COST Action CA15206 “Payments for Ecosystem Services (Forests for Water)” PESFOR - W

Short Term Scientific Mission 38953: “Approaches to quantify the cost-effectiveness of Forest for Water PES”

Final Scientific Report

STSM beneficiary: Cristian Accastello, PhD student
Home institution: University of Torino, Italy

STSM tutor: Serge Garcia, Senior researcher INRA, Deputy director of BETA (Bureau for Economic Theory and Applications)
Host institution: INRA Nancy, France

Date: 09/04/2018

Summary

Introduction on Water PES

In Europe, the economic and industrial development occurred in the last century has inevitably caused some environmental drawbacks on the quality and presence of forests, air and water bodies. In the last decades, the European Union tried to improve the quality of its environment by promoting several directives aimed at preserving pristine environments, as the Natura 2000 network; or improve the degraded ones, as the Water Framework Directive (WFD). The environmental objectives set by the WFD in 2000, were, for the first time, complemented by specific requests of adoption of the principle of cost-effectiveness (from now on, C-Eff) for their achievement (EC-WATECO 2003; Kallis and Butler 2001). Its actual application can be deployed evaluating the environmental and economic impact of the different measures that could be applied. The most common schemes adopted to achieve the goals set by the Directive in highly developed and intensively cultivated areas of Europe, were top-down measures of water quality-improving activities. Nonetheless, it is well known how these, sometimes, could be effectively substituted by more participatory and bottom-up approaches: the establishment of a Payment for Environmental Services (PES) scheme (Brouwer et al. 2011) can represent a suitable, but still rare, example of this strategy. Such projects are still considered innovative despite the growing literature on the topic (Stefanie Engel 2016). Their design is quite complex and multifaceted and not all elements characterising PES schemes and influencing their effectiveness are neither recognised nor well understood.

The Short Term Scientific Mission "Approaches to quantify the cost-effectiveness of forest for Water PES" held at the BETA (Bureau for Economic Theory and Applications) of Nancy, France from the 05/02/2018 to the 10/03/2018, tried to provide a state of the art on the elements affecting the C-Eff of the PES scheme and develop a framework to be applied for its improvement. According to the objectives of the mission, the achievement of these goals would support bridging the gap between the different actors involved in the design and implementation of a PES, developing an operational tool to analyse and improve the performance of the ongoing schemes and provide factual recommendations to all the actors involved in the process.

The reminder of the report is structured in two main sections. First, the methodology adopted for the literature review of previous experiences on quantifying the C-Eff of PES scheme is explained, followed by the description of the results achieved. Then, in consideration of the findings of the review, an operational framework has been developed and its structure and components are described. Finally, some conclusions are drawn in consideration of the aims of the STSM and the results obtained.

Bibliographic review

Methods

The bibliographic review focused on publications, in various forms, that analyse the existing PES schemes to provide insights and data about their effectiveness in the achievement of the set objectives. At the same time, aiming to include also the findings gained from other measures of water quality enhancement and fulfilment of the WFD (Water Framework Directive) requirements, also non-PES experiences were considered in this review. The research was performed with the most common scientific database, as Web Of Science, CAB, Scopus and Google Scholar employing the keywords: "PES" "cost-effectiveness" "Effectiveness" "transaction costs" "Water Framework Directive" "water quality" "PES schemes" "PES design" alone and matched with the proper Boolean operators. Only records in English and published in peer-reviewed journals were considered in the review. Even if studies considering experiences of Water PES or Water ES improvement realized in the Countries involved in the Cost Action were preferred, also examples coming from other areas of the world are included, when relevant. Moreover, the works previously collected from the members of the WG3 of the Action were included as well.

Collected information

From each paper complying with the criteria of the literature review were collected the following information. First, general data about authorship, journal, title, year and typology of publication. Then, other core information about the subject of the work were registered, noting, when possible, the Environmental Service (hereafter ES) provided by the scheme, its, geographical scale, the form of payment, the users and the providers of the ES. Finally, concerning the C-Eff itself, the information collected were mainly related to the methodology adopted for its assessment, the presence of alternative measures to be compared and the approaches adopted to minimize costs or to maximize the environmental effectiveness of the activities of the PES. Similarly, when dealing with works that were not analysing actual schemes but rather providing theoretical findings, the methodological aspects where considered, listing the elements and the approaches suggested as useful for the purpose of the review and resuming their pros and cons. This review does not expect to be exhaustive on all the experiences published on the topic, but rather to collect the most relevant and draw from them some operational insight to quantify, and improve, the cost-effectiveness of PES schemes.

Results of the bibliographic review

Cost-effectiveness definition

The review collected 51 papers dealing with the cost-effectiveness and the approaches to its quantification and improvement. Before describing their features, it is important to notice how all the works agreed, with minimal variations on the definition of C-Eff, that can be calculated "*by dividing the budget of each measure by the total goal level provided by the respective measure. The lower the budget costs per index, the higher the cost-effectiveness of the program or the single measures*", modified from Uthes et al. (2010). Accordingly, the C-Eff was measured applying the ratio reported in eq. 1, modified from Valatin and Price (2014).

$$C_{eff} = \frac{C_i}{E_i}$$

In the equation C_{eff} defines the cost-effectiveness of the measure; C_i the cost of the proposed measure and E_i the environmental benefits achieved with the measure. In the C_i should be accounted the implementation cost of an environmental measures, as PES schemes are, and also the transaction costs and the opportunity cost bear by the ES providers, that are equal to the forgone revenues of alternative land uses. Therefore, it is evident how the numerator of the ratio could not assume negative values or zero values, since even when implementation cost would be absent (e.g., simply stopping a damaging activity), the opportunity costs would still make C_i assuming positive values. On the other side, when the environmental benefits of a new strategy are lower than their initial level, the ratio would assume a negative value, highlighting the low C-Eff of the same. The ratio is suitable for being compared for different possible measures aimed to improve the same environmental benefit, including the initial situation, in order to define the most C-Eff one.

Only in two cases, a different methodology for the C-Eff quantification is adopted. Particularly, in the works by Valatin and Price (2014) and Nijnik et al. (2013) the following ratio is proposed (eq.2),:

$$C_{eff} = \frac{C_1 - C_0}{E_1 - E_0}$$

Where C_{eff} defines the C-Eff of the measure; C_1 the cost after implementing the proposed measure, C_0 the cost of the initial situation; E_1 the environmental benefits achieved with the measure and E_0 the environmental benefits ensured by the initial situation. In comparison with the eq.1, this ratio more explicitly highlights the gains achieved adopting an additional measure in comparison to the initial

situation, while in eq.1 a causal relation between the environmental benefits achieved and the proposed measure was not obvious. Nonetheless, some ambiguities remain even with eq.2, particularly concerning the meaning of the ratio in case of negative values. The numerator, in fact, could theoretically assume values lower than zero in cases when, e.g. a damaging and costly activity is stopped in favor of a cheaper and less pollutant one, leaving some uncertainties on its interpretation. On the other hand, possible negative values of the denominator would not be such problematic, since it is reasonably possible that a new strategy can fail and result in lower environmental benefits than the initial situation. However, C_{eff} is not defined if $\mathrm{E}_1 = \mathrm{E}_0$, i.e. there is no environmental effect of the measure.

One of the two versions of the ratio is adopted, implicitly or explicitly, by all the works dealing with the quantification of the C-Eff of an ongoing PES scheme. Since all of them also proposed alternative measures to improve the ratio, most of the times, the computation of the C-Eff was coupled with an optimization model. These models, in relation to the aim of the papers, allowed to minimize the budget for a given level of benefits, or, on the other side, maximize the environmental results within a given amount of money available (Barton et al. 2009; Chen et al. 2010; Gauvin et al. 2010; Wu and Yu 2017). The results of these two approaches were then compared to find the most cost-effective measure.

Thus, the C-Eff represents the link between the environmental and the economic aspects of a PES: optimizing this relationship would mean ensure the success of the PES schemes itself. Few works integrated the C-Eff assessment with qualitative information from surveys with stakeholders to rank the alternative measures, but this methodology was considered of marginal interest for the aims of the STSM.

PES related works

Concerning the collected papers, due to their different approaches, they were divided in three categories, believed to be appropriated to highlight their most important features. Particularly, they are:

1. Papers assessing the C-Eff of single PES schemes;
2. Papers quantifying the C-Eff of other, non-PES, environmental measures;
3. Studies analysing the C-Eff issue from a theoretical perspective.

The works included in each of these categories are now described in their similarities and differences.

First, papers assessing the C-Eff of single PES schemes, often propose alternative measures to improve it: only 11 works were found compliant with the requisites of this section (see Database attached). Generally, they analyse the characteristics of an ongoing PES schemes trying to develop alternative, more cost-effective management strategies. Concerning the studied schemes, in 10 out of 11 papers are compliant

with the “broad” definition of PES proposed by Wunder (2015), that includes all voluntary transactions between users and providers in relation to an agreed natural resource management, while only one was a “strict” PES voluntarily settled between private actors for a well-defined service (Kolinjivadi et al. 2015). Similarly, in all schemes except the “strict” one, the ES providers were farmers, and the user was the State paying for agro-environmental payment programs. Influenced by this structure, in most of the cases the geographical scale of the scheme was regional or national, while only in two cases the enrolled area was lower than 100 hectares (Chen et al. 2010; Claassen et al. 2008). The provided ES was mainly biodiversity conservation or a bundle of ES (eight schemes) and the reward to providers was monetary, occasionally integrated with technical support (Barton et al. 2009). The location of the analysed schemes is equally distributed in different continents: Europe, Asia and Central and South America have three schemes each, while two areas located in North America. The papers describing these schemes were all published in the last 12 years, with a peak of three works in 2010. No precise temporal information concerning the expected duration of the scheme were usually given in the works, implicitly considering its development indefinite, maintaining the current favourable conditions.

From the methodological point of view, some aspects should be highlighted. All the papers included in the review assessed the C-Eff of the PES scheme, which currently tend to adopt uniform and activity-based payments. This strategy can be considered influenced by a vast area managed by each scheme, since other payment methods based on individual-specific payments would significantly increase the amount of work needed to determine the payment of each provider. Nonetheless, in nine papers the current strategy is compared with alternative ones trying to improve the C-Eff of the scheme by focusing on the costs of the measure or on its environmental benefits. Concerning the former, all the nine works proposed the introduction of payments targeted on the benefits provided by the single farmer, better rewarding those supplying the highest ES level. In all cases but one (Matzdorf and Lorenz 2010), the effects of this approach were compared with the opportunity cost targeting, where the amount of the rewards are based on the forgone revenues from alternative, more profitable, land uses. A third approach, considered in only two works, is risk targeting: here the payments were higher for the farmers exposed to higher risks, usually poverty or land degradation (Gauvin et al. 2010; Narloch et al. 2011). On the other hand, the proposed approaches to maximize the environmental benefits were less considered in the reviewed papers. In most of the cases (eight works) an index to summarize the achieved benefits was developed: this happened mainly in the works that proposed payments targeted on ES provision, since its reliable assessment is fundamental to fairly distribute the payments (Tobias Wunscher et al. 2006). Finally, few works focused on the concept of additionality, i.e. the increment of ES delivered in consequence of the implementation of the PES scheme, aiming to increase the environmental benefits provided by each farmer in consideration of the set baseline level (Uthes et al. 2010).

Non-PES related works

The second category of reviewed articles deals with the evaluation of the C-Eff of environmental measures not involved in a PES scheme. These experiences were considered to be relevant to our scopes mainly from a methodological perspective, since the techniques adopted to evaluate the economic results of these measures are suitable for being applied on PES schemes too. Therefore, 10 works were collected on this topic. Differently from the previous category, here, all of them were referred to developed countries (eight in Europe, two in North America), on a smaller (NUTS3) geographical scale and most of them concerned stream restoration experiences, tree plantations or the management of protected areas. The ES provided were, consequently, quite different from the PES schemes previously analysed: in six cases the focus was on water quality, in one water quantity (Girard et al. 2015), in two carbon sequestration (Nijnik et al. 2013) and only in one case biodiversity (Hily et al. 2015). Concerning the methodologies applied to quantify the C-Eff, all these works, published between 2013 and 2017, focused more on the environmental aspects than the economic one, proposing a wide range of alternative measure to maximize the level of ES of interest and comparing the costs necessary to achieve it (Roley et al. 2016; Schöttker and Wätzold 2017). Often, specific models able to match environmental and economic data were adopted or developed to predict the consequences of the implementation of a measure (Hérivaux et al. 2013; Lescot et al. 2013; Martin-Ortega et al. 2015). From the economic side, in some cases lacks in the analysis resulted evident, e.g. limiting the estimation to the implementation cost without considering the opportunity cost of the areas involved in the measure (Girard et al. 2015; Honey-Roses et al. 2013; Lescot et al. 2013). Another distinction with the works on the PES schemes is related to stakeholders' involvement. While for PES scheme their inclusion in the program, and often in the decision process too, is fundamental to achieve relevant results; here this was rarely acknowledged, and the evaluation of their willingness to adopt the proposed measures not investigated.

Theoretical works

The last category of papers is constituted by those who analysed the issue from a theoretical point of view: no direct quantification of the C-Eff was performed, but rather the elements that influence it the most were listed and studied. Naturally, this approach was reflected in the structure of the works as well: of the 30 works collected, the 37% was reviewing ongoing PES scheme in order to draw some insights from their features and results; 23% were books, mainly dealing with PES design and implementation (Stefanie Engel 2016; Mayrand and Paquin 2004; OECD 2010). Another 23% is composed by papers proposing a framework to be applied for the C-Eff assessment (de Lima et al. 2017; Gomez-Baggethun and Muradian 2015; Hejnowicz et al. 2014; Muradian et al. 2010), 10% proposed theoretical models (Drechsler 2011; Lundberg et al. 2018; Persson and Alpizar 2013) and 7% performed a meta-analysis of previous works (Brouwer et al. 2011; Gios and Rizio 2013). In most of them, whose publication is steadily spread across the last 15 years,

the C-Eff is rarely the main topic of the publication, but it is mentioned in each work as a reliable approach to evaluate the performances of PES schemes.

Consequently, the different approaches proposed were analysed and grouped in order to ease their comprehension. In some work the C-Eff is considered only an ancillary issue in the overall PES design, so the topic is often considered from a "negative" perspective, highlighting the lacks of the current PES schemes in measuring it and listing the main causes of it (Ansell et al. 2016; S. Engel et al. 2008; Kurkalova 2015; Naeem et al. 2015; Wunder 2007; Wunder et al. 2008). Namely, these include unclear baseline setting, lack of data on environmental benefits delivered by the scheme and inefficient setting of the paid amount due to difficulties in evaluating the opportunity cost of the providers.

In the remaining works, where the C-Eff is the main focus, some interesting elements are highlighted. Particularly, 10 works stated the importance of targeted payments to minimize the costs of the schemes, comparing the different targeting options and discussing the pros and cons of each (Jack et al. 2008; T. Wunscher and Engel 2012). Five works discussed the role of promoting the implementation of payment schemes based on the environmental results achieved by the providers instead of their activities (Borner et al. 2017; Hanley et al. 2012). This change would imply a greater level of monitoring and control efforts, but would be the premise for setting the most efficient distribution of the payments. Surprisingly, three works only proposed the institution of inverse auctions to elicit the Willingness To Accept (WTA) of the providers and set the least payment amount (Lundberg et al. 2018). The reduced number of works on the topic probably reflect the recent introduction of this approach in the subject and the logistic difficulties that its adoption would imply (Publishing 2010). Concerning the approaches to maximize the environmental benefits, two inter-related aspects were studied: the additionality of the activities and the baseline setting (Pascual et al. 2010; Pettenella et al. 2012; Valatin and Price 2014). These topics, discussed in 13 works, have a strong influence on the willingness of the providers to adopt the scheme and respect its requirements, thus determining the success of the scheme.

Other relevant issues cited in this works for their influence on the C-Eff are:

- A strict control of the transaction costs, i.e. all those costs sources different from the mere payment of the ES providers (10 works), as the expenses for project and design of the PES; its implementation and management Since their impact is expected to raise in parallel with the implementation of result-based payments, targeting approaches, in-depth environmental benefits measurement… their overall amount should be always kept under control (Phan et al. 2017; Verdone 2015);

- bundling several ES to achieve a synergy of benefits: a possibility that should be considered where adding new ES would not impede the management and/or the provision of the original ones (Publishing 2010; Russi et al. 2013);
- the equity-efficiency trade-off: particularly relevant in developing countries, occurs when an exasperated maximization of the environmental benefits required to the providers causes negative spillover in the participation rate of the scheme. Often the trend brings to the exclusion of the owner of the lands with low provisioning level, that often are the poorest people of the community (Stefanie Engel 2016; Jack et al. 2008; Pascual et al. 2010);
- the conditionality of the scheme, that is the possibility that the activities or results required to the providers would have been fulfilled the same without implementing the PES scheme. Therefore, high conditionality level ensure its C-Eff and prevent from free riding (S. Engel et al. 2008; Stefanie Engel 2016);
- the adoption of other Market Based Instruments (MBI), to be considered in those cases where PES schemes would not represent the most suitable policy to achieve a given ES provision (Gomez-Baggethun et al. 2010; Russi et al. 2013).

The operational framework to improve the cost-effectiveness of PES schemes

Framework structure

In consideration of the main elements emerging from the review, an operational framework has been developed to group and structure them (fig. 1).

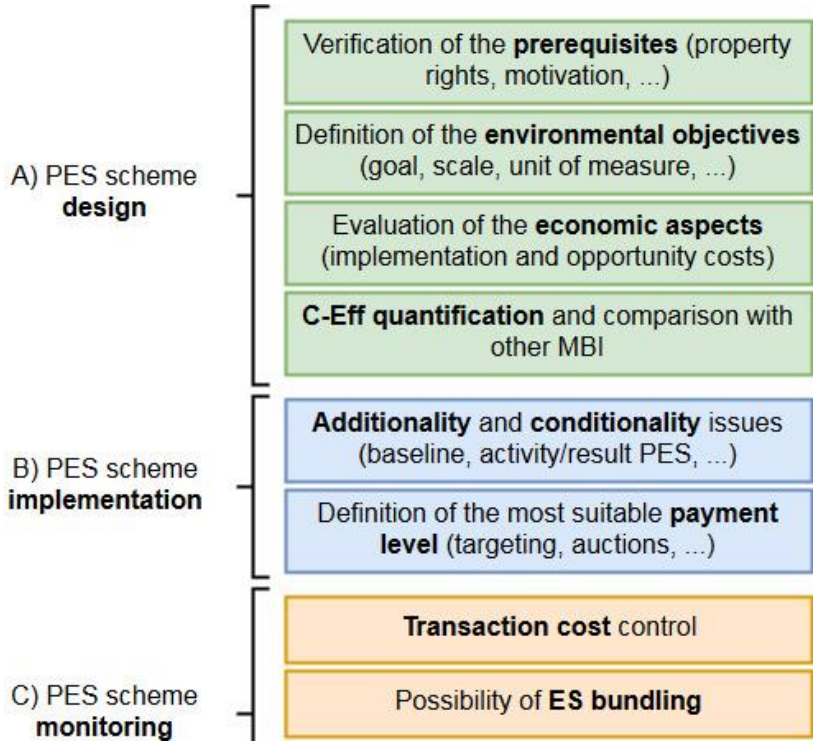

Figure 1 – Operational framework for the quantification and improvement of PES C-Eff

In the author's intention, the framework should be intended as a tool for PES designers, the technical-scientific consultant that project the scheme; and practitioners, the people in charge of running the scheme as intermediary between users and providers; to be applied on a PES scheme in order to enhance its performances. Therefore, the framework was structured in three phases and eight actions, or steps, to be fulfilled. The deployment of the different phases is chronological on purpose, aiming to support the designers of the scheme along the whole development process. In the following paragraphs the different elements composing the three phases of the framework will be described and discussed in depth.

A) PES scheme design

In the first phase, the PES design, several aspects are expected to contribute the cost-effective development of the scheme, starting from the verification of the essential prerequisites to the creation of the scheme. It is in fact obvious how some basic requirements must be met to allow setting up an efficient project: among the others, a clear definition of the property rights and an intrinsic motivation by the future ES providers should be verified (Stefanie Engel 2016; Gomez-Baggethun et al. 2010). The lack of these

elements would constitute a serious obstacle for the implementation of the scheme itself (Wunder et al. 2008).

The second important step is the definition of clear and measurable environmental objectives (Wunder 2007). Particularly, should be precisely defined which ES will be provided to the users, the area where to establish the scheme and, consequently, setting the environmental goals to be pursued, adopting scientifically sound measurement procedures (Borner et al. 2017; Jack et al. 2008). These elements should clearly reflect the environmental features of the eligible area and its possibilities to provide the ES in the expected shape and quantity. The definition of indexes and parameters to measure the benefits produced should be reliable and at the least cost possible, in order to follow the principle of C-Eff. Moreover, if more ES are provided or more parameters are considered for a single ES, indexes should be adopted, or developed, to assess the level of benefit provided. This situation resulted to be frequent for water-related PES, where the quality was measured referring to the concentration of several substances, e.g. nitrates, phosphorous, pesticides, faecal matter, … (Claassen et al. 2008; Russi et al. 2013).

Once defined the environmental objectives of the scheme, the economic ones should be developed consequently. In particular, to minimize the costs the PES will incur in, a preliminary evaluation of the monetary amount to be paid the ES providers should be performed. The main difficulties to face in this phase are mainly due to the asymmetric information that lies between PES designers and landholders that, as possible ES providers, usually have better knowledge on costs (Stefanie Engel 2016). To bridge this gap, a thoughtful data collection campaign should be planned, possibly involving the providers through a participatory approach. This, coupled with a economic analysis needed to evaluate the implementation cost of the scheme, will allow collecting all the necessary data to develop a reliable evaluation of the opportunity cost of the providers, determining the most suitable payment to correspond them. For this step, the most common estimation methods that resulted from the review are: budget computations, inference from land values, estimation based on economic and environmental data and WTA elicitation (Birol et al. 2006; Publishing 2010).

The fulfilment of these first three steps already allows the PES designers to forecast the level of C-Eff of their scheme. In the last step of this first phase a preliminary assessment of the C-Eff is suggested, employing the data collected. This testing stage allows to evaluate the expected performances of the scheme and compare them with other possible options, modifying its original design where needed. This first PES design phase should be therefore intended as a cyclical and dynamic sequence of trials and errors aimed to select the best option in consideration of the aims of the users, the needs of the providers and the features of the environment (de Lima et al. 2017).

B) PES scheme implementation

Once the scheme is defined in its basic elements, the second phase of the framework depicts the actions to be fulfilled for its actual implementation. Here, once again, the key elements to consider are the two terms of the ratio: the environmental and the economics aspect.

First, additionality and conditionality issues must be addressed. Thresholds should be set in order to define the level of engagement of the providers, their degree of freedom in pursuing the objectives of the scheme and the set of obstacles to free-riding phenomena, starting from a baseline proper definition. Two main options can be adopted by the PES designers: the setting of historical baseline, reporting a given amount of benefit of the ES of interest at some point before the implementation of the scheme, or an adaptive baseline, constantly updated in consideration of the results achieved after the PES implementation. To take back the problem to water-related PES, we could refer, e.g., to a certain level of nitrate measured the year before the PES creation, with payments based on the reductions achieved after setting aside buffer areas along water stream; or, on the other side, comparing the values of each year to the previous ones in order to detect the relative yearly quality improvements and "verify" the fulfilment of the requirements by the ES providers (Russi et al. 2013). Obviously, the baseline setting option is strictly linked with the typology of requirement asked to the providers to receive the payment. Here as well two main options are possible. The first consists in establishing an activity-based payment, where the money is given if and only if some eligible activities are implemented, e.g. tree plantations around water streams. Considering the activity itself as a proxy measure of the ES provided, the monitoring activities required are basic, since precise measurements of the gained benefits are not necessary. This implies a reduction of the transaction costs of the whole PES but an unknown, at best, or arguable, at least, environmental effectiveness of the whole scheme (Gomez-Baggethun et al. 2010). On the other side, setting up a result-based payment scheme, where how to achieve the environmental benefit is not pre-defined, would involve greater efforts in terms of monitoring activities and technical support to the providers, with negative drawbacks on the transition costs. Nonetheless, the major accountability of the ES benefits provided and the high level of freedom left to the providers could support the introduction of innovative and more effective practices and ensure a higher cost-effectiveness of the payments (Matzdorf and Lorenz 2010). The adoption of each of the presented options cannot be defined *a priori*, but should rather reflect the expectations of the designers, the available budget, the willingness of the community of providers to engage the scheme, and the environment of the PES area. Generally, high budgets, high level of involvement of providers and/or high variability of the environment would suggest the adoption of adaptive baselines and result-based PES (Stefanie Engel 2016).

The second action of this phase, mainly dealing with the economics of the scheme, concerns the definition of the most suitable payment level in consideration of the aim of the scheme. If the objective of the PES

designers was to maximize the level of ES supplied, they should set high payments to few high-level providers. This can be achieved with uniform payments and high baseline requirements: this way only few, well paid, providers could ensure the required level of benefits, thus maximizing the C-Eff of the scheme. Otherwise, differentiated payments could be set, rewarding more the providers supplying more environmental benefits: here, only the providers receiving more than their opportunity cost would be enrolled. Both approaches imply high monitoring activities, high additionality of the actions required to be compliant, strong opposition to free-riding, reduction the area enrolled in the scheme and high rewards for the owners of the more productive plots (Hanley et al. 2012; Uthes et al. 2010). On the other hand, aiming to maximize the number of participants and/or the area enrolled in the scheme, the designers should acknowledge low payments to a large number of providers. Setting uniform payments, this would imply low additionality from the baseline; on the opposite, differentiated payments would reflect the opportunity costs, rewarding each provider in relation to the forgone revenue he bears. These strategies imply lower monitoring activities, precise definition of the opportunity cost for each land use, lower obstacles to free riding behaviours, lower level of effort of the providers for being compliant and a larger share of the budget among the components of the local community (Kolinjivadi et al. 2015; Xu et al. 2018).

Finally, the last element to be considered for a C-Eff PES implementation phase is an alternative, and recently introduced methodology for eliciting the WTA of the PES providers: the Inverse Auction (Lundberg et al. 2018; Persson and Alpizar 2013). This technique consist in an auction organized by the PES designers for the possible PES providers in order to define the least payment amount: the term “inverse” in fact imply that the accepted bid will be the lowest one. Auction can be adopted both for uniform payments schemes, where the payment will be equal to the lowest bid presented by one the participants; and differentiated payments, where each participant will receive the amount of his own bid. The organization of these events can be quite complex, and often several trials are required, but they can provide relevant gains in terms of C-Eff, especially in area where the environmental variability is high. Basic elements to organize an effective auction are: flexibility in the final enrolled area, seek the participation of large numbers of potential providers, ensure a high level of competition between them and hinder strategic behaviours of the participants, e.g. replicating the auctions over time (Narloch et al. 2011).

C) PES scheme monitoring

In the last phase, the elements to be considered in the ongoing schemes area are, indeed, different from the previous ones, since here is not possible anymore to introduce substantial changes in the structure and the organization of the scheme itself, unless peculiar situations. Therefore, the most useful approaches to improve the performances of the schemes mainly focus on transaction cost control and inclusion of further ES in the payment scheme.

Concerning the former, their amount can range largely, from being elements of marginal relevance to constitute the main cost item of the whole project (Brouwer et al. 2011). For this reason, a strict control of the transaction costs should be established in the scheme from the beginning in order to minimize their weight. In relation to the several possible design strategies previously proposed, it should be noticed how most of them would actually imply an increase of the monitoring activities and of the administrative load to be managed by the scheme organization, causing, in parallel, rising management cost. Therefore, the adoption of these approaches should always be carefully evaluated by the scheme designers in order to avoid extreme situations where few gains in C-Eff are obtained through additional and costly administrative burdens.

Finally, another element to be considered for C-Eff improvement is the bundling of more ES into one single PES scheme. In relation to water schemes, considering more ES at the same time seems to represent a potentially relevant synergy, mainly thanks to the intrinsic characteristics of the ES itself and the assessment methods that their measurement implies (Claassen et al. 2008; Tobias Wunscher et al. 2006). Particularly, a water PES scheme where trees were planted to improve water-quality could be positively matched with carbon sequestration (a ES easily measurable with standard methodologies), erosion control, recreational activities and others ES. On the other hand, trade-offs between water and other ES are reported in literature too, mainly dealing with water-quantity. The inclusion of several ES into the same scheme would allow the designers to enlarge the number of both investors and providers potentially interested in joining the project. Moreover, transaction costs are expected to raise less than proportionally for each ES inclusion, allowing to achieve higher and measurable environmental benefits at lower costs.

Conclusions

The aim of the STSM, focused on investigating the most promising approaches to enhance the C-Eff of the PES schemes, has been achieved with an extensive bibliographic review and developing an operational framework for the application of its findings.

The results of the review can be considered relevant for the future activities of the Action: particularly, it is interesting to notice how few experiences of C-Eff quantification are available to date, mainly dealing with ES different from those of interest for the Action. On the other side, useful findings can be derived from the many works that evaluated the performance of non-PES environmental measures or considered only the theoretical aspects of them. Thus, the actual application on real case studies of the information collected from these works could represent an interesting future development of the Action's activities.

Concerning the framework, as can be noticed by its structure, the C-Eff cannot be reached or maximized with the adoption of one single strategy or approach, but rather several of them contribute to the same

goal, and many are needed to design a cost-effective scheme. Both measures dealing with cost reduction and enhancement of the environmental benefits proved to be essential for the success of a PES. Therefore, we believe establishing which approach should be applied must be thoroughly considered by the PES designers at the planning stage. Each of the proposed measures will determine positive results for the scheme only if its application will fit the design of the scheme itself, the needs and the expectations of the providers and the possibilities of the environment as a whole. The adoption of the best strategies for each scheme will also imply positive consequences on the transaction costs, contributing to design a cost-effective PES scheme.

Acknowledgments

The author wish to acknowledge the support of the home institution, of the hosting institution and of the members of the Working Group 3 for the support received during and after the STSM. Their suggestions were highly considered.

References

Ansell, D., et al. (2016), 'The cost-effectiveness of agri-environment schemes for biodiversity conservation: A quantitative review', *Agriculture Ecosystems & Environment,* 225, 184-91.

Barton, D. N., et al. (2009), 'Environmental service payments: Evaluating biodiversity conservation trade-offs and cost-efficiency in the Osa Conservation Area, Costa Rica', *Journal of Environmental Management,* 90 (2), 901-11.

Birol, E., Karousakis, K., and Koundouri, P. (2006), 'Using economic valuation techniques to inform water resources management: A survey and critical appraisal of available techniques and an application', *Science of the Total Environment,* 365 (1-3), 105-22.

Borner, J., et al. (2017), 'The Effectiveness of Payments for Environmental Services', *World Development,* 96, 359-74.

Brouwer, R., Tesfaye, A., and Pauw, P. (2011), 'Meta-analysis of institutional-economic factors explaining the environmental performance of payments for watershed services', *Environmental Conservation,* 38 (4), 380-92.

Chen, X. D., et al. (2010), 'Using Cost-Effective Targeting to Enhance the Efficiency of Conservation Investments in Payments for Ecosystem Services', *Conservation Biology,* 24 (6), 1469-78.

Claassen, Roger, Cattaneo, Andrea, and Johansson, Robert (2008), 'Cost-effective design of agri-environmental payment programs: US experience in theory and practice', *Ecological economics,* 65 (4), 737-52.

de Lima, L. S., Krueger, T., and Garcia-Marquez, J. (2017), 'Uncertainties in demonstrating environmental benefits of payments for ecosystem services', *Ecosystem Services,* 27, 139-49.

Drechsler, M. (2011), 'Trade-offs in the design of cost-effective habitat networks when conservation costs are variable in space and time', *Biological Conservation,* 144 (1), 479-89.

EC-WATECO (2003), 'Common Implementation Strategy for the Water Framework Directive (CIS)', *Guidance document* (Office for Official Publications of the European Communities), 69.

Engel, S., Pagiola, S., and Wunder, S. (2008), 'Designing payments for environmental services in theory and practice: An overview of the issues', *Ecological Economics,* 65 (4), 663-74.

Engel, Stefanie (2016), 'The devil in the detail: a practical guide on designing payments for environmental services', *International Review of Environmental and Resource Economics,* 9 (1–2), 131-77.

Gauvin, C., et al. (2010), 'Cost-Effectiveness of Payments for Ecosystem Services with Dual Goals of Environment and Poverty Alleviation', *Environmental Management,* 45 (3), 488-501.

Gios, Geremia and Rizio, Dina (2013), 'Payment for forest environmental services: a meta-analysis of successful elements', *iForest-Biogeosciences and Forestry,* 6 (3), 141.

Girard, C., Rinaudo, J. D., and Pulido-Velazquez, M. (2015), 'Index-Based Cost-Effectiveness Analysis vs. Least-Cost River Basin Optimization Model: Comparison in the Selection of a Programme of Measures at the River Basin Scale', *Water Resources Management,* 29 (11), 4129-55.

Gomez-Baggethun, E. and Muradian, R. (2015), 'In markets we trust? Setting the boundaries of Market-Based Instruments in ecosystem services governance', *Ecological Economics,* 117, 217-24.

Gomez-Baggethun, E., et al. (2010), 'The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes', *Ecological Economics,* 69 (6), 1209-18.

Hanley, N., et al. (2012), 'How should we incentivize private landowners to 'produce' more biodiversity?', *Oxford Review of Economic Policy,* 28 (1), 93-113.

Hejnowicz, A. P., et al. (2014), 'Evaluating the outcomes of payments for ecosystem services programmes using a capital asset framework', *Ecosystem Services,* 9, 83-97.

Hily, E., et al. (2015), 'Assessing the cost-effectiveness of a biodiversity conservation policy: A bio-econometric analysis of Natura 2000 contracts in forest', *Ecological Economics,* 119, 197-208.

Honey-Roses, J., et al. (2013), 'Examining the Demand for Ecosystem Services: The Value of Stream Restoration for Drinking Water Treatment Managers in the Llobregat River, Spain', *Ecological Economics,* 90, 196-205.

Hérivaux, Cécile, Orban, Philippe, and Brouyère, Serge (2013), 'Is it worth protecting groundwater from diffuse pollution with agri-environmental schemes? A hydro-economic modeling approach', *Journal of environmental management,* 128, 62-74.

Jack, B. K., Kousky, C., and Sims, K. R. E. (2008), 'Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms', *Proceedings of the National Academy of Sciences of the United States of America,* 105 (28), 9465-70.

Kallis, Giorgos and Butler, David (2001), 'The EU water framework directive: measures and implications', *Water policy,* 3 (2), 125-42.

Kolinjivadi, V., et al. (2015), 'Juggling multiple dimensions in a complex socio-ecosystem: The issue of targeting in payments for ecosystem services', *Geoforum,* 58, 1-13.

Kurkalova, L. A. (2015), 'COST-EFFECTIVE PLACEMENT OF BEST MANAGEMENT PRACTICES IN A WATERSHED: LESSONS LEARNED FROM CONSERVATION EFFECTS ASSESSMENT PROJECT', *Journal of the American Water Resources Association,* 51 (2), 359-72.

Lescot, J. M., et al. (2013), 'A spatially-distributed cost-effectiveness analysis framework for controlling water pollution', *Environmental Modelling & Software,* 41, 107-22.

Lundberg, L., et al. (2018), 'Context Matters: Exploring the Cost-effectiveness of Fixed Payments and Procurement Auctions for PES', *Ecological Economics,* 146, 347-58.

Martin-Ortega, J., et al. (2015), 'A transdisciplinary approach to the economic analysis of the European Water Framework Directive', *Ecological Economics,* 116, 34-45.

Matzdorf, B. and Lorenz, J. (2010), 'How cost-effective are result-oriented agri-environmental measures?- An empirical analysis in Germany', *Land Use Policy,* 27 (2), 535-44.

Mayrand, Karel and Paquin, Marc (2004), 'Payments for environmental services: a survey and assessment of current schemes'.

Muradian, R., et al. (2010), 'Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services', *Ecological Economics,* 69 (6), 1202-08.

Naeem, S., et al. (2015), 'Get the science right when paying for nature's services', *Science,* 347 (6227), 1206-07.

Narloch, U., Pascual, U., and Drucker, A. G. (2011), 'Cost-effectiveness targeting under multiple conservation goals and equity considerations in the Andes', *Environmental Conservation,* 38 (4), 417-25.

Nijnik, M., et al. (2013), 'An economic analysis of the establishment of forest plantations in the United Kingdom to mitigate climatic change', *Forest Policy and Economics,* 26, 34-42.

OECD (2010), *Paying for Biodiversity: Enhancing the Cost-Effectiveness of Payments for Ecosystem Services* (Paris, France: OECD Publishing).

Pascual, U., et al. (2010), 'Exploring the links between equity and efficiency in payments for environmental services: A conceptual approach', *Ecological Economics,* 69 (6), 1237-44.

Persson, U. M. and Alpizar, F. (2013), 'Conditional Cash Transfers and Payments for Environmental Services-A Conceptual Framework for Explaining and Judging Differences in Outcomes', *World Development,* 43, 124-37.

Pettenella, D., et al. (2012), 'Paying for water-related forest services: a survey on Italian payment mechanisms', *Iforest-Biogeosciences and Forestry,* 5, 210-15.

Phan, T. H. D., Brouwer, R., and Davidson, M. D. (2017), 'A Global Survey and Review of the Determinants of Transaction Costs of Forestry Carbon Projects', *Ecological Economics,* 133, 1-10.

Publishing, Oecd (2010), *Paying for Biodiversity: Enhancing the Cost-Effectiveness of Payments for Ecosystem Services* (OECD Publishing).

Roley, Sarah S., et al. (2016), 'How cost-effective are cover crops, wetlands, and two-stage ditches for nitrogen removal in the Mississippi River Basin?', *Water Resources and Economics,* 15, 43-56.

Russi, Daniela, et al. (2013), 'The economics of ecosystems and biodiversity for water and wetlands', *IEEP, London and Brussels*, 78.

Schöttker, Oliver and Wätzold, Frank (2017), 'Buy or lease land? Cost-effective conservation of an oligotrophic lake in a Natura 2000 area', *Biodiversity and Conservation*, 1-19.

Uthes, S., et al. (2010), 'Spatial Targeting of Agri-Environmental Measures: Cost-Effectiveness and Distributional Consequences', *Environmental Management,* 46 (3), 494-509.

Valatin, Gregory and Price, Colin (2014), 'How cost-effective is forestry for climate change mitigation?', *Challenges and Opportunities for the World's Forests in the 21st Century* (Springer), 297-339.

Verdone, M. (2015), 'A cost-benefit framework for analyzing forest landscape restoration decisions', *IUCN (International Union for Conservation of Nature), Gland, Switzerland*.

Wu, J. J. and Yu, J. L. (2017), 'EFFICIENCY-EQUITY TRADEOFFS IN TARGETING PAYMENTS FOR ECOSYSTEM SERVICES', *American Journal of Agricultural Economics,* 99 (4), 894-913.

Wunder, S. (2007), 'The efficiency of payments for environmental services in tropical conservation', *Conservation Biology,* 21 (1), 48-58.

--- (2015), 'Revisiting the concept of payments for environmental services', *Ecological Economics,* 117, 234-43.

Wunder, S., Engel, S., and Pagiola, S. (2008), 'Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries', *Ecological Economics,* 65 (4), 834-52.

Wunscher, T. and Engel, S. (2012), 'International payments for biodiversity services: Review and evaluation of conservation targeting approaches', *Biological Conservation,* 152, 222-30.

Wunscher, Tobias, Engel, Stefanie, and Wunder, Sven (2006), 'Payments for environmental services in Costa Rica: increasing efficiency through spatial differentiation', *Quarterly Journal of International Agriculture,* 45 (4), 319-38.

Xu, Z., et al. (2018), 'Climate change mitigation strategies in the forest sector: biophysical impacts and economic implications in British Columbia, Canada', *Mitigation and Adaptation Strategies for Global Change,* 23 (2), 257-90.