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Costs of Natural Water Retention Measures What are the costs 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 (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: Economic cost, financial cost, capital costs, maintenance and operational costs, opportunity costs, sunk cost, cost per unit of intervention, cost per unit of water retained, foregone benefits.

Please check the NWRM glossary for more information.

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I. Introduction

Unlike common wisdom, the overall economic cost linked to the implementation of a NWRM (or a combination of them) is not just its financial cost, but also the so-called opportunity costs and sunk costs.

A basic distinction should thus be made between the **economic cost** and the financial cost, often (wrongly) presented as synonyms. The former includes all the resources, foregone opportunities and other sacrifices required to implement a given measure, so that any economic cost is an opportunity cost in itself. The latter includes all the cash outflows required for both, the setting up of all the infrastructures and other features required for the operation of the measure once in place.

The **financial cost** you would incur in the design and implementation of these measures includes: **upfront capital expenditure** (the investments in equipment, infrastructures and other assets required throughout the lifespan of the NWRM); **depreciation allowances** (annualised cost of replacing the accounting value of existing assets in the future); **maintenance expenditure** (all the financial outflows required to preserve existing or new assets in good functioning); and the **operational expenditure** (those incurred to keep he NWRM running in an efficient manner on a daily basis).

Yet, despite being of paramount importance, financial costs are not all that matters: opportunity costs and trade-offs are crucial regarding NWRM implementation.

Opportunity costs are commonly linked to NWRM that consists in changing land use modes and they result from the deviation from what farmers, foresters or other agents consider as their preferred decision. These opportunity costs or disadvantages are borne by particular individuals or stakeholders (e.g. farmers getting lower yields per hectare, reduced crop areas or incurring in additional costs) that must be identified and factored in, as far as the implementation and the performance of the measure might depend on the acceptability and the voluntary agreement of those individuals bearing these opportunity costs (see Synthesis Document 11).

Despite its name, **foregone benefits** are real opportunity costs, or disadvantages resulting from the implementation of the measure. Alike, avoided costs are real benefits or advantages of some measures (See Synthesis Document 4)[1]. Any particular measure (such as a soil conservation practice) might entail opportunity costs (as the reduced yields), and benefits in the form of avoided costs (such as reduced water and energy requirements due to the higher water retention). However, the distinction between foregone benefits (or costs) and avoided costs (or benefits) is essential to avoid double counting and biases in costs and/or benefit assessment. Nevertheless the set of definitions and accounting practices mentioned in this note are just one of the alternatives available. Many projects do not consider opportunity costs at all and those that actually do may present a net opportunity cost (subtracting the avoided costs and/or the ancillary benefits). Better and more insightful comparisons would be possible in the future provided a standardization of definitions and practices were agreed.

Besides financial and opportunity costs there might also be **sunk costs.** These are those expenditures that, once incurred, cannot be (easily) recovered, since they arise from activities requiring specialized

[1] These benefits (or avoided costs) accrue to the individuals responsible or directly affected by the measure (such as the avoided noise protection and energy expenditure as well as other benefits receive by a household after the installation of a green roof).

assets that may not be easily diverted to other uses. These costs are highly relevant to NWRM since they are usually higher for innovative alternatives. Once these costs are paid, usually before the implementation of the measure, they do not depend of how well or bad the measure performs. Sunk costs include all expenditure applied to research and development, consultancy, project designs, stakeholder engagement, bargaining processes and consensus building, etc. They tend to decrease throughout time as far as more projects are considered, the uncertainty about the biophysical impacts is reduced, more experience is gained and society progresses along its learning curve. Sunk costs are then higher for NWRM than for traditional and well established water management alternatives. These costs are rarely reported.

II. What are the capital, operation and maintenance costs of NWRM?

Ecosystem-based approaches are linked to a more varied cost structure

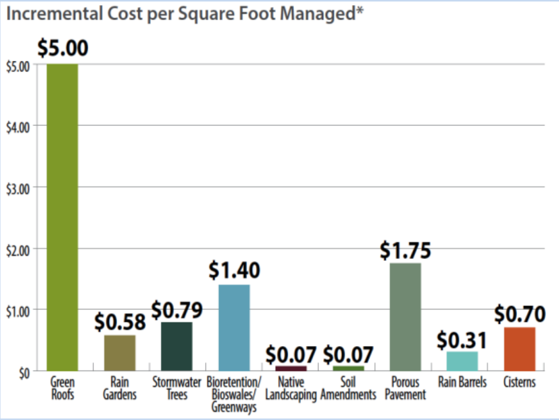
NWRM are complex nature-based approaches that modify current land use practices in order to restore complex ecosystems. Unlike with traditional water management measures, financial costs imply the setting up of a variety of actions instead of the installation and use of a single device or infrastructure, the restoration of the ecosystem might result in a plethora of opportunity costs and sunk costs (as above) might also be significant. The following list adjusted from Escobedo (2011) presents a preliminary list of cost concepts to be considered for the assessment of urban forests and in particular when, as in the case of London, a program is developed to obtain new services such as increased flood storage in addition to the other services already provided by the city forests, such as better air quality, reduced stormwater run-off and carbon sequestration. In particular a £3.8 million program has been implemented to add river restoration, floodplain improvements and the creation of diversified woodland habitats (Oldfield *et al*, 2013, based on Everard *et al.*, 2011).

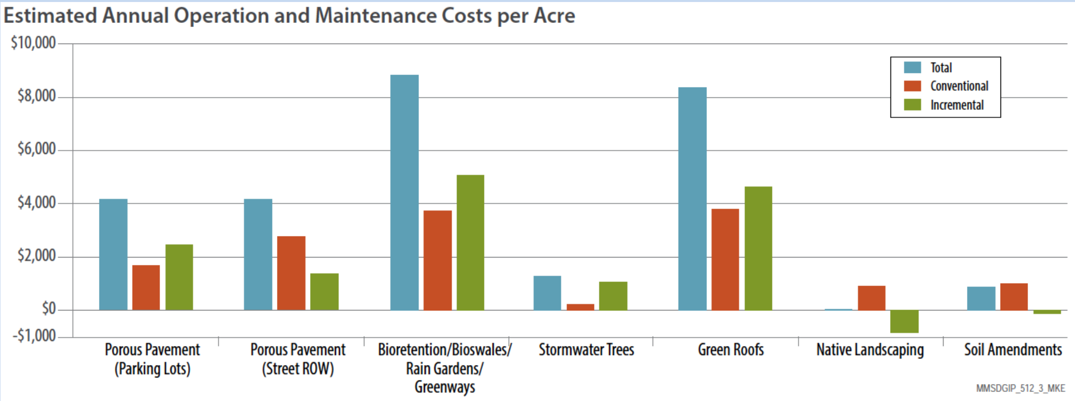
Examples of cost concepts associated to urban forest

Financial costs	Pruning, planting, replacement, removal, transplants, pest-disease control, irrigation…
Opportunity costs	Pest disease control, foregone land use opportunities, increased energy use, wildlife/insects bite, allergenic pollen, fear of crime, safety hazards from tree fail, displacement of native species, introduction of invasive species…
Sunk costs	Litigation, consultancy, project design…

Though financial costs of NWRM follow standard and well-established methodologies (similar to those used for other water measures and, in general, for any investment project) comparisons between data from projects (and scientific literature) are challenging due to the lack of standards as per the assumptions used to estimate costs indicators (such as unit costs), and in particular the difference between nominal and real prices, the discount rate, the base year, the lifespan considered, or often the lack of a clear distinction between costs and benefits.

Additional challenges emerge when assessing a measure (e.g. when the use of incremental costs is required) or a combination of them (e.g. comparison on the basis of unit cost of retaining a unit of water – contribution to water policy objectives - instead of cost per unit of intervention), or when cost estimates need to be transferred to other locations (as in the case of NWRM benefits these can be heavily biased given their site-specificity – e.g. floodplains and wetland restoration).





The Milwaukee Metropolitan Sewerage District (MMSD) collected the best information available in order to obtain benchmark numbers for the installation costs of different urban sustainable drainage systems.

Source: MMSD (2013)

Traditionally costs are summarised as the cost per unit of intervention. Nevertheless, while informative about the size of the financial effort required to put the measures into practice, costs per unit of transformed area are only the first step in providing the information required for considering the convenience of implementing NWRM.

First of all, in most of the cases, the costs that need to be considered are those that are additional. In other words only those *incremental costs* that can be explained by the implementation of the measure as compared to baseline should be considered. For example, in new buildings installing green roofs entails costs but the decision will actually depend on the excess cost over installing a conventional roof instead. A different situation arises when retrofitting is the best option (e.g. installing a green roof on top of an existing building or replacing conventional by porous pavements)[i]. Some methods might make NWRM look dearer than they really are. For new endeavours the relevant financial cost is not the overall but the incremental one while for adaptation measures the relevant cost is the one of transforming the existing structure (a roof, the soil, etc.) into a NWRM[ii].

Second, since NWRM are the means and not the ends of the program of measures, the costs that are relevant to find the best combination of measures are not those of the measure itself but those of using that particular measure to contribute to a common, and hopefully well defined, goal. For instance, sustainable urban drainage systems (SuDS) could only be compared to each other if all those costs are measured with respect to a common standard (for example, the unit cost of retaining a unit of water).

Moreover, NWRM costs are still imperfectly known. The cost per unit of intervention is better known than the more policy relevant cost per water retention unit. For example, a substantial number of references show the real possibility of obtaining substantial savings by choosing different design and materials (as in the example about green roofs below). This design data, though, is useless without reliable information about how effective cheaper options (as compared with the more expensive ones) are in retaining water.

Sound and comprehensive costs assessments might be useless in the context of a cost benefit analysis. They are nevertheless a step further in the knowledge of NWRM

Peri *et al.* (2012) provides reference prices for green roofs in the EU by using a life-cycle assessment framework. He shows, for example that disposal costs, largely neglected, may amount to a 5% of the total costs of the average green roof. But how much more/less water is retained by the cheap and the expensive green roof?

Table 4
Selling price, product and installation costs of each green roof component considered in the present study (costs for the whole green roof and for 1 m^2 of green roof).

	Specific selling price (on average)	Amount of product used in 82 m^2	Cost for the whole green roof [Euro]	Product cost (materials cost + labour for manufacturing)	Installation cost for the whole green roof [Euro]	Amount of product used in 1 m^2 of green roof	Total cost per 1 m^2 [Euro/m^2]
Agriterram TVS (substrate)	175.50 Euro/m^3	15,375 m^3	2698.3[a]	1618.99	1079.33	0.19	33.35
Igroperlite 1/10 (water storage layer)	14,070 Euro/pillow	125	1758.8[b]	1055.25	703.50	1.6	22.51
Ecodren SD5 (drainage layer)	7.4 Euro/m^2	82 m^2	606.8[b]	364.08	242.72	1	7.4
Soiphren H 20 kg (waterproofing membrane)	75 Euro/can	9 cans	675.0[c]	675	288[d]	0.1	7.5
Total	–	–	5738.9	3713.3	2313.5	–	2.89

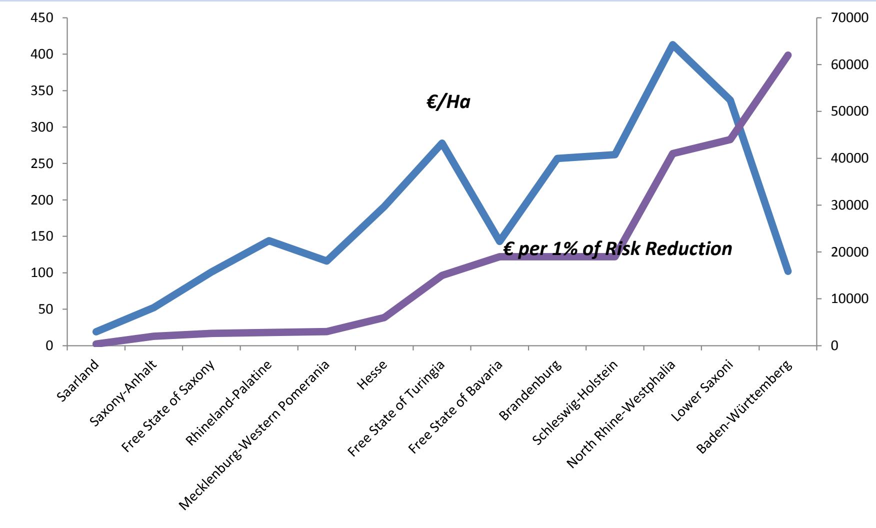
[a] This cost includes product cost, the transportation from the extraction site/production plant (Lazium) to the construction site (Palermo, Sicily) and installation cost.
[b] This cost includes product and installation costs; it doesn't include the transportation from the production plant (Milan, Lombardy) to the construction site (Palermo, Sicily).
[c] This cost includes only the product cost.
[d] This cost has been estimated based on the personal communications of the C.R.A. responsible for the project.

Third, it can be hypothesised that some NWRM costs are site specific and then harder to transfer than those of more conventional water management practices. For instance, with the exception of the land acquisition costs and few other easy to control design parameters, the cost of building a water treatment plant does not vary too much from place to place. Nevertheless the costs of some kinds of NWRM are site dependent and the results obtained in one site are basically uninformative about the effort required to apply the same measure in other places (floodplains and wetland restoration costs are heavily determined by local conditions.

The cost per unit of intervention is not equivalent to the cost per unit of contribution to the objective of water policy and both may vary from place to place

Sieber *et al.* (2010) offers one of the rare studies that allow cost and effectiveness comparisons between measures at different places. As early as in the 1990s, Germany's Advisory Council on the Environment (SRU), along with technical bodies and water management associations, demanded the installation of riparian buffer strips. Wide almost natural riparian strips should be protected against fertiliser and pesticide applications so to be functional as buffer zones protecting water bodies against pollution. The figure below, built with information obtained from the referred source makes clear how unitary prices might change among German landers from few euros up to more than 300 €/hectare and, may be more interesting, unitary costs are not correlated with effectiveness: more expensive buffer strips are not necessarily more effective to reduce pollution or to retain water.

Average cost and cost effectiveness of 3 meters wide buffer strips in Germany



Wetland restoration costs: hard to transfer from site to site

According to Ockenden *et al.* (2012) the establishment costs for the ten analysed field wetlands located in the UK ranged from £280 to £3100 per ton of sediment retained and depended more on site specific factors, such as fencing and gateways on livestock farms, rather than on wetland size or design. Wetlands with lower trapping rates would also have lower maintenance costs, as dredging would be required less frequently.

Table 2 – Total sediment trapped, trapping rates and construction and maintenance costs for each wetland in first two years after construction. Paired ponds are described as shallow (S) or deep (D). Construction costs include excavation, drainage, fencing and vegetation.

Site	No.	Name		Method (2011)	Sediment trapped 2009/2010 ($t\ yr^{-1}$)	Sediment t rapped 2010/2011 ($t\ yr^{-1}$)	Contrib. area (ha)	Trapping rate 2009/2010 ($t\ ha^{-1}\ yr^{-1}$)	Trapping rate 2010/2011 ($t\ ha^{-1}\ yr^{-1}$)	Construct. cost £ €	Maint. cost £ €
Loddington	1	Upper Ponds	Pond 1 (S)	Dry mat	0.6	0.09	10	0.07	0.01	£1200	–
			Pond 2 (S)	Dry mat	0.1	0.02				€1490	–
	2	Paradise	Pond 1 (D)	Wet mat	0.09	0.03	4	0.07	0.02	£1500	–
			Pond 2 (S)	Wet mat	0.2	0.06				€1870	–
	3	Little Owl		Dry mat	0.05	0.06	9	0.01	0.01	£460	–
										€570	
Crake Trees Manor	4	Bill & Ted	Pond 1 (S)	Wet mat	0.2	3	20	0.02	0.2	£1000	–
			Pond 2 (S)	Wet mat	0.2	0.9				€1240	–
	5	William		Wet mat	4	0.2	10	0.4	0.02	£1500	–
										€1870	
	6	India		Survey	Not built	14	50	–	0.3	£2700	–
										€3360	
Whinton Hill	7	Shelduck	Pond 1 (D)	Survey	23	3	30	0.8	0.5	£3100[a]	–
			Pond 2 (S)	Survey	3	11				€3860[a]	–
	8	Yellowhammer		Survey	Not built	16	20	–	0.8	£500	–
										€620	
	9	Gully Trap	Pond 1 (S)	Survey	Not built	5	1.5	–	6	£280	£180
			Pond 2 (S)	Survey		4				€350	€220
Newton Rigg	10	Willow Coppice		N/A	Not built	N/A	1	–	–	£500	–
										€620	

[a] Includes estimate of £1000 (€1240) for fencing, as actual area fenced enclosed much wider area than wetland, at farmer's request.

III. What are the opportunity costs and/or forgone benefits of NWRM?

Many kinds of NWRM are associated with fundamental changes in land use and land-use practices. In essence these measures amount to recovering the natural functions that were passed over in the past (soil formation, infiltration, erosion control, pollutants retention and transformation, etc.). Productivism may lead to the neglect of these functions (in order, for example, to intensify farming, increase urban space, or to channelling as much water as possible to families and businesses) and to the neglect of the ecosystems functions in place.

In many cases implementing a NWRM amounts to reversing these developments with the consequence of deviating farmers, families and business from what they are actually doing or from what they consider their preferred course of action. In these cases NWRM are associated to some relevant opportunity costs. They are, for example, foregone benefits derived from giving room to the river in the floodplains, leaving water and space for intercrop grassland, or leaving the extra yields of applying fertilizers.

These opportunity costs might be significant in size and might be the main barrier for farmers and households to adopt voluntarily the adoption of NWRM even when the installation cost is fully covered by subsidies.

The opportunity cost of changing current practice might be substantial

For instance, Gooday *et al.* (2014) collect the opportunity costs of a series of soil conservation practices in dairy and cereal farms in UK. Similar to the analysis of installation costs, the authors provide information on costs per unit of abatement obtained.

Table 6
Impact of mitigation methods on the dairy and cereal farms, expressed as a percentage reduction in whole farm losses for the different pollutants and expenditure per kg of pollutant saved.

Farm	Scenario	Cost (£)	NO_3-N	P	Sed.	NH_3-N	CH_4	N_2O
Dairy	Baseline Loss (kg ha^{-1})	–	20	1.8	277.8	38.2	186.9	9.9
Cereal		–	28.4	1	645.7	6.8	0	6.8
			(%)	(%)	(%)	(%)	(%)	(%)
Dairy	All mitigation	550	5	3.5	5	0.7	–	2.9
Dairy	Cover crops	430	4.4	0.9	4.2	–	–	–
Dairy	Riparian buffer strips	110	0.1	0.1	0.9	0	–	0
Dairy	Manure & fertiliser integration	0[a]	0.5	2.5	–	0.7	–	2.8
Cereal	All mitigation	3290	4.4	3.2	5.4	1.8	–	1.3
Cereal	Cover crops	1560	4	1.9	2.2	–	–	–
Cereal	Riparian buffer strips	1730	0.4	1.3	3.3	1.8	–	1.3
Cereal	Manure & fertiliser integration	0	–	–	–	–	–	–
			(£ kg^{-1})	(£ kg^{-1})	(£ kg^{-1})	(£ kg^{-1})	(£ kg^{-1})	(£ kg^{-1})
Dairy	All mitigation	–	5	85	0.36	21	–	17
Dairy	Cover crops	–	5	255	0.34	–	–	–
Dairy	Riparian buffer strips	–	69	510	0.41	160	–	220
Dairy	Manure & fertiliser integration	–	[a]	[a]	[a]	[a]	–	[a]
Cereal	All mitigation	–	14	528	0.52	140	–	192
Cereal	Cover crops	–	7	417	0.61	–	–	–
Cereal	Riparian buffer strips	–	84	692	0.46	–	–	–
Cereal	Manure & fertiliser integration	–	–	–	–	–	–	–

[a] This method was assumed to be cost-neutral, so a cost-effectiveness value has not been given.

The opportunity cost of changing current practice might be substantial (1)

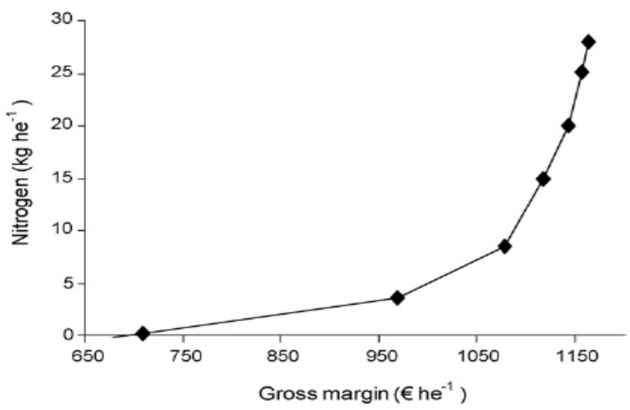


Fig. 4. Efficient frontier income-nitrogen for the land use combinations reported specified in Table 6.

Reductions in the use of fertilizers might have substantial impact over yields and revenues. Borin *et al.* (2010) uses this kind of information to assess the opportunity costs of mitigation practices.

The opportunity cost of changing current practice might be substantial (2)

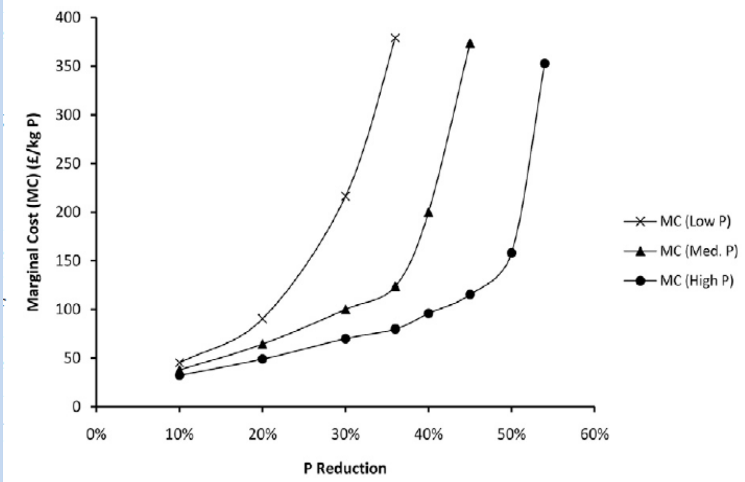


Fig. 4. Marginal abatement cost curves (to achieve a percentage of the mean P loading reduction target) under the low, medium, and high P input scenarios.

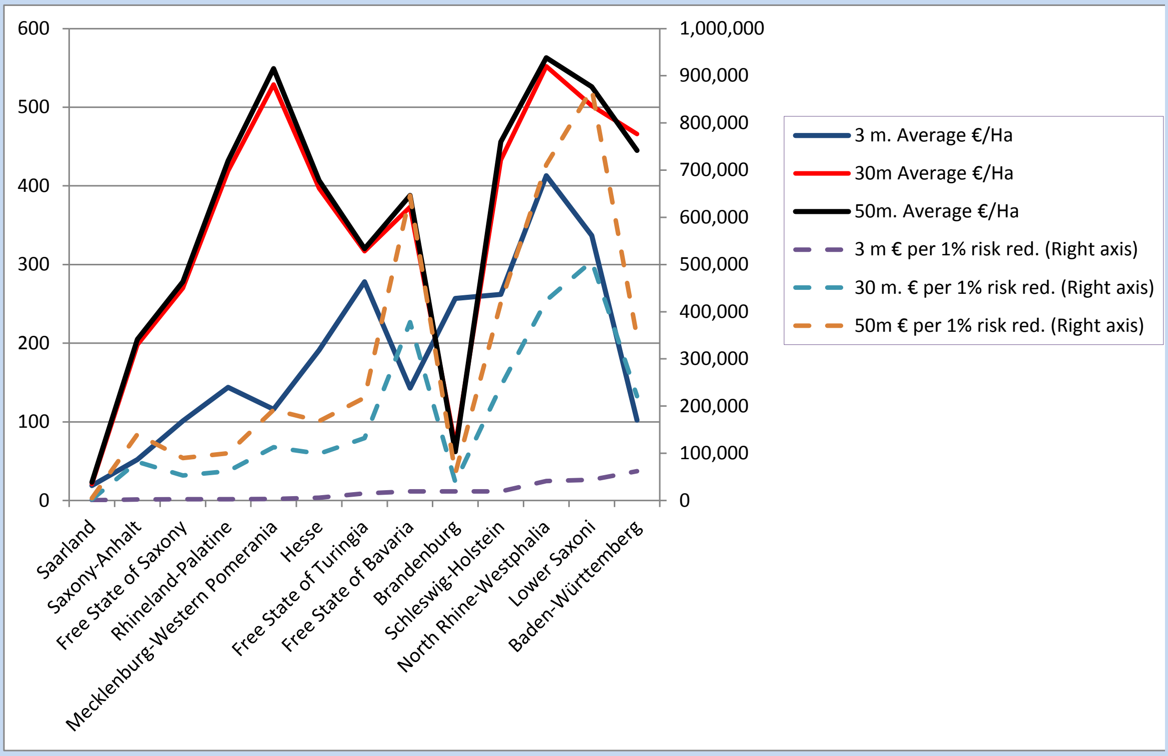
Other authors such as Balana *et al.* (2012) show how rather than constant, unit abatement costs in agriculture marginally increase.

The opportunity costs associated with changes in land use, while little explored so far, might have important effects over the social acceptability of NWRM and might result in local opposition, principally from farmers concerned about the loss of agricultural production and associated tax revenues. Examples from the literature (Bullock *et al.*, 2011) highlight the fact that restoration can generate costs at locations other than that at which the restoration takes place.

[*Note on the following box]

Opportunity costs do not change proportionally with the scale of intervention

Sieber *et al.* (2010) shows that the opportunity cost for bufferstips is strongly correlated to loss of income from the arable land being taken out of production, thi comparison between 3, 30 and 50 meters buffer strips in different Geman Landers illustrates how opportunity costs are largely determined by local conditions.



Source: own elaboration based on data from Sieber *et al*. (2010)

Another issue is that the costs and benefits of restoration should be distributed equitably in relation to the benefits that are provided. This case emphasises the crucial role of property rights and local institutions in shaping the distribution of benefits. Approaches needed to achieve equitability are therefore likely to vary among communities and socio-economic contexts. Analysis of factors influencing distribution of the costs and benefits of restoration, and associated ecosystem services, remains an important research priority.

Opportunity costs are key to understand social perceptions of NWRM

For instance, MacDonald *et al.* (2009) illustrate how the perception of opportunity costs might lead to social reactions against improving forest practices in the UK, besides the evidence against these costs being substantial. Opportunity costs seem to be linked to the need to change practice rather than to reduced yields or incomes. Authors analyse the effects of transformation of even-aged stands to continuous cover forestry in the UK and demonstrates that:

- In terms of the quality (reduction/improvement) of the produced timber no clear effects are foreseen. However variation increase in log sizes and wood properties of the products available on the market is predicted. On the other hand, regular selective thinning techniques expected to be applied to larger diameter individuals would entail in the end interesting wood properties (as concerns for mechanical performance and drying stability).

- Changes required in the mechanized harvesting systems (currently optimized for breast height average diameter of 25-35 cm, but in the future bigger as older trees will be produced) are expected to increment operational costs (Ireland, 2007 in *op. cit.*, 2009) but additional evidence needs to be gathered in this regard.

IV. How do local circumstances affect costs of NWRM?

Local circumstances may affect the costs of implementing the measure, its operation and maintenance costs or the opportunity costs thereby associated. For example, soil conservation practices may be more costly in arid and semiarid lands, water infiltration in less permeable soils, and drainage systems might be more difficult to maintain in areas with more variable rainfall patterns. Factors that affect costs are often the same that shape in turn the effectiveness of the measure and their identification is an important element to assess the cost-effectiveness of the measure.

Apart from equipment, maintenance and operation costs, that are mostly similar from place to place, all other costs depend on local conditions. Energy costs are highly variable, opportunity costs depend on local yields, temperatures, water supply, soil characteristics and many other local characteristics.

Opportunity costs when relevant need to be compared with the private benefits mentioned in the previous section. It is not casual that best examples chosen to present the opportunity costs, or foregone benefits, associated to NWRM are mostly soil conservation and rural sustainable drainage systems. In contrast to that, the most interesting examples of private benefits (or avoided costs) are found in urban NWRM, particularly in urban sustainable drainage systems. Not surprisingly the latter are perceived as promising alternatives while the implementation of the former are still perceived as an important financial and institutional challenge.

Nevertheless, the private benefits of agricultural NWRM might also be important and their recognition may serve to lower the perceived opportunity cost.

NWRM' Costs might be site and specific and are sensitive to design and adaptation to local conditions

For example, soil improvements have positive impacts over yields that can compensate other opportunity costs. For instance: intercropping effectiveness depends on how it affects the water balance. Although perceived as negative to farmers in arid in semiarid areas because of competition for water resources some studies show that improvements in soil structure and water retention can compensate for potential losses and lead even to increased yields and incomes. In an extensive revision of intercropping in Mediterranean Vineyards a number of authors (Battany and Grismer, 2000; Celette *et al.*, 2005; Klik *et al.*, 1998 in Celette *et al.*, 2008) have confirmed that this practice ensures soil water profile replenishment improvement due to the amelioration in water infiltration as a consequence of runoff attenuation (correlated to the soil covered area), specially in the Mediterranean region (suffering from heavy storms, Wassenaar *et al.*, 2005 in *op. cit.*, 2008). Moret *et al.* (2006) in *op. cit.* (2008) found out, in fallow land that cover cropping can improve the small efficiency of rainfall (measured as infiltration/runoff ration) occurring when soil hydraulic conductivity is low (as demonstrated by Jayakrishnan et al., 2005; Mapfumo *et al.*, 2004 in *op. cit.*, 2008). Celette (Celette *et al.*, 2005; 2008) show that the referred soil water profile replenishment improvement under a perennial cover crop was frequently enough to compensate for the subsequent water uptake linked to grass transpiration. Under experimental conditions (in wintertime) up to an 80% supplementary water infiltration of the extra water uptake in the presence of a permanent intercrop was observed.

V. Other relevant information

Both the installation and incremental costs for most NWRM may decrease over time as they become more widespread and become standard practice, to be conservative, this de-escalation cost was not included in the analysis. This is why cost measures rapidly become obsolete.

VI. References

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[i] These incremental costs are also (wrongly) referred as additional or marginal, and they compare only any NWRM with the best available alternative.

[ii] The calculation of the unitary cost must not consider the costs avoided by the whole program of measures (such as the construction of a high capacity storm tank), nor the other costs avoided by the program (such as energy, water treatment, health expenditure, etc.). These avoided costs are in fact benefits that must be taken into account at a more advanced stage (when the cost effectiveness analysis is conducted to get the minimum cost program of for applying a cost benefit methodology.