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Economic assessment methods for the costs and benefits of the Natural Water Retention Measures

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Office International de l'Eau

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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 (NWRM) 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 NWRM cover as described in *SD n°0: Introducing NWRM. 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 NWRM 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, assessment and valuation methods

Please consult the NWRM glossary for more information.

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I. Which methods are used to assess costs and benefits of NWRM?

Whereas assessing the financial costs of NWRM might be straightforward and based upon a transparent, accountable and well-established method, the identification of other costs (opportunity costs) and multiple benefits is a more demanding task hardly performed in available examples. The synthesis documents on costs and benefits (See Synthesis Documents 5 and 4) already include a definition and the classification of these costs and benefits, along with a pool of illustrative examples drawn from case studies and a literature survey. Both documents underline the varied nature as well as the fact that assessment methodologies must adapt to each type of opportunity cost and individual benefit considered.

These methods include assessments of production losses, additional operational costs and other alternatives to assess opportunity costs. Furthermore, for intangible benefits, alternatives range from the use of market and non-market valuation methods, to observed (revealed) and stated preferences. A quick survey of the literature and the different experiences covered in the project reveals that the strategies applied to classify, identify and assess the different advantages and disadvantages are as varied as the nature of these benefits and costs themselves. In addition to that the methods used must adapt to the information available which in most the cases produce results that are valid for the local situation analysed but are not easily transferable to the same kind on measures in other places.

Moreover it is not expected that individual NWRM assessments include ad hoc valuation studies (i.e. developed from scratch). Nevertheless some of them might rely on benefit transfer methods or rather on proxy variables to approximate a value of certain relevant benefits or costs. These benefits and costs are context-based (and potentially site-specific) and therefore difficult to identify and quantify. In practice, assessment and valuation follow a practical rule of parsimony and economy, in such a way that only the minimum valuation required selecting (or rejecting) the measure should be conducted.

In other words, if these intangible costs and benefits are relevant to select the measure, it is also likely that some valuation exercise may need to be conducted. Hence, it is important to focus not on 'ideal' valuation exercises but on the simple analyses that are critical to select the measure. Sometimes the only information required is that a NWRM will make redundant other and more expensive measures with the same purpose (in this case the main argument is cost-effectiveness and one type of benefits to be accounted for is the avoided costs of those redundant measures).

Ancillary benefits (or co-benefits) of NWRM might be (or not) relevant to the decision, and their valuation might in turn be useful (or not). In case they are, these benefits must be identified and measured, although not valued, in order to mainstream this information into the decision-making process. In this case the information used must be available from the cases study and documented for the guidance.

Usually, there are many alternatives to measure the value of any opportunity cost or benefit. In practice, the method, if any, is selected through the use of practical considerations such as production losses or the cost of defensive and replacement measures (i.e. averting behaviour). Thus, it is important to explore the reasons that led to the adoption of any particular measure implemented so far.

A particular consideration must be made to the fact that most of the costs and benefits that are relevant for policy making are highly context specific and determined mainly by local conditions. This is the fact of all opportunity costs related with yield losses in agriculture but also the case of potential gains from energy savings, pollution control or peak flood reduction which all depend on particular local conditions. The double consequence of that is, on one side the limited usefulness of median or average values obtained from typical costs or benefits of the measures and the loss of robustness implied in the transfer of values among sites and contexts.

The concept of NWRM is still an emerging one, as is also the case of a whole family of nature-based approaches to respond to water management challenges. While promising as alternatives for water policy, as well as for purposes such as climate change adaptation, land use management and disaster risk reductions, there still is a lack of robust empirical information on the costs and benefits of the different measures and any generalization, besides the appearance of precision, may hide the important uncertainties surrounding the actual size of the costs and benefits implied. In fact most of the values of the costs and benefits presented in practical studies represent design or simulated values obtained ex-ante rather than observed facts[1].

As a general principle, efforts devoted to value the benefits and costs can only be justified by the value of the information such studies can provide and, particularly, by its potential to improve the quality of individual and collective decisions. As discussed in the synthesis documents on benefits, financial benefits are worth to be explored in order to understand to what extent individual farmers might be, for example, interested in implementing a NWRM by themselves , but also non-financial costs and benefits are essential to understand if a collective action is required to implement these measures even if they are not in the best interest of the individuals affected or they don't rank first according to a single criteria (but they are rational from a social cost benefit perspective and adding up all the contributions made to the different policy relevant areas).

In practical terms the right valuation strategy depends on the policy making context. For example, if the relevant management issue is whether a particular course of action, let us say a NWRM, must be included in a particular program with a given objective in terms of, for instance reaching a status of a water body or reducing flood risk to a target level, then the only relevant benefit of a single measure is the cost avoided by the best alternative measure available that can perform the same role. In the same sense, there is no practical point in valuing the benefits for water retention of a measure which adoption is already justified by its contribution to climate change adaptation, or biodiversity protection. However, the monitoring and assessment of a measure should always take all its benefits into consideration to ensure that the knowledge and experience of such an implementation are not lost.

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[1] Some studies are meta-studies others are individual studies which can be very locally specific. Sometimes the costs are based on program support for measures, sometimes theoretical estimates. There is no weighting of the sources but simple averaging regardless of the extent of the areas where the measures are applied or where they are applied. The focus is on converting a cost based on any data that names the particular measure without reviewing applicability or credibility of the source and extrapolating an effect (potential for the measure) based on JRC models.

II. Can some of the benefits of NWRM be measured and valued and to what extent?

Obtaining an economic value for some, if not most, of the policy relevant benefits of NWRM is, in general a feasible, and not always straightforward, task. A quick literature review will make it clear that there are practical alternatives to value most of the benefits and costs of NWRM. For practical reasons, related with policy relevance and cost of information effectiveness, these more frequently used valuation approaches rely in proxy measures that make extensive use of market information to value changes in welfare due to avoided costs and foregone benefits. These methods are less sophisticated than preference revelation alternatives (such as contingent valuation, stated preferences, hedonic or travel cost methods), but given the state of the art they provide reliable information, easy to communicate to stakeholders and adaptable to local circumstances. These methods are also better suited to consider the marginal and incremental changes characteristic of NWRM.

Valuation of non-market benefits is always a complex issue. NWRM add a new complexity layer as each of the multiple benefits of particular measures is subject to different and specific valuation strategies depending on data availability and the possibility of building robust connections between the measures, the flow of the benefits obtained from its implementation and the monetary value of these benefits. The following tables show a series of benefits that are relevant to solve the two basic policy questions that are relevant in the forcefully limited economic analysis that can be performed of green roofs. The first table tries to highlight the basic collective benefits that may be relevant to assess whether as a society we must be interested in going further with the implementation of green roofs (so these are the benefits that may be more relevant for conducting a social cost benefit analysis). For each category of benefits, the table presents its definition and rationale from a social welfare standpoint and, in the last column we present the economic valuation approaches that are most commonly found in the literature.

Collective or Social benefits of Green Roofs		
Benefit	**Identification and Rationale**	**Valuation**
Improvements in air quality	Green roofs reduce air pollution with benefits over health and result in lower morbidity and mortality rates than can be valued by using avoided health expenditure, working day losses and eventually using the value of a statistical life.	Dose–response functions: the methods assess pollution concentration reductions and calculate an impact over a scenario base obtaining a number of events (such as events of reduced health, working days lost, etc.) that can be valued at a unitary rate. Studies for Flanders (VMM, 2009 in Claus and Rousseau, 2012) estimate external health effects associated with the long-term effects of particulate matter to amount from 483 to 546 euro per inhabitant per year. Assuming that approximately 5–10% of surrounding NOx and SO2 concentration is absorbed by green roofs (Clark et al. (2008) over a baseline a yearly average of 0.995 kg NO2 per m2 per year. Clark et al. (2005) the reduction can be valued at 3375 USD per US ton. Other studies estimate that 1 kg NOx reduced is worth 4912 euro (Marien et al., 2001 in Claus and Rousseau op. cit.). According to Claus and Rousseau (2012) the value of NO2 absorption by green roofs lies between 0.246 and 0.491 euro per m2 per year, with an average of 0.369 euro per m2 per year.

Run off attenuation	Water retention and runoff by green roofs influence the municipal water purification costs as well as the risk of flooding (Tomalty et al., 2010). Since less water will end up in the sewer system, communal water purification costs will decrease. Evaporation or evapotranspiration is influenced by the total leaf surface present on the green roof and takes place when the green roof is sufficiently humid (Lazzarin et al., 2005). On a warm summer day in Flanders, Hermy et al. (2005) in Claus and Rousseau op. cit. have calculated that approximately 0.5 l water evaporates per m2 for a green roof with a 3 cm substrate layer.	**Avoided costs**: In the Dilbeek project, the estimated runoff is approximately 0.4 m3, which amounts to 190.8 m3 for the total roof surface of 477 m2. Since the purification costs of waste water in Flanders are estimated by 0.7580 euro per m3 (SERV, 2007 in ibid.), Claus and Rousseau (2012) estimate the savings of the decrease in rainwater that needs to be purified at approximately 0.303 euro per m2. A pilot project by De Cuyper and Dinne (2006) in Limette (Belgium) shows that the peak volume of downpours is postponed by 8 min and is decreased with 52% when an extensive green roof with a 4 cm substrate layer is compared to a classic roof cover (ibid.). Green roofs mean not only a lower volume of water reaching the sewer system, but also a quantity more evenly distributed over time. A study in Rotterdam (Netherlands) estimates the transportation costs of rainwater through sewers at an average of 0.10 euro per m2 roof cover (Arcadis, 2008 in ibid.).
Water quality	Green roofs may improve water quality since rainfall is filtered. Moreover results are still of opposing sign (Berndtsson, 2010) as effects are heavily influenced by local conditions and green roof design. In general, it can be said that green roofs retain heavy metals such as zinc, copper, cadmium and lead and that the amount and type of fertilization determine the share of organic substances in runoff water (Berndtsson, 2010; De Cuyper and Dinne, 2006 in Claus and Rousseau op. cit.). In empirical analysis green roofs seem to enrich rather than purify rainwater and the conductivity of the water increases as well as the concentration of organic substances (Claus and Rousseau, 2012).	The local conditions and the effect of green roof design may result in positive or detrimental effects over water quality. This has precluded the publication of validated results over the value of these likely benefits.
Greenhouse gas reduction	Green roofs mitigate CO2 emissions through two different pathways: directly through the absorption of CO2 by the plants and indirectly by the reduction in energy used in buildings, Li et al. (2010). This effect depends on the condition of the plants, the position of the green roof, weather and ambient conditions (ibid.).	**Indirect effect of energy savings**: the direct effects are less known than the annual savings in energy consumption in Flanders which equalled 316.92*0.015 kWh per m2 or 4.75 kWh per m2. Given that the average greenhouse gas emissions in Flanders were 319 g CO2-eq per produced kWh in 2010 (MIRA, 2010 in Claus and Rousseau, op cit.), then the green roof reduces greenhouse gas emissions by 1516 g CO2-eq per m2. At a price of 20 euro per ton CO2, the greenhouse gas reductions can be valued at 0.03 euro per m2 per year (ibid.).

Biodiversity	Green roofs provide a habitat for fauna and flora (Mentens et al., 2002 in Claus and Rousseau, op cit.; Hermy et al., 2005 in ibid.; Oberndorfer et al., 2007; WTCB, 2006 in Claus and Rousseau, op cit.), host a variety of invertebrate and avian communities (Coffman and Davis, 2005; Brenneisen, 2006; Kadas, 2006; Schrader and Böning, 2006; Köhler and Poll, 2010) are inhabited by insects (Coffman and Davis op. cit.), rare plants and lichens (Brenneisen op. cit.) and are used by nesting birds (Baumann, 2006). Green roofs may be part of wildlife corridors, park areas, gardens and graveyards (see also Vergnes et al., 2012).	The greening of roof has a positive effect on biodiversity, but the specific valuation of this benefits is particularly challenging as these benefits are local, specific, highly dependent on design and do not have any monetary value in a market. There is the potential for using revealed preferences methods but no single study has been register so far. This may be a consequence of lack of information, weakness of the potential results and the limited importance of such monetary values for policymaking.

As explained in the policy document about the benefits of NWRM the valuation of the more policy significant benefits of NWRM may provide useful information not only to judge the convenience of its implementation for the society as a whole, but also to assess the incentives that the direct beneficiaries and, in particular, whether some individuals directly affected may be interested in implementing the measure spontaneously and whether and to what extent they need to be financially supported by the government. These are the private or financial benefits that are presented in the table below for the particular case of green roofs.

Private or Financial Benefits of Green Roofs		
Life span of the roof covering	Green roofs last significantly longer than standard roof covering (Hermy *et al.*, 2005 in Claus and Rousseau, o*p. cit.*; Saiz *et al.*, 2006; Oberndorfer *et al.*, 2007; Getter *et al.*, 2009, Ekaterini and Dimitris, 1998; Teemusk and Mander, 2009). Thus the expected renovation costs of the roof decrease as long as the roof covering offers sufficient resistance against root perforation. According to Mann (2002) in Claus and Rousseau, *op. cit.* a standard EPDM roof covering has a life span of some 25 years, while a green roof can be expected to last twice as long (see also Porsche and Köhler, 2003; Hermy *op. cit.*; Saiz *et al.*, *op. cit.*).	**Avoided replacement costs:** The renovation costs of the roof decreases as the roof covering offers sufficient resistance against root perforation. A green roof can be expected to last twice as long as a conventional one (see also Porsche and Köhler *op cit.*; Hermy *et al.*, *op. cit.*; Saiz *et al. o.p cit.*; Mann *op. cit.*). Savings may amount 180.3 euro per m^2 in the 25^{th} year (Claus and Rousseau, *op. cit.*)
Decreasing energy costs	A green roof enhances insulation (Niachou *et al.*, 2001; Wong *et al.*, 2003a,b; Kumar and Kaushik, 2005; Carter and Keeler, 2007; Oberndorfer *et al. op. cit.*), which results in lower energy demand and increased comfort (WTCB, 2006 in Claus and Rousseau, *op. cit.*).	**Avoided costs:** In Flanders, the expected energy reduction of 1.5% by constructing a green roof in Dilbeek is equivalent to an annual savings of 40.6 euro in total or 0.133 euro per m^2 green roof surface given the natural gas price of 7.83 euro per GJ in 2008. (Claus and Rousseau, *op. cit.*)

Private or Financial Benefits of Green Roofs		
Aesthetic impact	Green roofs may influence mental, physical and social well-being and may also have a positive effect over productivity. View to nature may reduce stress, blood pressure and increase job satisfaction (Rowe, 2011)	Aesthetic values are difficult to measure in general and even more to attribute to a particular component of the urban landscape. These benefits are identified, characterised but barely valued in monetary terms. Tomalty *et al.* (2010) value a view onto a green roof with trees as 9% of the value of the portion of a building that affords a direct view onto the green roof.
Noise reduction	Green roofs reduce noise (Van Renterghem and Botteldooren, 2009), by muffling traffic noise (VMM, 2006 in Claus and Rousseau, *op. cit*.), and this effect depends on the environment and the own design. According to WTCB (2006) in Claus and Rousseau, *op. cit*., abating noise by approximately 38–40 dB Botteldooren (2011).	**Hedonic Valuation:** On average the estimated market value of a property decreases with 0.6% when the ambient noise level increases with 1 dB (A) (Proost and Rousseau, 2007 in Claus and Rousseau, *op. cit*.). Green roofs with a life spam of 50 years, covering 15.8% of the building plot will increase the value of office spaces by 0.6*23 = 13.8%. In Brussels, with an estimated current market value of the office is 1.5 million euro or 312.3 euro per m^2 and a discount rate of 5% (see Tomalty *et al*., 200), the benefit of noise level reductions can be approximated by 0.138 * 312.3/3 = 14.4 euro per m^2 over the whole life span, or 0.287 euro per m^2 per year (i.e. annuity at 9% discount rate and 50 year life span).

III. What are the most appropriate methods to value the benefits of NWRM?

In addition to the methods that have been suggested for valuation of direct benefits, such as estimating avoided costs for flood defences and water purification, the valuation of associated indirect benefits (or ancillary benefits) such as biodiversity, amenities and recreation must rely on other approaches, e.g. ecosystem service analysis. In three case studies from Portugal, France and Germany, the research project ESAWADI (ESAWADI, 2013) investigated the possibility and suitability to apply Ecosystem Services Approach for the WFD implementation. The investigation found that stakeholders (RBM-planners) across all three study areas judge ESA to be potentially beneficial to assess cost- efficiency of suggested measures under special conditions and circumstances. Four such situations were identified: 1) as a support to conventional CE analysis of alternative measures where ES are evaluated qualitatively as a second criteria by means of a scoring system, 2) as support to prioritize between different measures that create additional benefits (e.g. biodiversity or employment) 3) as support for prioritization between different water bodies based on potential for ecological improvement, e.g. strengthening of ES flows and/or ecological processes, 4) as a mean to visualize the diverse impact of measures and in doing so, facilitates dialogue and acceptability for ambitious environmental objectives.

In one of the case studies (Portugal), a multi-criteria analysis (MCA) approach (tool: MOULINO) was applied as a mean to examine different options for measures in terms of effectiveness, costs and risk. In addition, a semi-qualitative approach was applied to assess the impact on ES provisioning from the proposed measures. The lesson learnt was that the approach broadens the view of the proposed measures compared to the economic analysis required by the WFD. By using MCA, the need to attribute monetary value to all environmental factors could be avoided and the method was thus regarded as a complement to more classical cost-efficiency analysis.

One of the major findings of the project was that ESA can be a useful addition to the tools used to assess cost- efficiency of measures on condition that the analysis is not only limited to achieving Good Ecological status. It requires that the scope is broadened to also include additional benefits that are realised through water protection measures. This in turn facilitates a more comprehensive analysis of costs and benefits of the measures.

The survey was based on a proposal to install a 10 meter deep riparian buffer zone on a five-year scheme and the analysis was based on principal components analysis, contingent valuation methodology and a Generalised Tobit Interval Model. A principal component analysis (PCA) was used to extract and identify underlying farmer latent attitudes and peer influences. Respondents who indicated a willingness to participate in the proposed scheme were presented with a contingent valuation willingness to accept (WTA) question to establish the minimum amount the landowner would be prepared to accept (s ha-1 equiv. per annum) for the change of land use from productive agriculture to a riparian buffer zone. Following the work of Daniels and Rospabe (2005) and Hynes and Hanley (2009) a Generalised Tobit Model was used to model farmers WTA using maximum likelihood estimation procedures. [Buckley *et al.*, 2012: Supply of an ecosystem service—Farmers' willingness to adopt riparian buffer zones in agricultural catchments]

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