of life cycles of migratory species (incl. nursery service) |
| 17 | Maintenance of genetic diversity (especially in gene pool protection) |
| **CULTURAL AND AMENITY SERVICES** | |
| 18 | Aesthetic information |
| 19 | Opportunities for recreation and tourism |
| 20 | Inspiration for culture, art and design |
| 21 | Spiritual experience |
| 22 | Information for cognitive development |

The TEEB also proposes tools to help incorporate the values of nature into decision-making. The European Environmental Agency (EEA) published a report in 2011 presenting an overall experimental framework for ecosystem capital accounting (EEA, 2011), based on the Common International Classification of Ecosystem Services (CICES). The project aimed to frame ecosystem accounts and identify indicators and aggregates that could be used and integrated into national accounting systems.

Following the TEEB approach, the NWRM study has adopted 10 main categories of benefits and co-benefits relevant to NWRM (see Table 6). Due to their multi-functionality and ecosystem focus, NWRM can enhance multiple ESS and, as GI,

[12] Source: De Groot *et al*., 2010.

perform several ecosystem functions in the same spatial area. The criteria chosen to assess the related benefits and co-benefits were based on the effect of NWRM on these services.

**TABLE 6**
**CRITERIA TO ASSESS THE BENEFITS AND CO-BENEFITS OF NWRM**

| Assessment criteria (ESS) | **Description** (based on de Groot *et al*., 2002 and the MEA, 2003) |
|---|---|
| **16. Flood hazard reduction** | NWRM reduce the magnitude and timing of the damage caused by run-off or flooding, as they delay and mitigate the peak flow. For example, the storage capacity and surface resistance of the vegetative structure of floodplain forests can alter the potentially catastrophic effects of floods. |
| **17. Food/fibre/ fuel** | Photosynthesis and nutrient uptake by autotrophs convert energy, carbon dioxide, water and nutrients into a wide variety of carbohydrate structures, which secondary producers then use to create an even larger variety of living biomass. This broad diversity in carbohydrate structures provides many goods for human consumption, ranging from food and raw materials to energy resources and genetic material. NWRM vegetation, such as buffer strips and forests produce valuable biomass. |
| **18. Soil quality improvement** | NWRM and their vegetative cover (e.g., forest and agricultural measures) play an important role in soil formation (weathering of rock, accumulation of organic matter) and retention (role of vegetation root matrix and soil biota). Such services maintain soil fertility, agricultural productivity and prevent damage due to soil erosion. |
| **19. Water quality regulation** | NWRM (e.g., wetland, lakes, rivers) help filter out and decompose organic waste introduced into inland waters and assimilate and detoxify compounds through soil and subsoil processes. The water cycle through ecosystems is essential for living organisms. |
| **20. Water availability/ quantity** | NWRM play an active role in retaining and storing fresh water in aquifers. Benefits include providing water for human consumption (e.g., drinking, irrigation, and industrial use). Fresh water in rivers is vital for the survival of other species. Changes in land cover strongly affect aquifer recharge, including, in particular, the water storage potential of the system. This is distinct from disturbance regulation insofar as it maintains ‘normal’ conditions in a watershed and does not prevent extreme hazardous events. |
| **21. Air quality** | NWRM (e.g., green roofs and forests) both input chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality. The gas regulation function maintains clean and breathable air, and prevents diseases (e.g., skin cancer). |
| **22. Climate regulation** | NWRM (e.g., wetlands, forests) affect climate both locally and globally. At the local scale, for example, changes in land cover affect temperature and precipitation. At the global scale, ecosystems affect the climate by either sequestering or emitting greenhouse gases. |
| **23. Ambient air temperature** | Reflectance properties of ecosystems and ETP are also important in determining weather conditions. The heat island effect is a temperature phenomenon in which buildings absorb heat, especially those with dark roofs and non-reflective surfaces; then, the heat absorbed from sunlight is released into the surrounding atmosphere. Vegetative cover (e.g., green roofs) is a way to combat the heat island effect. Benefits for communities include decreasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and improving water quality. |

| **Assessment criteria (ESS)** | **Description** (based on de Groot *et al*., 2002 and the MEA, 2003) |
|---|---|
| **24. Cultural services** | Non-material benefits from NWRM include spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. |
| **25. Provision of habitat** | NWRM provide or sustain refuges and reproduction habitats for aquatic fauna and flora (in ponds, lakes and wetlands) and terrestrial wild plants and animals (in forests, urban or agricultural land) and thereby contribute to the *in situ* conservation of biological and genetic diversity and evolutionary processes. |

Ecosystems provide bundles of ESS that interact with one another in a dependent and nonlinear fashion. Decisions to exploit a particular ESS affect the type, magnitude, and mix of services provided by that ecosystem. ESS trade-offs may have negative consequences for the people dependent on them, and together with the associated erosion of biodiversity, can ultimately undermine the optimisation of the ESS. The MEA presents evidence of the trade-offs in the global bundle of ESS and human well-being. It demonstrates that over the past 50 years, enhancements in four of the 24 ESS assessed by the MEA (crop production, livestock production, aquaculture and carbon sequestration) have largely come at a cost to 15 other services assessed (mostly regulating and supporting services). The MEA concludes that many of these declines are characteristically nonlinear and abrupt, impact the poorest people, and are often a cause of poverty.

Potential trade-offs between water retention and other ESS are particularly stark in regions where water is scarce, biodiversity values are high, and/or the biomass of native vegetation is lower than that which the landscape can sustain. Understanding these trade-offs between ESS is a necessary precondition to sensible decision-making about when and where NWRM are economically and ecologically justified land-use options. The internalisation of environmental values into economic markets is an essential step towards the sustainable use of environmental resources. However, the internalisation of some environmental values but not others (e.g., biodiversity and scenic values) can lead to suboptimal outcomes. This study has not internalised the benefits of NWRM because of a lack of adequate data.

### 3.5.2 Assessment of the benefits and co-benefits

As mentioned above, there was little information allowing a monetisation of the benefits. In addition, the final results of the JRC modelling exercise were not available, which significantly reduced the possibilities for assessing the benefits of these measures. Therefore, a qualitative assessment was undertaken, based on the sources of information, principally the 153 sources already mentioned. The results were recorded in 21 Fact Sheets, one per measure (see Annexes 2-12).

Annex 15 provides a brief methodology of the quantification of benefits resulting from the implementation of NWRM that would have been followed had the modelling results been available.

## 3.6 Calculation of the aggregated costs of the modelled measures

The following sections describe the methodology of calculating the aggregrated costs of the 16 NWRM that were to be modelled by the JRC.

### 3.6.1 Identification of the key cost components

The cost of any NWRM depends largely on the nature of the measure itself, as well as site conditions and the drainage area. This study initially identified five main categories of cost components:

1. Land requirement: Acquisition and compensation;
2. Construction and rehabilitation: Investment, design and contingency;
3. Construction and rehabilitation: Operation and maintenance;
4. Administrative costs: Enforcement costs, monitoring, extension of networks; and
5. Other costs.

Table 7 presents more details on each of these types of costs.

**TABLE 7**
**CRITERIA TO ASSESS THE COSTS OF NWRM**

| Assessment criteria | Description |
|---|---|
| **25. Land requirement: Acquisition and compensation** | Some NWRM require land acquisition, and some can be supported by a land compensation scheme or service payments. These two approaches imply different types of costs.<br>Land acquisition costs vary greatly from site to site, and depending on the amount of land required, as in urban areas, for example, land must be set aside for both grey and GI. In urban conditions, bio-retention areas and swales can be incorporated into landscaping, in rights-of-way along roadsides, and in or adjacent to car parks.<br>Agriculture and forest land occupy a large part of watershed areas. Therefore, stakeholders such as farmers are key actors in the implementation of a combination of practices consistent with natural water retention objectives. The adoption of these types of agricultural practices requires financial incentives and investments in extension networks. In this framework, enforcement costs (described below) rely on strategies and policies favouring private initiatives which will provide public services. |
| **26. Construction and rehabilitation: Investment, design and contingency** | The base capital costs refer primarily to the cost of constructing/implementing the NWRM. Capital costs include new investments, their depreciation allowance and the opportunity cost of capital. Construction costs also cover rehabilitation costs if needed. As most of the NWRM require careful planning, design costs should also be taken into account. |

| Assessment criteria | Description |
|---|---|
| **27. Construction and rehabilitation: Operation and maintenance** | According to Wateco, 2003, operating costs are incurred to keep an environmental facility running (e.g., material and staff costs) while maintenance costs are incurred for maintaining existing (or new) assets in good functioning order until the end of their useful life.<br>Differences in maintenance requirements should also be considered when comparing costs. Following USEPA, 1999, maintenance can be broken down into two primary categories: aesthetic/nuisance maintenance and functional maintenance. Functional maintenance is important for performance and safety reasons, while aesthetic maintenance is important for public acceptance. |
| **28. Administrative costs: Enforcement costs, monitoring, extension of networks** | Administrative costs consist of monitoring and enforcement costs. Monitoring and enforcement includes monitoring and inspections by enforcement authorities (Cohen, 1999) as well as incentives (tax reduction and/or subsidies); note that land compensation is not be counted here as it was already considered above (under 25). If in theory the costs of incentives (subsidies, lower premiums or taxes) are compensated by other benefits or lower costs, they are nonetheless costs which will be borne by society. Public spending might also be allotted to extension networks, which would promote the adoption of NWRM. |
| **29. Other costs** | Other costs include productivity losses (e.g., loss of agricultural production that would not otherwise be compensated), environmental risks (e.g., risk of ground water contamination in high percolation areas or risk of mosquitoes and pest breeding) and cost savings including:<br>• Reducing grey infrastructure;<br>• Energy savings; and<br>• Material with increased life cycle. |

The 153 sources of information were reviewed for information on these criteria. The results are presented in 21 Fact Sheets, one per measure (see Annexes 2-12).
The first two cost components above (land and investment, design, and contingency) can both be grouped under a single "Investment" category. Similarly, the last three components (operation and maintenance, administrative, and others) can be grouped under "Operation and maintenance" (O&M) (see Table 8). For the purpose of the cost assessment in this study (see Section 4) only these two broader categories are considered.

**TABLE 8**
**CROSS-REFERENCE BETWEEN COST COMPONENTS AND COST CATEGORIES**

| Cost category | Cost component |
|---|---|
| Investment | 1. Land requirement: Acquisition and compensation |
| | 2. Construction and rehabilitation: Investment, design and contingency |
| O&M | 3. Construction and rehabilitation: Operation and maintenance |
| | 4. Administrative costs: Enforcement costs, monitoring, extension of networks |
| | 5. Other costs |

This is a typical way of presenting costs and is based on the timing of cost incurrence. Investment costs occur once at the start of implementation of the measure. Usually, the amount is fairly large and involves the purchase and installation (or planting) of equipment and GI (e.g., trees). O&M costs, on the other hand, are usually incurred on a regular basis over the lifetime of the investment; in some cases, they are incurred continuously (e.g., electricity). The cost assessment in Section 4 has assumed that O&M costs are incurred once a year.

### 3.6.2 JRC land-use simulations

The JRC has modelled five land-use changes resulting from the implementation of 16 of the NWRM identified by this study, as well as two baseline scenarios (in 2006 and 2030, reflecting 'business as usual') for reference purposes (see Annex 16).

This section presents the assumptions and model used for these simulations. The results of the modelling (specifically the impacts on floods) were not however available. Therefore, the analysis is based only on the aggregated costs associated with the land-use changes, but not the benefits as the impacts are not known.

The five land-use scenarios are:

1. Forest;
2. Urban;
3. Agriculture;
4. Storage in river basin; and
5. Storage alongside rivers.

These scenarios are further subdivided into 10 sub-scenarios (see Table 9), which cover 16 of the 21 NWRM. The remaining five NWRM (A7, S3, S5, S6, and S7) were not modelled; as a result, their costs were only assessed qualitatively based on the available literature.

**TABLE 9**
**CROSS-REFERENCE BETWEEN THE SCENARIOS AND THE 16 SIMULATED NWRM**

| Simulated scenarios | | NWRM measures | |
|---|---|---|---|
| **1 Forest** | 1.1 Riparian Forest | F2 | Maintaining and developing riparian forests |
| | 1.2 Reforestation | F1 | Continuous cover forestry |
| | | F3 | Afforestation of agriculture land |
| **2 Urban** | 2. Urban | U1 | Filter strips and swales |
| | | U2 | Permeable surfaces and filter drains |
| | | U3 | Infiltration devices |
| | | U4 | Green roofs |
| **3 Agriculture** | 3.1 Grassland | A1 | Restoring and maintaining meadows and pastures |

| Simulated scenarios | | NWRM measures | |
|---|---|---|---|
| | 3.2 Buffer strips | A2 | Buffer strips |
| | 3.3 Grassed waterways | A2 | Buffer strips |
| | 3.4 Crop practices | A3 | Soil conservation crop practices |
| | | A4 | No or reduced tillage |
| | | A5 | Green cover |
| | | A6 | Early sowing |
| **4 Storage in river basin** | 4. Buffer ponds | S1 | Basins and ponds |
| **5 Storage alongside rivers** | 5.1 Wetlands | S2 | Wetland restoration and creation |
| | 5.2 Re-meandering | S4 | Re-meandering |

The JRC used the Land Use Modelling Platform (LUMP) to determine the spatial distribution of land-use classes. LUMP was developed to support the policy needs of different services of the EC. The land use/cover model EUClueScanner (EUCS100), developed in collaboration with DG ENV, is the core component of the platform, linking specialised models and data within a coherent workflow (Lavalle *et al.,* 2011). This set of specialised models and data can be divided into two main categories: those driving the land use model (*land use demand*) and those quantifying the impacts of land use change (*indicators*). Water retention measures and land use scenarios were fully integrated, even for the baseline scenario.

#### 3.6.3 Calculation of costs of the modelled measures

Due to the nature of NWRM themselves, and the information on which this study is based, the costs calculated in this report are "broad-brush" estimates with large uncertainties. Furthermore, the costs presented in this report are calculated at the national level. An analysis at the watershed level might have been more accurate, but it would have required more time and resources than were available. Finally, as explained above, this study also expected to provide quantitative estimates of the benefits of NWRM; however, this was not possible as the JRC modelling results were not available. The estimates provided nevertheless provide an idea of the order of magnitude of the costs; as such, they should provide sufficient information for decision-makers to base policy recommendations upon, which is the ultimate goal of this study.

The rest of this section presents in more detail the assumptions used for the analysis and the results.

For each of the simulated scenarios, the incremental surface area (difference between surface area under scenario in 2030 and surface area in 2030 baseline (i.e., without scenario)) was multiplied by a unit cost or benefit to obtain a total cost or benefit. The cost estimate was based on four steps:

1. Review the sources of information for data and figures on the unit costs of the modelled measures;

2. Estimate the incremental surface area in each Member State in 2030 that will result from the implementation of the simulated scenario;
3. Estimate the unit costs of each scenario (see Table 10 and Section 4); and
4. Estimate the incremental cost of each scenario in each Member State by multiplying the unit cost by the incremental surface area.

In general, the unit investment cost is a large amount of money that will be invested in the first year (see Table 10); subsequent smaller amounts are then incurred annually to operate and maintain the investment. In some cases (e.g., grassland), there are no annual costs. In other cases (i.e., buffer strips and grass waterways), the investment is relatively low, but the annual costs are much higher, almost 10 times higher. For crop practices, there is no investment, just an annual cost. The unit costs in Table 10 correspond to the unit costs at the EU level; Section 4 provides more details on the calculations of these unit costs.

**TABLE 10**
**UNIT COSTS BY SCENARIO**

| Scenario | Investment unit cost (€/ha) | Operation and maintenance unit cost (€/ha/year) |
|---|---|---|
| 1.1 Riparian forests | 7,527 | 502 |
| 1.2 Reforestation | 3,310 | 500 |
| 2. Urban | 469,362 | 30,647 |
| 3.1 Grassland | 0 | 371 |
| 3.2 Buffer strips | 48 | 509 |
| 3.3 Grass waterways | 48 | 509 |
| 3.4 Crop practices | 0 | 81 |
| 4. Buffer ponds | 53,360 | 58 |
| 5.1 Wetlands | 15,776 | 348 |
| 5.2 Re-meandering | 610 | 2 |

There was not enough information in the sources of information reviewed to determine whether the unit costs estimated for each scenario depend on the size of the measure (e.g., number of hectares of riparian forests). Economies of scale that characterise the construction of grey infrastructure (i.e., a large industrial facility costs less than a small one to build per unit of produced output) will also apply to NWRM, but probably to a lesser extent because these measures are usually more labour-intensive than machine-intensive. In any case, the unit costs in Table 10 reflect the costs of implementing typical sizes of NWRM in various Member States. None of the sources reviewed in the literature mentioned possible economies of scale.

In addition, even if there had been information in the literature allowing the construction of cost curves reflecting economies of scale, it would not have been possible to use them in this study because the simulated scenarios do not provide any breakdown on the distribution of the size of the incremental surface areas. In other words, it is not possible to know whether the simulated land-use changes correspond to a large number of small areas or to a small number of large areas.

The analysis was further complicated by the fact that the investment costs are incurred in various years between 2011 and 2030 and the maintenance costs between 2012 and 2060. In the absence of any information from the simulations, it was assumed that these investment costs are equally distributed over 2011-2030. The incremental cost of the scenario is equal to the present value (expressed in 2011 EUR and calculated with a 5% real discount rate) of the investment costs incurred in each year between 2011 and 2030 and the maintenance costs incurred between 2012 and 2060 (real discount rate of 5%). The rate of 5% is recommended in the guidance for cost-benefit analysis that must be conducted for major projects co-financed by the Cohesion and Structural Funds.

In a given year, the present value of the investment cost equals the discounted unit cost multiplied by the incremental surface area, as explained above. The maintenance cost corresponding to this investment equals the present value of the unit maintenance costs incurred in the 30 years of the investment's lifetime and multiplied by the incremental surface area. All discounting calculations until 2030 carried out, Member State by Member State, and for each NWRM, are recorded in two linked Excel models (see Annex 17).

To estimate the costs in each Member State, this study has adjusted the unit costs in Table 10 with the Comparative price levels of final consumption by private households including indirect taxes provided by Eurostat (see Table 11).

**TABLE 11**
**COMPARATIVE PRICE LEVELS BY EU MEMBER STATE**[13]

| Member state | Comparative price level |
|---|---|
| Austria | 106.2 |
| Belgium | 111.4 |
| Bulgaria | 50.8 |
| Cyprus | 89.1 |
| Czech Republic | 75.2 |
| Denmark | 142.3 |
| Estonia | 74.8 |
| Finland | 123.5 |
| France | 110.8 |
| Germany | 104.3 |
| Greece | 95.1 |

13 Eurostat. http://epp.eurostat.ec.europa.eu/tgm/download.do;jsessionid=9ea7d07d30f0f1c6a4711ff24a9a97b0e312dee9e58e.e34OaN8PchaTby0Lc3aNchuMbxiNe0?tab=table&plugin=1&language=en&pcode=tsier010

| Member state | Comparative price level |
|---|---|
| Hungary | 64.9 |
| Ireland | 119.1 |
| Italy | 103.5 |
| Latvia | 72.2 |
| Lithuania | 65.1 |
| Luxembourg | 120.5 |
| Malta | 77.9 |
| Netherlands | 107.6 |
| Poland | 61.9 |
| Portugal | 88.2 |
| Romania | 58.8 |
| Slovakia | 71.6 |
| Slovenia | 84.6 |
| Spain | 97.0 |
| Sweden | 121.6 |
| United Kingdom | 100.2 |
| EU 27 | 100.0 |

Indirect land-use change (ILUC) from any form of new demand on land resulting from the implementation of one or several NWRM can induce several economic, social, and environmental effects. ILUC results in displacement effects, including price-induced changes in global commodity markets, which, in turn, also lead to land being altered from one state to another. Estimating an overall net ILUC value for a specific NWRM involves complex modelling that is beyond the scope of this study.

## 3.7 Identification of no-regret measures

The most important aspects of no-regret measures are the flexibility of the measures and the fact that the measures will bring benefits no matter what climate changes might occur (if any). In addition, another very relevant aspect of no-regret measures is linked to their multi-purpose characteristics: in the context of NWRM, no-regret measures bring various benefits.

Based on the available information, this study assessed all of the 21 NWRM (either in groups or measure-by-measure) against the above no-regret characteristics to determine which NWRM can be considered as no-regret measures. The questions asked during the assessment are in Table 12; a measure should ideally answer yes to all questions to be considered a no-regret measure. These no-regret aspects have been identified by the World Bank[14], the Lasser *et al*., 2009 and World Water

[14] http://climatechange.worldbank.org/climatechange/content/adaptation-guidance-notes-key-words-and-definitions and http://www.unpei.org/PDF/resourceefficiency/KM-resource-MainstreamingGN6WB.pdf.

Council, Cooperative Programme on Water and Climate, IUCN, 2009. The results of the assessment are in Section 4.

**TABLE 12**
**NO-REGRET ASSESSMENT**

| No-regret aspects | Assessment questions |
|---|---|
| 1. Future climate change scenarios | Does the measure need to be based on accurate climate change data or detailed climate models? |
| 2. Timing | Can the measure be implemented immediately, since it does not depend on the analysis of the climate change impacts and effects on the hydraulic cycle? |
| 3. Planning horizon | Can the measure be implemented in a short-term planning horizon and therefore modified if the scenarios change? |
| 4. Flexibility | Can the measure be easily modified, without high cost, to changing circumstances? |
| 5. Risks (cost effective and beneficial measures) | Is the measure cost-effective and beneficial no matter climate change impacts? |
| 6. Local and regional scale | Can the measure be implemented on a local or regional scale? |
| 7. Economic analysis | Does the measure take into account future water supply and demand scenarios in view of the different climate change scenarios? |

### 3.8 Assessment of EU policies

One of the objectives of this study is to analyse the potential implementation barriers or critical success factors for NWRM in EU policies - with a specific emphasis on water policy, biodiversity policy, the CAP and adaptation policies - leading to practical recommendations and EU policy implications.

The study has identified the potential of the most relevant current EU legislation, policy and strategy documents and EU funding instruments to promote NWRM:

1. Water Framework Directive (WFD);
2. Floods Directive;
3. Biodiversity and nature policy;
4. Common Agricultural Policy (CAP);
5. LIFE+ programme;
6. Cohesion and Structural funds; and
7. Water Scarcity and Droughts Strategy.

This study defines a barrier as an obstacle posed by an EU policy or funding instrument that prevents or impedes a measure from being implemented. There are several types of barriers to implementing NWRM through EU policies: The results of this assessment are used to outline various policy recommendations in order to promote the uptake of NWRM at EU level and overcome barriers to their implementation.

The study provides an overview of the relevant of each policy or funding programme to NWRM. For each policy or funding programme, the study then identifies the weaknesses and opportunities for the implementation of NWRM. A weakness is defined as an impediment posed by the policy to implement a NWRM. Potentially, if this issue is changed, a better uptake of NWRM at EU level could be achieved. On the other hand, an opportunity is defined as a critical success factor that is necessary for the implementation or promotion of a measure through EU policies or funding instruments. It can also be seen as an opportunity presented in these instruments that could be taken advantage of for a better uptake of NWRM at EU level.

Finally, for each policy or funding programme, the study provides suggestions for improving the promotion of NWRM. This assessment incorporates the current promotion of NWRM, by group of measures or measure-by-measure, in the policy or funding programme. The study then suggests means of improvement.

Each section ends with an overview of the policy recommendations for that policy or funding programme. The results are presented in Section 5.

# 4. RESULTS OF THE ASSESSMENT OF MEASURES

This section presents the assessment of each of the measures or group of measures. The following sections present the results for each of the measures or groups of measures as follows:

1. **Forest measures** (F1, F2 and F3) reported together, corresponding to the simulated Forest scenarios which models them together;
2. **Urban measures** (U1, U2, U3 and U4) reported together, corresponding to the simulated Urban scenario which models them together;
3. **Agricultural measures** (A1, A2, A3, A4, A5 and A6) reported together, corresponding to the simulated Agriculture scenario which models them together;
4. **Traditional terracing** (A7) which is an agriculture measure, but it is reported alone, as it was not modelled;
5. **Storage in the river basin – buffer ponds** (S1), corresponding to the simulated Buffer ponds scenario;
6. **Storage alongside rivers – wetlands restoration and creation** (S2), corresponding to the simulated Wetlands scenario;
7. **Storage alongside rivers – floodplain restoration** (S3) reported alone, as it was not modelled;
8. **Storage alongside rivers – re-meandering** (S4) corresponding to the simulated Re-meandering scenario;
9. **Restoration of lakes** (S5) reported alone, as it was not modelled;
10. **Natural bank stabilisation** (S6) reported alone, as it was not modelled; and
11. **Artificial groundwater recharge** (S7) reported alone, as it was not modelled.

For each of these 11 measures or groups of measures, each section begins with a description of the measure(s), followed by the results of the assessments of each measure or group of measures:

- The conclusions of the assessment of the applicability of the measure or group of measures;
- The conclusions of the assessment of the effectiveness of the measure of group of measures;
- An overview of the benefits and co-benefits of each measure;
- A cost assessment for those measures that were modelled; and
- A discussion of the no-regret aspects of each measure.

The findings and conclusions are limited to the scope and resources available to this study.

## 4.1 Forest measures[15]

Forests and woodland facilitate water retention and therefore have the potential to reduce the effects of flooding and drought. However, despite the significant advances in scientific understanding of forest and water interactions, the role of forests in the sustainable management of water resources remains contentious. Uncertainty, and in some cases, confusion, persist because of difficulties in transferring research findings to different countries and regions, different watershed scales, different forest types and species and different forest management regimes. In fact, according to Hümann *et al*., 2011, run-off generation and water retention depend mainly on site-specific conditions and soil properties, which have a higher influence on run-off generation than forest types.

### 4.1.1 Applicability of the forest measures

According to the information available to the NWRM study, the forest measures can be implemented in all EU climate zones. The afforestation of agricultural land is restricted to agricultural land (Corine Land Cover (CLC) level 1: 2. Agricultural areas), while riparian forests are planted in the riparian zones of streams and rivers and CCF in forest land (CLC 1: 3. Forests and semi-natural areas).

The information on the location of the measures in the river basin is inconclusive. Nisbet and Thomas, 2006 indicate that forests are more effective for flood control at the headwater or small catchment level, but modelling suggests that the floodplain woodland can reduce extreme flood events at the large catchment scale. However, this should be tested in practice. According to the Forest Research (no date) planting riparian forests on the main course has more impact than planting them in tributaries.

There is little direct information on appropriate soil conditions. The UK forestry Commission indicates that CCF should be implemented on deep rooting soils to guarantee tree stability, as trees in wet or shallow rooting are prone to wind damage (Mason *et al*., 1999). The UK Forests and Water Guidelines suggest average buffer widths for different channels and suggests doubling the buffer widths on very erodible soils (Broadmeadow and Nisbet, 2004).

Concerning topography, CCF should be implemented on dry and sheltered sites (Mason *et al*., 1999 and UK Environment Agency, 2006); in highlands, CCF should be implemented on sites without wind-throw risk. Broadmeadow and Nisbet, 2004 indicate that the effectiveness of riparian areas for sediment attenuation is greatly reduced on slopes above 4°.

### 4.1.2 Direct impacts of the forest measures

There is little evidence of the impact of the forest measures on soil moisture. Messing *et al*., 1997 detect differences between soils under tree crops and field crops, especially regarding soil macroporosity and the soil water retention

[15] The Fact Sheets for the three forest measures are in Annex 2.

characteristics (or pore size distributions) on lighter textured soils. According to Hümann *et al*., 2011, forest ETP builds up soil moisture deficits.

Riparian forests affect water temperature in the river and streams. According to Broadmeadow and Nisbet, 2004, a riparian woodland 15-70 metres wide will maintain optimal water temperature, while too much shade can have negative impacts. The shade from riparian forests may help aquatic life adapt to climate change, as it helps reduce thermal stress (Calder *et al*., 2007).

There is limited information on the impact of the forest measures on ETP. Sabater and Bernal, 2011 suggest that riparian forests' access to water resources allows the continuous ETP of riparian trees, keeping levels of relative air humidity high. According to various measures and modelling studies, reforestation and afforestation increase ETP. Wattenbach *et al.*, 2007 confirm this through modelling, suggesting that 100% afforestation of abandoned arable land increases the mean annual ETP by 3.7%. Hümann *et al*., 2011 report that forests' interception and transpiration are below the precipitation amounts of storm rainfall events.

Forests can reduce or slow down run-off, but it is unclear to what extent. For Nisbet and Thomas, 2006, the improved run-off capacity of forest soils is due to the presence of a network of macropores that help transmit water quickly to depth; run-off control is more effective in dry conditions unless the soil has become hydrophobic. According to Rosenqvist *et al.*, 2009, the maximum run-off reductions after grassland afforestation occur about 10-20 years after planting. The modelling results of Wattenbach *et al.*, 2007 show that afforestation has a moderate impact on the mean annual run-off, but alters the peak flow (maximum run-off) dramatically; however, these modelling results need to be tested in practice. For Hümann *et al*., 2011, run-off generation and water retention depend mainly on site-specific conditions and soil properties, which have a higher influence on run-off generation than forest type.

The network of macropores in forested soils may help replenish groundwater aquifers more rapidly, as shown in the modelling results of Wattenbach *et al.*, 2007: they shown an increase of the mean annual groundwater recharge from 1.4% (10% afforestation) to 9.8% (100% afforestation). However, Calder *et al*, 2007, Sabater and Bernal, 2011 and Rosenqvist *et al.*, 2010 conclude that forests reduce groundwater recharge. In fact, according to Sabater and Bernal, 2011, dense riparian canopies can provoke hydraulic stress and decrease stream discharge or even promote streamflow intermittency in semi-arid catchments during drought periods. Rosenqvist *et al.*, 2010 confirm that a shift from cropland to forest reduces water recharge.

There is very little explicit information on land-use change; for Nisbet and Thomas, 2006, soils at risk of structural damage such as surface capping and shallow compaction would benefit most of a land-use change to woodland. Other sources also imply that a change from agriculture to woodland/forest would have positive impacts.

Sources agree that the root complex and the understory layer of riparian forests effectively protect against erosion (Broadmeadow and Nisbet, 2004 and Cermak *et al.*, 2002). Little information is however available on the impact of forest measures on the water storage capacity of the soil or landscape. For Nisbet and Thomas, 2006, the "sponge effect" of forests enhances the ability of soil to store rain water. According to Wattenbach *et al.*, 2007, trees make forests important for water storage, especially during convective rain events. Hümann *et al*., 2011 report that transpiration of tree stands increases soil moisture and storage capacity, but the latter is negligible when compared to the precipitation amounts of flood producing storms.

The NWRM study has identified three forest measures:

1. Continuous Cover Forestry (CCF) (F1);
2. Riparian forests (F2); and
3. The afforestation of agriculture land (F3).

The results of the benefits and cost assessments are presented below for each of these measures.

**Continuous Cover Forestry (F1)**

CCF maintains continuous woodland conditions, rather than periodically removing trees like clear-felling systems; therefore, there is no need to access them frequently with heavy machinery reducing the level and scale of disturbance.

***Benefits and co-benefits of CCF***

Lower soil disturbance, an increased interception rate and a higher water use together are likely to reduce the direct surface run-off (UK Environment Agency, 2006), thus improving water retention and flood mitigation. The reduction of soil disturbance and avoidance of clear-felling might also contribute to flood attenuation. CCF improves water quality by reducing the acidification of surface water caused by heavy rainfall on clear-felled sites (Stokes and Kerr, 2009). On the other hand, CCF may have a negative effect on water availability; however, there is a lack of data on these effects and more field and modelling studies are required. CCF could reduce nitrate leaching (Stokes and Kerr, 2009).

CCF with locally-adapted species also results in more diverse forests providing multi-purpose benefits. Co-benefits of CCF include a lower visual impact than clear-felling, and the correspondence to societal demands, such as recreation, protection and habitat creation. CCF also has a greater structural diversity and therefore potential benefits for wildlife (Willoughby *et al.,* 2009). Furthermore, Stokes and Kerr, 2009 concluded that CCF has a higher potential than even-aged stand management to increase *in situ* carbon stocks on suitable sites. The UK Environment Agency, 2006 also supports this conclusion. However, there is no evidence that CCF produces a higher yield than even-aged stands (Mason and Simpson, 2005). However, it can be more difficult to predict the yield of CCF and regulate it, as CCF might require prolonging the rotation for some trees (Mason and Simpson, 2005).

## Afforestation of agricultural land (F2)

The objective of **afforesting agricultural land** is to increase ETP, slow surface run-off and increase infiltration in the catchment.

Afforesting agricultural land refers to developing a forest stand on former agricultural areas.

### *Benefits and co-benefits of afforestation of agricultural land*

Intensively used agricultural lands provide rather limited ecosystem functions, while in comparison forests might positively influence ETP, surface run-off and infiltration characteristics in the catchment. According to Wattenbach *et al*., 2007, trees alter the regional run-off characteristics by intercepting rain, thus reducing peaks in surface run-off and making forests important for water storage, especially during convective rain events. Afforestation also contributes to improving water quality as trees remove harmful nutrients. Van de Salm, C *et al*., 2005 concluded that after afforestation, N concentrations (and leaching) decreased due to a decreased input of N by fertilizers. However, there is also evidence that the leaching from newly established forests on previous agricultural land is higher than those from old-growth forests.

Forests and woodlands improve soil quality more than agricultural soils, due to a greater amount of organic matter, tree root complexes and soil fauna, less anthropogenic influence and an increase of the sponge effect (Nisbet and Thomas, 2006). Afforestation and reforestation generally decrease near-surface temperatures. According to Sabater and Bernal, 2011, conversion from grassland or cropland to forest decreases the albedo[16] and increases the Leaf Area Index (LAI), canopy roughness and rooting depth affecting the near-surface energy fluxes, which influence temperature and humidity. Compared to intensively-used agricultural sites, forests provide better habitat conditions for wildlife; they also contribute significantly to carbon sequestration.

## Riparian forests (F3)

**Riparian forests** can contribute to flood alleviation by delaying the downstream passage of flood flows, reducing the volume of run-off, and promoting rainfall infiltration into the soil, thereby reducing the rate of run-off.

Riparian forests are forested areas of land along water bodies (such as rivers, streams, ponds and lakes). They serve as an ecological transition zone between terrestrial and aquatic ecosystems. These zones are also defined as ecotones.

### *Benefits and co-benefits of riparian forests*

Riparian forests contribute to flood alleviation by delaying the downstream passage of flood flows and promoting rainfall infiltration into the soil, thereby reducing the rate and volume of run-off (Forest Research, 2010). However, especially for small streams, badly maintained riparian forests run the risk of overgrowing the water

[16] "Albedo is the fraction of Sun's radiation reflected from a surface. It is quantified as the proportion, or percentage of solar radiation of all wavelengths reflected by a body or surface to the amount incident upon it. An ideal white body has an albedo of 100% and an ideal black body, 0%". Source: The Encyclopaedia of Earth (http://www.eoearth.org/article/Albedo).

body. Woody debris, although beneficial for the improvement of roughness, can aggravate flood events by blocking passages and retaining water; it can also damage buildings and bridges. The main stream cannot drain the flood event as it is blocked by dead trunks or branches with autumn leaves acting like a natural dam that reduce the main course flow and increase the aside over flows. This can increase backwater and aggravate flood events.

The scale of the river catchment plays an important role when introducing riparian forests; in smaller catchments, riparian forests play an important role in flood mitigation while in larger catchments, this effect is diluted by other land uses and there is no more clear evidence of the riparian forest effect only. In the upper part of the river catchment, riparian forests often appear as rather narrow stretches, while in the lowland they cover wider areas. In any case, according to Forest Research (no date) (Slowing the Flow at Pickering), planting riparian forests on the main course has more impact than planting them in tributaries.

Riparian forests provide various ESS. According to Broadmeadow and Nisbet, 2004, a riparian woodland 15-70 metres wide will maintain optimal water temperature. Too much shade issuing from bad management or inappropriate species restoration, as well as part of natural cycles of the ecosystem itself, can have negative impacts as it can lead to a reduction of primary production in the stream. However, the shade from riparian forests may help aquatic life adapt to climate change, as it helps reduce thermal stress (Calder *et al*., 2007). Riparian forests also provide habitat and can act as wildlife corridors.

Riparian forests improve water quality; they can protect the river from over-fertilisation, very important for streams in intensively agricultural catchments. They help address diffuse pollution problems through run-off control, particularly when they form a buffer between the water course and agricultural land (Nisbet and Thomas, 2006; Broadmeadow and Nisbet, 2004; Sabater and Bernal, 2011; Kohler and Heinrichs, 2011; Forest Research, 2010).

A negative impact of riparian forests in semi-arid catchments and during droughts is their water use. Sabater and Bernal, 2011 suggest that riparian forests' access to water resources allows the continuous ETP of riparian trees keeping levels of relative air humidity high. Dense riparian canopies can provoke hydraulic stress and decrease stream discharge or even promote streamflow intermittency in semi-arid catchments during droughts. They conclude that riparian strips can deplete the water budget in arid areas or in summertime in semi-arid areas. Van der Salm *et al.*, 2005 support this: water recharge declines with an increase in forest cover, while it is generally larger also for coniferous forest compared to deciduous forests. However, these reductions in recharge vary from site to site due to differences in climate, site characteristics and under storey vegetation.

### 4.1.3 Cost assessment of forest measures

The unit costs are presented for the two types of forest plantation to be simulated by the JRC:

1. Riparian forests; and
2. Afforestation.

## Riparian forests (F2)

For Kohler and Heinrichs, 2011, the costs of creating riparian forests are "high" (between €100,000 and €1 million; they do not refer to any land unit or size, but state that the final amount of money depends on the scale of the measure). A project in the UK (Slowing the Flow at Pickering) incurred costs of £4,216 - 8,395/ha for implementing riparian woodland for the first five years. The NWRM adjusted this cost according to the comparative price levels in Table 11 above, resulting in an EU average cost of €7,527/ha[17] for five years. According to Kohler and Heinrichs, 2011, countryside management programmes in several alpine countries have given annual compensation payments of €289 - 715/ha (average of €502/ha per year) for renouncing land use because of riparian strips. Therefore, the NWRM study assumes two unit costs at EU level: investment of €7,527/ha and annual operation and maintenance of €502/ha/year (see Table 10).

The JRC modelled a total increase of riparian forests of 1,119,970 ha; most of this increase is in France, the UK and Italy (see Table 13). The present value of the costs for the 27 EU Member States is €11 billion, which corresponds to an annualised cost of €912 million, i.e., 0.01% of the Gross Domestic Product (GDP) or €1.82 per person and per year. As a percentage of GDP, this annual cost is the highest in Estonia (0.13% of GDP) and in Latvia (0.23%). The annual cost per person is the highest (above €14) in Latvia, Estonia and Finland.

**TABLE 13**
**COSTS OF RIPARIAN SCENARIO**

| Member State | Increase in surface area of riparian forests (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 57,723 | 0.65 | 53.40 | 284.4 | 8.4 | 0.02% | 6.36 |
| Belgium | 10,535 | 0.12 | 10.22 | 352.9 | 10.8 | 0.00% | 0.95 |
| Bulgaria | 31,544 | 0.17 | 13.96 | 36 | 7.6 | 0.04% | 1.84 |
| Cyprus | 1,898 | 0.02 | 1.47 | 17.5 | 0.8 | 0.01% | 1.84 |
| Czech Republic | 39,313 | 0.31 | 25.75 | 145 | 10.5 | 0.02% | 2.45 |
| Denmark | 13,109 | 0.20 | 16.25 | 234 | 5.5 | 0.01% | 2.95 |
| Estonia | 28,512 | 0.22 | 18.58 | 14.5 | 1.3 | 0.13% | 14.29 |
| Finland | 95,884 | 1.25 | 103.16 | 180.3 | 5.3 | 0.06% | 19.46 |
| France | 119,395 | 1.39 | 115.24 | 2,080.80 | 63.1 | 0.01% | 1.83 |
| Germany | 45,953 | 0.50 | 41.75 | 2,498.80 | 81.8 | 0.00% | 0.51 |
| Greece | 5,619 | 0.06 | 4.66 | 230.2 | 11.3 | 0.00% | 0.41 |
| Hungary | 30,999 | 0.21 | 17.53 | 98.4 | 10 | 0.02% | 1.75 |
| Ireland | 15,295 | 0.19 | 15.87 | 153.9 | 4.4 | 0.01% | 3.61 |
| Italy | 99,305 | 1.08 | 89.54 | 1,548.80 | 60.3 | 0.01% | 1.48 |
| Latvia | 66,002 | 0.50 | 41.51 | 18 | 2.2 | 0.23% | 18.87 |

17 Taking an average of £6305.5/ha and using an exchange rate of £1.00 = €1.20093. (http://www.oanda.com/).

| Member State | Increase in surface area of riparian forests (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Lithuania | 28,203 | 0.19 | 15.99 | 27.4 | 3.2 | 0.06% | 5.00 |
| Luxembourg | 852 | 0.01 | 0.89 | 41.6 | 0.5 | 0.00% | 1.79 |
| Malta | 2 | 0.00 | 0.00 | 6.2 | 0.4 | 0.00% | 0.00 |
| Netherlands | 5,019 | 0.06 | 4.70 | 591.5 | 16.6 | 0.00% | 0.28 |
| Poland | 81,243 | 0.53 | 43.81 | 354.3 | 38.2 | 0.01% | 1.15 |
| Portugal | 30,268 | 0.28 | 23.26 | 172.7 | 10.6 | 0.01% | 2.19 |
| Romania | 60,173 | 0.37 | 30.82 | 121.9 | 21.5 | 0.03% | 1.43 |
| Slovakia | 15,182 | 0.11 | 9.47 | 65.9 | 5.4 | 0.01% | 1.75 |
| Slovenia | 7,686 | 0.07 | 5.66 | 36 | 2 | 0.02% | 2.83 |
| Spain | 84,970 | 0.87 | 71.80 | 1,062.60 | 46 | 0.01% | 1.56 |
| Sweden | 52,479 | 0.67 | 55.59 | 346.7 | 9.3 | 0.02% | 5.98 |
| United Kingdom | 92,807 | 0.98 | 81.01 | 1,696.60 | 62 | 0.00% | 1.31 |
| EU 27 | 1,119,970 | 11.02 | 911.90 | 12,268.40 | 501 | 0.01% | 1.82 |

### Afforestation (F1 and F3)

In the Czech Republic, the cost of an afforestation project of 17,000 hectares of arable land was about CZK1.7 billion (in 2002 prices) or CZK2.1 billion (€84 million[18]) (in 2011 prices[19]) over 10 years - i.e., €4,941/ha, which was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €6,570/ha. In Willoughby *et al*., 2009, the cost of afforesting 450,000 ha of agricultural land in Spain, between 1994 and 1999, was €1,350/ha - i.e., a unit cost of €1,512/ha (in 2011 prices[20]). This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU average cost of € 1,559/ha. Hart *et al.* 2011 in Tucker and Mazza, 2011 report one-off costs of €1,800/ha for afforesting agricultural land. Hart *et al*. 2011 in Tucker and Mazza, 2011 also reports annual costs of €500/ha for afforesting agricultural land. The NWRM study assumes two unit costs at EU level: investment of €3,310/ha in 2011 prices – i.e., average of figures from the three sources – and annual operation and maintenance of €500/ha/year.

The JRC modelled a total increase of forest land within hilly and mountainous areas of 3,021,807 ha; most of this increase is in Austria, France, Italy and Spain; there is no increase in Estonia, Finland, Latvia, Lithuania, Malta or the Netherlands (see Table 14).

18 Using an exchange rate of CZK 1 = €0.04

19 A factor of 117.1/95.4 was used to convert 2002 prices into 2011 prices, see http://www.czso.cz/eng/redakce.nsf/i/inflation_rate.

20 A factor of 117.72/104.7 was used to convert 1999 prices into 2011 prices, see http://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t25/p180&file=inebase&L=0

**TABLE 14**
**COSTS OF AFFORESTATION SCENARIO**

| Member State | Increase in surface area of forests (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 319,963 | 2.66 | 219.95 | 284.4 | 8.4 | 0.08% | 26.18 |
| Belgium | 1,790 | 0.02 | 1.29 | 352.9 | 10.8 | 0.00% | 0.12 |
| Bulgaria | 95,875 | 0.38 | 31.53 | 36 | 7.6 | 0.09% | 4.15 |
| Cyprus | 5,138 | 0.04 | 2.96 | 17.5 | 0.8 | 0.02% | 3.70 |
| Czech Republic | 158,867 | 0.93 | 77.33 | 145 | 10.5 | 0.05% | 7.36 |
| Denmark | 38 | 0.00 | 0.04 | 234 | 5.5 | 0.00% | 0.01 |
| Estonia | 0 | 0.00 | -0.12 | 14.5 | 1.3 | 0.00% | -0.09 |
| Finland | 0 | 0.00 | -0.34 | 180.3 | 5.3 | 0.00% | -0.06 |
| France | 503,906 | 4.37 | 361.40 | 2,080.80 | 63.1 | 0.02% | 5.73 |
| Germany | 161,524 | 1.32 | 109.05 | 2,498.80 | 81.8 | 0.00% | 1.33 |
| Greece | 40,759 | 0.30 | 25.09 | 230.2 | 11.3 | 0.01% | 2.22 |
| Hungary | 1,114 | 0.01 | 0.47 | 98.4 | 10 | 0.00% | 0.05 |
| Ireland | 4,867 | 0.05 | 3.75 | 153.9 | 4.4 | 0.00% | 0.85 |
| Italy | 373,189 | 3.02 | 250.02 | 1,548.80 | 60.3 | 0.02% | 4.15 |
| Latvia | 0 | 0.00 | - | 18 | 2.2 | 0.00% | - |
| Lithuania | 0 | 0.00 | - | 27.4 | 3.2 | 0.00% | - |
| Luxembourg | 456 | 0.00 | 0.36 | 41.6 | 0.5 | 0.00% | 0.71 |
| Malta | 0 | 0.00 | - | 6.2 | 0.4 | 0.00% | - |
| Netherlands | 0 | 0.00 | - | 591.5 | 16.6 | 0.00% | - |
| Poland | 77,794 | 0.38 | 31.17 | 354.3 | 38.2 | 0.01% | 0.82 |
| Portugal | 138,327 | 0.95 | 78.97 | 172.7 | 10.6 | 0.05% | 7.45 |
| Romania | 260,015 | 1.20 | 98.96 | 121.9 | 21.5 | 0.08% | 4.60 |
| Slovakia | 119,056 | 0.67 | 55.18 | 65.9 | 5.4 | 0.08% | 10.22 |
| Slovenia | 44,439 | 0.29 | 24.34 | 36 | 2 | 0.07% | 12.17 |
| Spain | 531,267 | 4.03 | 333.57 | 1,062.60 | 46 | 0.03% | 7.25 |
| Sweden | 89,927 | 0.86 | 70.78 | 346.7 | 9.3 | 0.02% | 7.61 |
| United Kingdom | 93,496 | 0.73 | 60.64 | 1,696.60 | 62 | 0.00% | 0.98 |
| EU 27 | 3,021,807 | 22.19 | 1,836.37 | 12,268.40 | 501 | 0.01% | 3.67 |

The present value of the costs for the 27 EU Member States is €22.2 billion, which corresponds to an annualised cost of €1.8 billion, i.e., 0.01% of the GDP or €3.7 per person and per year. As a percentage of GDP, this annual cost is the highest in Bulgaria (0.09%) and in Romania (0.08%). This annual cost per person is the highest (above €9) in Austria, Slovakia and Slovenia.

### 4.1.4 No-regret aspects of forest measures

To qualify as no-regret measures, forest measures should be planned to be adaptable and easily modifiable to changes and to new scenarios, without investing too much, which might not be always possible. They should be planned on a case-by-case basis, taking into account the local circumstances such as rainfall, type of trees, among other factors. The results of the no-regret assessment of forest measures are in Table 15.

**TABLE 15**
**NO-REGRET ASSESSMENT OF FOREST MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | In some areas, for example, in particular drought-prone areas, forests may worsen the current or future situation depending on the impacts of climate change. In others, forests will improve rain interception, will release moisture in the atmosphere and will act as carbon sink. However, there is still debate on the role of vegetation cover in the earth hydrological cycle, in particular regarding the biotic pump hypothesis. It is therefore important that forest measures planning takes into account future climate change scenarios and the role of forests on the hydrological cycle of the area. |
| 2. Timing | Forest measures cannot be implemented immediately (regardless of any climate change), and require an analysis of the different climate change scenarios. |
| 3. Planning horizon | Forest measures do not necessarily have a short-term planning horizon; for example, a long time period is needed to transform regular stands to CCF. |
| 4. Flexibility | Forest measures are not easily modifiable; forest management can be modified but it requires mid to long-term scenarios. |
| 5. Risks (cost effective and beneficial measures) | As land availability is essential for planting forests, land very often has to be purchased and/or subsidies have to be paid to establish forests. Afforesting agricultural land may also reduce farmers' income and food production, unless the measure is implemented in abandoned or unproductive agricultural land. CCF also requires an increased effort and skilled personnel for managing, monitoring and planning compared to even-aged stand management, leading to increased maintenance costs. Therefore, forest measures are likely to have high investment and O&M.<br>Forests provide habitat, cultural services and improve water quality. However, the contribution of forests to flood hazard reduction and the increase of water availability has to be evaluated on a case-by-case basis, as these depend on *in situ* conditions and the scale (e.g., catchment level or local level) of the forests. |
| 6. Local and regional scale | Forest measures should be implemented at a local scale. |
| 7. Economic analysis | Forest measures should take into account future water supply and demand (water budget) scenarios. |

## 4.2 Urban measures[21]

In the urban environment, NWRM mainly coincide with the eco-hydrological and non-point source control strategies, such as SuDS. SuDS aim to mimic natural systems that use cost-effective solutions with low environmental impact; they are Best Available Techniques (BAT) to manage urban storm-water run-off.

### 4.2.1 Applicability of the urban measures

The four urban measures are applicable to all EU climate zones, although according to Prokop *et al*., 2011, green roofs should not be implemented on roofs exposed to wind. Green roofs are applicable to urban areas (CLC 1: 1. Artificial surfaces); the other three measures are also applicable to agricultural lands (CLC 1: 2. Agricultural areas) and meadows and pastures (CLC 3: 2.3.1 Pastures and 3.2.1 Natural grassland). The four measures have mostly been implemented upstream in the catchment. According to the FP5 Urban River Basin Enhancement Methods (URBEM) project, infiltration basins are most effectively used in watersheds of 5-20 acres.

All of the measures, except green roofs, have mostly been implemented with low to high soil permeability. However, according to Gordon-Walker *et al*., 2007, soakaways and infiltration trenches should be implemented in soils providing a long-term permeability. The URBEM project also recommends not implementing infiltration basins in limestone or other karst-sensitive areas due to the high potential for groundwater contamination.

Filter strips and swales, permeable surfaces and infiltration devices can be implemented at any soil depth. For green roofs, the growing medium should be at least 10 cm deep, according to the “The green roof regulations” for Basel, Switzerland (Kazmierczak and Carter, 2010). Prokop *et al*., 2011 consider that the depth of planting medium is one of the factors determining the amount of maintenance needed: extensive green roofs have a 60-200mm depth of substrate while intensive green roofs have 150-400mm.

Filter strips and swales, permeable surfaces and infiltration devices can be implemented at topographies with 0-10% slope. The slope of green roofs should be designed to a fall of 1 in 40; however greater falls can be used if the depth of the growth medium substrate is increased (Gordon-Walker *et al*., 2007).

### 4.2.2 Direct impacts of the urban measures

There is no clear indication whether urban measures affect soil moisture. However, according to Gordon-Walker *et al*., 2003, the increase of soil moisture at a site as a result of implementing soakaways and infiltration trenches, may constrain urban development on the site.

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[21] The Fact Sheets for the four urban measures are in Annex 3.

There is no information pointing to an impact of filter strips and swales or infiltration devices on water temperature; for green roofs and permeable surfaces, an impact on water temperature is not expected. Little evidence suggests that urban measures increase ETP. For Prokop *et al*., 2011, permeable surfaces improve micro-climates by increasing water evaporation. According to Kasmin *et al*., 2010, after a storm event, ETP restores the retention capacity of green roofs.

SuDS attenuate, delay or reduce the urban run-off and decrease the amount of run-off going to drains and sewers. There are various estimates of the potential run-off volume retention rate of green roofs. According to Prokop *et al*., 2011 green roofs retain 50-90% of rain water, depending on their design. CIRIA 'Building Greener'[22] suggests up to 40% reduction in run-off for a 50-80mm green roof. In a pilot project in Augustenborg, Sweden, the green roofs intercepted about half of the total rainwater run-off over a year (the amount absorbed at any time varies depending on the saturation level of the roof surface) (Kazmierczak and Carter, 2010).

All urban measures, except green roofs, contribute to groundwater replenishment. For Prokop *et al*., 2011, permeable surfaces contribute to the formation of natural groundwater. There is no indication whether green roofs contribute to groundwater replenishment.

Green roofs have no impact on land use, while the rest of the urban measures result in land-use changes; however, the information on this impact is scarce.

All urban measures contribute to increasing water storage capacity. A case study of the Caledonian Road Housing in London (Robert Bray Associates Ltd., 2011a) proposes storing run-off with permeable block or other small-unit surfacing in car parking and amenity surfaces servicing apartments: an average 300mm of crushed stone sub-base, with a void ratio of 30%, could store 100mm in the permeable pavement. For Prokop *et al*., 2011, permeable surfaces such as concrete grass grids increase water storage capacity by at least 60% and porous asphalt by 20% compared to conventional asphalt pavements. However, there is no information on the impact of green roofs or infiltration devices on storage capacity.

The NWRM study has identified four urban NWRM:

1. Filter strips and swales (U1);
2. Permeable surfaces and filter drains (U2);
3. Infiltration devices (U3); and
4. Green roofs (U4).

The results of the assessments are presented below for each of these measures.

[22] http://www.ciria.com/buildinggreener/

### Filter strips and swales (U1)

Filter strips and swales are vegetated strips, ditches or berms that intercept and drain water evenly off impermeable areas to slow down the flow and encourage infiltration, thus contributing to run-off mitigation. Filter strips and swales are often integrated into the surrounding land use, for example, public open spaces or road verges.

**Filter strips and swales** encourage infiltration, thereby contributing to run-off mitigation.

#### *Benefits and co-benefits of filter strips and swales*

Filter strips and swales mimic natural drainage patterns by allowing rainwater to run in sheets through vegetation, slowing and filtering the flow. Swales can also be designed for a combination of conveyance, infiltration, detention and treatment of run-off. Both remove polluting solids through filtration and sedimentation. The vegetation traps organic and mineral particles that are then incorporated into the soil, while the vegetation absorbs any nutrients. These infiltration devices also contribute to unsealing urban areas.

### Permeable surfaces and filter drains (U2)

Filter drains contain a volume of permeable material below ground to store surface water. Run-off flows to this storage area via a permeable surface, which can be grass, if the area is not travelled on, gravel, porous paving blocks, continuous surfaces with an inherent system of voids, or solid paving blocks with gaps between individual blocks. Permeable surfaces can be integrated into pavements where they cover a few square metres, but also on larger areas such as car parks. Due to their size, and given that otherwise they would produce large completely sealed areas in cities, large parking areas are very well suited for implementing permeable surfaces (Prokop *et al*., 2011).

**Permeable surfaces** and **filter drains** retain water by infiltrating rainwater and surface run-off directly into the soil.

#### *Benefits and co-benefits of permeable surfaces and filter drains*

Permeable surfaces and filter drains can maintain larger areas of exposed soil than traditional covered areas (traditional pavements, for example). Therefore, they increase the infiltration and lead to better storage of water in the soil (Development Agency of Eastern Thessaloniki Anatoliki S.A. et al., 2010). Permeable surfaces and filter drains retain water by infiltrating rainwater and surface run-off directly into the soil. By catching rainwater, permeable surfaces and filter drains deal with run-off directly at its source. Permeable surfaces and filter drains therefore play an important role in mitigating flood events in urban areas. A case study of the Caledonian Road Housing in London (Robert Bray Associates Ltd., 2011a) proposes storing run-off with permeable block or other small unit surfacing in car parking and amenity surfaces servicing apartments: an average 300mm of crushed stone sub-base, with a void ratio of 30%, could store 100mm in the permeable pavement. For Prokop *et al*., 2011, permeable surfaces such as concrete grass grids increase water storage capacity by at least 60% and porous asphalt by 20% compared to conventional asphalt pavements.

Permeable surfaces and filter drains also contribute to removing the load of wastewater treatment plants: water that otherwise would have to be treated in such facilities is discharged into the soil. This is very important, especially during periods of heavy rainfall. The measures also improve water quality as they collect and infiltrate the water before it is contaminated with pollutants from the streets. Groundwater is recharged more efficiently as permeable surfaces contribute to the conservation of soil functions by leaving parts of the soil unsealed and vegetated increasing soil permeability and improving soil quality (Prokop *et al*., 2011). Permeable surfaces and filter drains also prevent the soil from being fully sealed, thus increasing evaporation and improving the local climate.

**Infiltration devices (U3)**

Infiltration devices include soakaways, infiltration trenches and infiltration basins, as well as swales and infiltration basins. Soakaways and infiltration trenches are completely below ground, while swales and infiltration basins store water on the surface; they are dry except during heavy rainfall.

**Infiltration devices** drain water directly into the ground and are generally integrated into the landscape. By storing and infiltrating water, infiltration devices contribute to water retention.

***Benefits and co-benefits of infiltration devices***

For flood mitigation, water retention and the prevention of soil sealing, infiltration devices provide effects and benefits similar to those of permeable surfaces and filter drains. These devices should be implemented as a mix of measures to achieve good results. As infiltration devices have a limited capacity for storing rainwater, they should also be planned including the possibility to overflow into the landscape or into a conventional drainage system. However, they are very effective in removing pollutants and can improve soil quality: soakaways and infiltration trenches help to increase the soil moisture content by infiltrating water directly into the ground (Prokop *et al*., 2011).

While storm-water is normally discharged from streets and residential areas to a waste water treatment plant, infiltration devices provide several benefits for conventional rain- and storm-water treatment:

- Reduction of peak storm-water flows;
- Reduction of downstream flooding;
- Improvement of groundwater recharge;
- Improvement of storm-water quality; and
- Reduction of the costs for storm-water drainage (Lower Hunter and Central Coast Regional Environmental Management Strategy, 2002).

**Green roofs (U4)**

Green roofs are areas of living vegetation on top of buildings of all sizes, from small garages to large industrial structures. In addition to plants, green roofs can also include drainage and irrigation systems.

### ***Benefits and co-benefits of green roofs***

Green roofs contribute significantly to run-off management in urban areas as the plants capture rainwater on their foliage and absorb it in their roots, encouraging ETP and preventing at least part of the storm-water from entering the run-off stream. According to Kasmin *et al*., 2010) after a storm event, the retention capacity of green roofs is restored by ETP.

Green roofs contribute to reducing sewerage-derived flooding (delay and attenuate storm run-off at source) (Gordon-Walker *et al*., 2007), leading to reducing pluvial flooding risk and incidents (Prokop *et al*., 2011). Depending on their design, green roofs can retain 50-90% of rainwater (Prokop *et al*., 2011). CIRIA 'Building Greener'[23] suggests up to 40% reduction in run-off for a 50-80mm green roof. In a pilot project in Augustenborg, Sweden, the green roofs intercept about half of the total rainwater run-off over a year (the amount absorbed at any time varies depending on the saturation level of the roof surface) (Kazmierczak and Carter, 2010).

Green roofs also have a range of other -benefits:

1. Green roofs improve the quality of living, particularly in very densely built areas (Livingroofs.org, 2004 and Prokop *et al*., 2011) and can reduce sound reflection by up to 3 dB and improve sound proofing by up to 8 dB (Prokop *et al*., 2011).
2. By filtering water, green roofs also improve the quality of run-off water. According to Gordon-Walker *et al*., 2007, green roofs can also neutralise acid rain.
3. Green roofs cool down the air temperature, thereby mitigating the heat island effect of cities (Prokop *et al*., 2011). One study on the effects of green roofs on ambient air temperature carried by the Trent University in the UK, found that on a typical day where ambient temperature was 18.4°C, a bare membrane roof had a surface temperature of 32°C while an identical roof covered with a thin layer plant system had a surface temperature of about 15°C.
4. Green roofs improve air quality by filtering airborne particulates by binding dust and toxic particles: 10-20% of the dust from the air is filtered (Prokop *et al*., 2011).
5. Livingroofs.org, 2004 concludes that green roofs contribute to reducing $CO_2$ production due to plant activity on green roofs and by providing thermal insulation, thus reducing energy consumption and buffering hot temperatures.
6. Green roofs contribute significantly to biodiversity conservation in urban areas; they can provide new micro habitats for different species, such as insects and birds. For example, blooming green roofs can help maintain bee populations in urban areas.

[23] http://www.ciria.com/buildinggreener/

### 4.2.3 Cost assessment of urban measures

The JRC model combined the four measures: filter strips and swales (U1), permeable surfaces (U2), infiltration devices (U3) and green roofs (U4) into one urban scenario. The unit cost for this scenario is the average of the unit costs of each of these four measures.

In Gordon-Walker, *et al*., 2007, capital expenditure (Capex) is £12.50/m$^2$ (€150,000/ha[24], or €163,500/ha in 2011 prices[25]) for **swales** and £60/m$^2$ (€720,000/ha[26] or €784,800/ha in 2011 prices[27]) for **infiltration trenches**. These costs were adjusted according to the comparative price levels in Table 11, resulting in EU costs of €163,174/ha for swales and €783,234/ha for infiltration trenches.

For **permeable surfaces**, Prokop *et al*., 2011 report costs of €15-20/m² (average of €17.5/m²) for gravel turf and €30/m² for plastic grass grids. Gordon-Walker *et al*., 2007 report Capex for permeable surfaces of £54/m$^2$ (€64.9/m$^2$ or €70.7/m$^2$ in 2011 prices[28]). This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €705,589/ha. The average of these three figures is €393,530/ha.

For **green roofs**, Prokop *et al*., 2011, report costs of €50-100/m² for extensive sedum matted green roofs. According to Livingroofs.org and Ecology Consultancy Ltd, 2004, the average cost of green roofs is about €20-40/m$^2$ in Germany (or €33.9/m$^2$ in 2011 prices[29]). This cost was adjusted according to the comparative price levels in Table 11, resulting in EU cost of €325,024/ha. The average of these two costs is €537,512/ha.

Averaging the unit costs above results in an investment cost of €469,362/ha.

In Gordon-Walker, et al., 2007, O&M (Opex) for swales are £2.3/m$^2$ (€27,600/ha[30], or €30,084/ha in 2011 prices[31]); these costs were adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €30,024/ha. For permeable surfaces, the same author reports Opex of £0.4/m$^2$ (€4,800/ha[32] or €5,232/ha in 2011 prices[33]); these costs were adjusted according to the comparative

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24 Using an exchange rate of £1.00 = €1.20093. (http://www.oanda.com/).
25 A factor of 114.5/104.7 (UK) was used to convert 2007 prices into 2010 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en. Information for HICP in the UK for the year 2011 not available.
26 Using an exchange rate of £1.00 = €1.20093. (http://www.oanda.com/).
27 A factor of 114.5/104.7 (UK) was used to convert 2007 prices into 2010 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en. Information for HICP in the UK for the year 2011 not available.
28 A factor of 114.5/104.7 (UK) was used to convert 2007 prices into 2010 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en. Information for HICP in the UK for the year 2011 not available.
29 A factor of 111.1/98.1 (Germany) was used to convert 2004 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en
30 Using an exchange rate of £1.00 = €1.20093. (http://www.oanda.com/).
31 A factor of 114.5/104.7 (UK) was used to convert 2007 prices into 2010 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en. Information for HICP in the UK for the year 2011 not available.
32 Using an exchange rate of £1.00 = €1.20093. (http://www.oanda.com/).
33 A factor of 114.5/104.7 (UK) was used to convert 2007 prices into 2010 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en. Information for HICP in the UK for the year 2011 not available.

price levels in Table 11, resulting in an EU cost of €5,222/ha; for Infiltration trenches, the Opex of £5.6/$m^2$ (€67,300/ha[34] or €73,357/ha in 2011 prices[35]) resulted in an EU cost of €73,211/ha after adjustment.

According to Livingroofs.org and Ecology Consultancy Ltd, maintaining extensive green roofs adds about £1/$m^2$ (€12,000/ha, or €14,160/ha in 2011 prices[36]) per year to the cost of maintaining a standard roof. Correcting this cost by UK price level result in an UK cost of €14,132/ha.

Averaging the O&M above results in an operation and maintenance unit cost of €30,647 /ha/year.

The JRC modelled a total increase of urban green surface areas of 3,423,078 ha (almost the same as forest land); most of this increase is in France, Germany and the UK; there is no increase in Cyprus or Luxembourg, which is combined with Belgium (see Table 16).

**TABLE 16**
**COSTS OF URBAN GREEN SCENARIO**

| Member State | Increase in urban green surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 35,650 | 24.57 | 2,033.10 | 284.4 | 8.4 | 0.71% | 242.04 |
| Belgium | 61,894 | 44.75 | 3,702.62 | 352.9 | 10.8 | 1.05% | 342.84 |
| Bulgaria | 71,189 | 23.47 | 1,942.01 | 36 | 7.6 | 5.39% | 255.53 |
| Cyprus | 0 | 0.00 | - | 17.5 | 0.8 | 0.00% | - |
| Czech Republic | 25,987 | 12.68 | 1,049.42 | 145 | 10.5 | 0.72% | 99.94 |
| Denmark | 63,920 | 59.03 | 4,884.46 | 234 | 5.5 | 2.09% | 888.08 |
| Estonia | 7,550 | 3.67 | 303.27 | 14.5 | 1.3 | 2.09% | 233.28 |
| Finland | 73,357 | 58.80 | 4,865.01 | 180.3 | 5.3 | 2.70% | 917.93 |
| France | 389,693 | 280.22 | 23,186.63 | 2,080.80 | 63.1 | 1.11% | 367.46 |
| Germany | 496,858 | 336.32 | 27,828.63 | 2,498.80 | 81.8 | 1.11% | 340.20 |
| Greece | 52,602 | 32.47 | 2,686.32 | 230.2 | 11.3 | 1.17% | 237.73 |
| Hungary | 119,444 | 50.31 | 4,162.79 | 98.4 | 10 | 4.23% | 416.28 |
| Ireland | 19,305 | 14.92 | 1,234.69 | 153.9 | 4.4 | 0.80% | 280.61 |
| Italy | 206,519 | 138.72 | 11,478.25 | 1,548.80 | 60.3 | 0.74% | 190.35 |
| Latvia | 18,133 | 8.50 | 703.04 | 18 | 2.2 | 3.91% | 319.57 |

34 Using an exchange rate of £1.00 = €1.20093. (http://www.oanda.com/).
35 A factor of 114.5/104.7 (UK) was used to convert 2007 prices into 2010 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en. Information for HICP in the UK for the year 2011 not available.
36 A factor of 115.38/97.77 (EU 27 average) was used to convert 2004 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

| Member State | Increase in urban green surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Lithuania | 25,611 | 10.82 | 895.33 | 27.4 | 3.2 | 3.27% | 279.79 |
| Luxembourg | 0 | 0.00 | - | 41.6 | 0.5 | 0.00% | - |
| Malta | 320 | 0.16 | 13.39 | 6.2 | 0.4 | 0.22% | 33.47 |
| Netherlands | 152,550 | 106.53 | 8,814.54 | 591.5 | 16.6 | 1.49% | 531.00 |
| Poland | 118,477 | 47.59 | 3,938.22 | 354.3 | 38.2 | 1.11% | 103.09 |
| Portugal | 51,338 | 29.39 | 2,431.55 | 172.7 | 10.6 | 1.41% | 229.39 |
| Romania | 167,961 | 64.09 | 5,303.48 | 121.9 | 21.5 | 4.35% | 246.67 |
| Slovakia | 20,036 | 9.31 | 770.37 | 65.9 | 5.4 | 1.17% | 142.66 |
| Slovenia | 2,720 | 1.49 | 123.57 | 36 | 2 | 0.34% | 61.79 |
| Spain | 216,260 | 136.14 | 11,264.79 | 1,062.60 | 46 | 1.06% | 244.89 |
| Sweden | 143,951 | 113.60 | 9,399.91 | 346.7 | 9.3 | 2.71% | 1,010.74 |
| United Kingdom | 881,753 | 573.39 | 47,444.94 | 1,696.60 | 62 | 2.80% | 765.24 |
| EU 27 | 3,423,078 | 2,180.92 | 180,460.34 | 12,268.40 | 501 | 1.47% | 360.20 |

The present value of the costs for the 27 EU Member States is €2,181 billion, which corresponds to an annualised cost of €180 billion, i.e., 1.47% of the GDP or €360 per person and per year. These costs are very high; they are due to very high unit costs and large increases in surface areas. As a percentage of GDP, this annual cost is the highest in Bulgaria (5.39%) and in Romania (4.35%). This annual cost per person is the highest (above €400) in Denmark, Finland, Hungary, the Netherlands, Sweden and the UK.

### 4.2.4 No-regret aspects of urban measures

Preliminary conclusions support urban measures as no-regret measures (see Table 17).

**TABLE 17**
**NO-REGRET ASSESSMENT OF URBAN MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | SuDS are beneficial no matter how climate change impacts materialise, as they mimic natural processes by slowing flow, providing storage and encouraging water to soak into the ground that replace or supplement conventional sewerage systems and decrease waste water treatment plans required operating capacity. They have little impact on the water balance at the catchment level as they are restricted to small areas. |
| 2. Timing | As they do not depend on the analysis of the climate change impacts, they can be implemented immediately. |
| 3. Planning horizon | Not applicable. |

| No-regret aspects | Assessment |
|---|---|
| 4. Flexibility | They are somewhat more flexible than conventional drainage systems, although some of the SuDS need to be retrofitted to the conventional systems. This might reduce their flexibility. |
| 5. Risks (cost effective and beneficial measures) | SuDS are also less expensive than conventional drainage systems or hard-engineered drainage systems. They also provide many co-benefits, including landscape enhancement, contribution to biodiversity and increase of water quantity and quality; benefits that are not provided by conventional drainage systems. |
| 6. Local and regional scale | They are planned on the basis of local conditions. |
| 7. Economic analysis | SuDS remove the urban run-off stormwater usually mixed with domestic wastewater to the conventional wastewater treatment plants which are by-passed during storm events as they are overloaded. SuDS provide a better use of the conventional sewage system. Rainwater is properly managed. |

## 4.3 Agricultural measures[37]

Probably the most important NWRM is the use of the water storage capacity of the soil, which is the largest natural storage pool in many countries[38]. However, soil erosion represents one of the most well-known causes of land degradation and loss of fertile soil. According to the EEA, 2000, the main driver for soil erosion is the intensification of agriculture. The proper agricultural use of soil is therefore very important. The best strategy to maintain a good soil structure in cultivated land is to adopt appropriate soil conservation techniques, such as avoidance or reduction of tillage, well-planned and careful terracing, strip-cropping, soil improvement and crop rotation methods.

### 4.3.1 Applicability of the agricultural measures

All agricultural measures seem to be applicable to all EU Climate zones. Restoring and maintaining meadows and pastures only applies to meadows and pastures (CLC 3: 2.3.1 Pastures and 3.2.1 Natural grassland), while the other measures also apply to agricultural land (CLC 1: 2. Agricultural areas). Green cover has also been implemented in forests (CLC 1: 3. Forests and semi-natural areas) and buffer strips along rivers (CLC 3: 5.1.1. Water courses).

Soil conservation crop practices, no and reduced tillage and green cover can be implemented upstream and downstream of the river basin. Gowing *et al*., 2002 recommend introducing restoring meadows and pastures in uncompacted alluvial clay loams, conditions presented in extensively used floodplains; however, this is only applicable to MG4 grasslands[39]. According to the Nationalpark Donau-Auen GmbH, 1998, meadows and pastures have been introduced in lower floodplains; and according to Lippert, 1998, in both the lower and upstream-middle. Buffer strips on the other hand have been implemented downstream (Aragón River in Navarra - INTERREG (FLAPP project); Wilkinson *et al.*, 2010; Borin *et al*., 2009), along rivers

[37] The Fact Sheets for the six agricultural measures are in Annex 4.
[38] http://www.mta-taki.hu/hu/tagok/prof-dr-varallyay-gyoergy/publikaciok.
[39] British NVC community MG4 *Alopecurus pratensis – Sanguisorba officinalis* (Meadow foxtail – Great burnet).

(Aragón River in Navarra - INTERREG (FLAPP project)), in floodplains (Wilkinson *et al.*, 2010) and in low areas (Borin *et al*., 2009).

There is next to no information on soil permeability in the sources; for Hangen *et al.*, 2002, implementing no and reduced tillage (conservation tillage) on silty soils could reduce fast run-off. Soil conservation practices, green cover and early sowing have been implemented on any soil depth. Gowing *et al*., 2002 provide information on the soil depth required for meadows, but this is only applicable to MG4 grasslands. Hangen *et al.*, 2002 carried out experiments to determine the infiltration behaviour under different tillage practices in soil depths of 0-120 cm; for silty soils, conservation tillage improved vertical connectivity and the macropore network; the maximum depth of stained pores was 120 cm.

The measures have been implemented in a wide range of topographies:

- Meadows and pastures: flat topography (Gowing et al., 2002) and low and medium slope river sections (Lippert, 1998).
- Buffer strips: extremely flat topography with dikes and dunes as well as more hilly parts (EC-JRC, 2009a) and other topographies such as: steep (Wilkinson et al., 2010); 1-2% slopes (Anderson et al., 2009); and 1.8% slope (Borin et al., 2009). Buffer strips are probably not effective for water retention in lowland plains (Alterra, 2005-2008).
- Soil conservation practices: various topographies, but depends on the acceptable slope limit for mechanical systems (EC-JRC, 2009 and b and 2009c; EC, 2005; Local Authority of Kortenberg, 2003; Strauss, 2005).
- Green cover has been implemented on 0-10% slopes (EC-JRC, 2009a, 2009b and 2009c; EC, 2005). According to Strauss, 2005, green cover has also been implemented in the alpine region.
- Early sowing has been implemented in 0-10% slopes (EC, 2005).
- There is no information on no and reduced tillage.

### 4.3.2 Direct impacts of the agricultural measures

These agricultural measures increase soil moisture. For meadows and pasture, the evidence mentions increased soil moisture as an objective of the measure, without giving more information. The EC-JRC, 2009 considers that appropriate crop practices minimise the risk of soil degradation by increasing the soil water capacity of soils, which can increase soil moisture. The same document confirms that cover crops improve moisture content. The Local Authority of Kortenberg, 2003 also mentions that crop growing measures are assumed to increase soil infiltration capacity. Only for no and reduced tillage are quantitative data available: no and reduced tillage increase the soil moisture content by up to 300% and 35%, respectively, as they reduce soil evaporation and thus water loss (EC-JRC, 2009).

The information on the impact of agricultural measures on ETP is scarce. No information for buffer strips, soil conservation crop practices, green cover or early sowing; for meadows and pastures, Gowing *et al*., 2002 provide figures on ETP and rain, but they are probably limited to MG4 grasslands. EC-JRC, 2009 mentions that no and reduced tillage reduce soil evaporation, one of the factors determining ETP.

All of these measures, except meadows and pastures and soil conversation practices, contribute to reducing or slowing down run-off. According to Borin *et al*., 2009, young buffer strips reduced total run-off by 33% over 3 to 5 years, while Alterra, 2005-2008 concluded that narrow grass buffer strips of less than 5 metres could prevent surface run-off of soil particles and spills of agrochemicals. According to EC-JRC, 2009, no tillage can reduce spring time run-off; if the soil is also covered and has significant biological activity, run-off can be reduced by a factor of 1 to 5, compared to conventional tillage. Hangen *et al.*, 2002 confirm that conservation tillage on silty soils under agricultural land use can increase water retention capacity reducing the significance of fast run-off components. The AMEWAN project implemented in Germany, the Netherlands and the UK (AMEWAM Project, 2003-2006) implemented green cover crops in order to hold “water up on the land" and limit surface water run-off. Although the Local Authority of Kortenberg, 2003 does not specifically link early sowing to run-off reduction, it confirms that agricultural land helps increase hydraulic roughness and infiltration, which probably contributes to reducing or slowing down run-off. Most of these measures increase water infiltration in the soil, but no detailed study has proven that they contribute to groundwater replenishment.

No evidence is available on the impact of these measures on land use, since there is probably no land-use change as a result of their implementation.

All of the measures control or reduce soil erosion**,** although the information is rather general in nature, except for soil conservation practices. According to EC-JRC, 2009, for parcels with a high susceptibility to soil erosion, it is important to select a specific crop rotation to maximise soil cover; intercrops, contour tillage, and grass strips are the most effective measures against erosion. For green cover, the same authors report a 50% reduction in soil erosion by covering soil that would be otherwise left bare. EC, 2005 also presents an example in Belgium that supports this. According to the same source, conversion of arable to grassland in Italy has reduced soil erosion by 30 ton/ha per year.

Meadows and pastures and buffer strips increase water storage capacity in the soil. Although, only applicable to good examples of MG4 grassland communities, Gowing *et al*., 2002, conclude that these are associated with deep well-structured soils, which show a large storage capacity for water. According to the experiments carried out by Anderson *et al.*, 2009, agroforestry buffer strips increase water storage.

The NWRM identified six agricultural NWRM:

1. Restoring and maintaining meadows and pastures (A1);
2. Buffer strips (A2);
3. Soil conservation crop practices (A3);
4. No or reduced tillage (A4);
5. Green cover (A5); and
6. Early sowing (A6).

The results of the assessment by measure and presented in the following sections.

**Restoring and maintaining meadows and pastures (A1)**

**Meadows and pastures** provide good conditions for the uptake and storage of water during temporary floods. They also protect water quality by trapping sediments and assimilating nutrients.

Meadows are areas or fields whose main vegetation is grass, or other non-woody plants, used for mowing and hay-making. Pastures are grassed or wooded areas, moorland or heathland, generally used for grazing. The line between the two can often be blurred: after hay-making is over, meadows can be turned into pastures to be grazed until the end of autumn or beginning of winter. Pastures can also be used as meadows when grazing is abandoned and the grass is used for hay-making.

***Benefits and co-benefits of restoring and maintaining meadows and pastures***

Compared to other agricultural land uses, meadows and pastures show the best conditions for water retention. Due to their rooted soils and their permanent cover, meadows and pastures provide good conditions for the uptake and storage of water during temporary floods. Pastures are similarly suitable parts of catchments for water retention, especially when they are temporarily flooded and/or are subject to good grass "treatment" by traditionally grazed animals. The most effective contribution to flood reduction is achieved when flat areas with soils showing a high water storage capacity are used as meadows (Wagner *et al*., 2009).

Old extensively used pastures contribute significantly to reducing erosion, being more effective than young grass compacted by tractors (Van Dijk, 1996). According to EC, 2005, conversion of arable to grassland in Italy has reduced soil erosion by 30 ton/ha per year.

Meadows and pastures also contribute significantly to mitigating climate change impacts and to maintaining biodiversity. Conant *et al*., 2001 conclude that grassland management improvements and conversion into pasture increase soil C content and net soil C storage, although other variables such as climate, native vegetation, depth, time and original soil C, also affect rates of soil C content.

Although meadows and pastures are suitable areas for natural water retention, attention should be paid to ensure adequate drainage. Water should not be stored in the landscape longer than necessary as this can cause serious damage to flora and fauna (Gowing *et al*., 2002). Long term humidity in pastures is harmful to grazing cattle and to specific pests. It allows the completion of the cycle of worms which are toxic for animals and humans.

### 4.3.3 Buffer strips (A2)

Due to their extensively used green cover, **buffer strips** offer good conditions for effective water infiltration and therefore promote the natural retention of water. They can also significantly reduce the amount of suspended solids, nitrates and phosphates originating from agricultural run-off.

Buffer strips are areas of natural vegetation cover (grass, bushes or trees) at the margins of fields, arable land, roads, rivers or any area whose anthropogenic use produces run-off and leads to the transport of sediment or contaminants into surface water bodies.

### *Benefits and co-benefits of buffer strips*

Buffer strips, together with other features for run-off storage and mitigation, such as woody debris dams or willow barriers, are very effective in retaining water. Due to their extensively used green cover, buffer strips offer good conditions for effective water infiltration and therefore promote the natural retention of water. According to the experiments of Anderson *et al*., 2009, agroforestry buffer strips increase water storage.

The water retention ability of buffer strips also reduces non-point source water pollution from agriculture land. Buffer strips can reduce the volume of suspended solids, nitrates and phosphates by 70 to 90% (EC-JRC, 2009b), reduce losses of N by 44% and P by 50%, abate $NO_3$-N, dissolve phosphorous concentrations by 100% and act as a barrier for herbicides (abated by 60% and 90%) (Borin *et al*., 2009). However, as mentioned by Borin *et al*., 2009 citing Daniels and Gilliam, 1996; Schmitt *et al*., 1999; and Abu-Zreig *et al*., 2003, the pollutant abatement achieved by buffer strips depends on width, pollutant type and chemical form.

Buffer strips slow down and reduce run-off; they also filter the water, improving the quality of groundwater (Dosskey, 2001), by reducing the amount of suspended solids, nitrates and phosphates from agricultural run-off. In addition to protecting surface water bodies from contamination, buffer strips can also protect streams in forestry systems, enhance biodiversity and landscape values along rivers and ditches, and mitigate wind erosion.

Buffer strips also reduce river bank erosion by stabilising river banks naturally (Van Dijk, P. M. *et al*, 1996). According to Borin *et al*., 2009, young buffer strips reduced total run-off by 33% over 3 to 5 years, while Alterra, 2005-2008 concluded that narrow grass buffer strips of less than 5 m could prevent surface run-off of soil particles and spills of agrochemicals. Buffer strips also act as atmospheric $CO_2$ sinks; the monitored buffer strips stored up to 80 t/ha/year, considering the $CO_2$ immobilised in the wood and in the soil together (Borin *et al*., 2009).

Buffer strips also improve landscape aesthetics. A survey of the rural aesthetic value-added of hedgerows in agroforestry buffer strips (Borin *et al*., 2009) has confirmed the importance of hedgerows to improve the perceived naturalness of the territory and to hide man-made elements; those made of taller trees (6 m) are more appreciated than those made of smaller trees.

## Soil conservation crop practices (A3)

Conservation crop practices on agricultural land lead to maintaining and promoting a good soil structure and quality.

> Various **soil conservation crop practices** (e.g., crop rotation, strip cropping, intercropping, interlayer crops) can ensure that the soil retains water by maintaining good soil characteristics.

### *Benefits and co-benefits of soil conservation practices*

Various soil conservation crop practices (e.g., crop rotation, strip cropping, intercropping, interlayer crops, sub-soiling, contour farming) can ensure that the soil retains water by maintaining good soil characteristics. These practices minimise the alteration of the composition and structure of the soil, thereby safeguarding it against erosion and degradation, and also preserving soil biodiversity (EEA, 2003). They contribute to water retention (EC-JRC, 2009a) by increasing ETP, biological activity, soil fertility and organic carbon stock. The Local Authority of Kortenberg, 2003 also mentions that crop growing increases soil infiltration capacity.

Crop rotation involves cultivating different crops in temporal succession on the same land, which improves nutrient cycles, increases microbiological diversity, and enhances soil structure. Perennial cover crops are beneficial, as they promote altering the porosity of subsurface soil horizons and increase future soil productivity and decrease future run-off amounts and rates (Dabney, 1998). Intercropping leads to a more stable plant system, avoiding pests and weeds; it also leads to a better soil structure and increases yields. Sub-soiling promotes a better root growth and better infiltration of water and nutrients. It also reduces run-off. Contour farming leads to better infiltration capacities, thus reducing water loss and erosion (JRC, 2009).

### No or reduced tillage (A4)

**Tillage** is a mechanical modification of the soil. Intensive tillage can disturb the soil structure, thus increasing erosion, decreasing water retention capacity, reducing soil organic matter through the compaction and transformation of pores.

Tilled soil tends to dry out and to become friable. In addition, tillage disturbs the soil, causing it to move vertically and horizontally, often making it more susceptible to further movement by wind and water. The horizontal movement of soil can lead to tillage erosion. Nevertheless, intensive tillage is widely carried out, especially on big farms, together with the use of fertilisers, as it promotes the mass production of crops.

### *Benefits and co-benefits of no or reduced tillage*

To maintain the soil's water retention capacity, tillage should be minimised (through reduced or no tillage). No tillage is preferable as it does not destroy the soil structure, thus promoting a network of intact pores needed for water uptake and infiltration. Where tilling cannot be avoided, it should be reduced as far as possible. Ridge tillage (cultivating crops on pre-formed ridges) or contour tillage (tilling parallel to the contours of the slope) can also be adopted, as it appears to be more soil-friendly than conventional tillage.

No or reduced tillage can increase organic carbon stock, thus improving biological activity, soil fertility and soil structure, and contributing to maintain the water retention capacity of the soil. No and reduced tillage increase the soil moisture content by up to 300% and 35%, respectively, as they reduce soil evaporation and thus water loss (EC-JRC, 2009a). Strudley *et al.,* 2008 reports that the available soil water content decreased in the order no tillage > reduced tillage > conventional tillage.

According to EC-JRC, 2009a, no tillage can reduce springtime run-off; if the soil is also covered and has significant biological activity, run-off can be reduced by a factor of 1 to 5, compared to conventional tillage.

Tillage practices have pronounced effects on the soil hydraulic properties immediately after application, but these effects diminish rapidly (even after the first wetting/drying cycle (Strudley *et al.,* 2008)); the long-term effects can be less pronounced and sometimes impossible to distinguish from natural variability.

For Strudley *et al.,* 2008, tillage releases nitrous gases into the atmosphere at certain times of the year; however, due to spatial variability, natural soil heterogeneity and perhaps measurement errors, it is not possible to attribute the different nitrous gases fluxes to the different tillage treatments.

**Green cover (A5)**

Green cover refers to crops planted temporarily, in late summer or autumn, usually on arable land, to protect the soil against wind and water erosion. Crops suitable for green cover are catch crops (quick-growing crops, such as lettuce, radishes, spinach, rye, millet). It is important to establish these crops in the winter as soils are not used for crop growing and heavy rainfall and storms increase the intensity of water and wind erosion.

**Green cover** refers to crops planted in late summer or autumn, usually on arable land, to protect the soil, which would otherwise lie bare during the winter, against wind and water erosion.

***Benefits and co-benefits of green cover***

Green cover has a positive impact on soil quality through an improved soil structure. As crops planted to create a green cover develop roots, they install a rooting network and therefore lead to better infiltration into the soil. They also take up nutrients and prevent them from eroding into streams. Thus, green cover contributes not only to retaining rain water, but also increases water quality, and is therefore especially used in drinking water catchment areas (EC-JRC, 2009a). Green cover seems to mitigate nitrate leaching by taking up the residual nitrate in the soil (EC-JRC, 2009a).

For green cover, EC-JRC, 2009b report a 50% reduction in soil erosion by covering soil that would be otherwise left bare. EC, 2005 also presents an example in Belgium that supports this. Green cover crops also diversify the cropping system.

**Early sowing (A6)**

Early sowing refers to sowing up to six weeks before the normal sowing season. The period in which the soil lies bare becomes shorter; therefore, erosion and run-off are less significant and water infiltration is improved. However, early sown plants are frost sensitive; therefore farmers run the risk of losing the crops because of the low temperatures. In northern countries, temperature in spring (March) can be adequate but the risk of frost is still serious until May. Therefore, early sowing requires specific

**Early sowing** allows for an earlier and quicker development of crops and of a root network that leads to soil protection. Early sowing can also help to mitigate the extreme ETP rates typical of Mediterranean summers.

tools (plastic tunnel covers, onsite green house, etc.) and therefore cannot be applied by any farmers for any crops.

### *Benefits and co-benefits of early sowing*

Early sowing allows for an earlier and quicker development of crops and of a root network that leads to soil protection. As the soil does not need to be tilled, soil compaction is decreased and tillage costs are reduced. Early sowing prevents the soil from becoming friable and therefore has positive impacts on soil quality. Early sowing can also help to mitigate the extreme ETP rates typical of Mediterranean summers. For Arvidsson *et al.*, 2000, early-sown plots show significant higher water content than conventional sown plots. Furthermore, the seeds have more time to germinate and to grow, which increases yields. Arvidsson *et al.*, 2000 mention that the larger the difference in sowing date (of spring cereals without harrowing), the greater the yield increase due to early sowing.

### 4.3.4 Cost assessment of agricultural measures

The JRC was to model these agricultural measures in four scenarios:

1. Grassland (A1);
2. Buffer strips (A2);
3. Grassed waterways (A2); and
4. Crop practices (A3, A4, A5, and A6).

**Grassland (A1. Restoring and maintaining meadows and pastures)**

In the Impact Assessment on the Thematic Strategy on soil protection[40], the annual cost of converting arable land into pasture is €14/ha (discounted and annualised) or €15.8/ha[41] in 2011 prices. The Impact Assessment also estimates the annual loss of revenues at €140/ha or €158/ha[42] in 2011 prices.

In addition, Annex 2c of the Impact assessment of the CAP towards 2020[43] estimates the subsidies for various measures linked to permanent pastures, including management and restoration for most of the EU countries based on the Rural Development Programme (RDP) agri-environmental premiums 2007-2013. Country subsidies average €198/ha/year.

In total, the annual cost of grassland is assumed to be the sum of the annual cost of converting arable land into pasture (€158/ha), the annual loss of revenues (€15.8/ha) and the average EU subsidy (€198/ha), i.e., 371/ha/year in 2011 prices.

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[40] European Commission, 2006. SEC(2006)620 Impact assessment of the Thematic Strategy on soil protection. http://ec.europa.eu/environment/soil/pdf/SEC_2006_620.pdf

[41] A factor of 115.38/102.31 (EU 27 average) was used to convert 2006 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

[42] A factor of 115.38/102.31 (EU 27 average) was used to convert 2006 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

[43] EC, 2011. Impact assessment Common Agricultural Policy towards 2020. ANNEX 2C. http://ec.europa.eu/agriculture/analysis/perspec/cap-2020/impact-assessment/annex2c_en.pdf

The JRC modelled a total increase of grassland surface areas of 782,718 ha (less than riparian forests); most of this increase is in France, Germany, Ireland, Spain, and the UK; there is no increase in Belgium, Greece, Malta, Portugal or Sweden (see Table 18).

**TABLE 18**
**COSTS OF GRASSLAND SCENARIO**

| Member State | Increase in grassland surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 55,737 | 0.25 | 20.80 | 284.4 | 8.4 | 0.01% | 2.48 |
| Belgium | 0 | 0.00 | - | 352.9 | 10.8 | 0.00% | - |
| Bulgaria | 16,107 | 0.03 | 2.88 | 36 | 7.6 | 0.01% | 0.38 |
| Cyprus | 2,830 | 0.01 | 0.89 | 17.5 | 0.8 | 0.01% | 1.11 |
| Czech Republic | 4,773 | 0.02 | 1.26 | 145 | 10.5 | 0.00% | 0.12 |
| Denmark | 37 | 0.00 | 0.02 | 234 | 5.5 | 0.00% | 0.00 |
| Estonia | 385 | 0.00 | 0.10 | 14.5 | 1.3 | 0.00% | 0.08 |
| Finland | 155 | 0.00 | 0.07 | 180.3 | 5.3 | 0.00% | 0.01 |
| France | 95,979 | 0.45 | 37.38 | 2,080.80 | 63.1 | 0.00% | 0.59 |
| Germany | 82,167 | 0.36 | 30.12 | 2,498.80 | 81.8 | 0.00% | 0.37 |
| Greece | 0 | 0.00 | - | 230.2 | 11.3 | 0.00% | - |
| Hungary | 5,246 | 0.01 | 1.20 | 98.4 | 10 | 0.00% | 0.12 |
| Ireland | 140,527 | 0.71 | 58.82 | 153.9 | 4.4 | 0.04% | 13.37 |
| Italy | 9,087 | 0.04 | 3.31 | 1,548.80 | 60.3 | 0.00% | 0.05 |
| Latvia | 1,112 | 0.00 | 0.28 | 18 | 2.2 | 0.00% | 0.13 |
| Lithuania | 156 | 0.00 | 0.04 | 27.4 | 3.2 | 0.00% | 0.01 |
| Luxembourg | 340 | 0.00 | 0.14 | 41.6 | 0.5 | 0.00% | 0.29 |
| Malta | 0 | 0.00 | - | 6.2 | 0.4 | 0.00% | - |
| Netherlands | 139 | 0.00 | 0.05 | 591.5 | 16.6 | 0.00% | 0.00 |
| Poland | 18,628 | 0.05 | 4.05 | 354.3 | 38.2 | 0.00% | 0.11 |
| Portugal | 0 | 0.00 | - | 172.7 | 10.6 | 0.00% | - |
| Romania | 64,163 | 0.16 | 13.26 | 121.9 | 21.5 | 0.01% | 0.62 |
| Slovakia | 65,762 | 0.20 | 16.55 | 65.9 | 5.4 | 0.03% | 3.06 |
| Slovenia | 11,685 | 0.04 | 3.47 | 36 | 2 | 0.01% | 1.74 |
| Spain | 104,082 | 0.43 | 35.48 | 1,062.60 | 46 | 0.00% | 0.77 |
| Sweden | 0 | 0.00 | - | 346.7 | 9.3 | 0.00% | - |
| United Kingdom | 103,621 | 0.44 | 36.49 | 1,696.60 | 62 | 0.00% | 0.59 |
| EU 27 | 782,718 | 2.87 | 237.71 | 12,268.40 | 501 | 0.00% | 0.47 |

The present value of the costs for the 27 EU Member States is €2.9 billion, which corresponds to an annualised cost of €238 million, i.e., less than 0.01% of the GDP or €0.47 per person and per year. As a percentage of GDP, this annual cost is the highest in Ireland (0.04%) and Slovakia (0.03%). This annual cost per person is the highest (above €3) in Ireland and Slovakia.

**Buffer strips and grassed waterways (A2. Buffer strips)**

The Impact Assessment on the Thematic Strategy on soil protection estimates at €57/ha (based on an investment of €800) the annual discounted investment in buffer strips of 3m wide every 30m on steep slopes (12-25%) in serious erosion zones and €28/ha (based on an investment of €400) in moderate erosion zones. Since *a priori* the number of hectares or proportion of land in the EU suffering from serious or moderate erosion is unknown, the annual investment cost is assumed to be the average of these two costs: €42.5/ha or €48/ha[44] in 2011 prices.

The same document also provides annual maintenance costs: €150/ha for serious erosion zones and €75/ha for moderate erosion zones; the average of these two costs is €112.5/ha or €127/ha[45] in 2011 prices. The same source reports an annual loss of revenues of €20/ha (or €22.6/ha[46] in 2011 prices) in both erosion risk zones. Countryside management programmes also provide farmers with annual compensation payments. For Kohler and Heinrichs, 2011, payments are €289-715/ha/year - i.e., an average of €502/ha/year; for Tredanari, 2011, compensation payments are €335.7 – i.e., €447ha/year (average of €391.7/ha/year) in Sweden and DKK600/1,200 – 2,000/3,000 DKK/ha/year (average of DKK1,700/ha/year or €228.7/ha/year[47]) in Denmark. These costs were adjusted according to the comparative price levels in Table 11, resulting in an EU average compensation payment of €328/ha/year. Total O&M are €509/ha/year, the sum of maintenance costs, loss of revenues and compensation payments.

The JRC modelled a total increase of buffer strip surface areas of 2,191,506 ha (two thirds of the afforestation scenario); most of this increase is in France, Germany, Poland and Spain; there is no increase in Cyprus (see Table 19).

**TABLE 19**
**COSTS OF BUFFER STRIP SCENARIO**

| Member State | Increase in buffer strip surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 30,775 | 0.19 | 15.82 | 284.4 | 8.4 | 0.01% | 1.88 |
| Belgium | 19,598 | 0.13 | 10.57 | 352.9 | 10.8 | 0.00% | 0.98 |

44 A factor of 115.38/102.31 (EU 27 average) was used to convert 2006 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en
45 A factor of 115.38/102.31 (EU 27 average) was used to convert 2006 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en
46 A factor of 115.38/102.31 (EU 27 average) was used to convert 2006 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en
47 Using an exchange rate DKK 1.00 = €0.134525.

| Member State | Increase in buffer strip surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Bulgaria | 85,983 | 0.26 | 21.15 | 36 | 7.6 | 0.06% | 2.78 |
| Cyprus | 0 | 0.00 | - | 17.5 | 0.8 | 0.00% | - |
| Czech Republic | 83,145 | 0.37 | 30.27 | 145 | 10.5 | 0.02% | 2.88 |
| Denmark | 32,965 | 0.27 | 22.71 | 234 | 5.5 | 0.01% | 4.13 |
| Estonia | 12,362 | 0.05 | 4.48 | 14.5 | 1.3 | 0.03% | 3.44 |
| Finland | 14,150 | 0.10 | 8.46 | 180.3 | 5.3 | 0.00% | 1.60 |
| France | 409,083 | 2.65 | 219.43 | 2,080.80 | 63.1 | 0.01% | 3.48 |
| Germany | 247,472 | 1.51 | 124.96 | 2,498.80 | 81.8 | 0.01% | 1.53 |
| Greece | 51,854 | 0.29 | 23.87 | 230.2 | 11.3 | 0.01% | 2.11 |
| Hungary | 37,525 | 0.14 | 11.79 | 98.4 | 10 | 0.01% | 1.18 |
| Ireland | 14,668 | 0.10 | 8.46 | 153.9 | 4.4 | 0.01% | 1.92 |
| Italy | 114,848 | 0.70 | 57.55 | 1,548.80 | 60.3 | 0.00% | 0.95 |
| Latvia | 25,134 | 0.11 | 8.79 | 18 | 2.2 | 0.05% | 3.99 |
| Lithuania | 36,765 | 0.14 | 11.59 | 27.4 | 3.2 | 0.04% | 3.62 |
| Luxembourg | 2,115 | 0.01 | 1.23 | 41.6 | 0.5 | 0.00% | 2.47 |
| Malta | 201 | 0.00 | 0.08 | 6.2 | 0.4 | 0.00% | 0.19 |
| Netherlands | 2,211 | 0.01 | 1.15 | 591.5 | 16.6 | 0.00% | 0.07 |
| Poland | 191,740 | 0.69 | 57.46 | 354.3 | 38.2 | 0.02% | 1.50 |
| Portugal | 72,766 | 0.38 | 31.07 | 172.7 | 10.6 | 0.02% | 2.93 |
| Romania | 100,568 | 0.35 | 28.63 | 121.9 | 21.5 | 0.02% | 1.33 |
| Slovakia | 24,318 | 0.10 | 8.43 | 65.9 | 5.4 | 0.01% | 1.56 |
| Slovenia | 5,373 | 0.03 | 2.20 | 36 | 2 | 0.01% | 1.10 |
| Spain | 400,456 | 2.27 | 188.05 | 1,062.60 | 46 | 0.02% | 4.09 |
| Sweden | 54,023 | 0.38 | 31.80 | 346.7 | 9.3 | 0.01% | 3.42 |
| United Kingdom | 121,408 | 0.71 | 58.89 | 1,696.60 | 62 | 0.00% | 0.95 |
| EU 27 | 2,191,506 | 11.95 | 988.88 | 12,268.40 | 501 | 0.01% | 1.97 |

The present value of the costs for the 27 EU Member States is €12 billion, which corresponds to an annualised cost of €989 million, i.e., 0.01% of the GDP or €1.97 per person and per year. As a percentage of GDP, this annual cost is the highest in Bulgaria (0.06%), Latvia (0.05%) and Lithuania (0.04%). This annual cost per person is the highest (above €4) in Denmark and Spain.

The JRC modelled a total increase of grassed waterway surface areas of 3,957,266 ha (the largest, even more than urban green); most of this increase is in France, Germany, Poland and Spain; there is no increase in Cyprus (see Table 20).

**TABLE 20**

**COSTS OF GRASSED WATERWAY SCENARIO**

| Member State | Increase in grassed waterway surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 58,559 | 0.36 | 30.11 | 284.4 | 8.4 | 0.01% | 3.58 |
| Belgium | 42,847 | 0.28 | 23.11 | 352.9 | 10.8 | 0.01% | 2.14 |
| Bulgaria | 129,049 | 0.38 | 31.74 | 36 | 7.6 | 0.09% | 4.18 |
| Cyprus | 0 | 0.00 | - | 17.5 | 0.8 | 0.00% | - |
| Czech Republic | 102,499 | 0.45 | 37.32 | 145 | 10.5 | 0.03% | 3.55 |
| Denmark | 89,597 | 0.75 | 61.72 | 234 | 5.5 | 0.03% | 11.22 |
| Estonia | 34,171 | 0.15 | 12.37 | 14.5 | 1.3 | 0.09% | 9.52 |
| Finland | 49,740 | 0.36 | 29.74 | 180.3 | 5.3 | 0.02% | 5.61 |
| France | 645,646 | 4.19 | 346.33 | 2,080.80 | 63.1 | 0.02% | 5.49 |
| Germany | 417,047 | 2.54 | 210.58 | 2,498.80 | 81.8 | 0.01% | 2.57 |
| Greece | 95,084 | 0.53 | 43.78 | 230.2 | 11.3 | 0.02% | 3.87 |
| Hungary | 142,589 | 0.54 | 44.80 | 98.4 | 10 | 0.05% | 4.48 |
| Ireland | 41,586 | 0.29 | 23.98 | 153.9 | 4.4 | 0.02% | 5.45 |
| Italy | 305,581 | 1.85 | 153.12 | 1,548.80 | 60.3 | 0.01% | 2.54 |
| Latvia | 70,209 | 0.30 | 24.54 | 18 | 2.2 | 0.14% | 11.15 |
| Lithuania | 102,019 | 0.39 | 32.15 | 27.4 | 3.2 | 0.12% | 10.05 |
| Luxembourg | 2,552 | 0.02 | 1.49 | 41.6 | 0.5 | 0.00% | 2.98 |
| Malta | 292 | 0.00 | 0.11 | 6.2 | 0.4 | 0.00% | 0.27 |
| Netherlands | 37,474 | 0.24 | 19.52 | 591.5 | 16.6 | 0.00% | 1.18 |
| Poland | 448,137 | 1.62 | 134.29 | 354.3 | 38.2 | 0.04% | 3.52 |
| Portugal | 68,769 | 0.35 | 29.36 | 172.7 | 10.6 | 0.02% | 2.77 |
| Romania | 281,624 | 0.97 | 80.17 | 121.9 | 21.5 | 0.07% | 3.73 |
| Slovakia | 42,630 | 0.18 | 14.78 | 65.9 | 5.4 | 0.02% | 2.74 |
| Slovenia | 9,693 | 0.05 | 3.97 | 36 | 2 | 0.01% | 1.98 |
| Spain | 474,483 | 2.69 | 222.82 | 1,062.60 | 46 | 0.02% | 4.84 |
| Sweden | 97,073 | 0.69 | 57.15 | 346.7 | 9.3 | 0.02% | 6.14 |
| United Kingdom | 168,316 | 0.99 | 81.65 | 1,696.60 | 62 | 0.00% | 1.32 |
| EU 27 | 3,957,266 | 21.16 | 1,750.68 | 12,268.40 | 501 | 0.01% | 3.49 |

The present value of the costs for the 27 EU Member States is €21.2 billion, which corresponds to an annualised cost of €1.75 billion, i.e., 0.01% of the GDP or €3.5 per person and per year.  As a percentage of GDP, this annual cost is the highest in Latvia (0.14%) and Lithuania (0.12%).  This annual cost per person is the highest (above €10) in Denmark, Latvia and Lithuania.

## Crop practices (A3. Soil conservation practices, A4. No and reduced tillage, A5. Green cover and A6. Early sowing)

Soil conservation practices (A3), no and reduced tillage (A4), green cover (A5) and early sowing (A6) are modelled together; information on the costs of these four measures is very limited.

For **soil conservation practices**, there are no quantitative data on investment costs; however, these costs are very low and there is no loss of revenue, as explained in Annex 2c of the Impact assessment CAP towards 2020 based on a UK case study. Therefore, the study assumes that the only cost is the subsidy given to farmers. According to Strauss, 2005, €93-113/ha (average €103/ha or €117/ha in 2011 prices[48]) was given as a subsidy for implementing "soil erosion control in farmland". This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €110/ha/year

This is also supported by the costs reported by Hart *et al*., 2011 for changing crop rotations and increasing fallow index in crop rotations: €32/ha (Tucker and Mazza, 2011). In Annex 2c of the CAP Impact assessment, the average subsidy for crop rotation based on the RDP agri-environmental premiums 2007-2013 is €128/ha/year. Therefore, the study assumes an annual cost of €90/ha for soil conservation practices.

For **no and reduced tillage**, the information is also limited. For the EC-JRC, 2009a, reduced and no tillage do not increase O&M, but reduce fuel consumption by 10-20% (up to 50%) and 25-35% (up to 60%), respectively, and labour hours by 30-40 and 50-75%, respectively, depending on the geographical location (northern or southern Europe). A case study in the Uckermark area, Denmark, shows that reduced tillage was driven by the cost reductions to farmers (e.g., fuel, equipment, and labour reduction). Experts have calculated cost savings of €28-70/ha/year or an average of €49/ha/year (€51.4/ha/year in 2011 prices[49]). This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost saving of €36/ha/year. However, the Impact Assessment on the Thematic Strategy on soil protection reports payment for conservation tillage of €59/ha/year or €67/ha/year in 2011 prices[50]. Therefore, the study assumes annual costs of €31/ha/year (payments minus costs savings) for no and reduced tillage.

There is no information on the investment and O&M for **green cover**. However, in Annex 2c of the Impact assessment CAP, the average subsidy for green cover based on the RDP agri-environmental premiums 2007-2013 is €144/ha/year. Therefore, the study assumes an annual cost of €144/ha for green cover.

For **early sowing**, the information is also very limited; the Impact Assessment on the Thematic Strategy on soil protection reports payment for off-season cover crops of

[48] A factor of 113.42/100 (Austria) was used to convert 2005 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

[49] A factor of 113.8/108.4 (Denmark) was used to convert 2005 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

[50] A factor of 115.38/102.31 (EU 27 average) was used to convert 2006 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

€57-€64.4/ha/year in 2011 prices[51], based on the premiums paid in agri-environmental schemes.

On the basis of the subsidies and payments for these four agricultural practices, the study assumes an average unit cost of €81/ha/year.

The JRC modelled a total increase of crop practices surface areas of 111,254,424 ha (more than one order of magnitude larger than the other scenarios); most of this increase is in France, Germany, and Spain; there is no increase in Cyprus, Poland, Portugal, Romania, Slovenia or Sweden (see Table 21).

**TABLE 21**
**COSTS OF CROP PRACTICES SCENARIO**

| Member State | Increase in crop practices surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 2,343,260 | 2.30 | 190.72 | 284.4 | 8.4 | 0.07% | 22.70 |
| Belgium | 1,377,220 | 1.42 | 117.58 | 352.9 | 10.8 | 0.03% | 10.89 |
| Bulgaria | 4,927,960 | 2.32 | 191.86 | 36 | 7.6 | 0.53% | 25.24 |
| Cyprus | 0 | 0.00 | 0.00 | 17.5 | 0.8 | 0.00% | 0.00 |
| Czech Republic | 3,822,710 | 2.66 | 220.31 | 145 | 10.5 | 0.15% | 20.98 |
| Denmark | 2,851,950 | 3.76 | 311.02 | 234 | 5.5 | 0.13% | 56.55 |
| Estonia | 1,154,730 | 0.80 | 66.20 | 14.5 | 1.3 | 0.46% | 50.92 |
| Finland | 1,963,120 | 2.25 | 185.81 | 180.3 | 5.3 | 0.10% | 35.06 |
| France | 22,438,700 | 23.03 | 1,905.40 | 2,080.80 | 63.1 | 0.09% | 30.20 |
| Germany | 14,587,000 | 14.09 | 1,166.00 | 2,498.80 | 81.8 | 0.05% | 14.25 |
| Greece | 4,056,540 | 3.57 | 295.65 | 230.2 | 11.3 | 0.13% | 26.16 |
| Hungary | 5,066,640 | 3.05 | 252.01 | 98.4 | 10 | 0.26% | 25.20 |
| Ireland | 1,739,560 | 1.92 | 158.78 | 153.9 | 4.4 | 0.10% | 36.09 |
| Italy | 12,005,100 | 11.51 | 952.26 | 1,548.80 | 60.3 | 0.06% | 15.79 |
| Latvia | 2,447,820 | 1.64 | 135.45 | 18 | 2.2 | 0.75% | 61.57 |
| Lithuania | 3,384,080 | 2.04 | 168.84 | 27.4 | 3.2 | 0.62% | 52.76 |
| Luxembourg | 88,775 | 0.10 | 8.20 | 41.6 | 0.5 | 0.02% | 16.40 |
| Malta | 10,129 | 0.01 | 0.60 | 6.2 | 0.4 | 0.01% | 1.51 |
| Netherlands | 1,237,470 | 1.23 | 102.05 | 591.5 | 16.6 | 0.02% | 6.15 |
| Poland | 0 | 0.00 | 0.00 | 354.3 | 38.2 | 0.00% | 0.00 |
| Portugal | 0 | 0.00 | 0.00 | 172.7 | 10.6 | 0.00% | 0.00 |
| Romania | 0 | 0.00 | 0.00 | 121.9 | 21.5 | 0.00% | 0.00 |
| Slovakia | 1,909,910 | 1.27 | 104.80 | 65.9 | 5.4 | 0.16% | 19.41 |

51 A factor of 115.38/102.31 (EU 27 average) was used to convert 2006 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

| Member State | Increase in crop practices surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Slovenia | 0 | 0.00 | 0.00 | 36 | 2 | 0.00% | 0.00 |
| Spain | 18,077,400 | 16.24 | 1,343.87 | 1,062.60 | 46 | 0.13% | 29.21 |
| Sweden | 0 | 0.00 | 0.00 | 346.7 | 9.3 | 0.00% | 0.00 |
| United Kingdom | 5,764,350 | 5.35 | 442.66 | 1,696.60 | 62 | 0.03% | 7.14 |
| EU 27 | 111,254,424 | 100.55 | 8,320.06 | 12,268.40 | 501 | 0.07% | 16.61 |

The present value of the costs for the 27 EU Member States is €101 billion, which corresponds to an annualised cost of €8.3 billion, i.e., 0.07% of the GDP or €16.6 per person and per year. As a percentage of GDP, this annual cost is the highest in Bulgaria (0.53%) and Latvia (0.75%). This annual cost per person is the highest (above €50) in Denmark, Estonia Latvia, and Lithuania.

### 4.3.5 No-regret aspects of agricultural measures

Preliminary conclusions support agricultural measures as no-regret measures (see Table 22).

**TABLE 22**
**NO-REGRET ASSESSMENT OF AGRICULTURAL MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | It is important that these measures be designed and implemented at a local scale and adapted to local circumstances, taking into consideration soil types and suitable crops. This will ensure that they are advantageous no matter how and if climate change impacts materialise. |
| 2. Timing | The measure needs to be adapted to local circumstances to be effective, therefore it cannot be immediately implemented, unless is at a local scale. |
| 3. Planning horizon | The planning horizon of these measures depends very much on the local circumstances and on the nature of the measure itself. |
| 4. Flexibility | These measures are flexible enough to be easily modifiable to changes and new climate change scenarios without high costs (although changing farmers' practices supposes great challenges in some cases as they are naturally reluctant to new practices). |
| 5. Risks (cost effective and beneficial measures) | Agricultural measures aim to retain the water retention capacity of soils and therefore soil fertility, which is a basic requirement for successful agricultural production. The measures also reduce the risk of erosion, improve soil quality, contribute to reducing or slowing down run-off and increase soil moisture, all of which help counteract the potential negative impacts of climate change on the soil and on food production. Some of the measures, however, can be very costly in the short term, in particular given the training required for farmers; however, they can reduce the costs of fuel, machinery, and labour time in the long term |
| 6. Local and regional scale | The measure must be implemented at a local scale. |

| No-regret aspects | Assessment |
|---|---|
| 7. Economic analysis | The measures must take into account future water supply and demand scenarios as well as food demands. |

## 4.4 Traditional terracing[52]

Traditional terraces consist of nearly level platforms built along contour lines of slopes, mostly sustained by stone walls, used for farming on hilly terrain. When properly built and well maintained, terraces can reduce erosion and surface run-off by slowing rainwater to a non-erosive velocity. Traditional terracing involves less disturbance of the terrain, as it does not involve significant levelling or cutting.

### 4.4.1 Applicability of traditional terracing

Traditional terracing has been implemented across the Mediterranean climate zone, but also in the south Alpine zone; it is relevant to agricultural land-uses, including vineyards.

There is no information in the sources on the location in the river basin. The measure is not suitable for implementing on coarse or sandy soils, presumably because of the stability of the terracing (Dorren and Rey, 2004). There is no available information on soil depth. However, the measure is suitable for most except perhaps the most extreme slopes (from less than 8% slopes (Dorren and Rey, 2004) to over 50% (Martinez-Casasnovas, 2010).

The relevance of traditional terracing for the EU can be assumed from where it has been implemented (Austria, Greece, and Spain).

### 4.4.2 Direct impacts of traditional terracing

Martínez-Casasnovas *et al*., 2008 analysed the impacts of traditional terracing (e.g., hillslope cultivation on slopes steeper than 50%, partly with small stonewalls, partly without) and modern terracing (e.g., bench terraces with unprotected borders suitable for cultivation with machinery, built up using bulldozers and backhoe loaders). The case study shows that traditional terracing does not lead to significant changes in slope morphology, and terracing can only be considered as a NWRM when done in accordance with natural conditions, respecting the fact that mountainous areas cannot be cultivated with the same intensity as can flat areas.

There is little direct information on the impact of the measure on soil moisture. However, EC, 2006a mentions the displacement of large amounts of earth (about 5,437$m^3$ per hectare), which can lead to landscape transformation and loss of soil profiles from <u>modern</u> (opposed to traditional) terracing techniques. Matczak *et al*., 2009 similarly mentions problems such as the burial of original top soils and changes in physical and biological properties of the soil.

There is no information on water temperature or ETP. The key positive impacts of terracing of all kinds are the mitigation of erosion and soil loss, through encouraging

52 The Fact Sheet for Traditional terracing is in Annex 5.

the accumulation, infiltration, evaporation or diversion of run-off water. Because of its beneficial contribution to run-off control, traditional terracing also improves infiltration rate and capacity, potentially leading to groundwater replenishment (Matczak *et al*., 2009 and EC-JRC, 2009).

There is no available information on land-use change. Some sources address the issue of abandonment of terraces, which can lead to instability and therefore erosion (EC-JRC, 2009).

The measure is designed for and therefore supposed to be effective in erosion control; however, there is no explicit information. Nor is there any information on the measure's impact on landscape storage capacity.

### 4.4.3 Benefits and co-benefits of traditional terracing

When properly built and well maintained, terraces can reduce erosion and surface run-off by slowing rainwater to a non-erosive velocity. Providing better infiltration abilities than steep slopes, terracing also increases soil moisture content, thus contributing to the reduction of peak discharge rates of rivers (Dorren and Rey, 2004). Hence, terracing also promotes water retention.

However, modern terracing causes large movements of material with a consequent alteration of the soil profiles. EC, 2006a mentions the displacement of large amounts of earth (about 5,437 $m^3$/ha), which can lead to landscape transformation and loss of soil profiles from modern terracing techniques.

Because of its beneficial contribution to run-off control, traditional terracing also improves infiltration rate and capacity, potentially leading to groundwater replenishment (Matczak *et al*., 2009 and EC, 2009a). However, the impact on floods appears ambivalent (EC, 2009a) and depends on the slope's stability. It is generally acknowledged that terraces play a role in water conservation through improved infiltration. However, one source indicated that this can depend on how well the terraces are constructed; if they are constructed only for traffic, their water conservation role might be reduced (Martinez-Casasnovas, 2008).

The implementation of additional measures, such as maintaining a permanent soil cover, soil conservation practices and the planning of adequate cover crops are very important for the effectiveness of terracing in water retention and reduction of soil erosion (Dorren and Rey, 2004).

### 4.4.4 Qualitative cost and benefit analysis of traditional terracing

The cost of terrace installation includes earth work costs associated with the terrace construction, the establishment of an adequate outlet such as a grassed waterway or underground outlet and vegetation establishment of the respective terrace slopes on grassed back slope or narrow base terraces. In some cases, terracing may result in potential losses in production because of construction and some reduction in crop acres may result from terrace and waterway placement. Terrace construction costs vary widely and range from $1 to $6 per linear foot of terrace (Carman (no date))), with additional costs associated with construction of waterways and underground outlets for conveyance of water to the outlet. The average cost of land terracing is about €10,818/ha, which represents 34% of the total costs for starting a new terraced vineyard (EC, 2006a).

The high maintenance required, coupled with the high cost of labour and the significant changes in the socio-economic structure of the agricultural population in the last decades, have led farmers to abandon terraces. Socio-economic structures play a very important role and have to be taken into account with regard to terracing as there is evidence that terraces have been abandoned because of underlying trends in the socio-economic structure of the agricultural population. Merely carrying out a cost-benefit analysis is therefore often not sufficient to establish the profitability of terracing.

#### 4.4.5 No-regret aspects of traditional terracing

Based on the evidence available, this measure is most likely a no-regret measure (see Table 23), although this depends on local conditions (e.g., environmental and socio-economical).

**TABLE 23**
**NO-REGRET ASSESSMENT OF TRADITIONAL TERRACING MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | Terracing should not be affected to a great extent by different climate change scenarios and climate change's impacts on the hydrological cycle, particularly because the measure has a very local scale and therefore is adapted to local circumstances. |
| 2. Timing | The measure can be implemented immediately. |
| 3. Planning horizon | Terracing has a long-term horizon planning; if terraces are abandoned or poorly maintained, they can have negative effects, making terracing neither cost-effective nor flexible. |
| 4. Flexibility | Traditional terracing is more flexible and less costly than modern terracing. |
| 5. Risks (cost effective and beneficial measures) | All terracing practices contribute to mitigating erosion and reducing or slowing down run-off. Traditional terracing does so with fewer of the negative impacts of modern terracing, including less impact on the landscape and soil, as it does not require heavy machinery or moving large amounts of soil. |
| 6. Local and regional scale | The measure is implemented at a local scale. |
| 7. Economic analysis | Not applicable. |

### 4.5 Basins and ponds[53]

Basins and ponds are areas for storing surface run-off. Detention basins are free from water in dry weather flow conditions (CIRIA, SuDS). These structures include:

- Detention basins; and
- Extended detention basins.

[53] The Fact Sheet for Basins and ponds is in Annex 6.

Ponds contain water in dry weather, and are designed to hold more when it rains. They include:

- Balancing and attenuation ponds;
- Flood storage reservoirs;
- Lagoons;
- Shallow impoundments; and
- Retention ponds.

Basins and ponds can be implemented as SuDS in urban areas, or in river basins and forest areas. Extensively used floodplains are suitable areas for basins and ponds. Sufficient space is available and the groundwater is often high enough to guarantee that ponds do not dry out in warm weather. The creation of shallow impoundments, however, has to be considered critically. Shallow impoundments lead to the accumulation of silt and to the accumulation of pollutants. While this is beneficial for the water quality further downstream, it can have negative impacts on the flora and fauna within the shallow impoundment.

### 4.5.1 Applicability of basins and ponds

Basin and ponds can be implemented in all EU climate zones. Basins and ponds have been implemented in urban areas (CLC 1: 1. Artificial surfaces), agricultural areas (CLC 1: 2. Agricultural areas), meadows and pastures (CLC 1: 2. Agricultural areas and 3. Forests and semi-natural areas), forest areas (CLC 1: 3. Forests and semi-natural areas) and a river catchment (CLC 2: 4.1. Inland wetlands). It has also been implemented up- and downstream, but mainly downstream to collect run-off water.

There is no information on soil permeability or depth. However the DEX case study in Scotland (CIRIA, 1995-1999) is primarily on low permeability clay soil while the case study in the Railfreight Terminal, Telford, Shropshire (Robert Bray Associates Ltd., 2011b) is on silty sands with some permeability. According to Heal (no date), SuDS ponds should not have slopes greater than 30° for safety reasons. The topography in the Railfreight Terminal, Telford, Shropshire case study was relatively flat.

### 4.5.2 Direct impacts of basins and ponds

Evidence on the impact of basins and ponds on soil moisture is very limited. Francés *et al*., 2007 compares micro ponds and traditional retention basins based on their findings from the humid/midland Kamp basin in Austria. According to their results, micro ponds mainly decrease soil moisture in the landscape while traditional retention basins reduce stream flow in the stream.

There is no information in the sources on the impact on water temperature. According to the modelling results of a case study in Augustenborg, Malmö in Sweden (Naumann, *et al*., 2011a), ETP from channels and retention ponds between the rain events reduces the total run-off volume by about 20% compared to the conventional system.

Basins and ponds contribute to controlling run-off. The HYDROCOM and AMHY projects provide guidance on the design of basins and ponds to prevent floods. The run-off reduction in the Augustenborg case study is due to the entire SuDS and not only to the implementation of basins. The objective of the SuDS in the case study in the Red Hill C. of E. Primary School, Worcester (Robert Bray Associates Ltd., 2011c) was to control the flow. However, the case study combines various SuDS techniques and discusses the objectives and impacts of the combined scheme.

According to Forest Research, 2010, water storage in detention ponds/ basins and wetlands promotes natural groundwater recharge. According to the Pilot Project Thanovce in Slovakia, water has filled in the groundwater system after the implementation of three water retention levees.

There is little explicit information on land-use change; however, according to Heal (no date), SuDS ponds have a large land take.

There is no information on the impact on erosion control, except as a side effect of run-off control (HYDROCOM). The design of basins and ponds on agricultural lands for flood prevention may integrate a sediment trap. When sediments are trapped, erosion is partly controlled as it becomes less aggressive for the lower part of the catchment and will not induce mudflow.

By their nature, basins and ponds are designed to increase water storage in the landscape. Forest Research, 2010 only mentions the water storage capacity of basins and ponds, without any quantitative data. Reid*et al*., 2009 have designed SuDS using basins, as well as other SuDS techniques, to increase storage. The system can easily be re-designed to make one of the basins an off-line area for long-term storage. Wilkinson *et al*., 2010 reports that the pilot Runoff Attenuation Features (RAF)[54] can store 800 $m^3$ of floodwater in a catchment of 0.5 $km^2$; however, this value is linked to the entire RAF system implemented. According to the case study in the Red Hill C. of E. Primary School, Worcester, the selection of SuDS features, including basins and ponds, has reduced the volume requirement as “interception storage” by at least 5 $mm/m^2$.

### 4.5.3 Benefits and co-benefits of basins and ponds

Basins and ponds are very effective in retaining water after heavy rainfall, discharging it into the ground, and therefore allowing for a better control of rainwater. Their structure allows the concentration of rainwater in a sink, preventing it from flowing into surrounding areas and from getting contaminated. As basins and ponds contain still waters, sediments that otherwise would probably be transported to streams with run-off are deposited (CIRIA, SuDS). They therefore influence both the quality and quantity of run-off.

[54] For this pilot study, the RAF included: bunds, drain barriers, runoff storage features (ponds, online and offline), wood debris, buffer strip management and willow barriers.

According to the modelling results of a case study in Augustenborg, Malmö in Sweden (Naumann *et al*., 2011a), ETP from channels and retention ponds between the rain events reduces the total run-off volume by about 20% compared to the conventional system. Therefore, basins and ponds contribute to flood attenuation. This study proves that a SuDS (including basins and ponds) can reduce the flood hazard of a 50 year rainfall event. However, like other case studies (Railfreight Terminal, Telford, Shropshire, and the DEX case study in Scotland), the benefit of flood attenuation cannot be attributed only to basins and ponds, but to the SuDS as a whole.

Basins and ponds also contribute to groundwater replenishment. According to Forest Research, 2010, water storage in detention ponds/ basins and wetlands promotes natural groundwater recharge. Water has filled in the groundwater system after implementing three water retention levees in the Pilot Project Thanovce in Slovakia.

Heal (no date) describes the processes improving water quality in SuDS ponds; chemical (precipitation, destruction of pathogens by UV in sunlight), physical (sedimentation, adsorption to sediment) and biological (plant uptake of nutrients, microbial decomposition). The URBEM project (Wallingford, 2005) suggests that ponds with a surface area of 1% of the catchment size will remove 80-90% of suspended solids and ponds of 3-5% catchment size will remove 50-60% of macronutrients.

In addition to their role as water retention devices, basins and ponds also provide habitats for insects, waders and amphibians, improve ecological corridors along European rivers (SAND project); enhance biodiversity (the SuDS reported by Reid, S. *et al*., 2009). Moreover, Heal recommends not smoothing the banks of the ponds, to allow different water depths and therefore different habitats.

Moreover, basins and ponds have a positive impact on the landscape, enhance the value of recreational areas and increase tourism potential. In urban areas, basins and ponds are very well suited to green areas such as parks. They can be implemented together with other SuDS features, such as permeable surfaces and filter drains, for example. However, basins and ponds are not likely to change the sealing level of soils in urban areas, as they are implemented mostly in already existing green areas.

### 4.5.4 Cost assessment of basins and ponds

The measure S1. Basins and ponds covers different types of basins and ponds, including basins and ponds built as part of the SuDS in urban areas, as well as reservoirs built in the catchment along rivers. As the simulated scenarios introduce buffer ponds or retention areas in the river basins with outlets and inlets to the rivers, the pilot case Mödrath Flood Control Reservoir of the SAND project is relevant for calculating unit costs.

The project built a reservoir in a previously lignite pit. The retention reservoir comprises the retention area in the flood control reservoir (90 ha) and the retention area in the meadowland (40 ha). The flood control reservoir in by-pass of the Erft River required 5 hydraulic structures (sector weir (2-gate) in the flood channel, sluices of 1 and 3 gates, and retention and drainage structure), as well as construction work, designing and planning and control and monitoring equipment. In addition, land had to be bought and compensation payments were paid to the mining company owner of the lignite pit (see Table 24).

**TABLE 24**
**COSTS OF MÖDRATH FLOOD CONTROL RESERVOIR**

| Expenditure | Cost (€) |
|---|---|
| Land acquisition/land reallocation | 1,573,000 |
| Design/planning | 544,000 |
| Construction work | 5,165,000 |
| Total | 7,282,000 |

Therefore, the unit investment cost to build a 140 ha retention reservoir is €52,014/ha, or 55,655/ha in 2011 prices[55]. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €53,360/ha.

The operators of the Mödrath Flood Control Reservoir have estimated O&M of €8,500/year[56]. Therefore, the unit operation and maintenance cost is assumed to be €61/ha/year. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €58/ha/year.

The JRC modelled a total increase of 295 ha of surface areas of buffer ponds; most of this increase is in France, Germany and the United Kingdom (see Table 25).

**TABLE 25**
**COSTS OF BUFFER PONDS SCENARIO**

| Member State | Increase in buffer ponds surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 1.60 | 0.00006 | 0.00 | 284.4 | 8.4 | 0.000002% | 0.0006 |
| Belgium | 12.48 | 0.00048 | 0.04 | 352.9 | 10.8 | 0.000011% | 0.0037 |
| Bulgaria | 5.28 | 0.00009 | 0.01 | 36 | 7.6 | 0.000021% | 0.0010 |
| Cyprus | 0.00 | 0.00000 | - | 17.5 | 0.8 | 0.000000% | - |
| Czech Republic | 10.24 | 0.00027 | 0.02 | 145 | 10.5 | 0.000015% | 0.0021 |
| Denmark | 1.44 | 0.00007 | 0.01 | 234 | 5.5 | 0.000003% | 0.0011 |
| Estonia | 0.32 | 0.00001 | 0.00 | 14.5 | 1.3 | 0.000005% | 0.0005 |
| Finland | 0.64 | 0.00003 | 0.00 | 180.3 | 5.3 | 0.000001% | 0.0004 |
| France | 38.88 | 0.00149 | 0.12 | 2,080.80 | 63.1 | 0.000006% | 0.0020 |
| Germany | 95.04 | 0.00343 | 0.28 | 2,498.80 | 81.8 | 0.000011% | 0.0035 |

[55] A factor of 111.1/104.1 (Germany) was used to convert 2007 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

[56] Personal communication with Erftverband's department River Basin Management.

| Member State | Increase in buffer ponds surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Greece | 3.20 | 0.00011 | 0.01 | 230.2 | 11.3 | 0.000004% | 0.0008 |
| Hungary | 13.44 | 0.00030 | 0.02 | 98.4 | 10 | 0.000025% | 0.0025 |
| Ireland | 2.24 | 0.00009 | 0.01 | 153.9 | 4.4 | 0.000005% | 0.0017 |
| Italy | 28.48 | 0.00102 | 0.08 | 1,548.80 | 60.3 | 0.000005% | 0.0014 |
| Latvia | 1.12 | 0.00003 | 0.00 | 18 | 2.2 | 0.000013% | 0.0011 |
| Lithuania | 0.16 | 0.00000 | 0.00 | 27.4 | 3.2 | 0.000001% | 0.0001 |
| Luxembourg | 0.80 | 0.00003 | 0.00 | 41.6 | 0.5 | 0.000007% | 0.0055 |
| Malta | 0.00 | 0.00000 | - | 6.2 | 0.4 | 0.000000% | - |
| Netherlands | 1.28 | 0.00005 | 0.00 | 591.5 | 16.6 | 0.000001% | 0.0002 |
| Poland | 0.00 | 0.00000 | - | 354.3 | 38.2 | 0.000000% | - |
| Portugal | 0.00 | 0.00000 | - | 172.7 | 10.6 | 0.000000% | - |
| Romania | 0.00 | 0.00000 | - | 121.9 | 21.5 | 0.000000% | - |
| Slovakia | 3.52 | 0.00009 | 0.01 | 65.9 | 5.4 | 0.000011% | 0.0013 |
| Slovenia | 0.00 | 0.00000 | - | 36 | 2 | 0.000000% | - |
| Spain | 20.48 | 0.00069 | 0.06 | 1,062.60 | 46 | 0.000005% | 0.0012 |
| Sweden | 0.00 | 0.00000 | - | 346.7 | 9.3 | 0.000000% | - |
| United Kingdom | 54.56 | 0.00189 | 0.16 | 1,696.60 | 62 | 0.000009% | 0.0025 |
| EU 27 | 295.20 | 0.01023 | 0.85 | 12,268.4 | 501 | 0.000007% | 0.0017 |

The present value of the costs for the 27 EU Member States is €10 million, which corresponds to an annualised cost of €0.85 million, i.e., 0.000007% of the GDP or €0.0017 per person and per year.

### 4.5.5 No-regret aspects of basins and ponds

Preliminary conclusions support basins and ponds as no-regret measures (see Table 26), but only insofar as they can be implemented without heavy investment, and that they are implemented on a local level, taking into account local conditions.

**TABLE 26**
**NO-REGRET ASSESSMENT OF BASINS AND PONDS MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | All types of basins and ponds are positive no matter how the climate change impacts will materialise. They contribute to increasing the catchment's adaptive capacity to respond to future expected climate changes. Only the size of the ponds could vary over time. |
| 2. Timing | Basins and ponds can be implemented immediately as their effectiveness does not depend on the climate change impacts. |
| 3. Planning horizon | Basins and ponds have a short-term planning horizon, although modifying them will potentially require engineering works. |

| | |
|---|---|
| 4. Flexibility | Basins and ponds are more flexible than conventional wastewater treatment systems. However, the construction of basins or ponds in the floodplain or in forest lands is less flexible due to their land-use take. |
| 5. Risks (cost effective and beneficial measures) | Basins and ponds designed as SuDS appear to be cost-effective solutions to replace or supplement conventional sewerage systems (see Urban Section above). However, the construction of basins or ponds in the floodplain or in forest lands is likely to require heavy engineering works, resulting in potentially high investment and operation costs. All types of basins and ponds contribute to flood attenuation, improve water quality, support biodiversity conservation and provide cultural services. |
| 6. Local and regional scale | Basins and ponds are implemented at a local scale. |
| 7. Economic analysis | Not applicable. |

## 4.6 Wetland restoration and creation[57]

**Wetlands restoration** can improve the hydrological regime of degraded wetlands and generally enhance habitat quality. Creating artificial or constructed wetlands in urban areas can also contribute to flood attenuation, water quality improvement and habitat and landscape enhancement.

Wetlands have often been drained for agricultural purposes. Restoration and revitalisation of abandoned drained and sedimented wetlands can improve the hydrological regime of degraded wetlands and generally enhance habitat quality.

Restoring wetlands, including bog, fens, marshes, swamps and mires, consists of a mix of measures: technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); technical small-scale measures such as clearing trees; as well as changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. Rewetting, a very important part of wetland restoration, can include impounding measures such as blocking drainage ditches, changes in the type of land-use, and management measures such as the removal of tree and shrub cover.

Creating artificial, constructed or storm-water wetlands in urban and peri-urban areas can be part of the sewage system acting as a natural filter for run-off. These constructed wetlands are one of the features implemented as part of the SuDS in urban areas. Constructed wetlands have become common for primary, secondary and tertiary treatment of sewage. These wetlands differ from urban ponds in that they have a higher proportion of vegetation in relation to open water.

### 4.6.1 Applicability of wetland restoration and creation

The measure has been implemented in a wide range of EU climate zones and in a range or land uses: lakes, rivers (CLC 1: 5. Water bodies) and their wetlands, bogs, fens, mires (CLC 1: 4. Wetlands), as well as agricultural (CLC 1: 2. Agricultural areas) and urban areas (CLC 1: 1. Artificial surfaces). Mauchamp, 2002 considers that combining the restoration of wetlands with agriculture is advantageous.

57 The Fact Sheet for Wetland restoration and creation is in Annex 7.

From the available information it can be assumed that the measure can be efficiently implemented in upstream or downstream wetlands. For Wetlands International, 2006, wetlands have different types of flood attenuation efficiency depending on location: wetlands away from the river regulate water flows and affect the magnitude and timing of flood peaks while wetlands adjacent to rivers store, slow down and release flood waters affecting flood peaks. Wetlands in different tributaries can also have a cumulative flood attenuation effect further downstream where the tributaries converge.

Evidence on soil permeability is very limited. According to FAO, 2008, natural wetlands are most likely to occur in areas with low permeable soils. Wetlands International, 2006, considers that peatlands with deep organic porous soils are often viewed with the role of regulating floods by detaining or even retaining floodwaters from reaching river channels. However, it seems that soil permeability affects the ability of wetlands to attenuate floods (Ducks Limited Canada, 2001).

Evidence on soil depth is also very limited. As mentioned above, Wetlands International, 2006, considers that peatlands with deep organic porous soils are often viewed with the role of regulating floods by detaining or even retaining floodwaters from reaching river channels.

Evidence on the type of topography is limited. For Wetlands International, 2006, wetlands on slopes and plateaux, as well as in flatland areas can play an important role in regulating floods and storing water. Moreover, according to Ducks Limited Canada, 2001, wetlands can occur in topographic depressions created by glacial erosion and deposition or areas of steep land slopes such as embankments or river valley walls. Slopes affect the ability of wetlands to attenuate floods.

The restoration of wetlands is relevant to the EU territory. Wetlands International, 2006 emphasises the many hundreds of transboundary wetlands in Europe in northern and eastern European locations.

### 4.6.2 Direct impacts of wetland restoration and creation

There is no information in the sources on the impact of wetlands on soil moisture, water temperature or ETP.

Wetlands in urban areas can mitigate run-off (URBEM project; Forest Research, 2010; CIRIA and Robert Bray Associates Ltd., 2007) while restoring degraded wetlands can improve the hydrological regime and increase water retention (Kohler and Heinrichs, 2011; LIFE Dijlevallei Project). This is also supported by the fact that wetland drainage will reduce the capability of a river basin to attenuate runoff during flood conditions (Ducks Limited Canada, 2001).

In general, wetlands contribute to groundwater replenishment. According to Ducks Limited Canada, 2001, recharge of groundwater is a very important function of some wetlands, although the interactions between wetlands and groundwater are complex and site-specific. These interactions seem to be affected by the position of the wetland with respect to groundwater flow systems, geologic characteristics of the substrate and climate.

Evidence on the impact on land-use due to wetland restoration or creation is very limited. The LIFE Dijlevallei Project mentions that 109 hectares came under conservation control as a result of the project.

Wetlands contribute to erosion control. According to Wood and Van Halsema, 2008, wetlands contribute to erosion regulation as sediments settle when the water enters the wetlands and the velocity of the water decreases.

One of the functions of wetlands is to provide water storage. However, the capacity of wetlands to store water depends on the season and the rainfall conditions (Wood and Van Halsema, 2008).

#### 4.6.3 Benefits and co-benefits of wetland restoration and creation

Wetland restoration can improve the hydrological regime of degraded wetlands and generally enhance habitat quality. Due to their green cover and the open area they provide, wetlands offer many benefits with regard to water retention, flood mitigation, and groundwater quality and quantity.

Constructed wetlands can also reduce/detain run-off, remove suspended solids, nutrients and bacteria through biological treatment and settlement, thereby improving water quality. They also enhance the urban landscape, and provide habitat although they have less biodiversity than natural wetlands.

Wetlands provide space for flooding and for temporary retention of water in the landscape. However, the capacity of wetlands to store water depends on the season and the rainfall conditions (FAO, 2008). They can detain rainwater and run-off in the landscape and in the soil. In particular, a network of wetlands in a river catchment can significantly influence the quantity and severity of floods. For Wetlands International, 2006, wetlands have different types of flood attenuation efficiency depending on location: wetlands away from the river regulate water flows and affect the magnitude and timing of flood peaks while wetlands adjacent to rivers store, slow down, and release flood waters affecting flood peaks. Wetlands in different tributaries can also have a cumulative flood attenuation effect further downstream where the tributaries converge.

The effectiveness of wetlands to attenuate floods depends on their soil properties as well as on the saturation of their soil and on their size. Wetlands International, 2006, considers that peatlands with deep organic porous soils are often viewed with the role of regulating floods by detaining or even retaining floodwaters from reaching river channels. Slopes also affect the ability of wetlands to attenuate floods (Ducks Limited Canada, 2001). For Wetlands International, 2006, wetlands on slopes and plateaux, as well as in flatland areas can play an important role in regulating floods and storing water.

Wetlands can affect the quantity and quality of groundwater. According to Ducks Limited Canada, 2001, recharge of groundwater is a very important function of some wetlands, although the interactions between wetlands and groundwater are complex and site-specific. These interactions seem to be affected by the position of the wetland with respect to groundwater flow systems, geologic characteristics of the substrate, and climate.

Wetlands can act as natural filters and sinks for chemical compounds such as fertilizers and toxic compounds and as sediment traps contributing to the improvement of the water quality (Wetlands International, 2006). They influence nutrients, suspended solids, pathogenic microbes, and anthropogenic pollutants such as pesticides (Ducks Unlimited Canada, 2001).

Wetlands International, 2006 and Mazza *et al*., 2011 agree that wetlands contribute to drought management by increasing water availability and by regulating the frequency of drought periods: during periods with no rainfall, some wetland types can continue to supply small tributaries with water.

Wetlands offer habitats for flora and fauna that need high groundwater levels. The typical humid soils of wetlands provide unique living conditions for wetland vegetation such as crowfoot or lady's smock, as well as ground-nesting birds or waders which need wetlands as their habitat. The reconstructed wetland Kis-Balaton of Lake Balaton is a good example of how ecotones can improve lake water quality and provide multipurpose services (e.g., one of the largest water-bird sanctuaries of Central Europe (Jolánkai, 2004). Mauchamp, 2002, has documented an increase of species due to wetland restoration.

Wetlands also provide food/fibre/fuel including fish, wild game, fruits and grains and production of logs, fuelwood, peat and fodder (Wood and Van Halsema, 2008). According to Mazza *et al*., 2011 one hectare of restored wetland produces 34 kg of commercial-sized fish per year. They also provide recreational services. For instance, the WFD and hydromorphological pressures technical report, 2006 reports that the wetland restoration in Doñana increased tourism and leisure in the Guadiamar River.

### 4.6.4 Cost assessment of wetlands

For constructed wetlands, the information on costs is scarce, as they are normally combined with other SuDS features. The simulated scenario for wetland restoration, however, does not refer to small constructed wetlands in urban areas, but wetlands alongside rivers in the riparian areas. The unit costs for wetland restoration alongside rivers are presented below.

For Kohler and Heinrichs, 2011, the cost of wetland restoration is €150-6,000/ha (average of €3,075/ha). This measure involves removing trees and shrubs in bogs, fens, and wetlands. Naumann *et al*., 2011 provides unit costs for restoring wetlands from two projects in Belgium and Scotland. The LIFE project "Rehabilitation of heath and mires on the Hautes-Fagnes plateau" in Belgium restored 1,800 ha of peaty and wet habitats by removing conifer and restructuring plantations; the unit cost was €2,500/ha[58] of habitat restored. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €2,244/ha. Naumann *et al*., 2011 report a unit cost of €1,362/ha[59] of bog restored by the project: Restoration of

[58] It is unclear if these prices are in 2011 prices.
[59] It is unclear if these prices are in 2011 prices.

Scottish raised bogs. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €1,359/ha.

Mazza *et al*., 2011 also provide unit costs for various projects in the EU. The Scheldt Estuary Project restored 992 ha of wetlands for €60 million, i.e., a unit cost of €60,099/ha[60]. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €53,949/ha. According to Swartz, 2006 in Mazza *et al*., 2011 the investment unit cost of another wetland restoration project in the lower Danube was €200/ha[61]; however this cost did not include larger infrastructure works (such as polder in- and outlets) or compensation to farmers; they estimate an average unit cost of €5,000/ha. Both costs were adjusted according to the comparative price levels in Table 11, resulting in EU costs of €124/ha and €3,659/ha.

Kettunen, 2011 reports €62,000 as the restoration cost of 1 ha of wetland in Nummela, Finland. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €50,202/ha. However, this cost included the infrastructure for recreational purposes. In addition, Tucker and Mazza, 2011 report €8,375/ha unit costs for re-establishing freshwater wetlands in Denmark by reducing nitrogen load to down-stream recipients and to enhancing nature values in restored areas. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €5,885/ha.

Therefore, the study assumes an average investment unit cost of €15,776/ha (see Table 27).

**TABLE 27**
**UNIT INVESTMENT COSTS FOR WETLAND RESTORATION IN THE EU**

| Reference | Investment unit cost (€/ha) |
|---|---|
| 1.Kohler and Heinrichs, 2011 | 3,075 |
| 2.Naumann *et al*., 2011 (LIFE project “Rehabilitation of heath and mires on the Hautes-Fagnes plateau”) | 2,244 |
| 3.Naumann *et al*., 2011 (Restoration of Scottish raised bogs) | 1,359 |
| 4.Nocker and Mazza, 2011 (Scheldt Estuary Project) | 53,949 |
| 5.Swartz, 2006 (Lower Danube) | 365 |
| 6.Nocker and Mazza, 2011 (Lower Danube) | 9,124 |
| 7.Kettunen, 2011 (Nummela, Finland) | 50,202 |
| 8.Tucker and Mazza, 2011 (Wetland restoration in Denmark) | 5,885 |
| Average | 15,776 |

For the operation and maintenance, the information is more limited. For *et al*., 2011, the maintenance costs of managing wetlands based on the Article 133 of the French Grenelle II law are €251-521/ha/year; an average of €386/ha/year is assumed. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €348/ha.

60 It is unclear if these are 2011 prices.
61 It is unclear if these are 2011 prices.

Table 28 shows the costs of the wetland scenario by EU member state. The JRC modelled a total increase of wetland surface areas of 120,471 ha; most of this increase is in Finland, France, Germany, Romania and Sweden; there is no increase in Cyprus or Malta.

**TABLE 28**
**COSTS OF WETLAND SCENARIO**

| Member State | Increase in wetland surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 4,882 | 0.07 | 6.01 | 284.4 | 8.4 | 0.00% | 0.72 |
| Belgium | 553 | 0.01 | 0.71 | 352.9 | 10.8 | 0.00% | 0.07 |
| Bulgaria | 3,815 | 0.03 | 2.25 | 36 | 7.6 | 0.01% | 0.30 |
| Cyprus | 0 | 0.00 | - | 17.5 | 0.8 | 0.00% | - |
| Czech Republic | 1,617 | 0.02 | 1.41 | 145 | 10.5 | 0.00% | 0.13 |
| Denmark | 84 | 0.00 | 0.14 | 234 | 5.5 | 0.00% | 0.03 |
| Estonia | 614 | 0.01 | 0.53 | 14.5 | 1.3 | 0.00% | 0.41 |
| Finland | 9,351 | 0.16 | 13.39 | 180.3 | 5.3 | 0.01% | 2.53 |
| France | 14,473 | 0.22 | 18.59 | 2,080.80 | 63.1 | 0.00% | 0.29 |
| Germany | 9,740 | 0.14 | 11.78 | 2,498.80 | 81.8 | 0.00% | 0.14 |
| Greece | 1,696 | 0.02 | 1.87 | 230.2 | 11.3 | 0.00% | 0.17 |
| Hungary | 6,166 | 0.06 | 4.64 | 98.4 | 10 | 0.00% | 0.46 |
| Ireland | 590 | 0.01 | 0.81 | 153.9 | 4.4 | 0.00% | 0.19 |
| Italy | 6,451 | 0.09 | 7.74 | 1,548.80 | 60.3 | 0.00% | 0.13 |
| Latvia | 2,492 | 0.03 | 2.09 | 18 | 2.2 | 0.01% | 0.95 |
| Lithuania | 1,947 | 0.02 | 1.47 | 27.4 | 3.2 | 0.01% | 0.46 |
| Luxembourg | 75 | 0.00 | 0.10 | 41.6 | 0.5 | 0.00% | 0.21 |
| Malta | 0 | 0.00 | - | 6.2 | 0.4 | 0.00% | - |
| Netherlands | 1,278 | 0.02 | 1.59 | 591.5 | 16.6 | 0.00% | 0.10 |
| Poland | 8,286 | 0.07 | 5.95 | 354.3 | 38.2 | 0.00% | 0.16 |
| Portugal | 3,169 | 0.04 | 3.24 | 172.7 | 10.6 | 0.00% | 0.31 |
| Romania | 16,343 | 0.13 | 11.14 | 121.9 | 21.5 | 0.01% | 0.52 |
| Slovakia | 1,251 | 0.01 | 1.04 | 65.9 | 5.4 | 0.00% | 0.19 |
| Slovenia | 923 | 0.01 | 0.91 | 36 | 2 | 0.00% | 0.45 |
| Spain | 8,688 | 0.12 | 9.77 | 1,062.60 | 46 | 0.00% | 0.21 |
| Sweden | 14,707 | 0.25 | 20.74 | 346.7 | 9.3 | 0.01% | 2.23 |
| United Kingdom | 1,280 | 0.02 | 1.49 | 1,696.60 | 62 | 0.00% | 0.02 |
| EU 27 | 120,471 | 1.56 | 129.42 | 12,268.40 | 501 | 0.00% | 0.26 |

The present value of the costs for the 27 EU Member States is €1.6 billion, which corresponds to an annualised cost of €129 million, i.e., less than 0.01% of the GDP or €0.26 per person and per year. As a percentage of GDP, this annual cost is the highest in Bulgaria (0.01%), Finland (0.01%), Latvia (0.01%), Lithuania (0.01%), Romania (0.01%) and Sweden (0.01%). This annual cost per person is the highest (above €2) in Finland and Sweden.

### 4.6.5 No-regret aspects of wetland restoration and creation

Preliminary conclusions suggest that wetland restoration and creation is a no-regret measure (see Table 29), as long as it can be implemented without high investment costs (i.e., engineering work).

**TABLE 29**
**NO-REGRET ASSESSMENT OF WETLAND RESTORATION AND CREATION MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | Wetland restoration leads to the restoration of an important ecosystem, and healthy ecosystems benefit biodiversity, making it resilient to climate change impacts (Laaser *et al.,* 2009). Moreover, it does not need to be based on climate change data as the main aim of wetlands is to regulate water flows in the floodplain increasing resilience to the impacts of climate change. |
| 2. Timing | The measure can be implemented immediately as the effectiveness of the measure does not depend on the analysis of climate change or its effects on the hydraulic cycle. |
| 3. Planning horizon | Restoration of wetlands and creation of artificial wetlands require a long-term planning horizon. |
| 4. Flexibility | As it requires a large land take, restoring and creating artificial wetlands can be very expensive depending on the location and not easily modifiable. |
| 5. Risks (cost effective and beneficial measures) | Wetland restoration is not very flexible, in particular when it requires engineering work. In addition, land availability is essential for restoring wetlands and very often land has to be purchased and subsidies have to be paid; in some cases, it can even result in revenue losses. Therefore, the measure can be very costly. However, wetlands provide many benefits: they contribute to climate change adaptation no matter what impacts climate change will have, as they contribute to drought management and flood mitigation whether they are located next to or away from rivers. Wetlands also act as carbon sinks contributing to climate change mitigation. Finally, wetlands have an essential role in and contribute to an improved landscape water balance; they regulate water quality, increase water storage in the landscape, and improve groundwater recharge.<br>Constructed wetlands, designed as part of SuDS, also contribute to flood attenuation, improve water quality and increase water storage in urban areas, but they have less of an impact on the water balance. SuDS appear to be cost-effective and flexible solutions that replace or supplement conventional sewerage systems and provide multiple benefits for urban areas such as provision of habitat and provision of recreational and educational services. |
| 6. Local and regional scale | The measure can be implemented at local and regional scale. In some cases, a wetland restoration project can affect an entire floodplain. |
| 7. Economic analysis | As wetlands regulate water flows in the floodplain, it is expected that there is no need to take into account future water supply and demand scenarios in view of climate change. |

## 4.7 Floodplain restoration[62]

**Floodplain restoration**. A floodplain is a plain bordering a river which provides space for the retention of flood and rainwater.

The soils of floodplains are generally very fertile and they have often been dried-out for cultivation. More recently, the areas have been mechanically poldered to regulate flood waters. Therefore, major capacities for water retention in the floodplains have been lost due to land drainage, intensive urbanisation and river channelisation (Mant and Janes, 2006). The effect of these changes in the landscape has become very evident during the recent floods in Central Europe, for example.

The objective is now to restore floodplains for flood prevention, run-off mitigation, groundwater recharge, improved soil quality, and habitat revival. Restoring the water retention functions of floodplains requires measures such as reducing channel dimensions, as well as creating lakes or ponds in the floodplain together with extending agriculture.

### 4.7.1 Applicability of floodplain restoration

Floodplain restoration has been implemented in a wide range of EU climate zones. It is applicable to all land uses provided it is located in the floodplain, including agricultural (CLC 1: 2. Agricultural areas) and urban (CLC 1: 1. Artificial surfaces) areas as well as wetlands, bogs, fens, mires (CLC 1: 4. Wetlands), forests (CLC 1:3. Forests and semi-natural areas) and lakes, rivers (CLC 1: 5. Water bodies).

It can be located in the entire floodplain (upstream and downstream), but mostly in the upstream. The AMICE project, for example, has carried actions in the upstream and source area of small tributaries. For Blackwell and Maltby, 2005, measures for run-off reduction are focused on land-use management and are generally located in the run-off generation areas of rivers, namely in upstream catchment areas.

There is no information on soil permeability or soil depth. The measure has been implemented in a wide range of topographies, from low-lying lands to hilly areas. According to Habersack *et al*., 2008, the slope of the river and of the floodplains is one of the most important variables when evaluating the floodplain retention potential: shallow slopes reduce discharge peaks and prolong retention periods, while steeper slopes worsen the effects of retention, especially when the flood wave is totally discharged in the channel.

### 4.7.2 Direct impacts of floodplain restoration

There is limited information on the impact of floodplain restoration on soil moisture. Francés *et al*., 2007 suggest that the construction of micro-ponds in the floodplain decreases soil moisture in the landscape, while traditional retention basins reduce stream flow.

[62] The Fact Sheet for Floodplain restoration is in Annex 8.

There is no information on the impact on water temperature and limited evidence on the impact on ETP. For Blackwell and Maltby, 2005, water leaving the floodplain through transpiration and/or evaporation varies seasonally depending on temperature and stage of plant development.

Different measures targeted at floodplain restoration can result in run-off control. For instance, Giron *et al*., 2008 recommend avoid constructing in the run-off axis to minimise flood hazard and limit the intensive use of floodplains to control run-off. Pichler *et al*., 2009 recommend afforestation of the floodplain, or installing micro-ponds in the floodplain for controlling run-off, while Francés *et al*., 2007 conclude that afforestation of natural grasslands and pastures in the floodplain are the most effective measures for reducing run-off. The Technical report "WFD and hydromorphological pressures" published in 2006 recommends breaches in the summer dikes, by-pass channels and oxbow lakes to improve retention in the floodplain. Blackwell and Maltby, 2005 consider that run-off reduction measures are focused at land-use management in the run-off generation areas of the floodplains.

In general, actions to restore the floodplain have a positive impact on groundwater. According to Blackwell and Maltby, 2005, one of the two main functions of floodplains is the recharge and discharge of groundwater. The amount of groundwater recharge depends on local conditions, such as geology and the hydrological condition of the aquifer. Habersack *et al*., 2008, consider that the protection and enlargement of the floodplains will have a significant positive impact on the good ecological status of groundwater. Blasch, 2010 suggests that the creation of a by-pass allowing for man-controlled flooding in the Danube will improve groundwater dynamics.

Floodplain restoration results in land-use change, but explicit information is very limited. Land-use change from agricultural land to floodplain is the most common (AMICE project; FLAPP project in Aragón River in Navarra; Integrated development and management of the Saône Valley (SAONE DOUBS) – LIFE project; Habersack *et al*., 2008; Technical report "WFD and hydromorphological pressures"). RSPB, 1999 describes the creation of small and medium wetlands. According to Pichler *et al*., 2009, it is very difficult to balance the increase demand for land and the loss of land for flood mitigation.

Evidence on the impact of floodplain restoration on erosion control is limited and inconclusive. For Blackwell and Maltby, 2005, there is a connection between erosion and sedimentation and the hydrological dynamics of rivers and floodplains, but it does not discuss the impact of restoring floodplains on erosion control. In the Sustainable Development of Floodplains (SDF) – INTERREG project, one of the aims of the pilot projects was to reduce bed erosion. However, in a pilot project in the Netherlands, the erosion and sedimentation rates increased in the first years after the construction of side channels; a regional equilibrium was established later. The Technical report "WFD and hydromorphological pressures" recommends planting riparian vegetation and constructing a low dam of stones in the floodplain to prevent erosion.

For Blackwell and Maltby, 2005, one of the functions of floodplains is to provide floodwater detention, which is temporary storage of water, which enters the floodplain by overbank flows from a river or from adjacent hill-slopes as run-off; the water storage capacity of a floodplain can be increased by increasing:

- Floodplain area;
- Floodplain depth; and / or
- Storage time of water on a floodplain, e.g., by increasing floodplain roughness.

#### 4.7.3 Benefits and co-benefits of floodplain restoration

Floodplain restoration can result in run-off control. Francés *et al.,* 2007 conclude that afforesting natural grasslands and pastures in the floodplain is the most effective measure for reducing run-off. For Blackwell and Maltby, 2005, one of the functions of floodplains is to provide floodwater detention.

Floodplain restoration has a positive impact on flood mitigation (AMICE project; Donauauen – LIFE project; Sustainable Development of Floodplains (SDF) – INTERREG project; Sustainable use and management rehabilitation of flood plain in the Middle Tisza District (SUMAR) – LIFE project; RSPB, 1999; Pichler *et al*., 2009; Habersack *et al*., 2008; Francés *et al.,* 2007; Schanze, 2008; FORECASTER; Technical report “WFD and hydromorphological pressures”, 2006).

Blackwell and Maltby, 2005 consider that run-off reduction measures are most effective in small (local or regional) catchments and when implemented over a large proportion of the floodplain and for the reduction of low to medium peak flows. These measures are less effective for extreme flooding events in large rivers but in any case their effectiveness always depends on the characteristics of the precipitation and the antecedent conditions.

According to Blackwell and Maltby, 2005, one of the two main functions of floodplains is the recharge and discharge of groundwater. The amount of groundwater recharge depends on local conditions, such as geology and the hydrological condition of the aquifer.

For several authors (SWP Wallonie, 2009; Pichler *et al*., 2009; Habersack *et al*., 2008; Francés *et al.,* 2007), floodplain restoration contribute to water quality regulation and therefore might contribute to the good ecological status required by the WFD. Blackwell and Maltby, 2005 state that floodplains improve water quality by depositing sediments, in particular particle-bound substances such as phosphorus. Therefore, they can remove large quantities of pollutants, thus improving water quality. The contribution to water quality regulation of individual and small areas of floodplains might be small, but the combination of similar areas along the river basin can bring about significant improvements. According to Broekx *et al*., 2011 the new floodplains are expected to improve water quality through nutrient recycling, aeration and sedimentation.

Floodplains are expected to have an effect on climate regulation through fixation of carbon dioxide by photosynthesis of reed and willow and C-burial (Broekx *et al*., 2011). They can also provide habitat for species such as reptiles, amphibians, birds and insects. Blackwell and Maltby, 2005 report that 90% of the interviewees consider that the floodplain restoration project in the River Waal in the Netherlands had improved the visual quality of the area. They also consider that naturally functioning river systems enhance biodiversity at the landscape and local scales. The Klimatebuffers project considered that floodplain restoration projects provide new opportunities for hiking, biking, canoeing and swimming.

### 4.7.4 Cost assessment of floodplain restoration

Floodplain restoration projects differ from each other; some lower dikes while others extend agriculture; therefore, the costs vary by project. Table 30 (ICPR, 2006) summarises the costs of various actions in the Rhine river.

**TABLE 30**
**COSTS OF ACTIONS IN THE RHINE**

| Description of actions | Unit (km²) | Cost (€ million) | Unit cost (€/ha) |
|---|---|---|---|
| **Water retention in the floodplain** | | | |
| Reanimate the floodplain | 300 | 750 | 250,000 |
| Extend agriculture and reforest | >4570<br>>925 | 773 | 1,406.7 |
| **Water retention alongside the river** | | | |
| Reanimate the floodplain | 33 | 260 | 78,788 |
| | | **Average** | 330,194.7 |

The average unit cost in 2011 prices[63] is €360,572.6/ha. Mazza *et al*., 2011 report total costs of €148 million for a depoldering project of 1,082 ha, i.e., a unit cost of €136,542/ha. Therefore, the unit cost of a floodplain restoration project is assumed to be the average of €360,572.6/ha and €136,542/ha, i.e., €248,647.3/ha. It is also necessary to add the relocation costs which include replanting, soil improvement, drainage and sprinklers; they are assumed to be €10,000/ha for sugar beet, potato, vegetables, orchards and tree nurseries (Broekx *et al*., 2011). Therefore, the total unit investment cost of a floodplain restoration project is €258,647.3/ha.

Broekx *et al*., 2011, report maintenance costs equal to 10% of the investment costs. Based on this assumption, the maintenance unit cost is €25,865/ha.

Broekx *et al*., 2011 also present detailed unit costs for expropriation of grounds (e.g., residential) and of buildings (e.g., farms), as well as opportunity costs for agriculture, and unit costs for the consequences of flood events inside the flood control area (e.g., loss of crops, administrative costs and clean-up costs).

### 4.7.5 No-regret aspects of floodplain restoration

Floodplain restoration can entail different measures, including land-use management measures in the catchment area as well as natural flood defence measures. Given the nature and variability of the type of actions encompassed by this measure, it is

[63] An average factor of 109.2/100 (average of France, Germany, the Netherlands and Switzerland) was used to convert 2005 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

difficult to determine whether floodplain restoration is a no-regret measure (see Table 31). The different activities might have to be considered separately.

**TABLE 31**
**NO-REGRET ASSESSMENT OF FLOODPLAIN RESTORATION MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | In particular, flood defence measures need careful planning and have to be based on accurate climate change data or detailed climate models as their effectiveness depends on the impacts of climate change. However, it seems that floodplain restoration involving land-use management changes attenuates low to medium peak flows at a local/regional scale. Therefore, it does not need to be based on accurate climate change data or climate change scenarios, which makes these types of projects beneficial no matter what the impacts of climate change are. |
| 2. Timing | The measure cannot be implemented immediately when it involves lots of local actors. |
| 3. Planning horizon | Floodplain restoration projects require a long-term planning horizon and are not easily modifiable. |
| 4. Flexibility | The measure cannot be easily modifiable as it requires high costs and results in land-use changes. |
| 5. Risks (cost effective and beneficial measures) | Overall, floodplain restoration is likely to be expensive and not very flexible, since it causes major land-use changes and requires a medium- to long-term planning horizon. Land-use management measures are less expensive than natural flood defence measures that generally require hard-engineering works. However, very often, floodplain restoration requires land acquisition and potentially results in loss of revenue from agricultural land afforested or used for flooding. Floodplains also provide multiple benefits, including water quality improvement, climate change regulation, soil quality improvement, and cultural services and habitat for a wide range of species. |
| 6. Local and regional scale | Land-use management measures are local while flood defence measures have a wider scale of impact. |
| 7. Economic analysis | Not applicable. |

## 4.8 Re-meandering[64]

**Re-meandering** slows down the flow of a river. The new form of the river channel creates new flow conditions and very often has also an impact on sedimentation. The newly created or reconnected meanders also provide habitats for a wide range of aquatic and land species of plants and animals.

In the past, rivers were straightened by cutting-off meanders, mostly to enable better transportation with bigger vessels, to control floods or simply to gain land for cultivation. However, depending on the degree, straightening leads to a higher flow velocity, increased erosion, and a decrease in biodiversity. In addition, the straightening of rivers often increases the risk of flooding as water is transported at a higher velocity, without the possibility to discharge into the landscape as access to floodplains is also often cut-off in the process.

[64] The Fact Sheet for Re-meandering is in Annex 9.

Re-meandering refers to bringing a river back closer to its naturally meandering state, by creating a new meandering course and by reconnecting cut-off meanders. Re-meandering can be done on the basis of old maps, showing the former course of a river. Sometimes old meanders are still existent as oxbow lakes. Where this is the case, the barriers (mostly consisting of sediments) have to be breached. Where meanders are not existent anymore, they have to be newly created. The new form of the river channel creates new flow conditions (mainly by slowing down the flow) and very often reduces sedimentation. The new flow conditions lead to the development of bank structures, such as slip-off and undercut slopes.

### 4.8.1 Applicability of re-meandering

Re-meandering has been implemented in a wide range of EU climate zones, but mainly in the Atlantic, Mediterranean and Continental climate zones. It is mainly applicable to rivers (CLC 1: 5. Water bodies), but also to farmland (CLC 1: 2. Agricultural areas), urban areas (CLC 1: 1. Artificial surfaces), wetlands, bogs, fens and mires (CLC 1: 4. Wetlands) and forests (CLC 1:3. Forests and semi-natural areas). Re-meandering is often carried out together with the restoration of wetlands or other NWRM.

There is limited information on the location of the measure in the river basin, but it would appear to be implemented downstream. The Skjern River Restoration Project – LIFE in Denmark restored the lower part of the river. Kasahara and Hill, 2008 consider that river restoration projects are often implemented in lowland degraded streams.

There is no information on soil permeability or soil depth. According to the available information, the measure has been implemented in lowlands (below 200 metres); six of the case studies[65] in the FORECASTER database have been implemented in lowlands. The topography of the River Gels in Denmark is also lowlands. Friburg (no date) provides the slope before and after the restoration of the re-meanders in the River Gels in Denmark as 0.65% and 0.8%, respectively.

The measure is relevant to the entire EU, but particularly to those Member States that have channelled their river systems.

### 4.8.2 Direct impacts of re-meandering

There is no information on the impact of the measure on soil moisture**.** According to the FORECASTER database, re-meandering can increase water temperature, if riparian forest is missing.

For Kasahara and Hill, 2007, ETP by the dense vegetation cover might have caused the depression of the water table in the centre of the meander bends. According to the same authors (quoting Mann and Wetzel, 2000) the two meander bends functioned like riparian wetlands; the stream supplies water to the riparian wetland in dry periods due to water table lowering caused by ETP of vegetation.

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[65] i) Risle river - Saint-Philbert-sur-Risle project; ii) Weissenthurm; iii) Haselünne; iv) Ahlen-Dolberg - Optimisation of the pSCI “Lippe floodplain between Hamm and Hangfort”; v) Tordera - Restoration of a secondary channel of the Tordera River; and vi) the Skjern River Restoration Project – LIFE in Denmark.

There is no evidence on the impact on run-off control. It is also unclear whether re-meandering has a positive effect on groundwater replenishment. According to the FORECASTER database, re-meandering increases groundwater recharge and summer low-flow (Tague *et al.* 2008 in the FORECASTER database) and in the Emsaue NRW LIFE project, restoration of the natural dynamics improves the hydrological balance. However, for Kasahara and Hill, 2008, re-meandering increased water exchange between the stream and the subsurface environment, despite the large change in channel alignment; however, this increase was small due to the low permeable sediments. Kasahara and Hill, 2007, report similar findings; the channel re-meandering project at Kolb Creek did not create a large stream-subsurface exchange, even if stream water entered the meander bends from all directions, because the flow rate was very low as a result of low sediment conductivity. In addition, meanders behave as wetlands, lowering the water table due to the ETP of vegetation; therefore, the stream supplies the wetland/vegetation with water in dry periods.

Re-meandering results in land-use change: agricultural land has been converted into watercourses, meadows, forests and grassland (Skjern River Restoration Project – LIFE in Denmark; Emsaue NRW LIFE project; FORECASTER database). In the Skjern River restoration project, the length of the river's main course has increased from 19 km to 26 km. Friburg (no date) also reports large landscape changes and provides the example of the River Gels, which went from 0 to 16 meanders after restoration.

There is inconclusive, even contradictory, evidence of the impact of re-meandering on erosion control. The Emsaue NRW LIFE project, the Requalification of Taro fluvial habitats vital to avifauna (Taro) – LIFE project and case studies in the FORECASTER database suggest that reconnecting meanders and opening side channels returned natural dynamics, allowing erosion-sedimentation processes to pass through and preventing river banks from eroding. However, the WFD and hydromorphological pressures Technical report (2006) reports the contrary: reconnection of oxbow lakes and wetlands in the Slovakian case study decreased flow velocity and led to massive sedimentation. The deposits blocked the entrance of the meander bend. The flow conditions are now worse than prior to re-meandering.

There is limited evidence of the impact of re-meandering on storage capacity. According to the FORECASTER database, re-meandering increases water storage. Friburg (no date) and the Skjern River restoration project do not address storage capacity explicitly, but report the changes in the stream length before and after the re-meandering project (for the River Gels 1,340 m to 1,850 m, and 19 km to 26 km for the Skjern River). Reconnection of old meanders probably increased the storage capacity of the river.

### 4.8.3 Benefits and co-benefits of re-meandering

Re-meandering might contribute to the retention of water as it creates more space for water, slows down the flow of the flood, and potentially results in enhanced water retention features such as flood attenuation and run-off control. By slowing down the peak flow, re-meandering can reduce the severity of flooding downstream. However, the evidence is inconclusive. The FORECASTER database considers that re-meandering increases discharge travel time and flow variability, while Habersack *et al*., 2008 concludes that river elongation by meandering does not show a large influence on flood retention.

Re-meandering increases water storage according to the FORECASTER database. Friburg and the Skjern River report the changes in the stream length before and after the re-meandering project (for the River Gels 1340 m to 1850 m, and 19 km to 26 km for the Skjern River). Reconnection of old meanders probably increased the storage capacity of the river.

According to the FORECASTER database, re-meandering increases groundwater recharge and summer low-flow (Tague *et al.* 2008). In the Emsaue NRW LIFE project, restoration of the natural dynamics has improved the hydrological balance. The Emsaue NRW LIFE project, the Requalification of Taro fluvial habitats vital to avifauna (Taro) – LIFE project and case studies in the FORECASTER database suggest that reconnecting meanders and opening side channels returned natural dynamics, allowing erosion-sedimentation processes to pass through and preventing river banks from eroding. However, the WFD and hydromorphological pressures Technical report (2006) reports the contrary; reconnection of oxbow lakes and wetlands in the Slovakian case study decreased flow velocity and led to massive sedimentation. The deposits blocked the entrance of the meander bend. The flow conditions are now worse than prior to re-meandering.

The evidence on water quantity increase is limited. According to Emsaue NRW LIFE project and the Requalification of Taro fluvial habitats vital to avifauna (Taro) – LIFE project, re-meandering and reopening the canals have improved the hydrological balance, strengthened the natural dynamic of the river and improved water circulation. However, for Kasahara and Hill, 2008, the increase of stream-subsurface water exchange is small despite the large change in channel alignment. Kasahara and Hill, 2007 supports this and considers that the accumulation of fine sediments on the streambed may rapidly diminish stream-subsurface water exchange.

Re-meandering has provided habitat for species such as aquatic plants, otter, salmon, insects and birds, fish, macroinvertebrates, macrophytes and phytoplankton, and kingfishers. However, one action in the WFD and hydromorphological pressures Technical report (2006) reports that the reconnection of oxbow lakes and wetlands has decreased species richness of the local hydrofauna.

Re-meandering does not only promote the ecological quality of a stream as habitat (for a wide range of aquatic and land species of plants and animals) and water body; it also contributes significantly to landscape enhancement: re-meandering pleases the public aesthetically. Re-meandering can also ease access to some recreational areas.

#### 4.8.4 Cost assessment of re-meandering

Between 1991 and 1998, re-meandering of the River Brede in Denmark (Friburg) increased the length of the river from 19.3 km to 25.7 km. The total costs of the 7-year project were €2.12 million. Since the channel length increased by 6.4 km, it can be assumed that the unit investment cost was €331,250/km over seven years or €394,188/km in 2011 prices[66]. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €277,012/km.

The total costs of the four-year Skjern River Restoration LIFE Project in Denmark (2001-2004) were DKK 284 million, including DKK 100 million for land acquisition. The total cost of re-meandering was DKK 34,083,746 (€4.6 million[67] or €5.34 million in 2011 prices[68]) over four years. These works included soil works and construction of footbridges, removal of culverts, overflow ramp and cushion, alteration of transmission lines and changes of Pumping Station East. Given that the river length increased by 7 km, from 19 km to 26 km, the unit cost for re-meandering was €762,286/km. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €535,689/km.

The unit investment cost for re-meandering is the average of the two unit costs above, i.e., €406,351/km of river re-meandered.

The Skjern River Restoration LIFE Project also compensated the owners of 200 hectares of privately-owned land for establishing public trails, hunting restrictions and increasing flooded areas. Table 32 shows these one-time costs.

**TABLE 32**
**ANNUAL BREAKDOWN OF COMPENSATION COSTS IN SKJERN RIVER RESTORATION LIFE PROJECT**

| Year | Compensation for re-meandering (DKK) |
|---|---|
| **2001** | 58,112 |
| **2002** | 152,342 |
| **2003** | 0 |
| **2004** | 5,000 |
| **Total** | 215,454 |

Total compensation costs were DKK 215,454 (€28,959 or €33,592 in 2011 prices[69]); therefore, compensation costs for re-meandering are assumed to be €168/ha. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €118/ha. The Danish government also bought 2,000 hectares for DKK 87 million (€1.17 million or €1.4 million in 2011 prices[70]) in 1990-2002 at a unit cost of €700/ha. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €492/ha. Investment costs are assumed to equal the sum of compensation, land purchase and constructions costs (see Table 33). Investment unit costs of €406,351/km and €610/ha are assumed.

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66 A factor of 113.8/95.6 (2002 factor is the oldest year available) was used to convert 1991-1998 prices into 2011 prices; see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en.

67 Exchange rate from Euro to DKK used 7.44 (as reported by the LIFE's Final report budget).

68 An average factor of 113.8/98.3 (Denmark) was used to convert 2004 prices into 2011 prices, see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en.

69 An average factor of 113.8/98.3 (Denmark) was used to convert 2004 prices into 2011 prices; see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en.

70 An average factor of 113.8/95.6 (Denmark) was used to convert 2002 prices into 2011 prices; see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en.

**TABLE 33**
**SUMMARY INVESTMENT COSTS IN SKJERN RIVER RESTORATION LIFE PROJECT**

| Investment costs | Amount |
|---|---|
| **Construction works** | €406,351/km |
| **Compensation** | €118/ha |
| **Land purchase** | €492/ha |

The Skjern River Restoration LIFE Project also monitored 2,200 ha for a total cost of DKK 1,717,259 (€230,814 or €267,744 in 2011 prices[71]) over four years (see Table 34). Therefore, an annual unit cost of €3.04/ha for monitoring is assumed. This cost was adjusted according to the comparative price levels in Table 11, resulting in an EU cost of €2/ha.

**TABLE 34**
**ANNUAL COST OF MONITORING SKJERN RIVER RESTORATION LIFE PROJECT**

| Year | Monitoring Cost (DKK) |
|---|---|
| **2001** | 306,899 |
| **2002** | 535,979 |
| **2003** | 560,191 |
| **2004** | 314,190 |
| **Total** | 1,717,259 |

Table 35 shows the costs of the re-meandering scenario by EU member state. The JRC modelled a total increase of re-meandering surface areas of 91,447 ha; most of this increase is in Finland, France and Sweden; there is no increase in Cyprus or Malta.

**TABLE 35**
**COSTS OF RE-MEANDERING SCENARIO**

| Member State | Increase in re-meandering surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Austria | 2,594 | 0.10 | 8.19 | 284.4 | 8.4 | 0.00% | 0.97 |
| Belgium | 656 | 0.04 | 3.52 | 352.9 | 10.8 | 0.00% | 0.33 |
| Bulgaria | 1,909 | 0.06 | 4.86 | 36 | 7.6 | 0.01% | 0.64 |
| Cyprus | 0 | 0.00 | - | 17.5 | 0.8 | 0.00% | - |
| Czech Republic | 1,526 | 0.07 | 5.65 | 145 | 10.5 | 0.00% | 0.54 |
| Denmark | 285 | 0.03 | 2.42 | 234 | 5.5 | 0.00% | 0.44 |

71 An average factor of 113.8/98.3 (Denmark) was used to convert 2004 prices into 2011 prices; see http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en.

| Member State | Increase in re-meandering surface areas (Ha) | Present value of cost (2011 € billion) | Annualised cost (2011 € million) | 2010 GDP (€ billion) | Population (million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|---|
| Estonia | 1,211 | 0.07 | 5.87 | 14.5 | 1.3 | 0.04% | 4.51 |
| Finland | 11,758 | 0.90 | 74.80 | 180.3 | 5.3 | 0.04% | 14.11 |
| France | 11,000 | 0.75 | 61.74 | 2,080.80 | 63.1 | 0.00% | 0.98 |
| Germany | 5,078 | 0.33 | 27.57 | 2,498.80 | 81.8 | 0.00% | 0.34 |
| Greece | 1,539 | 0.08 | 6.25 | 230.2 | 11.3 | 0.00% | 0.55 |
| Hungary | 1,227 | 0.07 | 5.98 | 98.4 | 10 | 0.01% | 0.60 |
| Ireland | 1,167 | 0.07 | 5.42 | 153.9 | 4.4 | 0.00% | 1.23 |
| Italy | 7,008 | 0.32 | 26.52 | 1,548.80 | 60.3 | 0.00% | 0.44 |
| Latvia | 1,789 | 0.11 | 8.69 | 18 | 2.2 | 0.05% | 3.95 |
| Lithuania | 1,382 | 0.07 | 5.60 | 27.4 | 3.2 | 0.02% | 1.75 |
| Luxembourg | 133 | 0.01 | 0.76 | 41.6 | 0.5 | 0.00% | 1.52 |
| Malta | 0 | 0.00 | - | 6.2 | 0.4 | 0.00% | - |
| Netherlands | 344 | 0.02 | 1.68 | 591.5 | 16.6 | 0.00% | 0.10 |
| Poland | 5,417 | 0.25 | 20.71 | 354.3 | 38.2 | 0.01% | 0.54 |
| Portugal | 2,759 | 0.12 | 9.81 | 172.7 | 10.6 | 0.01% | 0.93 |
| Romania | 3,693 | 0.14 | 11.26 | 121.9 | 21.5 | 0.01% | 0.52 |
| Slovakia | 722 | 0.03 | 2.08 | 65.9 | 5.4 | 0.00% | 0.38 |
| Slovenia | 765 | 0.02 | 1.72 | 36 | 2 | 0.00% | 0.86 |
| Spain | 9,062 | 0.60 | 49.40 | 1,062.60 | 46 | 0.00% | 1.07 |
| Sweden | 15,020 | 1.01 | 83.83 | 346.7 | 9.3 | 0.02% | 9.01 |
| United Kingdom | 3,403 | 0.17 | 14.45 | 1,696.60 | 62 | 0.00% | 0.23 |
| EU 27 | 91,447 | 5.42 | 448.78 | 12,268.40 | 501 | 0.00% | 0.90 |

The present value of the costs for the 27 EU Member States is €5.4 billion, which corresponds to an annualised cost of €449 million, i.e., less than 0.01% of the GDP or €0.90 per person and per year. As a percentage of GDP, this annual cost is the highest in Estonia (0.04%), Finland (0.04%) and Latvia (0.05%). This annual cost per person is the highest (above €9) in Finland and Sweden.

### 4.8.5 No-regret aspects of re-meandering

Preliminary conclusions suggest that re-meandering is not a no-regret measure (see Table 36).

**TABLE 36**
**NO-REGRET ASSESSMENT OF RE-MEANDERING MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | Re-meandering needs careful planning and must be based on accurate climate change data or detailed climate models as these measures will be more or less effective depending on the impacts of climate change. |
| 2. Timing | Re-meandering requires long-term planning. It is also difficult to design a re-meandering project, as the previous and supposedly natural conditions or reference conditions are generally unknown, |
| 3. Planning horizon | Since re-meandering is not very flexible and requires long-term planning, it is not easily adaptable to different climate change scenarios. |
| 4. Flexibility | The measure is not easily modifiable and would require heavy-engineering construction works and large changes in the landscape and in the river basin. |
| 5. Risks (cost effective and beneficial measures) | Re-meandering is likely to require heavy-engineering construction works and large changes in the landscape and in the river basin; it can also involve large land-take and therefore compensation to farmers or owners and/or land purchase. As a result, some of these projects incur a loss of revenue in the project area and it is unclear if, for example, an increase in tourism - for example - will compensate for the loss of revenue. Overall, re-meandering tends to be expensive; its benefits and co-benefits are not evident and require more research. The construction works generate large disturbances in the river ecology, which stabilises only after a few years; therefore, the cost-effectiveness of re-meandering is questionable. |
| 6. Local and regional scale | The measure is implemented at a local scale. |
| 7. Economic analysis | Not applicable. |

## 4.9 Restoration of lakes[72]

In the past, lakes have sometimes been drained to free the land for agriculture purposes, or have simply not been maintained and have silted up. **Restoring lakes** is re-introducing them where they have been in former times or revitalising them.

Lakes, whether natural or man-made, are proper water retention facilities by definition. Depending on their size, on the water source they are fed from, and on the size of their watershed, lakes have a specific retention time (the average time that water stays in the lake (Lake George Association (no date)). Lakes with a large surface within a small catchment area have higher retention capacities while small lakes in big catchment areas show very little retention capacity or none at all. Attention should therefore be paid to maintain lakes in proper functioning order to make them more resilient to climate change.

72 The Fact Sheet for the Restoration of lakes is in Annex 10.

### 4.9.1 Applicability of restoration of lakes

The restoration of lakes has been implemented in a wide range of EU climate zones. It is applicable to lakes (CLC 1: 5. Water bodies) and surroundings (CLC 1: 5. Water bodies), wetlands, bogs, fens, mires (CLC 1: 4. Wetlands), and agricultural lands (CLC 1: 2. Agricultural areas). There is limited information on its location in the river basin, but it seems to have been implemented in the entire river basin (upstream and downstream).

There is no information on soil permeability or depth. The measure is more effective in mild topography (Moustaka *et al*., 2002) with gentle slopes (LIFE Lake Pape – conservation, preservation and evolution project).

### 4.9.2 Direct impacts of restoration of lakes

There is no information on the measure's impacts on soil moisture, water temperature, ETP, land-use change, erosion control or storage capacity.

There is only limited information on the impact on run-off control; the LIFE Lake Pape project and Moustaka *et al*., 2002, mention the positive impact in controlling run-off water. There is also limited information on the impact on groundwater replenishment. In the LIFE Lake Pape project, restoration allowed recuperating the supply of groundwater, which was stopped due to the construction of a drainage channel.

### 4.9.3 Benefits and co-benefits of restoration of lakes

Lakes provide water retention and availability; they store water (for flood control) and provide water for many purposes such as water supply, irrigation, fisheries, tourism, etc. In particular, their ability to store water moderates flood waves and delays the run-off peak. Moustaka *et al*., 2002, consider that lake restoration provided an adequate area for flood mitigation, and the LIFE Lake Pape project brought back the water level dynamics, which allow seawater to accumulate for short storm periods in autumn and spring floods.

Lakes are closely linked to groundwater and intercept rain water; thus, they are also an important element of the global water cycle. The LIFE Lake Pape project recharged ground water, which had been stopped due to the construction of a drainage channel. Therefore, lake restoration contributes to water availability; for Moustaka *et al*., 2002, the restored lake fulfils the irrigation water demands in the area.

Lake restoration also contributes to water quality regulation. The natural inflow restoration of fresh water into the Lake Pape (from the rivers, streams and run-off water) improves oxygen levels in the lake, limits eutrophication, decreases pollution and increases water quality. For Moustaka *et al*., 2002, one of the objectives of lake restoration was to increase water quality and quantity of the degraded underground aquifer. Zalidis *et al*., 2005, conclude that restoring Lake Karla has improved water quality.

Lakes also provide important habitats for numerous species of plants and animals, including waders; they shape the appearance of the landscape and provide recreational areas. Normally, new habitats are introduced or conserved and species linked to the water surface (i.e., birds) are protected.

#### 4.9.4 Qualitative cost and benefit analysis of lake restoration

Clearly, lake restoration is beneficial, starting with a contribution to flood reduction. There is no information, however, on the extent of this contribution and therefore no possibility to measure the effectiveness of lake restoration.

Information on the costs of lake restoration is also insufficient; Lippert, 1998 mentions the purchase of 108 ha of land, but without providing any information on costs. Naumann *et al*., 2011 mentions a unit cost of €3.9/ha for habitat restoration at Croxall Lakes Nature Reserve (UK National Forest project in Naumann *et al*., 2011). In any case, the costs will depend on the conditions of the degraded land.

#### 4.9.5 No-regret aspects of lake restoration

While it appears that the restoration of lakes is a no-regret measure (see Table 37), no firm conclusions can be made based on the available evidence. It also seems that it will depend to a large extent in the conditions of the degraded lake. More research on its cost-effectiveness is also necessary.

**TABLE 37**
**NO-REGRET ASSESSMENT OF LAKE RESTORATION MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | Restoring degraded habitats contributes to increasing the catchment's adaptive capacity to respond to future expected climate changes. Therefore, lake restoration can be effective even if the climate change impacts do not materialise |
| 2. Timing | The measure could be implemented immediately as it does not depend on the analysis of climate change impacts and effects. |
| 3. Planning horizon | It takes time to see the impacts of lake restoration requiring a long-term planning horizon. |
| 4. Flexibility | Lake restoration is not adaptable as changes made are not easily modifiable. |
| 5. Risks (cost effective and beneficial measures) | Lake restoration contributes to flood attenuation, improves water quality, supports biodiversity conservation and provides cultural services. Its costs depend on the conditions of the degraded land, but could be high |
| 6. Local and regional scale | The measure is implemented at a local scale. |
| 7. Economic analysis | Lakes contribute to flood control. Restoring lakes brings back the former ecosystem or revitalises it, by returning it to an adequate water level and more "natural" conditions. |

## 4.10 Natural bank stabilisation[73]

Natural bank stabilisation redresses past activities linked to the straightening of rivers, such as stabilising river banks with concrete or other types of retention walls. The straightening of a river, the cutting-off of meanders and the fixation of river banks can have significant negative impacts on rivers. They limit rivers' natural movements, leading to degradation of the river, increased water flow, increased erosion and decreased biodiversity. To cope with the increased erosion caused by straightening, especially in urban areas, river banks were usually stabilised using artificial materials (e.g., concrete). Nowadays, where possible, water managers aim to remove these hard defence structures from river banks, allowing the rivers to move more freely. Removing bank structure can be done to allow the re-connection of meanders or to allow rivers to widen their bed.

> In the past, various activities were undertaken to straighten rivers, such as the stabilisation of river banks with concrete or other types of retention walls. Such actions limited rivers' natural movements, leading to degradation of the river, increased water flow, increased erosion and decreased biodiversity. **Natural bank stabilisation** reverses such activities, allowing rivers to move more freely.

The choice of stabilisation material depends on the location of the river and the predominant natural conditions. Where bank stabilisation is necessary (e.g., in residential areas), natural materials such as roots or gravel can be used. However, natural bank stabilisation might not be possible in urban areas as this can lead to unsecure situations in the case of flooding.

### 4.10.1 Applicability of natural bank stabilisation

Natural bank stabilisation has been implemented in several EU countries (corresponding mainly to Atlantic north, Atlantic central and Continental climate zones). There is no information in the sources on land use although it can be assumed that it is relevant to rivers and lake banks. There is no information on the measure's location in the river basin, soil permeability, soil depth or topography.

### 4.10.2 Direct impacts of natural bank stabilisation

There is no information in the sources on soil moisture, run-off control, groundwater replenishment or land-use change. There is also no information on the impact of the measure on water temperature or ETP, but they are assumed not relevant to the measure.

While there is no quantitative data on erosion control, several of the case studies in the WFD and hydromorphological pressures technical report confirm that changes in the river bank, and therefore activation of the typical hydromorphological processes, can lead to small-scale erosion and sedimentation.

Finally, there is inconclusive evidence on the measure's impact on storage capacity. The WFD and hydromorphological pressures technical report mentions an increased storage capacity in Aylesbury (UK), resulting in 90,000 $m^3$ of storage volume

[73] The Fact Sheet for Natural bank stabilisation is in Annex 11.

providing a 1 in 100 year level of protection. However, this is the result of a combination of measures, not only bank stabilisation.

#### 4.10.3 Benefits and co-benefits of natural bank stabilisation

Natural bank stabilisation can lead to more space for the river, allowing the river flow to create new bank structures. The opened soil can also infiltrate water, contributing to the enhancement of water retention. However, there is inconclusive evidence on water storage capacity. The increased storage capacity in Aylesbury (UK), which now benefits from 90,000 $m^3$ of storage volume providing a 1 in 100 year level of protection is the result of a combination of measures, not only bank stabilisation. It can therefore be assumed that bank stabilisation combined with other measures has a positive impact on flood prevention due to increase of storage volume (Aylesbury (UK) which provides a 1 in 100 year level of protection.

Several of the case studies in WFD and hydromorphological pressures technical report (2006) confirm that changes in the river bank, and therefore activation of the typical hydromorphological processes, can lead to small-scale erosion and sedimentation.

Natural bank stabilisation may also have a positive impact on biodiversity; re-opened river banks provide nesting space for the kingfisher and spawning grounds for fish. The evolving vegetation leads to new habitats for insects and birds improving the quality and diversity of freshwater and terrestrial fauna and flora of the river, its corridor and surrounding open spaces. Natural bank stabilisation improves the landscape from a visual point of view and also eases access to the area, thus increasing use of the area for recreation.

#### 4.10.4 Qualitative cost and benefit analysis of natural bank stabilisation

The primary benefit of natural bank stabilisation seems to be the provision of habitats for fish and aquatic species; it also improves the quality and diversity of freshwater and terrestrial fauna and flora. It can also be assumed that bank stabilisation combined with other measures has a positive impact on flood prevention, but there is no information of flood hazard reduction.

Natural bank stabilisation projects can be expensive; the costs of the restoration of the River Brent in England totalled €1.75 million, excluding costs of monitoring and maintenance and the building of a stone wall in the Netherlands was estimated at €500,000 (per salt marsh, about 4-5 km).

Given the lack of any other information, it is not possible to compare the costs and benefits of natural bank stabilisation. As mentioned in the DICE study (Naumann *et al*., 2011), however, when the present value of future flows of costs and benefits is taken into account in appraising GI projects, the benefits of GI can significantly exceed its costs. Using the GI valuation toolkit developed in North West England, the DICE study assessed a few examples highlighting the benefits of GI in economic development, including its role in facilitating inward investment and job creation, and in enhancing urban property values and quality of life. The estimated ratio of benefits to costs ranges between 1.0 and 6.0; the DICE study confirms that these findings are consistent with the results of assessments of the benefits of various protected areas programmes in Scotland, England and Wales, and France with benefits to cost ratios ranging from 7:1 and 8:1. The benefits of natural bank stabilisation are also likely to exceed its costs, but quantifying any benefit to cost ratio is not currently possible with the information that has been collected for this study.

#### 4.10.5 No-regret aspects of natural bank stabilisation

From the evidence collected, it seems that this measure is not a no-regret measure (see Table 38); however, no firm conclusions can be made based on the available evidence. In particular, more research on its cost-effectiveness is necessary.

**TABLE 38**
**NO-REGRET ASSESSMENT OF NATURAL BANK STABILISATION MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | Natural bank stabilisation must be based on accurate climate change data or detailed climate models, as it will be more or less effective depending on the impacts of climate change. |
| 2. Timing | The measure cannot be implemented immediately |
| 3. Planning horizon | The measure needs to be implemented in a long-term planning horizon. |
| 4. Flexibility | Since natural bank stabilisation is not very flexible (due to the land-take and the fact that it is usually implemented along with a number of other measures), it is not easily adaptable to different climate change scenarios. |
| 5. Risks (cost effective and beneficial measures) | Natural bank stabilisation tends to be expensive as it is assumed to require some construction work and, potentially, land-take. Moreover, as natural bank stabilisation is usually combined with other measures, it is difficult to identify its specific benefits and co-benefits. It seems that the benefits and co-benefits affect a small area, thus having only a limited contribution to the provision of habitat, cultural services and potentially water erosion control, water storage and flood hazard reduction. |
| 6. Local and regional scale | The measure is implemented only at a local scale. |
| 7. Economic analysis | Not applicable. |

### 4.11 Artificial groundwater recharge[74]

AGR stores large quantities of water in aquifers to increase the quantity of groundwater for times of shortage. Underground aquifers provide the possibility to store large quantities of water accruing from floods or from heavy rainfall. AGR results in a lowering of run-off from surrounding land, and in an enhanced natural condition of aquifers and water availability. The natural cleaning process of water percolating through the soils when entering the AGR improves water quality.

[74] The Fact Sheet for AGR is in Annex 12.

### 4.11.1 Applicability of AGR

AGR has been implemented in several EU countries (mainly in arid or semi-arid regions, such as Mediterranean south and Mediterranean north climate zones). It is relevant to river basin land-uses. AGR projects have been implemented in the entire river basin: upstream and downstream (Llobregat aquifer (Escalante Fernández, 2009)).

The measure is suitable for implementation on very permeable materials such as gravels and sand to a lower extent (LIFE+ TRUST project; Spandre (no date); Pliakas *et al*., 2005). Al-Assa'd *et al*., 2010 discusses different AGR methods depending on the permeability of the ground: injection wells are applicable when the aquifer system is overlaid by a low permeable layer and surface dams when they are located at a ground of high infiltration rate. No information on soil depth.

There is only limited information on the topography where the measure is applicable. However, it seems that AGR is suitable for all types of slopes. One case study is from a hilly topography (LIFE+ TRUST project), while another case study (Pliakas *et al*., 2005) reports a uniform slope of 2%.

### 4.11.2 Direct impacts of AGR

There is no information on soil moisture, water temperature or erosion control. There is little explicit information on ETP. According to Al-Assa'd *et al*., 2010, up to 25% of the water injected and stored in surface dams is lost by evaporation in countries with a hot and dry climate.

There is no explicit information on run-off control. The measure does, however, through its nature, have a positive impact on groundwater replenishment. The LIFE+ TRUST project states that about 100 ha infiltrated about 50 million $m^3$/year of water into groundwater. Pliakas *et al*., 2005 report that the groundwater balance of the study area (difference between the groundwater inputs due to natural and artificial recharge, irrigation returns, lateral groundwater inflows and groundwater outputs due to pumping and lateral groundwater outflows) revealed positive values (+195 × 103 $m^3$ for 3 years) for the first time, due to the artificial recharge of old stream beds.

There is no information on the impact on land-use change. The LIFE+ TRUST project, however, suggests that adaptation strategies and agricultural planning could enable sustainable development of water resources.

There is no information on the impact on storage capacity. However, Escalante Fernández, 2009, states that Spain's estimated storage capacity is about 134,000 $hm^3$ ($2hm^3/km^2$), i.e., 15% of the territory.

### 4.11.3 Benefits and co-benefits of AGR

The main objective and benefit of this measure is groundwater replenishment and increase water availability. The LIFE+ TRUST project states that about 100 ha infiltrated about 50 million $m^3$/year of water into groundwater. Pliakas *et al*., 2005 report that the groundwater balance of the study area (difference between the groundwater inputs due to natural and artificial recharge, irrigation returns, lateral groundwater inflows and groundwater outputs due to pumping and lateral groundwater outflows) revealed positive values (+195 × 103 $m^3$ for 3 years) for the first time, due to the artificial recharge of old stream beds. Escalante Fernández, 2009, reports that the groundwater recharge went from 50 to 380 $hm^3$/year (in Spain) between 1994 and 2008.

The natural cleaning process of water percolating the soils when entering the AGR improves water quality. According to Spandre, the recharged water undergoes slow natural infiltration into the subsurface, which cleans and purifies it. Moreover, implementing the hydraulic barrier at the Llobregat aquifer case (Escalante Fernández, 2009) helped to prevent seawater progression into the river aquifer by injecting directly treated reclaimed water.

Although AGR improves the quality of the captured surface water and although it contributes to water retention, the potential of aquifers for storing water should not be overexploited. AGR can influence raw water negatively and can have impacts on the soil structure and on the aquifer chemical and biological processes. In addition, the water purification capacity of soil should not be overused.

### 4.11.4 Qualitative cost and benefit analysis of AGR

All sources state that one of AGR's main objectives is to increase water availability. It is not clear, however, whether AGR has reduced flood hazards. As there is no information on the costs of AGR, it is not possible to assess AGR's cost-effectiveness. It seems to be cost-effective; however, it must be in line with other measures to avoid contaminating aquifers (e.g., buffer strips; to prevent pollution from industrial, urban and dairy farms run-off).

### 4.11.5 No-regret aspects of AGR

It is possible to potentially conclude based on the evidence available that AGR is a no-regret measure (see Table 39). However, more research is needed to determine other potential co-benefits (e.g. soil quality improvement, climate change regulation).

**TABLE 39**
**NO-REGRET ASSESSMENT OF AGR MEASURES**

| No-regret aspects | Assessment |
|---|---|
| 1. Future climate change scenarios | Groundwater recharge stores water for times of shortage. Since climate change foresees an impact on water demand (especially peak demands during periods of droughts), it is worth supporting natural groundwater recharge with AGR. Moreover, flood events might be more frequent in the future, which gives an opportunity to capture water in aquifers. Therefore, the objective of maximising the retention of water in the ground is beneficial no matter which impacts climate change will cause. |
| 2. Timing | Although the impact of climate change will affect the utility of the AGR on basis of water demand, these impacts and the effects on the hydraulic cycle will not affect the effectiveness of the measure. Therefore, this measure can be implemented immediately. |
| 3. Planning horizon | The measure is easily modifiable. |

| | |
|---|---|
| 4. Flexibility | Most AGR techniques are very flexible and relatively inexpensive (stream modification, ditches, wells, pits, shafts, etc.). |
| 5. Risks (cost effective and beneficial measures) | AGR's main benefits are water quality regulation, water availability and potentially flood prevention. The risk is mixing surface water with groundwater in case of flood event |
| 6. Local and regional scale | The measure is mostly implemented at local scale. |
| 7. Economic analysis | The measure should be designed to take into account future water supply and demand scenarios. |

# 5. EU POLICY ASSESSMENT

This study has analysed the weaknesses and opportunities of the key EU directives and policies affecting NWRM; the results of this assessment are used to outline various policy recommendations in order to promote the uptake of NWRM at EU level and overcome the barriers in Table 40.

**TABLE 40**
**BARRIERS AGAINST FURTHER IMPLEMENTATION OF NWRM AT EU LEVEL**

| Type of barrier | Requirements for implementing NWRM at EU level | Possible reasons for barrier |
|---|---|---|
| Political | Cross-sectoral approach needed to implement NWRM in a wide range of land uses.<br>Involvement of a broad range of stakeholders, including national, local and regional public authorities, as well as economic sectors, such as forestry and farming sectors. | Conflicting interests of various stakeholders.<br>Lack of willingness on the part of politicians to adopt new Directives and/or establish binding targets that could promote a wider uptake of NWRM. |
| Institutional | EU policies provide a general framework for policy implementation in each Member State; consistent implementation from Member State to Member State and from region to region. | Lack of binding targets in policies; only voluntary measures. There are no compulsory obligations, and very often a lot of actors (municipalities, politicians, farmers, etc.) are concerned by NWRM implementation, their maintenance, the way to get funded, etc., and the process is too complex and become slow to be effective and applied at large scale.<br>Discretionary power given to Member States to decide where and how to implement NWRM results in wide disparities among Member States; e.g., Article 10 of the Habitats Directive gives full discretionary power to Member States to decide how and where to implement connectivity measures. |
| Spatial | Agreement among stakeholders on the effectiveness of NWRM.<br>Clear framework for NWRM implementation. | Current approach to spatial planning under environmental considerations and sustainable development are not necessarily taken into account. There are also potential conflicts of different land users.<br>Some of the NWRM, and in particular SuDS, might constrain urban development on the site as a result of the increase of soil moisture.<br>NWRM are very often implemented at very local and limited scale thanks to the personal motivation of few people. Some large areas would benefit from NWRM implementation but there is a lack of a framework providing clear answers to the questions: “implementing what? where and how?”<br>The actor implementing NWRM is not |

| Type of barrier | Requirements for implementing NWRM at EU level | Possible reasons for barrier |
|---|---|---|
| | | necessarily the beneficiary: the actor experiencing the inconvenience of having a measure implemented on his/her own land (e.g., agricultural measure) will provide the benefit to another actor (the inhabitant downhill where the measure results in a reduction of flooding). |
| Timing | Climate change is a dynamic process; adapting to climate change needs more flexibility than currently presented in the timing of EU Directives. | Climate change has been introduced in GD24 (published in 2009), too late to be included in the first management cycle of River Basin Management Plans (RBMP).<br>Possibility to overcome barriers in the second management cycle of the RBMP and the flood risk assessment in 2015.<br>Some of the NWRM require a long time to become effective; therefore the local actors do not necessarily see the benefits in the short-term. |
| Financial | Implementing NWRM is not usually as expensive as implementing man-made measures (e.g., construction of dikes), but funds are needed for the construction and the maintenance of the measure.<br>Implementing NWRM could also lead to loss of revenues as they often provoke land-use changes, involving the extensification of farming practices, losing productive land, and decreasing productivity (e.g. agricultural and forestry productivity). Land with economic value is also necessary to implement the measures and to restore or connect the landscape. | Lack of funding tools to implement NWRM at EU level; some EU funds such as the LIFE Programme have co-financed NWRM, but these funds are not enough for a wide implementation of NWRM. Other EU funds such as the Structural and Cohesion Funds are for large investments (tens or hundreds of million Euros) of man-made measures such as dikes, but usually not for NWRM.<br>Some EU policies, such as the CAP, provide subsidies to compensate for the loss of revenues, but the subsidies are low. For instance, the Natura 2000 payments do not usually cover all the costs of implementing measures such as wetland restoration. |
| Technical | Training would lead to a wider implementation of NWRM at EU level.<br>When planning measures today, local and regional authorities need the tools to take into account all likely or possible future changes in climate or to analyse the cost-effectiveness of measures. | Lack of training/advisory services for farmers regarding the measures proposed by the CAP (agri-environmental and forest-environment measures); this reduces the spatial scale and therefore the impact of the measures.<br>Most of the local and regional authorities do not have the capacity to implement the climate check introduced by the CIS.<br>The WFD and the CIS documents address no-regret measures, but the different terms and definitions could hinder their implementation at EU level. |
| Societal | Knowledge and/or willingness to use nature to avoid, minimise or solve environmental problems.<br>Society's desire to use nature in order to improve water quality and not only rely on technological and standard | Lack of willingness to implement "soft measures" for flood prevention and reduction; no incentive to move thinking away from hard flood defence measures; e.g., the Floods Directive does not highlight the role of wetlands in flood mitigation. |

| Type of barrier | Requirements for implementing NWRM at EU level | Possible reasons for barrier |
|---|---|---|
| | treatments. | Lack of awareness that nature can provide many ESS, including water quality improvement; for farmers, society in general, authorities and policy makers, nature conservation is a disadvantage and payments are made to compensate for economic losses rather than for the services that nature provides. This is because there is still a lack of tools to carry out cost-benefit analyses and provide an economic case for promoting nature for solving, avoiding or minimising environmental problems.<br>The effectiveness of NWRM is difficult to grasp. NWRM work best when a few measures are combined. If they are taken one by one, they seem to be meaningless but the combined result is positive Local actors do not understand that a small measure upstream combined with others can have a large effect (the butterfly effect) at the end (downstream), especially when the effect is even not visible (e.g., groundwater replenishment). |

This section is divided into seven sections, presenting the assessments of specific EU policy or funding programmes:

1. Water Framework Directive (WFD);
2. Floods Directive;
3. Common Agricultural Policy (CAP);
4. Biodiversity and nature policy;
5. LIFE+ programme;
6. Cohesion and Structural Funds; and
7. Water Scarcity and Droughts Strategy.

## 5.1 Water Framework Directive

Since its adoption in 2000, the WFD has changed the management of European rivers and river catchments significantly. Furthermore, the WFD will continue to be the most influential piece of legislation in water policy, dominating action in this field for years to come (Laaser *et al.,* 2009)..

The WFD sets a frame for implementing measures *to ensure protection and sustainable use of water in the framework of the river basin*. The WFD asks Member States to prepare River Basin Management Plans (RBMP), which include programmes of measures *adjusted to regional and local conditions*. It specifies environmental objectives and takes into account the necessity of an environmental-friendly approach to integrate qualitative and quantitative aspects to surface waters and groundwater. The Directive refers to other policies and asks Member States to take them into account; it also links water management to the spatial approach of river catchments.

#### 5.1.1 Weaknesses and opportunities of the WFD

The three main weaknesses of the WFD could become opportunities (see Table 41).

**TABLE 41**
**WEAKNESSES AND OPPORTUNITIES OF THE WFD**

| WFD Item | Weaknesses | Opportunities |
|---|---|---|
| Supplementary measures | The most relevant measures for the promotion of NWRM are considered supplementary. | Member States have discretionary power to implement (or not) supplementary measures in their catchments; they have to adapt the RBMPs to local circumstances; this is an opportunity to implement NWRM. |
| Cost-benefit assessment tools | As rightly identified by the Consultation Document on the Blueprint, there is a lack of *methodologies to calculate the adequate recovery of environmental and resource costs*. The lack of methodologies to assess the costs and in particular the benefits of ESS results in underestimating the benefits that nature provides. | Once the cost-benefit assessment tools are available, it will be possible to make decisions and design measures, programmes and policies with the complete socio, economic and environmental picture, which will ensure the success of the policy instrument. |
| Climate check of RBMPs and no-regret measures | The WFD provides a multi-matrix classification to categorise the ecological status of rivers, lakes, transitional and coastal waters, but it does not fully take into account climate change. | The matrix should take into account climate change or the necessity to take into account climate change impacts when designing measures. |

To address open questions and deal with challenges evolving from the implementation of the WFD, the EU Member States, Norway and the EC set up a CIS shortly after the WFD entered into force. The CIS has provided and continues to provide guidance for the implementation of the WFD. The CIS documents are for practitioners in the Member States and therefore form the link between the European and the regional level. These guidance documents are however not legally binding; the CIS has produced two documents relevant for the implementation of NWRM, including:

- CIS Guidance Document no. 12: The Role of Wetlands in the WFD (GD12); and
- N° 24 - River Basin Management in a changing climate (GD24).

In GD24, no-regret measures “contribute to more sustainable water management and bring benefits in terms of also alleviating already existing problems”, while win-win measures “entail side-benefits for other social, environmental or economic objectives”. Chapter 5.7 states that no-regret should be a sub-criterion when choosing “adaptation measures”.

**NWRM RECOMMENDED IN RIVER BASIN MANAGEMENT PLAN (RBMP)**

Member States need to prepare a RBMP, which includes a Programme of measures. As defined by the Directive, basic measures are the minimum requirements and supplementary measures are to be undertaken when necessary. The basic measures are those required under other relevant Directives (Part A of Annex VI), including the Birds, Floods and Drinking Water Directives.

Part B of Annex VI recommends the implementation of a few NWRM; namely: restoration of floodplains, *demand management measures, inter alia, promotion of adapted agricultural production, such as low water requiring crops in areas affected by droughts*, rehabilitation projects, artificial recharge of aquifers and other relevant measures.

GD24 proposes to undertake a "climate check" of the Programmes of Measures to identify measures that are robust and flexible to the uncertainty with a view to incorporating them in the next river basin management cycles. The document also recommends carrying out a sensitivity analysis to assess the cost-efficiency and the long-term effectiveness of measures under climate change conditions within the climate check so that measures are resilient to climate change. Only those measures that pass the climate check should be included into the next RBMPs.

The drafting of the first RBMPs without taking into account climate change is a missed opportunity that should be avoided in the second planning cycle. More guidance on the identification of no-regret measures will facilitate the understanding of these measures and create a common understanding of what no-regret measures are and which objectives they are expected to achieve. The specification could be undertaken in Annex VI of the WFD.

The WFD and GD24 introduce four different terms for measures adaptable to climate change: supplementary, adaptation, no-regret and win-win, which is confusing. This lack of clarity and the fact that GD24 and the climate checks are not legally binding have resulted in insufficient guidance and tools for local and regional authorities to climate proof their RBMPs and measures. The current guidance is insufficient and varies greatly from country to country and even from catchment to catchment.

**GUIDANCE ON HOW TO INCLUDE CLIMATE CHANGE INTO RIVER BASIN MANAGEMENT**

GD24 is not legally binding and only provides guidance to river basin managers on how to include climate change into the next river basin management cycles. GD24 recognises that climate change is not addressed explicitly in the WFD; however, it also emphasises that the process of river basin management planning, due to its cyclical approach, is well suited to adapt the plans to climate change challenges and impacts. Therefore, it recommends that the second RBMP, to be elaborated in 2015, take into account the impacts of climate change.

Table 42 presents suggestions for improving the promotion of NWRM in the WFD.

**TABLE 42**
**SUGGESTIONS FOR IMPROVING PROMOTION OF NWRM IN WFD**

| NWRM | Current promotion of NWRM in WFD | Suggestion for improvement |
|---|---|---|
| **Forest** | The WFD does not promote forest measures into the RBMPs. For example, the Western River Basin District RBMP does not integrate any of the three forest NWRM. It only states that the RBMP should be integrated with other plans such as the forest management plans. A similar situation was encountered when reviewing England and Wales' RBMPs of Anglian, Dee and Western Wales' river basin districts (Environment Agency (no date). | Include a Guidance Document on the integration of forest NWRM in all RBMPs. |
| **Urban** | The WFD does not explicitly promote SuDS for achieving the Directive's objectives. However, for point and diffuse sources, the WFD points to the Urban Waste Water Directive (91/271/EEC). Article 9 of the Urban Waste Water Directive asks Member States to implement measures at the source.<br>GD24 mentions SuDS as a win-win measure that reduces flood risk and at the same time improves water quality. | Provide more detailed recommendations (and potentially binding targets) for urban measures, such as filter strips and swales, permeable surfaces, etc.<br>RBMPs could provide a platform for coordinating a better uptake of SuDS among stakeholders.<br>Provide more guidance through the CIS documents. |
| **Agricultural** | The WFD promotes integrating water quality issues into other EU policy areas, such as agriculture. As part of the list of supplementary measures, it also suggests promoting adapted agricultural production such as low water requiring crops in areas affected by droughts. GD24 recommends sectoral adaptation measures that may positively interact with the WFD objectives, such as adopting agricultural soil moisture conservation practices. This recommendation is not binding, however, and remains vague. | Promote cooperation between water and agriculture stakeholders to integrate the WFD's objectives in the CAP.<br>Amend the WFD to refer more to the CAP, in particular as a funding instrument. |
| **Buffer strips** | The WFD does not promote the implementation of buffer strips, although measures under the Nitrates Directive (91/676/EEC) limit the land application of fertilizers, consistent with good agricultural practice and taking into account the characteristics of the vulnerable zone near water courses. The CAP also encourages the application of buffer strips along watercourses. | The WFD could also promote, as a supplementary measure, buffer strips along arable lands. |
| **Basins and ponds** | The WFD does not mention the necessity to create and maintain areas for water storage and retention, such as basins and ponds, but GD24 promotes the implementation of SuDS to attenuate floods in urban areas. | GD24 could provide further suggestions to implement basins and ponds in other land uses. |
| **Wetland restoration** | The WFD recognises the role of wetlands in water resources protection. In fact, recreation and restoration of wetlands is one of the supplementary measures suggested by the | Amend the WFD so that it recognises and promotes constructed wetlands in urban areas. The WFD should promote |

| NWRM | Current promotion of NWRM in WFD | Suggestion for improvement |
|---|---|---|
| | Directive in the non-exclusive list of measures that Member States may choose to adopt in each river basin district. A preliminary look at the UK RBMPs shows that wetlands have been well integrated into these plans. GD24 also clearly promotes wetlands as a win-win measure as they are robust in face of the uncertainty in climate projections since they contribute to flood attenuation and drought management, in addition to providing other benefits. | constructed wetlands as an alternative to improving water quality in urban areas. This is an opportunity for a better uptake of wetland restoration and creation under the WFD and Urban Wastewater Treatment Directive. |
| **Floodplain restoration** | GD24 promotes measures that increase natural retention and storage capacity (e.g., construction of artificial side channels, reconnection of old river arms, an increase of water transport and retention capacity of floodplains); these measures address flooding in view of the changing climate and they positively interact with the WFD's objectives. However, GD24 is not legally binding. | Provide more guidance to assist regional and local authorities to implement these types of projects. |
| **Natural bank stabilisation** | The WFD indirectly promotes natural bank stabilisation by defining as "high status" the morphological conditions of the river (channel patterns, width and depth variations, structure of the riparian zone, flow velocities) that are in totally or nearly totally undisturbed conditions. It also defines as "high status" the continuity of the river that is not disturbed by anthropogenic activities and allows undisturbed migration of aquatic organisms and sediment transport. Natural bank stabilisation also contributes to improving the composition and abundance of aquatic flora of benthic invertebrate fauna, as well as the composition, abundance and age structure of fish fauna, as required by the WFD. | Be more specific and provide guidance as neither the applicability nor the impacts and benefits and co-benefits are entirely clear. |
| **Re-meandering** | As for natural bank stabilisation. | The WFD should emphasise the importance of designing re-meandering projects following previous reference conditions, instead of totally or nearly totally undisturbed conditions. |
| **Artificial groundwater recharge** | In the non-exclusive list of supplementary measures, the WFD suggests that Member States may choose ARG. | Provide more guidance for a wider uptake of the measure at EU level. |
| **Lake restoration** | The WFD promotes indirectly lake restoration as it defines as "high status" lake conditions (biological, hydrological, morphological, chemical and physico-chemical) that are in totally or nearly totally undisturbed conditions. | Provide more specific guidance on the implementation of this measure. |

### 5.1.2 Policy recommendations for the WFD

The main policy recommendations are to continue the work of the CIS and provide more specific guidance on NWRM (e.g., make sure that the second round of RBMPs takes climate change explicitly into account, provide guidance on cost-benefit analysis):

- Take into account climate change explicitly for the second management cycle of the RBMPs by ensuring that the measures are climate proofed and therefore become no-regret measures.
- Come up with one common expression and definition for measures that fulfil the criteria of no-regret measures; currently, the WFD and GD24 introduce three different terms for measures adaptable to climate change: supplementary, adaptation, and no-regret. Better guidance would create a common understanding of what no-regret measures are and which objectives they are expected to achieve.
- Amend the WFD to establish a mechanism encouraging Member States to integrate a minimum percentage of no-regret measures in their RBMPs.
- Provide guidance on the cost-benefit analysis of measures so that local and regional authorities can identify the most effective measure in their catchment. Guidance and a clear methodology are essential to build the case for nature conservation, and therefore promote NWRM, and at the same time will potentially improve policy making. As mentioned by the EC Impact Assessment Guidelines (2009), the evaluation of the costs and benefits improves the quality of policy proposals.
- Include the following NWRM on the list of supplementary measures and provide guidance on them:
    - Floodplain restoration;
    - Buffer strips;
    - Re-meandering;
    - Restoration of lakes; and
    - Natural bank stabilisation.
- Highlight the environmental problems of the urban environment by providing a legal framework and/or guidance on urban measures. This could lead to a better uptake of filter strips and swales, permeable surfaces and filter drains, infiltration devices and green roofs, artificial wetlands, and basins and ponds. The CIS could share best practices since the implementation of these measures varies very much among EU countries. A guidance document presenting best practices would be very helpful.
- Better promote forest measures through a guidance document explaining how to take into account the practices and local conditions of different regions.

## 5.2 Floods Directive

Directive 2007/06/EC on the assessment and management of flood risks, also known as the Floods Directive, expands the frame set by the WFD from the achievement of qualitative and quantitative objectives to the mitigation and avoidance of floods. Like the WFD, the Floods Directive follows a cyclic river basin management approach. The timetable of the Floods Directive is closely linked to that of the WFD:

- In 2015, when the WFD requires the elaboration of the operational programmes of measures, the Floods Directive foresees the start of the participation process.
- With the end of the first management cycle of the WFD in 2015, the Floods Directive foresees the elaboration of Flood risk management plans. These Flood risk management plans also form part of the requirements of the WFD, as the second RBMP together with the first flood risk management plan will be due by the end of the first management cycle.
- The first management cycle of the Floods Directive ends in 2021, together with the end of the second management cycle of the WFD.

**CLIMATE CHECK OF THE FLOOD RISK MANAGEMENT PLANS**

The Floods Directive asks water managers to take into account the likely impacts of climate change on the occurrence of floods when setting up the Flood risk management plans. Article 4 requires assessing the potential adverse consequences of future floods, taking into account future impacts of climate change. The Floods Directive addresses explicitly the importance of natural water retention and the pressures from which areas for natural water retention are suffering. It asks Member States to take into account "*as far as possible issues such as the topography, the position of water courses and their general characteristics including floodplains as natural water retention areas*". The Floods Directive also requires Member States to include sustainable land-use practices and the improvement of water retention in their flood risk management plans.

The Preamble (14) of the Floods Directive clearly describes the measures to be implemented under the Floods Directive. When giving rivers more space, the maintenance and/or restoration of floodplains as well as the reduction and prevention of damage to human health, the environment, cultural heritage and economic activity should be considered, taking also into account the likely impacts of climate change on the occurrence of floods.

### 5.2.1 Weaknesses and opportunities of the Floods Directive

Guidance documents for the Floods Directive have not been as extensively developed as for the WFD. Chapter 6 of GD24 –Flood Risk Management and Adaptation - explains how to consider climate change when implementing the Floods Directive and which measures to implement. GD24 clearly states that climate change should be taken into account throughout the entire flood risk management cycle; preliminary flood risk assessment, flood hazard and risk mapping and Flood Risk Management Plans. The overall guiding principle of GD24 is that the adaptation of flood risk management to potential climate change should start as soon as possible.

**CONCRETE GUIDANCE FOR CLIMATE PROOFING UNDER THE FLOODS DIRECTIVE**

WFD GD24 states that it is crucial to carry out a climate check of the flood risk management measures. GD24 favours the implementation of no-regret and low-regret measures (*Guiding Principle: Favour options that are robust to the uncertainty in climate projections)*.

GD24 gives examples of no- and low-regret measures and asks water managers to carry out non-structural measures, which are not based on large structural components but on alternative solutions. They can therefore also be considered as no-regret measures, as they are flexible and cost-effective, due to their simple implementation. GD24 acknowledges that flood reduction requires a mix of structural and non-structural measures.

GD24 also identifies the catchment approach as a no-regret option, an approach that in some Member States has only been implemented since the WFD. This approach leads to better communication within the catchment as well as to catchment wide strategies to deal with challenges caused by climate change.

GD24 provides examples of no-regret measures, such as early warning systems and dykes that can be increased in height during flood events, as well as other measures that are adaptable to and efficient under current and all climate change scenarios. However, according to the essence of NWRM identified in this study, dykes should not be considered as no-regret as they require a high investment cost, have a very long term impact, and are not very flexible and adaptable to other climate change scenarios.

Table 43 presents suggestions for improving the promotion of NWRM in the Floods Directive.

**TABLE 43**
**SUGGESTIONS FOR IMPROVING PROMOTION OF NWRM IN FLOODS DIRECTIVE**

| NWRM | Current promotion of NWRM in Floods Directive | Suggestion for improvement |
|---|---|---|
| **Forest** | The Floods Directive does not mention forest measures to reduce flood hazard; the document “Towards better environmental options for flood risk management” describes the positive impacts of forests on flood mitigation. The Annex recommends practitioners to plant gully wetland and to introduce native mixed woodland on hill slopes. | This document could be legally binding; the Floods Directive provides an opportunity to promote these measures, but it is not currently exploited. |
| **Urban** | The Floods Directive does not promote urban measures explicitly; the document “Towards better environmental options for flood risk management” mentions the necessity to improve the soil’s water storage capacity and to conserve water in natural systems in urban areas as well as the possibility to improve the urban microclimate by introducing or maintaining green spaces and corridors. It mentions the possibility of introducing SuDS and states that natural measures can be more efficient than physical infrastructure to adapt urban areas to climate change. | An approach for a better uptake of these measures would be to recommend to Member States that they integrate them into the Flood risk management plans due in 2015. |
| **Agricultural** | The Floods Directive does not promote agricultural measures explicitly, but Article 7 asks Member States to take into account the promotion of sustainable land use practices and the environmental objectives of Article 4 of the WFD in Flood risk | The Directive could provide guidance or obligations to look into and adopt agricultural NWRM. |

| NWRM | Current promotion of NWRM in Floods Directive | Suggestion for improvement |
|---|---|---|
| | management plans. Although not suggested specifically, this gives an incentive to implement agricultural measures such as buffer strips, soil conservation practices, no and reduced tillage. Flood risk management plans may also include the improvement of water retention. | |
| **Basins and ponds** | The Floods Directive does not promote “soft measures” for flood mitigation such as basins and ponds, but GD24 already acknowledges that flood reduction requires a mix of structural and non-structural measures. | The Directive could provide an incentive to consider alternatives for flood mitigation other than hard flood defence. |
| **Wetland restoration** | The Floods Directive is a key piece of legislation that offers opportunities to enhance wetland restoration and creation. However, the Directive has failed to take into account the importance of wetlands for flood mitigation. It does not promote wetland restoration as a measure, although it mentions that maintenance and/or restoration of floodplains give more space to rivers. A recently published note: "Towards Better Environmental Options in Flood Risk Management" developed by DG ENV, promotes wetland restoration as a measure to enhance flood storage capacity. GD12 also acknowledges the role of wetlands in flood attenuation, but neither of these documents is legally-binding. | The Directive could be explicit and specify measures such as wetland restoration so that Member States do not implement whichever measures they consider best, with a potential detrimental effect. |
| **Floodplain restoration** | In the preamble of the Floods Directive, Member States are requested *to consider where possible the maintenance and / or restoration of floodplains*. Article 4 suggests that Member States assess the potential adverse consequences of future flood, considering floodplains as natural retention areas. Article 7 stresses the necessity to include the improvement of water retention into the Flood risk management plans. Moreover, the document “Towards better environmental options for flood risk management” mentions that restoring floodplains contributes to mitigating climate-related floods and droughts; due to their manifold functions, floodplains store carbon and water very efficiently. | There should be more guidance and legally binding targets for implementing floodplain restoration projects. |
| **Re-meandering** | The document “Towards better environmental options for flood risk management” introduces re-meandering as an important natural flood management technique because it improves the local floodwater retention capacity. | The Floods Directive, which is the only legally binding document for flood hazard reduction at EU level, should promote this measure at EU level and therefore encourage a better uptake of this measure in the Flood Management Plans. |

### 5.2.2 Policy recommendations for the Flood Directive

The two policy recommendations are to provide more guidance and to promote “soft” measures:

- Prepare a Guidance document linking flood mitigation, GI and biodiversity because so far, the Floods Directive does not take these aspects into account. This Guidance document could explain the link between flood mitigation and the need to introduce and conserve GI.

- Add the promotion of "soft" measures to the traditional hard-engineering defence approach to flood mitigation. This approach could promote including NWRM such as wetlands, basins and ponds, and SuDS in the Flood risk management plans.

## 5.3 Common Agricultural Policy

The CAP was established in 1957, after signing the Treaty of Rome. In recent years, the CAP has undergone several reforms; the 1993-1996 reforms and the implementation of the Agenda 2000 defined the financial framework of the CAP for 2000-2006 and introduced the first and second pillars of the CAP; market support measures and direct subsidies to EU producers belong to the first pillar; rural development programmes belong to the second pillar (UK Parliament, 2005). This has led to a new understanding of the role of farming in Europe: nowadays "farmers are no longer paid just to produce food. [..] they also have to respect environmental, food safety, phytosanitary and animal welfare standards".

### CAP's first pillar

The legal basis for the CAP's first pillar is Council Regulation (EC) No 73/2009[75], which governs all of the direct support schemes; of these schemes, cross-compliance is the most relevant to NWRM and is the subject of this policy analysis. The two core elements of cross-compliance are:

1. Statutory Management Requirements (SMR), addressing environmental, food safety, animal and plant health and animal welfare issues based on 18 legislative standards in these fields; and
2. GAEC, obliging farmers to keep land in good agricultural and environmental condition by setting standards for soil protection, maintenance of soil organic matter and structure, avoidance of deterioration of habitats, and water management[76].

Cross-compliance works like a Polluter-Pays principle, i.e., farmers pay the costs of avoiding or stopping environmental damage. The direct payments that a farmer receives depend on compliance with the SMR and GAEC and can be cut or reduced, if a farmer fails to comply. The GAEC sets compulsory and optional standards (see Table 44). Some of these are particularly relevant to NWRM, including:

- Minimum soil cover;
- Retain terraces;
- Arable stubble management;
- Standards for crop rotations;

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[75] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:030:0016:0016:EN:PDF

[76] European Commission, 2011, Cross-compliance. http://ec.europa.eu/agriculture/envir/cross-compliance/index_en.htm.

- Retention of landscape features, including ponds, trees in line, in group or isolated and field margins;
- Protection of permanent pasture;
- Establishment and/or retention of habitats; and
- Establishment of buffer strips along water courses.

**TABLE 44**
**GAEC FRAMEWORK, ACCORDING TO ANNEX III OF COUNCIL REGULATION (EC) NO 73/2009**

**FIRST COMPONENT**

To ensure that all agricultural land, especially land no longer used for production, is maintained in good agricultural and environmental conditions, Member States shall define minimum requirements, at national or at regional level, on the basis of 5 issues and 15 standards (8 compulsory and 7 optional) described in Annex III of Council Regulation (EC) No 73/2009.

| Issue | Compulsory standards | Link to NWRM | Optional standards | Link to NWRM |
|---|---|---|---|---|
| **Soil erosion**: protect soil through appropriate measures | Minimum soil cover | Soil conservation crop practices | Retain terraces | Traditional terracing |
| | Minimum land management reflecting site-specific conditions | Soil conservation crop practices | n.a. | n.a. |
| **Soil organic matter**: maintain soil organic matter levels through appropriate practices | Arable stubble management | Soil conservation crop practices | Standards for crop rotations | Soil conservation crop practices |
| **Soil structure**: maintain soil structure through appropriate measures | n.a. | n.a. | Appropriate machinery use | Soil conservation crop practices |
| **Minimum level of maintenance**: ensure a minimum level of maintenance and avoid the deterioration of habitats | Retention of landscape features, including, where appropriate, hedges, ponds, ditches, trees in line, in group or isolated and field margins (**) | Basins and ponds | Minimum livestock stocking rates or/and appropriate regimes | n.a. |
| | Avoiding the encroachment of unwanted vegetation on agricultural land | Green cover | Establishment and/or retention of habitats (*) | Green cover |
| | Protection of permanent pasture | Restoring and maintaining meadows and pastures | Prohibition of the grubbing up of olive trees | Green cover |

| | | | | |
|---|---|---|---|---|
| | n.a. | n.a. | Maintenance of olive groves and vines in good vegetative condition | Green cover |
| **Protection and management of water**: Protect water against pollution and run-off, and manage the use of water | Establishment of buffer strips along water courses (***) | Buffer strips | n.a. | n.a. |
| | Where use of water for irrigation is subject to authorisation, compliance with authorisation procedures (*) | n.a. | n.a. | n.a. |
| **SECOND COMPONENT** Member States shall ensure that land which was under permanent pasture at the date provided for the area aid applications for 2003 is maintained under permanent pasture. For new Member States, this condition refers to the land that was under permanent pasture on 1 May 2004 (for Bulgaria and Romania on 1 January 2007). Member States must maintain the ratio of land under permanent pasture over the total agricultural area. They also have to implement measures at the level of the farms if the ratio of permanent pasture in the member state decreases. | | | | |

(*) Applies since 1 January 2010
(**) The specification of landscape features applies since 1 January 2010
(***) Applies from 1 January 2010 at the earliest and by 1 January 2012 at the latest

### CAP's second pillar

The rural development policy enshrined in the second pillar of the CAP has also undergone several reforms over time. These reforms aimed to improve the competitiveness of the agricultural and forestry sector, improve the environment and the countryside by strengthening the links between primary activity and the environment, improve the quality of life in rural areas, and encourage the rural economy diversification.

The CAP's second pillar is based on Council Regulations 473/2009 and 1698/2005 and Council Decisions 2009/61/EC and 2006/144/EC. Council Regulation 1698/2005 lays out the rules of the EU Rural Development Policy for 2007-2013 and establishes a single fund for the second pillar of the CAP, the EAFRD (European Agricultural Fund for Rural Development), bringing together all the previous measures. The EAFRD is implemented in Member States through RDPs, which cover a set of measures grouped together in accordance to the axes defined by the Regulation.

Axis 2 of the EAFRD aims to improve the environment and the countryside by supporting a series of payments, including a few relevant to NWRM, namely:

- Natura 2000 payments and payments linked to Directive 2000/60/EC;
- Agri-environment payments that go beyond usual good farming practice;
- First afforestation of agricultural land;

- Forest-environment payments; and
- Non-productive investments.

Axis 3 (quality of life in rural areas and diversification of the rural economy) also provides opportunities for implementing NWRM in rural areas, e.g., habitat restoration (wetlands) and Natura 2000 management plans.

**CAP proposal**

In 2011, the Commission published a set of legal proposals for the CAP after 2013, which outline options for the future CAP. These proposals will be finalised by the end of 2013 after a debate in the European Parliament and the Council; implementation will start in 2014.

**First pillar**

The reform will introduce a strong greening component into the first pillar of the CAP. The CAP proposal foresees 30% of direct payments tied to greening. The proposal will "*reinforce the ability of land and natural ecosystems to contribute to address major EU biodiversity and climate change adaptation objectives*". Article 29 of the direct payments regulation promotes agricultural practices beneficial for the climate and the environment by providing payments to farmers under the basic scheme. Some of these measures are NWRM, namely:

- Maintain existing permanent grassland on their holding; and
- Have ecological focus area on their agricultural area.

Ecological focus areas, as defined by the CAP proposal, include:

- Land left fallow;
- Terraces;
- Landscape features;
- Buffer strips; and
- Afforested areas.

Farmers shall ensure that at least 7% of their eligible hectares, excluding areas under permanent grassland, are ecological focus area.

The CAP proposal on the financing, management and monitoring of CAP[77] also establishes SMR and GAEC standards. Member States should fully implement the SMR at farm level. Member States can define at national or regional level minimum standards for beneficiaries for GAEC based on Annex II of the proposal taking into account the specific characteristics of the areas concerned. In addition, the WFD will

[77] COM(2011) 628 final/2. Proposal for a Regulation of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy.

be considered as part of the cross compliance rules under Annex II once all Member States have implemented the Directive.

**Second pillar**

Article 5 of the CAP proposal for a rural development regulation[78] establishes the Union priorities for rural development. These priorities include a few relevant to NWRM, including *Restoring, preserving and enhancing ecosystems dependent on agriculture and forestry, with a focus on the following areas:*

(i) Restoring and preserving biodiversity, including in Natura 2000 areas and high nature value farming, and the state of European landscapes;

(ii) Improving water management;

(iii) Improving soil management.

These priorities would be translated into the Common Strategic Framework, which aims at better coordination among other EU-shared management funds.

The RDPs should also include measures as defined in Article 9. The types of measures relevant to NWRM include:

- Investments in forest area development and improvement of the viability of forests;
- Afforestation and creation of woodland;
- Establishment of agro-forestry systems (Article 24);
- Agri-environment- climate (Article 29);
- Natura 2000 and WFD payments (Article 31); and
- Forest-environmental and climate services and forest conservation (Article 35).

### 5.3.1 Weaknesses and opportunities of the CAP

The weaknesses of the first pillar of the CAP proposal could become opportunities during the finalisation of the proposal (see Table 45). The aim of the proposal is to integrate more closely other EU policies within the CAP and to involve many sectors; this offers a unique opportunity for achieving a better coherence among policies.

[78] COM (2011) 627 Final. Proposal for a Regulation of the European Parliament and of the Council on support for rural development by the European Agricultural Fund Development (EAFRD).

**TABLE 45**
**WEAKNESSES AND OPPORTUNITIES OF THE FIRST PILLAR OF THE CAP PROPOSAL**

| CAP Item | Weaknesses | Opportunities |
|---|---|---|
| **GAEC** | The proposal for direct payments includes only crop diversification, but not other standards such as crop rotation, which can provide more environmental benefits than crop diversification. The GAEC are voluntary and not very specific. | The proposal could promote standards for no and reduced tillage, green cover or early sowing. The proposal could also promote buffer strips at the margins of arable land, and not only along water courses. |
| **Landscape features** | The CAP gives discretionary power to Member States to choose measures and in particular determine the eligibility criteria for paying the landscape features. | The eligibility criteria of some Member States could be more ambitious for the environment/nature; this would still comply with the subsidiarity principles and take into account the regions' specificities. |
| **Traditional terracing** | Since 2000, the CAP has subsidised up to 50% of the actual costs of restructuring and converting vineyards, in particular soil preparation, including land terracing. In convergence regions (according to Regulation 1083/2006), the subsidies can reach 75%. These subsidies have financed modern terracing, which has negative impacts (see Section 4). | In addition to establishing retaining terraces as a cross-compliance measure, the CAP reform could establish an eligibility clause to promote only traditional terracing. |
| **Approach to nature conservation** | Nature conservation continues to be seen as a disadvantage; Article 11 of the CAP proposal for a rural development regulation mentions that Natura 2000 payments will be available to *compensate beneficiaries for costs incurred and income foregone resulting from disadvantages in the areas concerned*. | The proposal should recognise that nature in itself and the network of protected areas can provide ESS, such as water quality regulation. The payment should be for providing these services rather than compensating for loss of revenues/agricultural land. |
| **Ecological focus areas** | The eligibility criteria for the ecological focus areas are not defined yet.<br>Wetlands are not on the list of ecological focus areas. | Ecological focus areas have a high potential for promoting NWRM such as buffer strips and landscape features such as basins and ponds, trees, etc. This will depend on the definition of the eligibility criteria (where, how, for how long). It is important to define the landscape features at a farm level and to use ecological (not only economic) factors.<br>The CAP proposal should add wetlands to the list of ecological focus areas. |

The second pillar of the CAP offers two key opportunities for the uptake of NWRM:

1. **Training and raising awareness**; other rural development measures could further improve the uptake of NWRM:

   - Knowledge transfer and information actions (Article 15);

- Advisory services, farm management and farm relief services (Article 16);
- Co-operation (Article 36).

Farmers need more advice and training to implement NWRM. The measures above offer an opportunity to provide the needed training and advice to farmers. They can also provide more targeted advice on the climate change adaptation options available to farmers and promote sharing best practices among farmers/regions or countries. Raising awareness actions could overcome societal barriers, such as the lack of knowledge among farmers of the value and benefits of nature.

2. **Cross-border cooperation**; the LEADER local action groups proposed in Article 42 of the CAP proposal for a rural development regulation, provide another opportunity for implementing inter-territorial or transnational co-operation projects relevant to NWRM. This initiative could finance capacity building, training and networking activities targeted at local public-private partnerships implementing a local development strategy:

- On a rural territory within or outside the Union; or
- On a non-rural territory.

### 5.3.2 Policy recommendations for the CAP

For the **first pillar**, the policy recommendations are to make the voluntary measures compulsory, further define the ecological focus areas, and provide clear guidance on the cross-compliance requirements for a better uptake of the NWRM:

- The voluntary measures under the cross-compliance should become compulsory in the long term (or provide economic incentives).
- Further define, enforce and monitor ecological focus areas. The definition of these areas should take due account of the ecological benefits of the areas and these areas should be applicable to the entire farmland. These ecological features should also include ponds and wetlands. The proposal should go further and not only oblige farmers to maintain these areas, but to create/restore them, when feasible. The proposal should also highlight traditional terracing, as it provides more environmental benefits than modern terracing.
- Be more specific on the cross-compliance requirements and provide clear guidance on the measures for a better uptake of the NWRM (see Table 46).

**TABLE 46**
**MODIFIED RULES ON CROSS COMPLIANCE PURSUANT TO ARTICLE 93 (COM(2011) 628 FINAL)**

| Area | Main Issue | Requirements and standards | | Proposed by this NWRM study |
|---|---|---|---|---|
| Environment, climate change, good agricultural condition of land | Water | GAEC 1 | Establishment of buffer strips along water courses | *and along arable fields* |
| | | GAEC 3 | Protection of ground water against pollution: prohibition of direct discharge into groundwater and measures to prevent indirect pollution of groundwater through discharge on the ground and percolation through the soil of dangerous substances, as listed in the Annex to the Directive 80/68/EEC | *Add a list of measures that would protect ground water: wetland restoration, buffer strips, riparian forests, restoring and maintaining meadows and pastures.* |
| | Soil and carbon stock | GAEC 5 | Minimum land management reflecting site specific conditions to limit erosion | *Add a list of measures to limit erosion: traditional terracing, soil conservation practices including crop rotation, no- or reduced tillage, green cover and early sowing.* |
| | | GAEC 6 | Maintenance of soil organic matter including ban on burning arable stubble | |
| | Landscape, minimum level of maintenance | GAEC 8 | Retention of landscape features, including where appropriate hedges, ponds, ditches, trees in lines, in group or isolated, field margins and terraces, and including a ban on cutting hedges and trees during the bird breeding and rearing seasons and possible measures for avoiding invasive species and pests | *Add wetlands and highlight traditional terracing.* |

For the **second pillar**, the policy recommendations are to highlight the need for climate change adaptation in the RDPs, define specific NWRM in the Common Strategy Framework, and increase the Natura 2000 payments, promote CCF, and promote LEADER to share best practices on climate change adaptation:

- Fully exploit the RDPs and their measures. Training and advisory services should highlight the need for climate change adaptation for farmers (Farm's own environmental handbook).
- Define specific NWRM in the Common Strategic Framework 2014-2020:
  - ✓ Soil management: include crop practices such as green cover, early sowing, soil conservation practices (crop rotation), no or reduced tillage;
  - ✓ Biodiversity and water management: include wetlands and floodplain restoration.

- Increase the Natura 2000 payments to "pay" for the ESS that these areas provide and develop cost-benefit tools that take into account the costs and benefits when designing these payments. Currently, these payments do not cover wetland restoration, as shown in the unit costs in Section 4.
- Highlight CCF under Forest-environmental and climate services and forest conservation measures.
- Promote LEADER to local and regional authorities in order to fund cooperation projects for sharing best practices on climate change adaptation and implementing NWRM in trans-boundary river basins.

## 5.4 EU biodiversity and nature policy

The Habitats[79] and Birds[80] Directives form the cornerstone of EU nature conservation policy and aim to "maintain or restore at a favourable conservation status the natural habitats and the populations of species of wild fauna and flora" in the EU territory. Natura 2000, an EU-wide network of nature protection areas, covering the areas protected under the Birds and Habitats Directives, shall "enable the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range".

The EC has adopted a new Strategy to halt the loss of biodiversity and ESS in the EU by 2020, which followed the 2006 Biodiversity Action Plan. The EU 2020 Biodiversity Strategy, published in May 2011, encourages Member States to conserve and restore nature through the full implementation of the Birds and Habitats Directives. The Strategy also calls for maintaining and enhancing ecosystems and their services and ensuring the sustainability of agriculture, forestry, and fisheries. The Habitats and Birds Directives are legally binding documents, but the Biodiversity Strategy is not.

### 5.4.1 Weaknesses and opportunities

The Birds and Habitats Directives make no reference to the effects of climate change on the natural habitats and wild fauna and flora that they aim to protect. This is not surprising as these two Directives were enacted before the adaptation of habitats and species to climate change moved high up on the international agenda. This weakness can be turned into an opportunity to prepare guidance documents explaining how the uptake of NWRM can reduce the impact of climate change on species and habitats.

Climate change is already affecting and will have severe impacts on biodiversity. In fact, according to the MEA, 2005 by the end of the 21$^{st}$ century, climate change and its impacts may be the dominant direct driver of biodiversity loss and changes in ESS globally. Climate change, combined with land-use change and the spread of

79 Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
80 Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

exotic or alien species, are likely to limit both the capability of species to migrate and the ability of species to persist in fragmented habitats.

Article 3 of the Habitats Directive is clear on the measures needed to improve connectivity of habitats by suggesting that Member States *improve the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape, which are of major importance for wild fauna and flora*. Article 10 further encourages Member States *to encourage the management of features of the landscape, which are of major importance for wild fauna and flora* in order to improve the ecological coherence of the Natura 2000 network. The Directive provides examples of these features as follows: "*Such features are those which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species*".

However, Articles 3 and 10 give discretionary power to the Member States on whether the measures are necessary. In addition, these statements are not concrete and the Directive provides no further guidance on the landscape connectivity issue. In view of this, the EC published a report titled: Guidance on the maintenance of landscape connectivity features of major importance for wild flora and fauna (IEEP, IUCN and Ecological solutions, 2007), which provides further guidance on Articles 3 and 10 of the Habitats Directive. However, the guidelines are not legally binding for Member States.

The measures or actions derived from the framework proposed in the guidance document are likely to be no-regret measures since the framework clearly takes into account the risk of climate change to species and habitats. Moreover, the guidance provides recommendations for improving functional connectivity in the wider environment. No-regret measures overlap many of these recommendations. For example, buffer strips can act as semi-natural habitats in farmed areas or as a buffer to reduce pesticides and fertilisers. CCF is one of the sustainable forest management measures that can increase connectivity between highly managed forests and natural or semi-natural forests.

The EU Biodiversity Action Plan of 2006[81], the EU Biodiversity Strategy to 2020 and the White paper on adapting to climate change[82] emphasise climate change. They recommend maintaining a favourable conservation status of species and habitats in the face of climate with tools such as flyways, buffer zones, corridors, and stepping stones. They also recognise that *ecosystem-based approaches to climate change mitigation and adaptation can offer cost-effective alternatives to technological solutions* and that these approaches can deliver multiple benefits besides biodiversity conservation. However, they are not legally binding documents.

Annex I of the Habitats Directive lists the types of natural habitats types of community interest; it includes various habitats resulting from the implementation of NWRM:

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[81] Communication from the Commission halting the loss of biodiversity by 2010 — and beyond. Sustaining ecosystem services for human well–being.

[82] COM(2009) 147. White paper. Adapting to climate change: Towards a European framework for action.

- A few types of forests (including riparian forests)[83];
- A few species of raised bogs and mires and fens[84];
- A few types of rivers;
- Natural and semi-natural grasslands;
- A few types of lakes (standing bodies); and
- River banks including Fennoscandian, Alpine, constantly flowing Mediterranean rivers, and river banks with a few specific species only[85].

The suggestions for improving the promotion of NWRM in the biodiversity and nature policy are in Table 47.

**TABLE 47**
**SUGGESTIONS FOR IMPROVING PROMOTION OF NWRM IN BIODIVERSITY AND NATURE POLICY**

| NWRM | Current promotion of NWRM in biodiversity and nature policy | Suggestion for improvement |
|---|---|---|
| **Urban** | The Habitats Directive does not promote the implementation of urban measures because it does not aim to protect biodiversity in the urban environment.<br>The Birds Directive does not highlight the need to implement measures in the urban environment, such as basins and ponds, which can contribute to improve habitats in the urban environment. | The policy could promote green roofs, for example, which are not only beneficial for the retention of rainwater, but also provide habitats for animals threatened in an urban environment, such as bees. |
| **Agricultural** | The preamble of the Birds Directive states that "measures to be taken must apply to the various factors which may affect the number of birds [...], in particular the destruction and pollution of their habitats". This encourages the implementation of agricultural measures such as restoring and maintaining meadows and pastures or buffer strips as they not only aim at maintaining habitats but also at restoring and enhancing them.<br>Articles 3 and 10 of the Habitats Directive suggest that Member States improve "the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora". | By maintaining landscape connectivity features of major importance for wild flora and fauna, the EC Guidance promotes buffer strips, which can act as semi-natural habitats in farmed areas or as a buffer to reduce pesticides and fertilisers; to be more effective, this guidance could become binding. |
| **Basins and ponds and floodplain** | The Habitats Directive indirectly promotes floodplain restoration and basins and ponds. Article 10 asks Member States to promote those features that are | The Commission could provide guidance or set legally binding targets. |

83 Forests of Boreal Europe, Forests of Temperate Europe, Mediterranean deciduous forests, Mediterranean sclerophyllous forests, Temperate mountainous coniferous forests and Mediterranean and Macaronesian mountainous coniferous forests.

84 Sphagnum acid bogs, Calcareous fens and Boreal mires.

85 *Myricaria germanica, Salix elaeagnos, Glaucium flavum, Ranunculion fluitantis* and *Callitricho-Batrachion vegetation, Chenopodion rubri p.p.* and *Bidention p.p. vegetation, Paspalo-Agrostidion species, hanging curtains of Salix* and *Populus alba* and *Paspalo-Agrostidio*

| NWRM | Current promotion of NWRM in biodiversity and nature policy | Suggestion for improvement |
|---|---|---|
| **restoration** | "essential for the migration, dispersal and genetic exchange of wild species". It highlights that "rivers with their banks or their traditional systems for marking field boundaries" as well as "stepping stones (such as ponds or small woods") are of utmost important for those species. | |
| **Re-meandering** | The Birds Directive has missed the opportunity to promote this measure. | Promoting this measure would add value to the habitats of waders as well as migrating and breeding birds. |
| **Natural bank stabilisation** | The Habitats Directive promotes natural bank stabilisation indirectly by suggesting that Member States endeavour to encourage the management of landscape features, such as rivers and their banks in their land-use planning and development policies. | The Directive should be more specific and provide guidance or binding targets. |

### 5.4.2 Policy recommendations for biodiversity and nature policy

The two policy recommendations are to support an approach to connect the landscape and decrease habitat fragmentation and to propose specific measures and guidance to promote GI and NWRM:

- Support an approach to connect the landscape and decrease habitat fragmentation, which is one of the main threats to Europe's biodiversity; in the past years, the EU biodiversity and nature policy has focused on protecting isolated areas of habitats where key species inhabit. The policy should require Member States to assess the connectivity requirements (and other required conservation measures) for species and habitats at particular risk from habitat fragmentation and climate change. Legislative acts with binding force should also oblige Member States to monitor the impacts of climate change in biodiversity.
- Propose specific measures and guidance that could promote GI and NWRM: improve landscape connectivity and at the same time provide other environmental benefits, such as buffer strips, wetland restoration, among others.

## 5.5 LIFE programme

The Financial Instrument for the Environment (LIFE)[86] co-finances pilot or demonstration projects with European added value, which contribute to implementing, updating, and developing EU environmental policy and legislation. The programme has been supporting Member States since 1992. To date, there have been three complete phases of the programme: LIFE I (1992-1995), LIFE II (1996-1999), and LIFE III (2000-2006). During this period, LIFE has co-financed

86 REGULATION (EC) No 614/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 May 2007 concerning the Financial Instrument for the Environment (LIFE+). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:149:0001:0016:EN:PDF

some 3,104 projects across the EU, contributing about €2.2 billion to environmental protection. The latest, ongoing Programme (LIFE+) has a total budget of €2.143 billion for 2007-2013 and includes three components:

- LIFE+ Nature and Biodiversity: actions to protect, conserve, restore and monitor the functioning of natural systems, natural habitats, wild flora and fauna, in order to halt the loss of biodiversity in the EU.
- LIFE+ Environment Policy and Governance: actions to implement, update and develop EU environmental policy and legislation, in particular climate change, water, air, soil, urban environment, noise, chemicals, environment and health, natural resources and waste, forests, innovation and strategic approaches.
- LIFE+ Information and Communication: actions to disseminate information and raise awareness on environmental issues, including forest fire prevention and accompanying measures, such as information, communication actions and campaigns, conferences and training, including training in forest fire prevention.

The sixth LIFE+ call for proposals was published in the Official Journal (2012/C 74/08) on 13 March 2012. The total budget of the 2012 Call for proposals is €276 million; at least 50% of this amount should be allocated to the conservation of nature and biodiversity. LIFE+ is a bottom-up and relatively flexible tool that can be used by various stakeholders, including public authorities, to implement demonstrative projects with an environmental added value.

**LIFE proposal**

On 12.12.2011, the Commission published a proposal for a Regulation of the European Parliament and of the Council to establish a Programme for the Environment and Climate Action (LIFE)[87]. As several evaluations have confirmed that the LIFE Programme is a successful instrument for implementing EU environmental policy and legislation, with a significant added value, the Commission proposes to continue the LIFE Programme currently regulated by the LIFE+ Regulation.

**CONTINUATION OF LIFE PROGRAMME IN PROGRAMME FOR THE ENVIRONMENT AND CLIMATE ACTION**

This proposal for a new LIFE Regulation is designed as a LIFE Programme with two sub-programmes: one for Environment and one for Climate Action. The creation of a sub-programme for Climate Action upgrades the former thematic strand "climate change" under the LIFE+ Environment Policy and Governance component.

An important change to improve the efficiency of the LIFE Programme and to create closer links to Union policy priorities is the shift from a pure bottom-up approach to a flexible top-down approach.

The new challenges ahead and the achievement of Europe 2020 objectives and targets call for modifications to the Programme. Fighting climate change and making the EU more resilient to the associated risks are some of the greatest challenges

[87] COM(2011) 874 final. Proposal for a Regulation of the European Parliament and of the Council on the establishment of a Programme for the Environment and Climate Action (LIFE)

facing the EU and there is a need for urgent action as reflected in the Europe 2020 Strategy. The Commission recognises that challenge and states in its MFF Communication (Multi-annual Financial Framework for 2014-2020) that it intends to increase the proportion of the EU budget related to climate action to at least 20% with contribution from different policies. The Programme for the Environment and Climate Action (LIFE) should therefore contribute to that goal.

The total financial envelope for the LIFE Programme in the MFF Communication for 2014-2020 is €3,618 million (in current prices). Of this amount, €2,713.5 million is for the sub-programme for Environment, of which half of the resources shall be for the conservation of nature and biodiversity, and €904.5 million is for the sub-programme for Climate Action. The sub-programme for Environment shall have three priority areas: Environment and Resource Efficiency; Biodiversity; and Environmental Governance and Information.

### 5.5.1 Weaknesses and opportunities of the LIFE Programme

The weaknesses of the LIFE Programme can become opportunities during the finalisation of the proposal (see Table 48).

**TABLE 48**
**WEAKNESSES AND OPPORTUNITIES OF THE LIFE PROGRAMME**

| Item of LIFE Programme | Weaknesses | Opportunities |
|---|---|---|
| **NWRM** | The sixth LIFE+ call for proposals mentions specifically NWRM for the first time. Even if the previous Calls for proposals did not mention this term, however, LIFE+ has co-financed various natural water retention projects, which are recommended under the themes (e.g., forests, water, soil, climate change, etc.) of the "LIFE+ Environment Policy and Governance guidelines". In particular, under Water, indicative favoured actions include:<br>• Implementation of multifunctional NWRM in different catchment areas focusing on increasing climate change resilience of water resources –e.g., forestry, agricultural measures, SuDS, restoration of floodplains and wetlands and increasing river capacity.<br>• Development and implementation of flood risk reduction measures which provide synergies with water and environmental protection objectives, including setting up of demonstration sites for innovative measures, including GI / NWRM in rural and urban areas, in different parts of EU addressing different types of floods and climatic conditions. | The "LIFE+ Information and Communication" strand can promote communication actions and awareness among the different stakeholders. Therefore, the efficiency and wide impact of the programme is an opportunity to promote integrated projects for NWRM on all land uses. |
| **Co-financing rates** | The LIFE budget is limited and usually co-finances only up to 50%, except for a few species and habitats listed in Annex I of the Habitats Directive as natural habitats types of community interest whose conservation requires | In order to ensure that beneficiaries are not disadvantaged and to maintain similar levels of support for projects financed by way of |

| Item of LIFE Programme | Weaknesses | Opportunities |
|---|---|---|
| | the designation of special areas of conservation, which are then eligible for the LIFE+ Nature proposals' current co-financing rate of up to 75%. | action grants as in the LIFE+ Regulation, the LIFE proposal will increase co-financing rates to 70% and 80% in specific cases. |
| **Programme's budget** | The budget of the LIFE+ Programme is small compared to other EU funds, such as the Framework Programme or the Cohesion Policy Fund. | According to the MFF Communication, the total budget of the LIFE Programme is €3.6 billion, which represents a 75% increase from 2007-2013; it remains small compared to €80 billion for Research and Innovation and €376 billion for cohesion policy instruments. |

### 5.5.2 Policy recommendations

The LIFE proposal is already a big step toward climate change adaptation and the implementation of NWRM. The only recommendation is to boost further the budget of the LIFE Programme or make it possible to co-finance LIFE projects with other EU funds/programmes.

## 5.6 Cohesion and Structural Funds

The Structural Funds and the Cohesion Fund are the financial tools established to implement the Regional policy of the EU, also known as Cohesion Policy. Their goal is to reduce regional disparities in income, wealth, and opportunities. Europe's poorer regions receive most of the support, but all European regions are eligible for funding under the policy's various funds and programmes.

The Structural Funds include the European Regional Development Fund (ERDF) and European Social Fund (ESF). Together with the CAP, the Structural Funds and the Cohesion Fund represent the majority of total EU spending. The overall budget for the current programming period (2007-2013) is €347 billion: €201 billion for the ERDF, €76 billion for the ESF, and €70 billion for the Cohesion Fund.

The main focus of eligible activities and costs and the overall allocations of funds depend on three main objectives:

**ERDF, ESF AND COHESION FUND**

The ERDF supports programmes addressing regional development, economic change, enhanced competitiveness, and territorial co-operation throughout the EU. Funding priorities include modernising economic structures, creating sustainable jobs and economic growth, research and innovation, environmental protection and risk prevention. Investment in infrastructure is also important, especially in the least-developed regions.

The ESF focuses on increasing the adaptability of workers and enterprises, enhancing access to employment and participating in the labour market, reinforcing social inclusion by combating discrimination and facilitating access to the labour market for disadvantaged people, and promoting partnership for reform in employment and inclusion.

The Cohesion Fund supports the environment and trans-European transport networks in member states with a Gross National Income (GNI) less than 90% of the EU average. As such, it covers all 12 new member states as well as Greece and Portugal. Spain is also eligible for the Cohesion Fund, but on a transitional basis (so-called "phasing out").

1. **Convergence** to accelerate the economic development of regions with a GDP per capita below 75% of the EU average; it is financed by the ERDF, ESF, and Cohesion Fund. The priorities under this objective are human and physical capital, innovation, knowledge society, environment and administrative efficiency.
2. **Regional Competitiveness and Employment** to reinforce competitiveness, employment and attractiveness of all regions of the EU territory, except those already covered by the Convergence objective. The budget comes from the ERDF and ESF. This objective aims at innovation, the promotion of entrepreneurship, and environment protection.
3. **Territorial Cooperation** to promote cooperation among European regions and develop common solutions for urban, rural and coastal development, shared resource management or improved transport links. The budget comes from ERDF. This objective builds upon the INTERREG initiatives of previous years, which were originally planned to be fully incorporated into the main objectives of the structural funds. This objective is divided into three strands:

   i. Cross-border cooperation (formerly INTERREG IIIA) aimed at neighbouring border-regions.
   ii. Transnational cooperation aimed at the multilateral cooperation of regions from countries divided into wider programme areas (e.g. Central Europe, Southeast Europe, Mediterranean, etc.).
   iii. Interregional cooperation aimed at cooperation in policy making, research and capacity building, encompassing programmes Interact II, ESPON, INTERREG IVC and URBACT.

### Cohesion and Structural Funds proposal

In November 2011, the Commission adopted a draft legislative package which will frame the cohesion policy for 2014-2020. The proposals include:

- Regulation on the ERDF[88];
- Regulation on the ESF[89]; and
- Regulation on the Cohesion Fund[90].

88 COM(2011) 614 final. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on specific provisions concerning the European Regional Development Fund and the Investment for growth and jobs goal and repealing Regulation (EC) No 1080/2006.

89 COM(2011) 607 final /2. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the European Social Fund and repealing Council Regulation (EC) No 1081/2006.

90 COM(2011) 612 final/2. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the Cohesion Fund and repealing Council Regulation (EC) No 1084/2006

### 5.6.1 Weaknesses and opportunities of the Structural and Cohesion Funds

The Structural Funds and the Cohesion Fund support the EU's poorer regions, although all EU regions are eligible. During the current programming period (2007-2013), over 80% of the budget for cohesion policy: more than €40 billion per year, has been allocated to the EU's 100 poorest regions (out of a total of 271 regions). Therefore, not all EU regions have the same funding opportunities under these instruments.

Another weakness of the Cohesion and Structural Funds is the identification of investment priorities; the Cohesion fund proposal identifies a few investment priorities that could be further exploited by authorities to fund NWRM (see Table 49).

**TABLE 49**
**WEAKNESSES AND OPPORTUNITIES OF THE COHESION AND STRUCTURAL FUNDS**

| Item of Cohesion and Structural Funds | Weaknesses | Opportunities |
|---|---|---|
| **Investment priorities** | If the EU Directives were to address more specifically NWRM, relevant projects could have a better uptake by the Structural or the Cohesion Funds. However, most of the measures financed or to be financed by the Structural or Cohesion funds in 2007-2013 are for large investments (tens or hundreds of million Euros) of man-made measures such as dikes or reservoirs; therefore few or no investments promote NWRM. In addition, the indicators for measuring progress for the Cohesion Fund and the ERDF in the annexes of both EC proposals are too restrictive and in many cases not feasible for measuring NWRM projects' performance/benefits. As shown in this study, the benefits of NWRM are very difficult to quantify (i.e., green roof $CO_2$ sequestration potential). | Article 3 of the Cohesion fund proposal and Article 5 of the ERDF proposal identify a few investment priorities that could be further exploited by authorities to fund NWRM (see Table 50). It is yet to be seen how investments will be defined. |
| **Sustainable urban development** | The common indicators for ERDF support presented in the proposal are also very restrictive and do not comprise indicators to measure the performance of for instance sustainable urban strategies such as SuDS. The indicators basically promote grey infrastructures (i.e., square metres of new housing in urban areas). | Article 7 of the ERDF proposal establishes that at least 5% of the ERDF resources allocated at national level shall be allocated to integrated actions for sustainable urban development. Strategies should include the implementation of SuDS in the cities targeted by Member States.<br>Article 9 proposes that the ERDF supports innovative actions in the field of sustainable urban development. However, this remains dependent on |

| Item of Cohesion and Structural Funds | Weaknesses | Opportunities |
|---|---|---|
| | | the willingness of the EC. Studies and pilot projects should include SuDS. |
| **Exchange of best practices between Member States** | Article 8 of the ERDF proposal requires setting up an urban development platform by the EC to promote capacity-building and networking between cities and exchange of experience on urban policy at EU level. However, the criteria to select the cities are very general and do not emphasise the need for including cities with different levels of development in the platform: cities with a strategy for integrated actions to tackle environmental problems and cities without such strategies. The ERDF proposal could also specify sustainable urban strategies, including the implementation of SuDS. | Exchange of SuDS best practices and implementation should be explicitly included in this platform as the implementation of SuDS varies very much across the EU and there is a high potential for some cities benefitting from cities with more experience on the implementation of SuDS. |
| **ESF's Scope of support** | Although the Scope of support of the ESF (Article 3 of the ESF proposal) supports the shift to a low-carbon society, the proposal does not present specific actions such as training on SuDS implementation. In any case, it is clear that the ESF is less relevant for the implementation of NWRM at EU level. | The Scope of support of the ESF (Article 3 of the ESF proposal) includes supporting the shifts towards a low-carbon, climate resilient, resource efficient, and environmentally sustainable economy, through reform of education, training, creation of jobs, adaptation of skills related to the environment and energy. |

Table 50 shows the cross-reference between the Cohesion Fund investment and ERDF priorities, with NWRM.

**TABLE 50**
**CROSS-REFERENCE BETWEEN COHESION FUND INVESTMENT AND ERDF PRIORITIES AND NWRM**

| Cohesion fund Investment priorities | ERDF Investment priorities | Proposed NWRM addressing the Structural and Cohesion funds priorities |
|---|---|---|
| (a) supporting the shift towards a low-carbon economy in all sectors by: | | |
| *(v) promoting low-carbon strategies for urban areas;* | *(e) promoting low-carbon strategies for urban areas;* | • SuDS; and<br>• Green roofs. |
| (b) promoting climate change adaptation, risk prevention and management by: | | |
| *(i) supporting dedicated investment for adaptation to climate change;* | *(a) supporting dedicated investment for adaptation to climate change;* | • SuDS;<br>• Green roofs;<br>• Wetland restoration and creation; and |

| Cohesion fund Investment priorities | ERDF Investment priorities | Proposed NWRM addressing the Structural and Cohesion funds priorities |
|---|---|---|
| | | • Floodplain restoration. |
| (c) protecting the environment and promoting resource efficiency by: | | |
| *(ii) addressing the significant needs for investment in the water sector to meet the requirements of the Union's environmental acquis;* | *(b) addressing the significant needs for investments in the water sector to meet the requirements of the environmental acquis;* | • SuDS;<br>• Green roofs;<br>• Wetland restoration and creation; and<br>• Floodplain restoration. |
| *(iii) protecting and restoring biodiversity, including through green infrastructures;* | *(d) protecting biodiversity, soil protection and promoting ecosystem services including NATURA2000 and green infrastructures;* | • Buffer strips;<br>• Filter strips and swales;<br>• Green roofs;<br>• Wetland restoration and creation; and<br>• Restoration of lakes. |
| *(iv) improving the urban environment, including regeneration of brownfield sites and reduction of air pollution.* | *(e) improving the urban environment, including regeneration of brownfield sites and reduction of air pollution.* | • SuDS; and<br>• Green roofs. |

### 5.6.2 Policy recommendations for the Structural and Cohesion Funds

The two policy recommendations are to ensure that the Cohesion and Structural Funds identify investment priorities that can fund NWRM and to develop tools to quantify the benefits from investments in NWRM:

- Ensure that the Cohesion Fund identifies investment priorities that can fund NWRM.
- Develop tools allowing authorities to quantity the benefits from investments in NWRM (see recommendation for the WFD). The quantified benefits should be used to re-define the Cohesion fund's indicators and make them more adapted to the benefits of natural water retention features.

## 5.7 Water Scarcity and Droughts Strategy

According to the European Environment Agency (EEA), climate change will lead to more frequent and severe droughts all over Europe[91]. Based on an in-depth assessment of water scarcity and droughts in the EU, the EC published in 2007 the Communication "Addressing the challenges of water scarcity and droughts in the European Union", which has since become the core element of the EU Action on

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91 EEA 2009: Water resources across Europe – confronting water scarcity and droughts. EEA-Report no. 2 / 2009

Water Scarcity and Droughts, accompanied by 2008, 2009 and 2010 Follow-up Reports. As required in the Communication, the Strategy will be reviewed in 2012.

The Commission's Communication sets out some general principles to be followed if the EU is to move towards a water efficient and water saving economy, including full implementation of the WFD and horizontal integration of water issues into all sectoral policies. It takes into account climate change, stating that it will have a significant impact on droughts and water scarcity. The Communication identifies an initial set of seven main policy options to address water scarcity and drought issues:

### 5.7.1 Weaknesses and opportunities of the Water Scarcity and Droughts Strategy

The two weaknesses of the EU Water Scarcity and Droughts Strategy are opportunities to promote NWRM (see Table 51).

**TABLE 51**
**WEAKNESSES AND OPPORTUNITIES OF THE EU WATER SCARCITY AND DROUGHTS STRATEGY**

| Item of Droughts Strategy | Weaknesses | Opportunities |
|---|---|---|
| **NWRM** | Only a few of the seven policy options above address explicitly NWRM. Under *Allocating water and water-related funding more efficiently*, the Communication aims to address land-use planning; in particular sustainable agriculture practices. For river basins, the Communication proposes to set up appropriate regulations to restore a sustainable balance of water quality and quantity. If this is not enough, Member States should implement compulsory measures, targeting water saving and efficiency. These measures ultimately will be part of the WFD programmes[92]. Under *Improving drought risk management*, the Communication recommends that Member States develop drought management plans. | The Strategy should provide guidance and identify specific measures relevant to natural water retention. |
| **Climate change and no-regret measures** | The Communication specifies that the measures implemented should be designed for adaptation, but it does not address no-regret measures explicitly or how to design measures efficient in the adaptation to climate change. The Commission's Communication is accompanied by an Impact Assessment[93] that addresses the impacts of climate change on water resources. It does not use the term no-regret measures, but addresses measures that could mitigate the effects of climate change. The Impact Assessment identifies the need to implement adaptation measures to deal with | The Communication and accompanying Impact Assessment should introduce the concept of no-regret measures. The two documents are forward-looking, taking into account several aspects important for the implementation of no-regret measures. They should take into account the need for flexible adaptation or planning with regard to climate change. |

[92] European Commission 2007.
[93] European Commission Staff Working Document: http://ec.europa.eu/environment/water/quantity/pdf/comm_droughts/impact_assessment.pdf.

| Item of Droughts Strategy | Weaknesses | Opportunities |
|---|---|---|
| | concerns over water quantity. It elaborates an integrated approach taking into account measures to prevent droughts and to support efficient water allocation and sustainable land-use planning. The latter in particular is linked to other European sectoral policies, such as the CAP. | |

The suggestions for improving the promotion of NWRM in the EU water scarcity and droughts strategy are in Table 52.

**TABLE 52**
**SUGGESTIONS FOR IMPROVING PROMOTION OF NWRM IN EU WATER SCARCITY AND DROUGHTS STRATEGY**

| NWRM | Current promotion of NWRM in EU water scarcity and droughts strategy | Suggestion for improvement |
|---|---|---|
| **Forest** | The Strategy only mentions forests with regard to fires; linking forests to fires assigns a very negative connotation to forests, which could hinder implementing forest NWRM through the strategy. | The Strategy should mention that forests may increase in some cases the amount of water and improve the micro-climate in a region, thus decreasing the forest fire hazard. |
| **Urban** | The Strategy proposes measures contributing only to water savings, such as installing water meters in households or reusing grey water. The Impact Assessment merely mentions water in urban areas with regard to the potential loss caused by leakages. Like the Water Scarcity and Droughts Communication, it does not give incentives to implement urban measures. | The Strategy should take the opportunity to concretise and propose other urban measures such as green roofs, filter strips and swales, etc. |
| **Wetland restoration** | Neither the Strategy nor its Impact Assessment mention wetlands to help manage drought, and fail to recognise the advantages of wetlands and include them in any of the policy options proposed (i.e., improving land-use planning). | The Strategy should promote wetland restoration and creation. |
| **Artificial ground water recharge** | The Strategy and its Impact Assessment do not mention AGR to help manage drought, and fail to recognize its advantages and include it in any of the policy options. | The Strategy should promote artificial ground water recharge. |
| **Lake restoration** | The Strategy and its Impact Assessment do not mention lake restoration to help manage drought and water scarcity, fail to recognize its advantages, and do not include it in any of the policy options. | The Strategy should promote lake restoration. |

### 5.7.2 Policy recommendations for the Water Scarcity and Droughts Strategy

The policy recommendation is to adapt the Communication to climate change by including specific NWRM and by highlighting the importance of introducing and conserving GI:

- Revise and update the Communication and its accompanying documents to adapt them to climate change during the Policy Review in 2012;
- Include in the Communication specific measures such as AGR, wetland restoration and creation, lake restoration, and SuDS; and
- Highlight the importance of introducing and conserving GI in the Communication and Impact Assessment.

**SEVEN POLICY OPTIONS TO ADDRESS WATER SCARCITY AND DROUGHT**

1. Put the right price tag on water;
2. Allocate water and water-related funding more efficiently;
3. Improve drought risk management;
4. Consider additional water supply infrastructures;
5. Foster water efficient technologies and practices;
6. Foster the emergence of a water-saving culture in Europe; and
7. Improve knowledge and data collection.

# 6. CONCLUSIONS

NWRM refers to 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.

This study aimed to provide a solid methodological and quantitative basis for identifying the financial needs and policy implications at the EU level for NWRM, and to support the EC in identifying the best instruments to create synergies between the EU policy framework and measures at a river basin level.

## 6.1 Methodology

The knowledge-base of the NWRM Study consists of information relevant to NWRM gathered through a "Call for Evidence" launched by the EC, and supplemented by in-depth literature search and the preliminary results of a JRC modelling exercise. A total of 389 sources of information were gathered, comprising technical, scientific, project and policy documents (case studies, reports, studies, projects documents, websites, etc.).

Despite the large number of documents and sources identified and reviewed, the information base of the study is far from comprehensive. A study of this size and scope can only hope to scratch the surface of the vast amount of information that exists. Although all efforts were made to gather a large amount of sources of information focusing on NWRM, the information was not comprehensive enough to draw firm conclusions on many aspects of NWRM. The information was very variable in quality from one measure to another. In addition, NWRM are very often implemented in combination therefore it is impossible to distinguish between the benefits of the measures. In particular, it has been difficult to make firm conclusions on the cost-effectiveness of the measures and it was therefore not possible to carry out a full cost and benefit analysis on the basis of the available information.

In addition, the study was expected to include the results of a series of modelling exercises by the EC Joint Research Centre (JRC). Unfortunately, by the end of the contract, only a series of land-use simulations, based on the NWRM categories, were available. The full modelling results, presenting the impact of NWRM in terms of flood reduction capacity according to three climate change scenarios, were not available. This meant that several of the results – in particular, the assessments of effectiveness and benefits of the measures - had to be curtailed.

## 6.2 Findings

The study identified 21 NWRM, divided into four categories:

1. **Forest measures**: CCF; Maintaining and developing riparian forests; and Afforestation of agriculture land.
2. **Urban measures**: Filter strips and swales; Permeable surfaces and filter drains; Infiltration devices; and Green roofs.

3. **Agricultural measures**: Restoring and maintaining meadows and pastures; Buffer strips; Soil conservation crop practices; No or reduced tillage; Green cover; Early sowing; and Traditional terracing.
4. **Water storage measures**: Basins and ponds; Wetland restoration and creation; Floodplain restoration; Re-meandering; Restoration of lakes; Natural bank stabilisation; and AGR.

On the basis of the available information, the **applicability** of all the measures was assessed according to their EU climate zone; land-use; location; soil permeability; soil depth; topography; and EU geographical relevance. Based on the information collected, all NWRM are applicable across the EU in terms of the climate zone and the relevance to the EU. Information on the other applicability criteria varied considerably in its quality and quantity, and from one measure to another.

The following **direct impacts** of all NWRM were assessed: soil moisture; water temperature; evapotranspiration (ETP); run-off control; groundwater replenishment; land-use change; erosion control; and storage capacity. These criteria are all measures of the effectiveness of the measures. As the full modelling results were not available, conclusions on the effectiveness of the measures was based only on the available information in the sources. 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:

- Based on the information reviewed, wetlands are the most effective measure; they increase water storage, contribute to groundwater replenishment and attenuate run-off.
- Forests can also reduce or slow down run-off, but it is unclear to what extent. This depends on site-specific conditions and soil properties. They also contribute to water storage. Although it is commonly acknowledged that forests contribute to groundwater replenishment, evidence suggests that they reduce water recharge, in particular in semi-arid catchments during drought periods.
- SuDS attenuate, delay or reduce the urban run-off and decrease the amount of run-off going to drains and sewers and contribute to groundwater replenishment, but to a lesser extent.
- All agricultural measures, except meadows and pastures and soil conversation practices, contribute to reducing or slowing down run-off. Only meadows and pastures and buffer strips increase water storage capacity in the soil.
- Basins and ponds contribute to run-off control and they promote natural groundwater recharge and they are designed to store water in the landscape.
- Floodplain restoration involving land-use management changes attenuates low to medium peak flows at a local/regional scale and they have a positive impact on groundwater replenishment.

- The effectiveness of re-meandering is unclear.

In addition to their direct impacts on water retention, the following **benefits and co-benefits** were assessed for all measures: flood hazard reduction; soil quality improvement; 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. The modelling exercise was to have provided information on the key benefits of the NWRM (in particular, flood hazard reduction and increase in groundwater). As the modelling information was not available, qualitative assessments were carried out on the basis of the available sources of information.

The available information confirms that a number of NWRM provide a wide range of benefits and co-benefits, in addition to water retention. However, the available information is not sufficient to draw firm conclusions across all criteria. For example, the storage capacity measures generally contribute to the reduction of run-off and therefore flood hazard reduction, through their nature. They also contribute to cultural services and habitat provision. In some cases, however, such as re-meandering, the impacts and benefits are less than clear and even contradictory.

The study assessed the **Costs** of all measures, according to the following criteria: land requirement; construction and rehabilitation (investment, design and contingency); construction and rehabilitation (operation and maintenance); administrative costs; and other costs. The JRC land-use simulations were analysed, combining information on unit costs from the available information, to arrive at aggregated costs. Table 53 compares the total costs (at the EU level) of the scenarios. On a per person basis, the grassland and wetland scenarios are the least expensive with an annual cost below €1. The urban green scenario is by far the most expensive with an annual cost exceeding €350; this is primarily due to very high unit investment and operation and maintenance costs (O&M). The crop practice scenario is the second most expensive, primarily because of a very large increase in surface area (more than 100 million hectares).

The study concludes that the annualised costs of the NWRM range from €0.85 million (€0.002 per person) for buffer ponds, to €180,460 million (€360 per person) for the urban measures. The costs of the urban measures are very high and unlikely to be offset by the benefits of these measures. Crop practices are also expensive: €8,320 million per year (€17 per person); but in this case, if the 100 year flood period was reduced by 30%, it would result in a benefit of €11,040 million, which would make the scenario cost-effective.

**TABLE 53**
**COST COMPARISON OF SCENARIOS**

| Scenario | Increase in surface area (Ha) | Increase/ EU Surface area (%)[94] | Present value of costs (2011 € billion) | Annualised cost (2011 € million) | Annualised cost/GDP (%) | Annualised cost per person (2011 €) |
|---|---|---|---|---|---|---|
| 1.1 Riparian forests | 1,119,970 | 0.27% | 11.02 | 911.90 | 0.01% | 1.82 |
| 1.2 Afforestation | 3,021,807 | 0.72% | 22.19 | 1,836.37 | 0.01% | 3.67 |
| 2. Urban | 3,423,078 | 0.81% | 2,180.92 | 180,460.34 | 1.47% | 360.20 |
| 3.1 Grassland | 782,718 | 0.19% | 2.87 | 237.71 | 0.002% | 0.47 |
| 3.2 Buffer strips | 2,191,506 | 0.52% | 11.95 | 988.88 | 0.01% | 1.97 |
| 3.3 Grass waterways | 3,957,266 | 0.94% | 21.16 | 1,750.68 | 0.01% | 3.49 |
| 3.4 Crop practices | 111,254,423 | 26.39% | 100.55 | 8,320.06 | 0.07% | 16.61 |
| 4. Buffer ponds | 295.20 | 0.00007% | 0.01 | 0.85 | 0.00001% | 0.002 |
| 5.1 Wetlands | 120,470 | 0.03% | 1.56 | 129.42 | 0.001% | 0.26 |
| 5.2 Re-meandering | 91,447 | 0.02% | 5.42 | 448.78 | <0.01% | 0.90 |

[94] EU Surface area in hectares= 421,510,000

Preliminary conclusions on the cost-benefit assessment for the NWRM are mentioned below. However, as previously stated, these conclusions are necessarily tentative:

- Implementation of riparian forests and reforestation at EU level are not the most expensive measures (€1.82 and €3.67 per year per person, respectively) mainly because the surface area where these two measures are applicable is rather small (0.27% and 0.72% of the EU surface area, respectively). Although the benefits were not quantified, forests bring multiple benefits, in particular:
    - Flood hazard reduction, when implemented at the headwater or small catchment level;
    - Water quality improvement;
    - Provision of habitat and cultural services;
    - Carbon sequestration; and
    - Soil quality improvement.
- It is however clear that the species to be used need to be locally adapted species and the local conditions in the floodplain need to be carefully reviewed as forests generally increase water use; therefore these measures might not be suitable for semi-arid catchments droughts prone areas.
- Urban measures are the most expensive measures (€360.2 per year per person). SuDS mitigate floods in urban areas, improve water quality reducing the costs of conventional wastewater treatment and improve soil quality by unsealing urban areas. They all contribute to landscape enhancement and biodiversity in urban areas.
- Among the agricultural measures, crop practices are by far the most expensive measure (€16.61 per year per person) but this is because these practices are applicable to the entire arable land of the EU (26.39% of the EU surface area). Implementing grassland is the least expensive of the agricultural measures (€0.47 per year per person covering 0.19% of the EU surface area). Overall, all agricultural measures improve water quality and contribute to water retention through improving soil characteristics. Meadows and pastures show the best conditions for water retention and buffer strips the best efficiency on water quality improvement and provision of habitat. All measures improve the landscape.
- Wetlands are applicable to a very small area of the EU (0.03% of the EU surface area) and therefore the aggregated cost of implementing wetlands at EU level is low (€0.26 per year per person). They improve water quality and quantity and reduce flood hazard. They are very important for habitat provision and for recreation.
- Buffer ponds have a very small applicability in the EU, therefore the aggregated costs of implementing buffer ponds at EU level are much lower than the aggregated costs of other measures. Although basins

and ponds improve water storage and reduce flood hazard, their benefits regarding water and soil quality improvement and provision of habitat and cultural services are less evident.

- Although re-meandering has low applicability (0.02% of the EU surface area) and low costs (€0.9 per year per person), the benefits are unclear. The evidence shows contradictions on the provision of benefits and co-benefits of this measure.

The measures were also assessed against the following criteria to determine whether they can be considered as **no-regret measures**: future climate change scenarios; timing; planning horizon; flexibility; risks (cost effective and beneficial measures); local and regional scale; and economic analysis. Based on the effectiveness and cost and benefit analyses of the NWRM, it is possible to conclude that wetland restoration and creation is a no-regret measure. Although forests provide multiple benefits, the location and the future climate change scenarios are very important parameters that will determine the no-regret nature of these measures. All agricultural measures are also no-regret, in particular crop practices as they have a wide applicability and therefore will probably have a major impact than wetlands. However, based on the available information, it seems unlikely that re-meandering and natural bank stabilisation are no-regret measures.

The study concludes that it is of utmost importance that NWRM are planned taking into consideration the local conditions. In particular, the contribution of forest measures to water availability and flood hazard reduction has to be evaluated on a case-by-case basis, as these depend on *in situ* conditions and the scale (e.g., catchment level or local level) of the forests. Due to the absence of the expected modelling results, however, it was not possible to confirm the cost-effectiveness of the different measures against different climate change scenarios.

Finally, the study analysed the most relevant EU policies and funding programmes to determine the **barriers** and the **opportunities and weaknesses** of the current EU policy framework for promoting these measures at EU level. These included: the WFD; the Floods Directive; the CAP; EU biodiversity and nature policy; the LIFE+ programme; Cohesion and Structural Funds; and the Water Scarcity and Droughts Strategy. The NWRM study concludes that the 21 measures have been widely implemented throughout the EU, but could be further promoted through the EU policy framework. In particular, this should be done by:

- More explicit reference to NWRM in legislation;
- More research on quantifying and monetising the benefits of NWRM;
- A better acknowledgement of the role of the urban environment in flood mitigation, biodiversity and nature conservation;
- The promotion of the “soft measures” approach and the concomitant acknowledgement of the services that nature can provide for avoiding, mitigating or solving environmental problems such as flooding, water scarcity, etc.; and
- The provision of guidance and training on NWRM in the wide range of funding tools and platforms already available.

This study was unable to carry a full cost and benefit analysis and determine the effectiveness of these measures for three different climate change scenarios. It has been therefore difficult to make firm conclusions and recommendations on which measure should be promoted and to what extent. Moreover, the lack of monetisation of the benefits of NWRM has precluded making an economic case for the use of these measures at EU level.

Based on the qualitative information, it is clear that wetlands, agricultural measures and SuDS are the NWRM providing the most benefits and they should be further promoted by the EU policy framework. In many cases, what is needed is more explicit reference to these measures and the provision of more guidance and exchange of best practices at EU level.

## ANNEXES (IN SEPARATE FILES)

**1 - NWRM Database**
**2 - Report on Forest measures**
**3 - Report on Urban measures**
**4 - Report on Agricultural measures**
**5 - Report on Traditional terracing**
**6 - Report on Basins and ponds**
**7 - Report on Wetland restoration and creation**
**8 - Report on Floodplain restoration**
**9 - Report on Re-meandering**
**10 - Report on Restoration of lakes**
**11 - Report on Natural bank stabilisation**
**12 - Report on Artificial groundwater recharge**
**13 - Quality of information and gap analysis**
**14 - List of 42 candidate natural water retention measures**
**15 - Methodology to quantify the benefits of NWRM**
**16 - Description of simulated land-use scenarios**
**17 - Calculation of aggregated costs and results of simulated land-use scenarios (two linked Excel sheets: *Cost-IO* and *NWRMCost--04 03 2012)***

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