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Cost-effectiveness of Natural Water Retention Measures

What is the cost-effectiveness 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: Costs, financial costs, avoided costs, ancillary benefits, opportunity costs, cost-effectiveness analysis (CEA), cost-effectiveness indicators, co-benefits, transaction costs.

Please consult the NWRM glossary for more information.

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I. What is the cost-effectiveness of NWRM compared to traditional / structural measures in achieving individual policy objectives?

In implementing the Water Framework Directive (WFD) and the sister directives on water management cost-effectiveness analysis (CEA) is an essential methodology to combine the information about the costs, benefits and effectiveness of the different options available so as to support identifying the least cost Programme of Measures (PoMs) to reach a particular and well defined goal such as the good ecological status, the reduction of flood peaks or the vulnerability to droughts.

Nowadays the importance of cost-effectiveness analysis for integrated water resource management can be hardly underestimated. When properly applied the CEA integrates all the relevant information about the benefits (see Synthesis document 4), the costs (see Synthesis document 5) and the contribution to the objectives of water policy (see Synthesis document 2) of all the options available and conveys it in a comprehensive way in order to support stakeholders and authorities to identify the best combination of measures. The method performs as good as the analysts' ability to synthetizing and conveying the advantages and disadvantages of the options available in a concise and a transparent way. Traditional alternatives and NWRM differ in some substantial aspects that at the end may bias the comparison in favor of the first kind of measures.

While grey infrastructures are engineered solutions specialized in a single purpose whether it is channeling, storing, purifying, applying water, etc. NWRM belong to a class of ecosystem-based approaches that contribute to multiple purposes at the same time. NWRM are good for many purposes at the same time. For instance removing pollutants from soils and water but only in that respect, they could be compared for example with a water treatment plants. They serve to store water but probably not as fast or by the same amount as a half empty big dam. They might serve to recharge a depleted aquifer but at a slower pace than an injection pump. What is special of NWRM is that they may improve water quality, slow water down and recharge groundwater all at the same time. In addition to that, NWRM are also good for adaptation to climate change, to avoid different costs (e.g. energy costs and costs for water purification), to improve biodiversity and other advantages that are unlikely to be claimed as per wastewater treatment plants, dams or water injection pumps. For this reason the real potential of NWRM can only be appreciated if these multiple benefits are taken into account.

Two basic drawbacks may make NWRM look less attractive than they really are. The first one consists in limiting the analysis to a single purpose/effect, such as reducing peak flows, providing a target water storage capacity, recharging an aquifer, etc. This limitation may lead to ignore the multiple co-benefits of the NWRM. The second one arises when only those costs that are measurable in an undisputable way are considered; this is what happens when only financial costs (usually capital, operation and maintenance expenses) are used for the comparison.

Some NWRM rank first even when compared with unfair methods and incomplete information

Financial costs and a single purpose could be enough to justify the adoption of many NWRM and strategies. The village of Belford, downstream, had a history of flooding, but the cost of conventional flood defence improvements had been judged not to be cost effective, at around €3M. In contrast, upstream NWRM were estimated to deliver the same level of flood protection at a cost less than €0.25M. This make this the best alternative without the need to mention that besides providing the same size flood protection, NWRM do not have negative impacts over the village, reduce sediment loads and improve substantially water quality.

There is therefore a pressing need for better knowledge about the multiple benefits generated by NWRM and their values, and this can only be achieved through the improvement of current assessment and valuation techniques – and also by building consensus on such methods. Measuring those benefits has repeatedly proven to be a challenging task, and there is a need for a better knowledge about multiple benefits and their values. As observed during the Mediterranean workshop, currently evidence on effectiveness mostly refers to design conditions; thus NWRM contributions to multiple water policy objectives are rarely assessed.

The claimed co-benefits that can be obtained in exchange of a single cost are difficult to measure in an indisputable way with available methods and data. These co-benefits include, such as flood risk reduction, water quality improvement, biodiversity, carbon storage, amenities, increased possibilities for recreational activities and resilience to uncertain future supply of water.

What makes a NWRM special is not the ends pursued but the means used

Were it only for the cost of having more water underground the sustainable recharge will always be deemed as non-effective. This is about the same question asked in some small villages in Salamanca (Spain), where some LAST (*Land Application System* with a forest Mass) methods were adopted: Would recharge an aquifer with treated wastewater at a cost of 1 €/m3 be a good option in an agricultural area where water productivity averages only 0.2 €/m3?

The answer is yes provided the sustainable recharge comes along with some measurable co-benefits. In fact, besides restoration of natural infiltration to groundwater, it obtains savings in wastewater treatment (0.30-0.60 €/m3), wood production (0.04 to 0.10 €/m3), carbon sequestration (6.3 tons/ha) and other benefits such as landscape, and other recreation amenities.

Nevertheless these benefits are context and site specific. For example, benefits are lower in southern Spain where evapotranspiration is higher due to higher temperatures (see Sanz *et al.*, 2014 and Ortuño *et al.*, 2011).

The answer might also be yes even if water is treated and injected directly in the aquifer: In that case the answer will lie in the unique character of the method.

Building a strong evidence base on NWRM performance and, especially, on their cost-effectiveness, is perceived as a crucial step to induce a change in the policy processes and in public awareness. The ideal cost effectiveness indicators are generally easier to build for traditional measures than for NWRM. The two components of this indicator are problematic when implemented for ecosystem- based measures.

On the side of costs the ideal measure to be used in the selection of the more beneficial set of measures must include the overall cost, net of co-benefits. That is to say the combination of two elements: on one side the addition of the (incremental) financial cost plus the opportunity costs and the subtraction of the (financial) avoided costs plus the co-benefits (direct and indirect) that arises from implementing the measure. In other words to convey all the relevant information any cost effectiveness index must convey information of all the cost of the measure net of those benefits that are exclusive from the measure being considered.

Certainly this comprehensive cost account is a challenging task for any water management measure, but it can be hypothesized that this is harder for NWRM than for better-established alternatives. The reason lies in the multiple avoided costs, which eventually can be assessed, and monetised at market prices, but also in the series of ancillary benefits and positive externalities that can't be monetized by using robust, uncontroversial and easy to communicate valuation methods. As far as avoided costs and multiple ancillary benefits are distinctive of NWRM, the overall costs for the measures are less precise and more demanding than that of traditional measures. On the side of effectiveness any indicator must cope with the challenge of dealing with the multiple effects (or contributions to the purposes of water policy) associated to a NWRM. Thus the measure of effectiveness will be more precise as more specialised the measure considered.

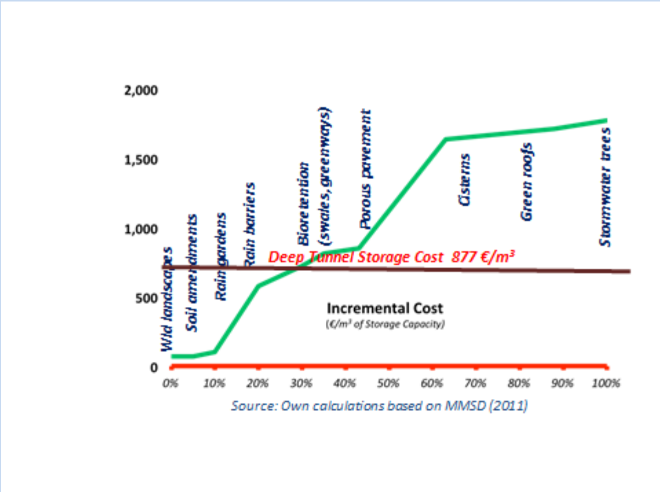
All this has a practical consequence for water management. NWRM might appear to be more expensive than "traditional" measures. But this may be due to the lack of knowledge on their effectiveness as well as the neglect of their intangible benefits. Failure to take these multiple effects and benefits into account may be one of the strongest impediments to widespread implementation. Proving the cost-effectiveness of NWRM in achieving not only multiple water policy objectives, but other policy objectives too, is thus key to raise public awareness and boost NWRM implementation.

Of course, for many relevant water challenges, there are some nature-based measures that might be more cost effective. These advantages appeared first in some areas such as storm water, where financial advantages are more evident, and extended gradually to other fields, such as flood management. Then, the knowledge about costs and benefits improved gradually. In the future improved knowledge combined with social awareness and policy support must result in a more extensive implementation of NWRM (to more fields and towards meeting more water policy challenges), but also to a more intensive use of these measures in the areas where they have already been considered. In other words, NWRM must not be implemented only in these situations where advantages, mostly financial, are self-evident and the bid in favour of nature-based approaches must go farther than picking the low hanging fruits.

As shown in the example of the box there are some alternatives for urban water storm management that are more (financially) cost-effective than traditional deep water storage. Nevertheless, they are not the kind of measures that could be extensively applied in the artificial soils that are prevalent in urban landscapes: like native landscaping, soil amendments and rain gardens. In other words, were it for pure financial reasons NWRM will be limited to marginal and then complementary measures.

In any case, the comparison is unfair and a completely different result would arise if the external costs of the deep tunnel storage were taken into account. The horizontal line in the figure would then move upwards, and the avoided externalities implied by the direct and ancillary benefits, or positive externalities, other than storing water would be considered. All the net costs of the NWRM would then be lowered.

Traditional cost-effectiveness analysis consider only one impact and anly financial costs. Even in this limited framework some NWRM rank in the first places.



But this is just as picking the low hanging fruits. NWRM are even more attractive than they appear at first glance. Even in this comparison of a set of SUDS (MMSD, 2013), the cost of the green infrastructure is underestimated (as the externalities of the deep tunnel storage are not accounted for), the cost avoided by the green infrastructures are ignored (savings in water treatment, reductions in energy consumption in households, etc.), as are the co-benefits (increase in property values, reduced pollutant loads, groundwater recharge, improved air quality, etc.). The comparison in the graph is incomplete and misleading because it considers only one effect (captured storm water run-off) and one benefit (reduced infrastructure cost). All other costs and benefits are basically ignored.

Another important reason to push the implementation of NWRM comes from the need to avoid the risk of going too far with conventional measures. As shown in the box above, NWRM may emerge as the best alternative, even considering only the financial costs and its effectiveness on a single criteria. This is more frequent in situations when all other alternatives available have been exhausted so that the marginal cost of obtaining further improvements by using conventional means is high enough, or the size of the challenge is sufficiently high due to the detrimental impacts of past water developments. This may be the case of situations where existing flood risk is in part due to the severe changes made in river hydro-morphology, or when extreme water scarcity is the result of excessive water use and freshwater canalisation. This might be the case of some river restoration measures to control floods and even to natural groundwater recharge[1].

This exemption serves only to confirm the overall rule: when considered against a single criterion and assessed only by observable costs, NWRM appear as costly and low effective options for water management. Although this is the prevalent evaluation methodology, it is inadequate to assess nature-based alternatives (NWRM amongst them).

Despite these uncertainties (ecosystem benefits are often unknown or imprecise), and although few analyses of the cost-effectiveness of ecological restoration have been undertaken to date, evidence

[1] In overexploited coastal aquifers controlling seawater intrusion might have yet became the main benefice of groundwater recharge (Koussis *et al.*, 2010).

suggests that restoration can be cost-effective, at least when relatively low-cost methods are used (see Bullock *et al.*, 2011).

II. What is the cost-effectiveness of NWRM with regards to their multiple objectives?

CE indicators are normally unit cost measures that combine standardized costs (normally in annual equivalent costs) with effectiveness indicators (or the contribution to a predetermined target: e.g. percentage points of reduction in peak floods, increase in water stored, reduction in nutrient concentration per litre…). By force these indicators refer to a single objective.

Traditional measures (like water saving devices or wastewater treatment plants) are specialised actions designed to attain a single water objective (e.g. to increase runoff or to reduce nutrient loads) and can be ranked by using a single CE indicator. Moreover, NWRM often contribute to many different objectives at the same time and therefore require to be characterized by different CE analysis, one per each objective. Rural SuDS contribute to reduce floods, soil formation, and carbon fixation, diffuse pollution control, and reduce erosion, among other objectives. For each of these objectives there is another traditional measure that may be more effective: fertilizers may replace the additional soil and some crops might be equally effective and much less expensive to fix the same amount of carbon.

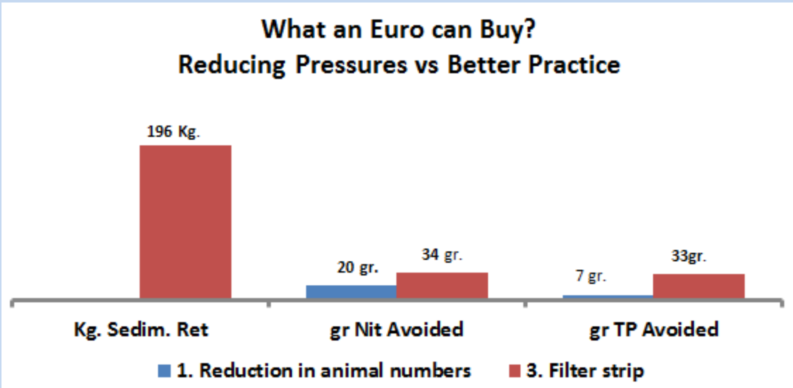
Yet, serving many objectives at the same time is one (if not the most) distinctive feature of NWRM. Whilst a single cost-effective indicator may in general characterize traditional measures, NWRM can only be characterized by a set of cost-effective indicators.

A practical alternative to complete the limited information delivered by cost-effectiveness analysis, in particular where multiple objectives are reached at the same time consist in complementing the analysis with the opposite indicator as the one used by cost-effectiveness analysis. In addition to identify at what cost a particular target can be reached (a cost-effectiveness indicator), it is possible to gather information about what can be obtained by one euro invested in a particular measure (the value for money). While the first indicator may favour conventional single-purpose measures, the second will shed light on information about multiple benefits.

Making visible the Natural Water Retention Measures' face value

When cost-effectiveness indicators risk conveying limited information and may lead to biased comparisons in favor of single-purpose measures, it is advisable to present what we can get from an Euro invested in NWRM instead of in a traditional alternative.

Filter strips may look at a first glance as more expensive and less effective to reduce pollution than reducing herd size. Moreover, Panagopoulos *et al.* (2011), shows that one euro invested in filter strips may allow a higher reduction in nitrate and phosphorus in soils that investing the same money in reducing animal numbers and additionally it may retain substantial amounts of sediments.



Source: Own elaboration based on data from Panagopoulos *et al.* (2011)

For example, the use of NWRM in sustainable urban drainage systems are only feasible when using many actions not just the least expensive ones, because achieving the objectives of the WFD and the sister Directives require a portfolio of NWRM that can address unique site conditions for buildings, streets, parking lots, and turf grass areas. This implies that cost-effectiveness comparisons among a portfolio of many, green and grey, measures on a one by one basis may be misleading. What needs to be compared is a combination of two broad packages of measures: one including NWRM and the other with more conventional alternatives. If both packages are assessed independently following cost-effectiveness criteria then the optimal combination can be identified by considering the overall costs and benefits. This is for example how the New York Green Infrastructure Plan was developed.

What needs to be cost-effective is the overall package of measures not any individual option

As showed in MMSD (2013) based on the MMSD (Milwaukee Metropolitan Sewerage District) Regional Green Roof Initiative incentive plan, green roofs are remarkable higher than other green measures in terms of incremental cost per area managed (square foot), due to the fact that they normally only capture direct rainfall on them. Actual costs of this measure are generally as a minimum 4 or more times higher than other green infrastructure measures. Despite of this, green roofs can be the only feasible option in certain contexts (e.g. with space limitation). In general terms, green roofs might become cost-effective provided there is a network of individual initiatives and all them are integrated in a green infrastructure strategy along with many other measures.

The multiple benefits of Soil Conservation practices in Europe

Panagopoulos *et al.* (2011) examined the impact of soil conservation practices on river loads (at the outlet) concluding with the estimate of 20 tn or 8% annual decrease of TP (Total Phosphorus) from the baseline. Filter strips in corn fields diminished annual sediment loss by 66 Ktn or 5%, NO_3–N (nitrates–nitrogen) by 71 tn or 9.5% and TP by 27 tn or 10%, entailing an additional cost of 3.1 €/tn, 3.3 €/kg and 8.1 €/kg of each pollutant respectively. An additional finding emerging from the study is that when bringing together specific implementation strategies at local scales (in small areas of the catchment), and thus at reduced total cost, remarkable diminutions of some pollutants can be simultaneously obtained as well. This is especially interesting for policy makers for factoring in local socio-economic issues.

Soane *et al.* (2012) might have made the same point regarding no tillage as a mean to retain water, soil and nutrients in southwestern Europe. In their literature review, the authors find out that this practice (widely extended in this part of Europe) is effective for reducing phosphorus losses due to runoff and, in certain cases, nitrate loss by leaching.

Making fair comparisons require adapting the methodologies to the differences between NWRM and conventional alternatives

To account for the environmental benefits of green roofs, Niu *et al.* (2010) propose obtaining a net present value (NPV) based on a 40-yr lifetime of green roofs, or one replacement of conventional roofs. By means of the application of a NPV analysis it is possible **to assess** if (and if so when) **the premium cost of a green roof system breaks even with that of a conventional roof system**. On the basis of this assumption on their lifetimes, the authors estimated and compared the benefits of installing a green roof and a conventional one (in a building with a roof area of 1795 m2**)** and found out remarkable differences in terms of their installation cost (green roof was 27% higher: 550598 US$ against 434731 US$) and also in their NPV (25 % lower in the case of the green roof).

III. Other relevant information

Cost-effectiveness depends on the extent to which engineered methods have been used in the past. Once the common alternatives to increase water supply have been exhausted, it is not unlikely that NWRM sprang as a preferable alternative. This may be the case of using natural means for groundwater recharge (such as river flow increases, rain capture or soil conservation practices in irrigation plots) rather that non-natural means for groundwater recharge such as the injection of regenerated or desalinated water (see Jha *et al.*, 2009 for a specific case study in Japan).

Cost-effectiveness depends on local conditions

Soane *et al.* (2012) illustrate how the same agricultural practice can be cost-effective according to the specific context where it is implemented. For example, ploughing is a very common and widely applied practice in certain areas in northern Europe characterized by high soil moisture thus contributing to improve their drainage and structure (less compaction) and topsoil aeration. In general terms this practice is naturally applied in this geographic area provided that economic incentives promoting other practices (e.g. no-till) are not more worthy.

Opposite to this, in the southwest of Europe ploughing (for winter-sown cultures) is a practice increasingly falling into disuse against the more and more encouraged no-tillage approach. The context promoting this tendency in the Mediterranean countries is different with a number of factors playing a key role: environmental (no-till is perceived to be a less "harmful" technique improving water an soil conservation) and economic (no-tillage seems to be producing same or higher yield than the conventional techniques apart from being cost-saving) among others.

Far away from these extreme situations, in general terms the adoption of one of the referred techniques in Europe is dependent on different (and specific according to the context) factors, such as for example: environmental (surface residues management, herbicides use and weed control practices…), economic (agricultural inputs costs), and legal, institutional, counseling and financial supporting framework.

Transaction costs might be important. As shown in the examples below it is relatively straightforward to obtain and communicate the evidence of multiple benefits of many kinds of NWRM. Nevertheless there are also disadvantages that in many cases arise to some agents that are called to play a critical role in implementing the measure, Besides some opportunity cost (as the higher cost of pumping water from the ground instead of a stream), there might be some risks associated (as the likely decrease in water quality) or the implementation of the measure which may require adapting more complex practices with the consequent resistance of critical actors.

Taking advantage of existing opportunities may imply substantial transaction costs

Zekri et al (2014) illustrate how a measure such as aquifer recharge can be considered an opportunity (especially in areas with hot and dry climate) due to its advantages, for example, in terms of water availability and security ("safe" water storage with few evaporation losses). However, as a consequence of some of its disadvantages, high transaction costs can be derived: the need of a sound legal framework (for protecting recharge areas and the aquifer, quality, management, allocation…), high-energy consumption requirements (pumping costs), quite complex associated operation and maintenance requirements and high risk of quality degradation due to the vulnerability of the aquifer.

Besides, it should be pointed out the need to take properly into account solid estimates on the financial cost (capital, operation and maintenance of aquifer recharge) of this measure in order to obtain insightful comparisons with other NWRM (see Synthesis Document 5 for further details).

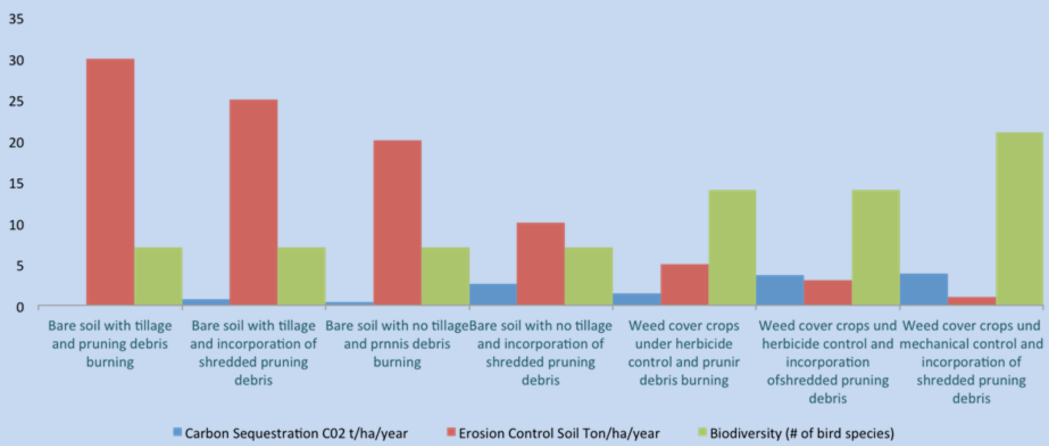
Cost and Effectiveness depend on smart design

Design adapted to local conditions may be key to determine the cost-effectiveness of many measures. As pointed out by Kulak *et al.* (2013) there are a number of factors affecting eco-efficiency of cropping systems that can be taken into account and modified directly or indirectly to achieve the same goal. For example, the direct application of optimum external input rates can be compensated by other means such as making the most of positive synergies between crops (for example, for minimising inputs waste such as nutrients and water), local organic waste use or increasing yields by applying sustainability criteria after verifying their appropriateness for the specific context where they are going to be applied (diversity enhancement, tillage/intercropping techniques, breeding…).

What we now define as NWRM are nature-based restoration alternatives that have been studied and developed long time before water management and policy focused their attention on them. Some of them were proposed as suitable alternatives to enhance the potential of modified landscapes to support birds and other species, others (eventually the same as shown in the following box) were independently assessed as suitable options to manage sediments and control erosion and many of them have been proposed as valid carbon sequestration alternatives. In this sense the water community is a newcomer to the world of nature-based approaches. But water retention is not just one of the many possible benefits these kinds of measures can deliver. Different than birds support, sediments retention or carbon sequestration, that are some of the services a healthy ecosystem can provide, water is an essential component of these ecosystems and none of these services could be delivered without water retention. In other words NWRM are class conservation practices based upon making water work to restore different ecosystems functions and make possible the delivery of multiple ecosystems services such as: climate change mitigation, sediment regulation, biodiversity protection, water quality control, etc. Nevertheless the history of how these measures came into the policy arena (first to other fields and last to the water sector), explain why some of these effects are better known than the water retention potential. As in the case of SuDS is Southern Spain the precise effects over water of most of the NWRM are still imperfectly known and this impairs the possibility of building reliable cost-effectiveness indicators able to inform water management decisions.

It is possible to know many relevant effects of NWRM but not how much water they allow to retain

Soil conservation practices in southern Spain have been studied for its contribution to sequester carbon (Nieto *et al.*, 2010; Smith *et al.*, 2008; Sofo *et al.*, 2005; IPCC, 2003), to retain sediments (Gómez *et al.*, 2009 and Francia-Martínez *et al.*, 2006) and for its effect to increase birds diversity (Duarte *et al.*, 2010; De la Concha *et al.*, 2007; Muñoz-Cobo *et al.*, 2003). All this information has been compiled and compared by Rodríguez-Entrena *et al.* (2014) and represented in the figure below. Nevertheless the existing literature is uninformative about the effect of each of the measures over water balances.



Source: own elaboration based on the above-mentioned references.

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