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Benefits of Natural Water Retention Measures

What are the benefits of NWRM?

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The present synthesis document has been developed in the framework of the DGENV Pilot Project - Atmospheric Precipitation - Protection and efficient use of Fresh Water: Integration of Natural Water Retention Measures (NWRM) in River basin management. The project aimed at developing a knowledge based platform and a community of practice for implementation of NWRM. The knowledge based platform provides three main types of elements:

- the NWRM framework with access to definition and catalogue of NWRM,
- a set of NWRM implementation examples with access to case studies all over Europe,
- and decision support information for NWRM implementation.

For this last, a set of 12 key questions linked to the implementation of Natural Water Retention Measures (NWRMs) has been identified, and 12 Synthesis Documents (SD) have been developed. The key questions cover three disciplines deemed important for NWRM implementation: biophysical impacts, socio economic aspects and governance, implementation of financing.

They rely on the detailed delineation of what NWRMs cover as described in *SD n°0: Introducing NWRMs. Natural Water Retention Measures (NWRM) are multi-functional measures that aim to protect water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes.* Evidences included into these synthesis documents come from the case studies collected within this project (see the catalogue of case studies) and from the individual NWRMs factsheets which are available on the page dedicated to each measure (see catalogue of measures). This information has been complemented with a comprehensive literature review.

More information is available on the project website *nwrm.eu*.

Key words: Benefits, Ecosystems services, Ecosystems functions, private benefits, economic benefits, ancillary benefits, valuation, avoided costs, network benefits, multifunctional, optimised design.

Please consult the NWRM glossary for more information.

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I. What are the benefits of NWRM?

Benefits of NWRM are all the advantages in terms of human wellbeing derived from the successful implementation of these measures and the resulting achievement of their particular objectives: improving and restoring water functions and aquatic ecosystems through the use of natural means.

Identifying, assessing and eventually valuing NWRM benefits require definitions and frameworks that are suitable to the distinctive features of these benefits. While responding to the challenges of water policy, NWRM are different from more traditional alternatives and so are their benefits.

By focusing on restoration of natural functions and processes most of the benefits of NWRM stem from new, more abundant or better-guaranteed flows of ecosystem services delivered by the water systems. In addition to the benefits of nature restoration and protection there might also be ancillary benefits derived from the way these objectives are pursued by using natural means, which might result in important savings in terms of energy, infrastructure investment, and environmental impacts.

Applying Ecosystem Services concept in the assessment of NWRM benefits is a suitable method for identifying and recognizing the whole spectrum of benefits that nature provides in this context. According to TEEB "…the flow of ecosystem services can be seen as the dividend that society receives from natural capital". Securing the natural capital, or the stock, is consequently a way to ensure future flows of services that we depend upon for human wellbeing. "(TEEB, 2010).

A number of NWRM have already been deployed as part of the Programme of Measures (PoMs) to achieve Good Ecological Status within the WFD (e.g. basins and ponds, wetlands, buffer strips and shelter belts). The advantages of applying Ecosystem Services Analysis (ESA) lies in its structured and systematic approach to describe how status and functioning of ecosystems is crucial for the provision of benefits to society. ESA has also proven effective when it comes to eliciting expert and stakeholder knowledge to support RBMP and decision-making (Blancher et al., 2013 –ESAWADI–, p. 72). The Floods directive, as well as other policy frameworks, include the principle of sustainability which makes the holistic and comprehensive approach of ESA suitable for highlighting the links between uses and ecosystem functioning. By identifying the full range of Ecosystem Services involved, ESA will help to facilitate the choice of relevant policies as well as to prevent selection of short termed and narrow sighted measures which may result in uneven distribution of benefits among stakeholders (*Ibid.*, p.72).

Under these circumstances, these benefits can only be ascertained if moving away from traditional benefit assessment methods and using an ecosystem services approach from the onset (Boyd et al. 2007; Euliss et al., 2011; Keeler et al., 2012). Within this framework it is possible to make the connection between undertaken measures, the biophysical impacts they yield, changes in the flows of ecosystem goods and services and ultimately the benefits derived from them.

These benefits can be understood within an ecosystem services approach by distinguishing between ecosystem functions and services. This distinction will also help us understand how the benefits of NWRM are connected to the effectiveness of their implementation (see policy questions 1, 2 & 3).

Within this context, NWRM can be interpreted as actions intended to restore the water storage potential of a particular system (soil, river, aquifer, delta, etc.), in order to improve its potential to perform some critical functions (such as water regulation by filtration, nutrient sequestration, storage, chemical quality of freshwater control, soil formation and maintenance, assimilation and self-treatment of effluents, attenuation of mass flows, etc.).

Water retention is therefore not the end but the means used to improve the way the system performs. Hence the impacts produced and the benefits obtained go way beyond water retention. From this viewpoint, multi-purpose emerges as a distinctive trait of NWRM that makes them different from more specialized water retention alternatives, such as a stormwater tank or a reservoir, which attain their main purpose by means other than natural ones and without restoring these other natural services, when not impairing them.

Stella (2012) explains that NWRM contribute to "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." Their main goal, according to that report, is to reduce surface runoff after rainfall events to reduce flood risk and as co-benefits "reduced erosion and leaching as well as increased groundwater recharge and climate regulation".

Concerning the NWRM and their relation to PoMs within the WFD, the ESAWADI project (Blancher et al, 2013) shows that ESA can be an effective method to illustrate the benefits of measures and by doing so, facilitate the dialogue with local operators and stakeholders to get the measures implemented. Through its structured and comprehensive approach, ESA might also help in prioritizing between different measures and water bodies.

Assessing the benefits of NWRM implies a thorough understanding of the different pathways through which a policy action, such as the implementation of any particular NWRM, affects human welfare. This implies building the link between natural and economic processes and, more specifically, to relate biophysical effects (which allows us to judge how effective a measure is) to economic impacts (that help us judge how beneficial a particular measure or programme of measures is).

NWRM include a wide array of actions such as sustainable urban drainage systems (SuDS) that emulate or mimic the functions performed by nature in the past. For instance, many conservation measures in rural areas intend to recover the structure and the functions of soil, to which water is an essential structural component.

Understanding the way ecosystems work is essential to understand, and assess the benefits of NWRM

For example Borin et al. (2010) found five different pathways through which buffers strips reduce non-point source water pollution from cropland: by attenuating surface runoff from fields, filtering surface runoff from fields, filtering groundwater runoff from fields, reducing riverbank erosion, and filtering pollutants from stream water.

Other measures in urban areas intend to build a sustainable drainage system through reproducing or emulating the functions performed by natural soils in the past; and many nature restoration alternatives intend to re-establish the connection between the river channel and its floodplain, the aquifers and other components of the system disconnected by previous development. Other alternatives, like afforestation or artificial lagoons, entail the development of new systems that may perform functions that are distinctive of pristine (or at least very natural) systems.

What all these measures have in common is that they use functions usually performed by nature, such as infiltration, sequestration, storage, accumulation by ecosystems, etc. to enhance the capacity of natural or anthropic systems to store water. Since water is a critical structural component of any ecosystem, by enhancing the water storage capacity, NWRM are means to improve a series of functions and processes that might result in the provision of new or better delivery of environmental services or benefits.

To understand the benefits of NWRM one first needs to connect them to the functions and processes performed by nature of anthropized water systems and, particularly, with those functions nature can better perform if its water storage capacity is improved.

Most of the benefits of NWRM consist in the additional environmental services obtained by restoring and enhancing the above mentioned ecosystems' functions and then from improving the structure and the way ecosystems work to provide the following services:

- ✓ Water provision to deliver water services in the economy for both drinking and non-drinking purposes;
- ✓ Water security (reliability of supply and resilience to drought);
- ✓ Health security (control of waterborne diseases);
- ✓ Flood security and protection (flood risk reduction, increased resilience and reduced exposure to flood risk);
- ✓ Storm protection;
- ✓ Benefits derived from biomass production;
- ✓ Amenities associated to habitat protection (fish and plants, tourism, recreation and other activities);
- ✓ Benefits of improved coastal water quality and ecological status for a sustainable commercial production of shellfish with human health and welfare values.

NWRM are effective means of water policy because of their direct and indirect impact over the water bodies' status. Besides their immediate effect they also have long-lasting and self-sustained positive effects throughout time. Actually, improvements in ecosystem functions and processes result in a better structure of the systems thus affected (for instance, urban and agricultural soil, river systems, etc.), and this is expected to improve the way these systems regulate water processes (such as runoff, sediment flows, water quality, etc.), with the subsequent positive effect over the status of the affected water bodies. This is why effectiveness (as discussed in the policy questions 1, 2 & 3) is based on biophysical models that might allow us to discern how any specific NWRM contributes to improve the status of a water body when compared to a baseline scenario.

The second step consists in linking positive changes in water bodies' status (and then in their ecosystem structure and processes), to improvements in the provision of environmental goods and services and to human wellbeing.

This requires connecting the biophysical tools and data, able to inform about effectiveness, with the economic tools that allow us to analyse

Besides contributing to reach the goals of the WFD, NWRM take advantage of the positive changes in water bodies' status (and then in their ecosystem structure and processes), to improve the provision of environmental goods and services and to human wellbeing. While equally effective to remove pollution NWRM are different from a wastewater treatment plant in its impact over nature.

While NWRM effectiveness is essential to understand the benefits of alternative courses of action, these positive effects are not yet the benefits of the applied measures (as Keeler *et al.*, 2012 remark, there is a gap between the metrics used by scientist and the atributes the public actually values).

the new environmental services provided and the resulting welfare gains. A final step is the valuation of these benefits.

Summing up, since NWRM are different from the best-established alternatives of water policy they also require specific assessment methods and data. Assessing the benefits of NWRM requires a basic understanding of the complex pathways through which these particular measures affect human welfare.

This requires linking both biophysical models and data, to assess the effectiveness of the measures to enhance, improve and protect the status of water bodies, and economic models and data, able to transform these effects into welfare gains. Most of these connections are still poorly understood, available models lead to insightful results that are still difficult to upscale and transfer and too often data are not available.

Nevertheless, few references in the existing literature are able to connect ecosystems

II. How are these benefits identified and classified?

The multiple benefits of NWRM can be classified according to different criteria. These criteria as shown in this section are particularly relevant for policy making. Although the terms are used with different and many times contradictory meanings in the literature, the three distinctions that are more relevant for policy analysis are the following:

Private (or financial) vs social (or collective) benefits: The basic criteria behind this distinction is based on who benefits from the positive consequences of the measure and particularly, what of these benefits favour the agent in charge of taking the decision to implement the measure and what benefits are external in the sense that they improve anyone's welfare and eventually the society as a whole. Both private and social benefits add up to obtain the overall economic benefits of the measure.

Collective (or social) vs Financial (or private) Benefits of NWRM

Many benefits of NWRM are social: they increase everybody's welfare while other might benefit the owner of the asset affected or the person who invest to implement the measures. Owners of green roofs benefit from reduced replacement costs, energy savings, less noise and other private goods and services, but probably not enough for them to make the decision to install the green roof on their own.

Social (external) benefits from	Private (financial/internal) benefits from
Improvements of air quality	*Increased lifespan of the roof covering*
Improvement of water quality	*Reduced energy costs*
Greenhouse gas abatement	*Fire protection*
Biodiversity conservation	*Enhanced noise muffling*
Urban temperature control	*Improved aesthetic quality*
Stormwater retention	

Literature review: Claus and Rousseau (2012)

Why is this distinction important? This classification deals with the two following questions in a systematic way. First, why a farmer or an urban family might have, or not have, the incentives to accept or take the initiative to implement a particular measure such as a soil conservation practice or a green-roof? Second, why should society as a whole be interested in promoting or implementing these measures? The distinction is essential to analyse to what extend private agents are willing to proceed to the courses of action that are convenient to society as a whole and then to discuss what are the incentives or the financial mechanisms required to voluntarily engage private agents in the implementation of the measure. As the examples below make clear, one of the private benefits that can make turn the balance in favour of adopting the measure is the subsidies potentially received from the government.

III. Benefits and co-benefits /Primary Benefits and ancillary benefits

Regarding NWRM as a set of valid alternatives to reach the purposes of water policy implies that the primary benefits that must be considered are those derived from pursuing water policy's primary aim, which is improving the water bodies' status, controlling flood risks, reducing scarcity and droughts, etc. By contrast, following the standards set by the IPCC (2001) regarding climate change policy, ancillary benefits are the monetized secondary or side benefits of water policy including the positive outcomes on climate change mitigation, biodiversity, energy savings and all those private and social benefits that are not the purpose of water policy. These are benefits from the measures but not from the induced improvement in the status of water bodies. In the scientific literature ancillary benefits are also referred to as "secondary benefits" and as "co-benefits".

Primary and ancillary benefits are important as both of them might be considered part of the defining character of NWRM. Since NWRM are multifunctional, while contributing to the same objective, NWRM contribute to many different policy purposes.

The Multiple Benefits of Wetlands and Wetlands Restoration

Vymazal (2011) highlights the relevance of the restored or created wetlands for providing ecosystem services on the landscape. Sometimes the wetlands are built or restored with the aim to attain DIRECT benefits in terms of water management (for example, water purification and flood control in the pioneer Des Plaines River Wetlands Demonstration Project in north-eastern Illinois, or nitrate removal In the San Joaquin Wildlife Sanctuary in California) but they provide a variety of ANCILLARY benefits (translated, for example in wildlife benefits like the 400% increase in waterfowl species and the 4000% in terms of individuals and the arrival of 2 endangered species in the first referred wetland –Fleming-Singer and Horne, 2006 and Hickman, 1994 in *op. cit.*, 2011).

Also in the same direction, other authors (Shuven *et al.*, 2001 in *op. cit.*, 2011) point out how the improvement of ecosystems (e.g. a 240 ha grassland turned into a reed wetland in the Yancheng Biosphere Reserve in China resulting in a 3.3 times increase in the total primary production of the system) can derive into remarkable ancillary benefits (increasing, in the same example, the waterfowls in terms of individuals –from 3459 to 97747– and also in species –from 16 to 37–). On the other hand, other authors (Tong et al., 2007 in *op. cit.* 2011) have deepened into the opposite idea (such as the case of the deteriorated urban wetland in Wenzhou –China– with the potential of providing ecosystems services with a 90% higher value than currently provided if its ecological status is improved).

The primary benefits of NWRM are also more diverse than those of traditional water measures which are specialised alternatives optimised to serve a single purpose. A wastewater plant is an effective way to reduce pollution loads, and a tank is a valid means to control stormwater. But NWRM, such as in the example of green roofs below, might deliver a more varied set of primary benefits: improving water quality and serving to manage stormwater at the same time. In other words, even considering only the primary benefits for water management, NWRM are not commensurable with single specialised measures but with packages of them.

Ecosystems are multifunctional and provide multiple services at the same time. By building and/or restoring ecoystems NWRM have the potential to provide a plethora of ancillary benefits besides their direct contribution to the purposes of water policy. These benefits are, for instance, the following as recognised by the Millennium Ecosystems Assessment (MA, 2005).

Table 2
Examples of benefits provided by wetlands categorized by Millenium Ecosystems Assessment to human communities (MEA, 2005).

Provisional services	
Food	Production of fish, wild game, fruits, grains
Fresh water	Storage and retention of water for domestic, industrial and agricultural use
Fiber and fuel	Production of logs, fuel-wood, peat, fodder
Biochemical	Extraction of medicines and other materials from biota
Genetic materials	Genes for resistance to plant pathogens, ornamental species, and so on
Regulating services	
Climate regulation	Source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climate processes
Water regulation (hydrological flows)	Groundwater recharge/discharge
Water purification and waste treatment	Retention, recovery, and removal of excess nutrients and other pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Food control, storm protection
Pollination	Habitat for pollination
Cultural services	
Spiritual and inspirational	Source of inspiration; many religions attach spiritual and religion values to aspects of wetland ecosystems
Recreational	Opportunities for recreational activities
Aesthetic	Many people find beauty or aesthetic value in aspects of wetland ecosystems
Educational	Opportunities for formal and informal education and training
Supporting services	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cycling	Storage, recycling, processing, and acquisition of nutrients

Source Vymazal (2011) based on MA (2005)

Ancillary benefits are distinctive of NWRM. A water treatment plant does not deliver any additional benefit besides those associated to the quality of the water body where the effluents were discharged in the past. In turn, the ancillary benefits of a stormwater tank can be safely ignored in the decision process. This is why ancillary benefits can be defined as the advantages associated to choosing a particular course of action, for example adopting nature-based measures, instead of other equally effective ones to get to the same purpose (for example, reducing pollution and managing stormwater).

The widely neglected ancillary benefits provide ground for taking advantage of synergies between different objectives of water policy, as well as opening the ground for advantageous cooperation between different areas of public policy such as water management, land planning, rural development and climate change adaptation.

Urban forests, a constituent part of many SUDS come along with substantial and varied ancillary benefits

Table 1
Benefits and associated final ecosystem services provided by urban forest ecosystem structure and functions.

Benefit	Ecosystem service	Intermediate ecosystem function
Information functions		
Outdoor recreation	Provision of natural areas for human use (exercise, cultural, wildlife viewing),	Primary productivity, biodiversity
Residential amenities	Provision of aesthetics, views	Primary productivity
Property value premiums	Habitat and refugia provision for humans and wildlife	Biodiversity, primary productivity
Production functions[a]		
Food harvests (crops; domesticated and wild animals)	Production of grains, fruits, nuts and seeds; water availability	Primary productivity, nutrient cycling, pollination, soil productivity; disease regulation
Wood products	Production of woody biomass	Primary productivity,
Fuel production	Production of woody biomass	Primary productivity
Regulation functions relevant to pollution mitigation		
Cooling/heating cost reduction	Tree shade	Primary productivity
Drinking water provision – avoided treatment costs	Aquifer and surface water quality (nutrient and sediment removal)	Soil quality, nutrient cycling, hydrologic cycle
Drinking water provision – avoided pumping/transport costs	Aquifer and surface water availability and decreased storm water runoff	Soil quality, hydrologic cycle
Damage avoidance – health		
Temperature-related mortality and morbidity	Tree shade and wind reduction, carbon sequestration	Primary productivity
Nutrient, bacterial, toxin-related mortality and morbidity	Drinking water quality	Soils quality; hydrologic cycle, biogeochemical cycling
Air pollution related mortality and morbidity	Air quality improvements (low pollutant levels)	Atmospheric deposition, filtering and interception of pollutants
Extreme weather event-related mortality and morbidity	Natural land cover and soils attenuation of tidal waves, floods, hurricanes through C sequestration	Primary productivity, biogeochemical cycling
Damage avoidance – property		
Built infrastructure repair costs	Storm water reduction; soil infiltration, air quality improvement	Soil quality, hydrologic cycle, atmospheric deposition
Climate mitigation and avoided damages	Attenuation of tidal waves and wind storms, C sequestration	Primary productivity, climate change,
Decreased fertilization use and resulting costs	Erosion control, soil nutrient retention	Primary productivity, biogeochemical cycling, soil quality

[a] These ecosystem services are also referred to as "ecosystem goods". C, Carbon.

III.1. Direct and indirect benefits

The difference between direct and indirect benefits is instrumental to factor in all the benefits derived from the way the economy adapts to a certain policy strategy. These are second-order effects that are not immediate and, in general, they result from changes in economic behaviour and market adjustments. Once, for example, farming practices are adapted to conserve water and soil, decisions about crops and uses of inputs and labour will change and these changes will modify production levels, employment and prices in many different areas of the economy. These changes will lead to indirect benefits that can be both private and social and affect water management and any other water policy area.

For example, the successful implementation of an urban sustainable drainage system may lead to significant savings in power consumption (due to the cooling effects of green roofs that reduce expenditure in air conditioning and the reduced need of energy to manage stormwater), this might have an indirect positive effect over water scarcity, reducing water demand for cooling thermal plants and might contribute to GHG mitigation. Similar effects can be recorded over employment opportunities and the demand of inputs.

Indirect effects of NWRM have not been studied in depth. They can only be captured through complex macroeconomic models, such as general equilibrium and input-output analysis and their importance for policymaking is still to be proved. The low priority assigned to these benefits in current research is understandable given the many information gaps that need to be covered to value social, primary and ancillary benefits.

Nevertheless, there are two indirect benefits that might deserve to be mentioned. Both of them belong to the category of indirect ancillary benefits: they come from the way the economy adapts and they are exclusive of these kinds of measures.

The first is the impact a wider adoption of NWRM might have on technological development and thus in the diffusion of environmentally friendly technologies all over particular sectors of the economy. For this to be possible, the number of farms adopting a particular soil conservation practice must reach a critical number. Then, the size of the inputs market may allow producing with profitable margins and this may speed up innovation and the uptake of more effective materials and practices. In other words, although not much empirical evidence is available, it is not unlikely that NWRM may trigger technical innovation.

The second one is the so-called network benefits, meaning that the social benefits might increase faster than the number of people adopting the NWRM practice.

III.2. Network Benefits

It is often said that individual NWRM might have small impact over any relevant water or environmental challenge. This apparently might be a handicap when a measure such as a green roof, or any other SUDS is compared with a big storm tank. It must be recognised that NWRM don't have the scale economies of more traditional and heavily engineered alternatives such as dams and storm tanks. Compare to them NWRM look small and their benefits, while varied may be also smaller. But, while not having scale economies, NWRM when introduced into a water management strategy will have benefits that increase with the number and the connections between the initiatives undertaken. This is what in modern terms is known as network economies. A network of well-connected SUDS will deliver a scale of benefits that amount to more than the addition of the individual measures and the same will happen with soil conservation practices in rural environments.

The benefits from a network are higher than the sum of the benefits of individual measures

As illustrated by Niu et al (2010) a very representative example of this fact is the scaling-up effects when green roofs are installed in a wider city area (instead of in a single building): ancillary benefits emerge (such as mitigation of air pollution and the Urban Heat Island –UHI– effect, grey infrastructure needs reduction and health impacts). Rosenzweig *et al.* (2006) in *op.cit.* (2010) estimated a remarkable thermal effect for a big city like New York provided green roofs were installed at large scale (if installed in the 50% of the area, average surface temperatures could be reduced between 0.1 and 0.8°C).

IV. How do local circumstances affect benefits of NWRM?

Unlike that, greenhouse gas mitigation measures (to which NWRM might contribute), most of the benefits obtained from NWRM are local and then difficult to transfer or generalize. This can be illustrated by many examples available in the literature:

Buffer strip are effective ways to deal with cropland non-point pollution, but effectiveness depends on context, design and local circumstances

According to Borin et al., 2010 studies show pretty satisfactory abatement effects (variable in runoff water according to width and pollutant type and its chemical form) in terms of suspended solids (70–90% abatement, as analysed in Abu-Zreig et al., 2003 and Blanco-Canqui et al., 2004), phosphorus (60–98%, in Duchemin and Madjoub, 2004; Borin et al., 2005; Dorioz et al., 2006) and nitrogen (70–95% abatement as reflected, for example, in Parkyn, 2004). Additionally, farmed fields buffer strips appear to be effective in reducing pesticide transfer to streams by surface runoff (Lacas et al., 2005 in Borin et al., *op. cit*). Relevant identified factors influencing buffer effectiveness (*ibid.*) are their composition, age and width and also the environmental features where they are located (e.g. land use, slope, and area).

And the same applies to private and to ancillary benefits

As illustrated by Claus et al., 2012 for the case of energy saving linked to the increased insulation of green roofs, these are dependent on design (type of roof, building size…) but also on external factors such as climate. In this sense, analysed literature by these authors show higher energy savings in tropic climate areas (e.g. 8% in Singapore, or 3.3% in Athens, US: Wong et al., 2003 and Carter and Keeler, 2007) than in temperate zones (e.g. 2% in Athens –Greece– or 1.2% in Madrid, Spain: Niachou et al., 2001 and Saiz, et al., 2006).

NWRM benefits depend on decisions that are taken in the design phase

The benefits of NWRM can be modulated and optimized by choosing improved designs. These decisions may, for example, tend to maximize private benefits (as it happens when soil conservation practices as considered as instruments of agricultural policy) or to increase some social benefits (as might happen when the same measures are considered from the perspective of water conservation or climate change mitigation).

Trade-offs between some objectives, such as evapotranspiration and carbon sequestration instead of groundwater recharge in riparian forest, might be relevant in some particular cases, but more commonly design options of NWRM offer a unique opportunity to take advantage of synergies between different purposes of water management (like reducing flood risk and improve water status) as well as to serve different policy areas contributing to greenhouse gases mitigation, biodiversity protection, disaster risk reduction and long term adaptation to climate change, etc.

NWRM can be purposely designed to maximize certain benefits at the expense of others

Based on the assessment of literature, Borin (2010) highlights the potential of the very productive riparian areas (located in Southern US) for providing the landowners with a quick return on the investment when planting fast-growing riparian trees as buffer strips in set aside areas. These crops, apart from retaining water also provide additional benefits such as pollutants removal, and provision of raw material (wood, fuel). An example of this is the riparian fuel wood production system designed in Iowa (*Ibid.*) based on fast-growing tree species (hybrid poplar, green ash, silver maple, black walnut, ninebark, red osier dogwood), grown as short-rotation woody crop systems producing different products within different time scales: biomass for energy (in 5–8 years) and timber products (5–20 years).

According to Alewell and Bebi (2011) in the assessment of the effects of forested areas on hydrological regime an associated issue comes up: their effect on climate. Recognised as being relevant, they have antagonistic effects and variable according to climate areas (so their net global effects seem to be unknown so far): on the one hand they contribute to climate warming by decreasing the albedo, and other to climate cooling due to carbon sequestration, evaporative cooling and cloud formation.

V. What is the comparative effectiveness of different NWRM with regards to the main Ecosystem services they bring?

As per NWRM, the effectiveness for each measure is the main Ecosystem Services it can bring which is closely linked to its biophysical impacts and that are different depending on the NWRM.

One feasible way to assess NWRM effectiveness is therefore by taking all 14 Ecosystem Services it can have and linking them to the measures in a matrix, like for the biophysical impacts and with the same qualitative range.

All benefit tables are available on the website here: www.nwrm.eu/benefit-tables

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VII. Annexes

The identification of impacts (as changes in state) and the delivery of biophysical flows of ecosystem service are clearly intertwined. In 2011, the JRC established a list of Ecosystem Services that applies to NWRM. "The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative focused on drawing attention to the economic benefits of biodiversity including the growing cost of biodiversity loss and ecosystem degradation." *(http://www.teebweb.org/)*. It "proposes a typology of 22 ecosystem services divided into 4 main categories: provisioning, regulating, habitat and cultural services, mainly following the MEA-classification (Millennium Ecosystem Assessment). An important difference, as compared to the MEA, is the omission of supporting services such as nutrient cycling. Instead, the habitat service has been identified as a separate category to highlight the importance of ecosystems to provide habitat for migratory species (e.g. as nurseries) and gene-pool protectors (e.g. natural habitats allowing natural selection processes to maintain the vitality of the gene pool). The availability of these services is directly dependent on the state of the habitat providing the service." *(JRC, 2011)*

Based on this, a structured grouping of Ecosystem Services of NWRM can be proposed, as detailed in the following table.

TABLE 1: STRUCTURED CLASSIFICATION OF POSSIBLE ECOSYSTEM SERVICES OF NWRM

Ecosystems Services Benefits - the benefits that derive from the changes to the function or structure of the ecosystem or hydrological system	**Provisioning**	**Water Storage**	Water storage: production, irrigation refers to storage of water for production and irrigation. Measures to ensure horizontal connectivity and re-introduce natural flooding of plains will most often be used to reduce floods in urban areas, limit the amount of pollutants being transported downstream and to prevent nutrients from entering downstream systems. The ecosystem service has the potential to store water during floods and to make the water available for other purposes, such as for agriculture, by offering moister soils or by storing water for irrigation after the flooding has ceased.
		Fish Stocks and Recruiting	Fish stocks and recruiting is an ecosystem service that is stimulated by numerous of measures related to restoration and rehabilitation of aquatic ecosystems and biodiversity with the aim of achieving the objectives of the WFD/FD. Commercially valuable fish will indirectly benefit from restoration and pollution load reductions and the fish stock will increase. Commercial fishing can be stimulated by ensuring sufficient environmental flows in surface waters, which will maintain migration pathways, foraging and spawning site. Regulation of surface water abstraction can play an active role in supporting this ecosystem service as it lowers the pressure on the flow regime of a river. Dams can inhibit migration, and thereby reduce reproduction of commercially interesting fish species, by restricting access to spawning grounds. The transfer of water between catchments may have positive and negative impacts on fish populations depending on the regulation and its extent. For marine areas, rehabilitation of hard substrates is known to attract a much wider biodiversity than a soft seabed, and reefs are also known to act as nurseries for many marine species.
		Natural Biomass Production	Natural biomass production aimed for human use is a very wide term, which can be used to describe all additional increases in (mainly but not only) terrestrial flora and fauna. The CICES system characterises the biomass from natural production in ecosystems as a provisioning service that can contribute to the CICES classes nutrition, material and energy (see Table 3 1). Restoration of ecosystems using the measures mentioned in table 3-3 will most often increase in biomass production and especially stimulate vegetation along banks, on flood plains and in other habitats. In some cases, increased vegetation, e.g. along river banks, may affect the aesthetic value of landscapes negatively or hinder access to water bodies. In other cases, it can have positive impact both on aesthetic and recreational values. Individual assessments are required.
	Regulatory and Maintenance	**Biodiversity Preservation**	Biodiversity preservation, in this context, means both terrestrial and aquatic biodiversity – and is an ecosystem services that will be stimulated by several of the measures mentioned. Urban measures for handling surface water runoff often include more green areas and thereby more habitats for plants and animals in urban areas. Restoration of wetlands and riparian zones will significantly increase habitat diversity in the entire catchment not only for aquatic species but also for a number of terrestrial species. In-stream restoration will increase habitat diversity and thereby biodiversity beyond the benefits of improving the water quality. Biodiversity preservation can be significantly influenced by any measure that modifies the flow pattern (hydrography). The impacts can be both positive and negative depending on how the regulation of the flow is managed and how the indicated measures are implemented.
		Climate Change Adaptation and Mitigation	Climate change adaption and combating/GHG reduction/ Carbon Sequestration (including but not restricted to Green House Gases (GHG) reduction and carbon sequestration) can be obtained through land management and the establishment of a riparian buffer zone, which can accumulate and store organic pools. Land use can also significantly influence GHG production, e.g. wetlands can either be net sinks or net sources of greenhouse gases (GHGs). Whether it is one or the other depends on precipitation and other factors like temperature, vegetation and land use. Several of the

			measures implemented to meet the objectives of the FD for handling urban runoff contain a climate adaption function as well with respect to avoiding or limiting urban flooding. At the same time, they can have positive impacts on the local climate conditions (see also comment on energy savings) and thereby on the potential CO2 production (climate change mitigation). The potential functions and stimulation of ecosystem services in wetlands are mentioned under the load reduction measures and water body restoration measures. Rainwater harvesting is a direct measure for combating drought impact, which can be one of the consequences of climate change. Increases in rainwater use will decrease the demand for water from other sources, thereby easing the pressure on the resources and the attached ecosystem services.
		Groundwater / Aquifer Recharge	Groundwater/aquifer recharge can be stimulated by rainwater infiltration in urban areas, changing land use, establishing floodplains/wetlands, managing the riparian zones, and promoting sustainable drainage in rural areas. When measures to restore horizontal connectivity in rivers are implemented and plains are flooded regularly in designated areas, the recharge of the aquifers will increase and ultimately ensuring more groundwater for different uses. An active floodplain/wetland and riparian zone will enable better surface-groundwater exchange, which will also benefit the water body during droughts. Furthermore, this can be achieved through extended and controlled flooding of plains and naturally through artificial groundwater recharge systems. Forests being a NWRM provide hydrological and water quality regulating services through the restoration and filtration of water.
		Flood Risk Reduction	Flood Risk Reduction comprise several measures, including utilisation of connected wetlands and floodplains. These measures (and other NWRM) have the capacity to mitigate flood events, which will ease the pressure on the aquatic habitats by reducing the erosive/abrasive characteristics of floods. However, this ability depend on the activities within the flood plain and appropriate flood plain management, e.g. the capacity of different ecosystems (e.g. forests, grasslands) to regulate floods through vegetation and soil cover. Consequently, the ecosystem services delivered by a well-functioning flood plain/wetland are both numerous and significant. Ecosystem services associated with flood plains/wetlands include water supply, flow and filtration, climate regulation, food, fuel, soil erosion control and soil formation, control of pests and diseases, nutrient cycling/waste processing, carbon sequestration, biodiversity and pollination. They also provide aesthetic, recreational, tourism, cultural and educational services.
		Erosion / Sediment Control	Erosion/sediment control are other key ecosystem services related to the FD. They may be a result of spatial measures such as land use management, wetlands and the riparian zone. Further, also related to the WFD and a working group on water accounts are formed under the CIS. In some cases, the urban measures for handling surface runoff can modify erosion, but compared with other processes regulating the erosion in catchments, urban runoff does normally not contribute significantly to controlling erosion and sediments. Changes of land use (vegetation cover, type, etc.) and restoration of wetland and riparian zones are examples of NWRM that can significantly change and reduce erosion to the river system. In-stream restoration such as meandering, ensuring optimal bed substrate and submerged vegetation can highly influence the erosion and sediment transport through the river system.

		Filtration of Pollutants	Filtration of pollutants and decomposition in the soil can be further stimulated by changes in land use, restoration of wetlands and the establishment of riparian zones. Pollutants (e.g. nutrients and pesticides) can be absorbed and/or degraded before ending up in the water body through appropriate design and management of the areas. In-stream restoration can also accelerate the filtration of different pollutants in the water body due to increased submerged vegetation cover, biofilms, sediment accumulation and increased retention time.
	Cultural	**Recreational Opportunities**	Recreational opportunities are very often the most valued ecosystem services because they give the public access to new or restored areas. The possibilities can be significantly increased though land use management, establishment of riparian buffer zones in rural areas, in-stream restoration projects and by establishing green spots in urban areas. Activities like bird watching, hiking, picnicking or simply relaxation can be stimulated if the areas are properly designed and opened to the public. The recreational opportunities can also be used to promote tourism.
		Aesthetic/Cultural Value	Aesthetic/cultural values will also be stimulated. Urban green spaces along streets to support infiltration and green roofs to mitigate stormwater run-off increase the aesthetic value. Measures such as riparian zones, land use management and in-stream restoration can be used as part of landscape design to increase aesthetics. The aesthetic/cultural ecosystem services are closely linked to the recreational ecosystem services.
	Abiotic	**Navigation**	Historically, navigation and access to coastal waters, rivers and lakes have been and still are highly appreciated services. The most obvious places for navigation are already in use, but there may still be water bodies that can offer services to smaller vessels and pleasure boats. In many cases, identification of water bodies for boating activities must be weighed against other interests, such as the wish to protect habitats if there is a risk that access to the areas may negatively affect habitats and species in the area.
		Geological Resources	Access to the natural transport of geological materials downstream in all water bodies is a service. Geological materials can be used for a wide range of purposes, but striking a balance between the exploitation of available materials and biota living in the sediments may be delicate.
		Energy Production	Energy from hydro power is one of the abiotic ecosystem services or water services that often conflicts with the achievement of the objectives of WFD/FD, because a naturally functioning river system has a natural variation and dynamics in its discharge pattern (hydrography) and sediment transport. In addition, energy production will most often counteract the river continuum connectivity, thus preventing the natural upstream migration. Dams and hydro-power utilisation will have a significant influence on these variables.

(Source: adapted from COWI 2014 ecosystem services and WFD report).