Compensatory mitigation: an indicator of the environmental cost

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Abstract

Due to the extent of damage caused to the environment and ecosystems, international and European legislation gradually emphasize the integration of environmental damage in decision-making processes. As a consequence, land planners may, for instance, soon have to take more rigorously into account environmental damage resulting from their infrastructure development plans. Environmental economists thus have to assess more accurately the environmental costs of such plans. Yet, when dealing with land planning in complex natural areas, existing valuation methods are reaching their limits. In this paper, we propose to use the compensatory mitigation process to assess environmental costs by adapting an equivalence-based valuation method used in the United States.

Keywords: compensatory mitigation, environmental damage assessment, cost-benefit analysis, equivalence-based valuation methods.

When an infrastructure development plan is implemented, damages caused to nature are reducing the ecosystem services supplied by natural areas. These services provide men with several benefits leading to direct use values, indirect use values and non-use values. The assessment of direct use values is easily done through existing markets. Indirect use values, for their part, can be assessed through the use of proxies or revealed preference methods. Stated preference methods, such as contingent valuations [Mitchell and Carson, 1989] or more recent methods such as conjoint analysis [Louviere et al., 2000], are used to assess non-use values. However, when dealing with land planning in complex natural areas, stated preference methods are reaching their limits. Interviewed people don't really know the natural systems they are supposed to value. They are not capable of taking into account all the services these systems provide [Laroutis, 2006]. Due to this limited knowledge, the given values then only catch a part of the non-use value. The research question is then: how can the valuation of natural areas be improved ? How can these complex systems be integrated to the decision-making processes of infrastructure development plans ?

In the steps of Costanza et al. [1997], the Millenium Ecosystem Assessment conceptual framework [MEA, 2005] bases the valuation of ecosystems on ecosystem services. This framework is used as well as a starting point by the work group "The Economics of Ecosystems and Biodiversity" [TEEB] led by Pavan Sukhdev [Balmford et al., 2008]. The TEEB recommends notably to study the american equivalence-based valuation methods that use non-monetary trade units. Thus, the suggested methodology is based on the Habitat Evaluation Procedure [HEP] created in the United States in the early eighties [USFWS, 1980]. The original HEP method is used in the wetland mitigation banking system in order to help achieve the objective of "no net loss" of wetlands. There is no such banking system in Europe and, thus, the use of the HEP method as an evaluation tool requires some adaptations.

Our methodology, called "adapted" HEP, aims to assess the environmental cost of an infrastructure development plan as a whole, taking notably into account the non-use values usually provided by the damaged areas. The principle is to use compensatory mitigation actions as an ex ante valuation tool. The first stage consists in estimating the environmental damage the plan would induce. The second stage involves identifying the compensatory mitigation measures that would completely mitigate these damages. Finally, the cost of implementing these measures is used to assess the plan's environmental cost. This paper is organized as follows: section 1 examines the analytical framework with respect to the mitigation banking process and the associated equivalence-based valuation method. Section 2 presents the "adapted" HEP method from a case study.

1 Analytical framework

1.1 Mitigation banking and the original HEP

The major piece of the american federal legislation related to development plans in wetlands is the Section 404 of the Clean Water Act (1972). According to this Act, when an infrastructure development plan implies the destruction of a wetland, the developer has to follow a complex validation procedure. First he will have to follow a mitigation sequence (supress and reduce the estimated impacts) so as to minimize the plan's adverse impacts [Gilman, 1997, Holland and Kentula, 1992]. Then, when the permit applicant has attempted but has been unable to avoid or minimize such losses, compensatory mitigation plans are required to offset the residual impact on wetlands.

Wetland mitigation banking is one type of compensation. It refers to a process where a developer purchases a land area and restores, enhances, or creates plant or animal wetland habitats. The improvements brought to the compensation area are quantified and credits are placed in a mitigation bank [Weems and Canter, 1995]. The number of credits that specialized developers obtain per dollar of investment depends on the success of the restoration (which is stochastic due to the complex biological, chemical, and physical factors affecting the recovery of an ecosystem).

At a later date, when unavoidable impacts due to a development occur, credits can be withdrawn. Restoration credits are bought by firms to fulfill the legal obligation to restore the environmental assets damaged by the constructions or operations of the company [Arquitt and Johnstone, 2007]. Restorations are then usually completed before credits are sold, ensuring that there is no intertemporal net loss of environmental stocks. In an ideal version, the system should negate the net environmental damage due to economic activity since these activities should be compensated by a restoration of equal value. These compensatory mitigation wetlands are typically monitored for a period of 3 to 5 years to determine whether they meet a set of site-specific performance standards approved by the U.S. Army Corps of Engineers (which processes the permit applications) [Matthews and Endress, 2008]. For example, in New Jersey, the restoration costs of a wetland are comprised between $25,000 and $130,000 per acre whereas credits were sold up to $250,000 per acre [Hallwood, 2007].

The Habitat Evaluation Procedure is based on the fundamental assumption that habitat quality and quantity can be numerically described. This procedure, developed by the U.S. Fish and Wildlife Service [USFWS] [USFWS, 1980], is a species-habitat approach to impact assessment where habitat quality for selected evaluation species is documented with an index, the Habitat Suitability Index

[HSI]. This index value ranges from 0.0 and 1.0 and is multiplied by the area of available habitat to obtain habitat units, a non-monetary unit that allows for an equivalence to be obtained between natural areas destroyed by the infrastructure development plan on the one hand and areas created through compensatory mitigation measures on the other hand. These habitat units constitute "credits" traded on the market.

Our assessments are run in the specific framework of infrastructure development plans. Our interest is therefore focused on the procedure used to determine the number of credits a firm will have to buy so as to offset the impact induced by the plan. We believe that this procedure can be adapted and used to assess the plan's environmental impact. In the mitigation banking system, the compensation is made in terms of habitat units. These units being exchanged on a market, a price for the mitigation can easily be obtained by multiplying the number of credits bought by the market price. Opposite to traditional valuation methods, the HEP method is based on an in-kind equivalence, the monetary valuation only appearing in the very last stage. Furthermore, the number of units is not only determined by the price of habitat units but depends also on the quality of created and destroyed areas (which determines the number of credits to be bought). Consequently, we believe that the values obtained "catch" a greater part of the damaged ecosystem real value.

1.2 Compensatory mitigation in France

At present, in France, the law concerning the protection of Nature (1976) requires impact studies including compensatory mitigation measures for the bigger plans. It is particularly true for plans representing a significant threat for the environment, such as land planning in sensitive environments. Compensatory mitigation is defined by the ministry in charge of the environment (MEEDDAT) as "all action allowing the conservation of biological diversity in a condition equivalent or better than the one observed before the implementation of the development plan". These actions should be taken only once a mitigation hierarchy has been pursued. The environmental code indeed says that impact studies should include "the considered measures to suppress, reduce and, whenever possible, compensate for the consequences of damage on public health and the environment". Compensatory mitigation then applies to residual damage only. It is relevant to highlight that compensatory measures have nothing to do with a payoff for damage caused to biodiversity or with a bank transfer for mitigation or restoration actions required in impact studies.

According to the report from Laffitte and Saunier [2007], this legislation shows some deficiency in its implementation. These restrictions refer to the fact that small plans are not taken into account when, considered as a whole, they could lead to substantial environmental damage. Furthermore, the time scale of compensatory mitigation is limited to the time scale of the plan and, consequently, there is a lack of monitoring concerning the management of compensation areas and what they will become in the future. In addition, international and European legislation tends towards an increasing use of compensatory mitigation procedures. For example, concerning wetlands, compensatory mitigations are cited in the Ramsar Convention (art. 4.2.) which states that "Where a Contracting Party in its urgent national interest, deletes or restricts the boundaries of a wetland included in the List, it should as far as possible compensate for any loss of wetland resources". The European Community also refers to compensatory mitigation in the legislation from 1992 (art. 6.4) concerning Natura 2000. The principle is to refuse any plan that might have a significant impact on Natura 2000 sites. However, when there are "imperative reasons of overriding public interest", infrastructure development plans can be allowed by "taking compensatory measures to ensure the overall coherence of the Natura 2000 network". Most of these laws have been in existence for several years, but their practical implementation is more recent and intensifies with time.

Compensatory mitigation measures tend to be more present at an international level. However, their implementation in France seems to encounter some dysfunctions. This is why it is relevant to seek for other ways of integrating such measures into the decision-making process of development plans. Consequently, the adaptation of the original HEP method to our framework will lead us to use the "ideal" compensatory mitigation actions (measures suited to completely offset the net environmental impact) to assess the environmental cost of the infrastructure development plan.

2 The "adapted" HEP method

Our objective is to adapt the orginal HEP method so as to assess the plan's environmental cost within the cost-benefit analysis of an infrastructure development plan in a sensitive environment. The idea consists in using "ideal" compensatory measures as an assessment of the plan's environmental cost. Current research in the field of ecosystem valuations are focusing on the valuation of ecosystem services. Consequently, ecosystem services will form the core of our "adapted" HEP method, thus modifying the method's usual implementation.

The adaptation of the HEP method was made through an empirical case study. A pilot area, located in Lauterbourg (Alsace, France), was selected due to an existing development plan at an advanced stage. The impact and incidence studies already completed guaranteed us an access to numerous field data. As recommended by the USFWS, the same equivalence-based valuation method has to be used twice: first, to determine the net environmental impact resulting from the plan, second, to identify the compensatory measures required to create ecosystem services equivalent to those lost due to the plan. Our aim is focused on the methodology more than on the result itself. We thus simplified the different stages to the maximum. An operational use of the "adapted" method could then be made more complex so as to optimize the results obtained.

2.1 Net environmental impact

The case study deals with opportunities of harbors expansion on the Rhine river. As pointed out, the objective is less the valuation of a pilot area with the "adapted" HEP method than the adaptation of the original HEP method and its validation. We will follow as much as possible the USFWS [1980] recommended procedure, highlighting the necessary adjustments. The stages to follow are:

1. Define study limits: delineation of study area, delineation of cover types, selection of evaluation species.
2. Calculate study area habitat units.
3. Assess habitat using habitat units.
4. Measure the net impact of the plan.

Delineations of study site and cover types have been made and required no adaptation. The first changes appear with the selection of evaluation species stage, and will have repercussions on the following stages.

2.1.1 Study limits

Delineation of study area: all areas where biological changes due to the use of land or water are expected to occur (either directly or indirectly affected) must be included, along with contiguous areas with significant biological linkages.

The study site delineation is given by a map from the impact study [OTE-Ingénierie, 2006]. This map presents the existing land cover and natural areas on the pilot area. The plan's delineation is specified as well. We consider that all areas within this boundary will be affected by the plan (either destroyed or spoiled).

Delineation of cover types: the level of delineation depends on mapping constraints, on the requested level of precision and on available data. Fortunately, cover type studies have been well developed during the past years and are mostly based on spatial and satellite imagery completed with field data. Several databases are available, providing us with the required imagery and mapping information.

In Europe, the Corine Land Cover database allows us to identify the existing cover types on the pilot area. These cover types are then entered into a classification table specifically created for our study. This classification was mainly inspired by the US nomenclature of Anderson and from the European program Corine Land Cover. In order to be consistent with the local scale of our study, our classification was also crossed with the nomenclature of a local database (BD-OCS). The cover types identified in the impact study carried out at Lauterbourg were entered into this mixed classification.

Selection of evaluation species: we could deal with single species, a group of species, a species life stage or a species life requisite. Once selected among all the species identified on the study site, evaluation species are used in the HEP method to calculate the HSI indices.

This step constitutes the first change from the original HEP method. Indeed, the original method links species with the different area types and then uses these species to assess habitat quality. The "adapted" HEP method uses species as proxies to assess habitat quality as well, but bases the selection of evaluation species on ecosystem services provided by these species. Therefore, we have to make sure that we do pick the most representative species of the ecosystem services provided on the pilot area. In this regard, wildlife and flora inventories from the impact study are a starting point.

As mentioned, our aim is to choose the most representative species for the different areas according to provided ecosystem services. In other words, identify species that, if they were to disappear, would prevent natural areas from providing their ecosystem services. The first step links the inventoried species to natural areas. To make things clear, the inventories had been divided into 4 groups: mammals, reptiles/amphibias/insects, birds and flora. In a second step, we connect the listed species with the 17 ecosystem services identified in the paper "Scoping the Science" [Balmford et al., 2008], specifically designed for the economic valuation of ecosystem services. Finally, the third step transposes the identified links into a single matrix connecting natural areas to ecosystem services by indicating, for each type of area, which species provide the different ecosystem services.

Species are selected from the matrix so as to be the most representative of the services provided by each area type. They are made of both flora and wildlife species. The integration of flora species constitutes another modification of the original HEP method. It is necessary because flora species provide men with numerous services and, thus, cannot be neglected. The links between species, natural areas and ecosystem services were crossed, for wildlife species, with these species specific diet so as to guarantee a certain stability of the ecosystem.

2.1.2 Baseline conditions in habitat units

For each evaluation species, habitat units are measured by the product of the area of available habitat (made of all the areas used by the species) with its quality represented by the HSI index. This index is measured with a model called HSI model. According to the USFWS, it is possible either to use an existing model, or to create a model specifically fitted for the studied species.

Area of available habitats: the total size of available habitat for a given species corresponds to the sum of all cover types used by the species. The matrix indicating in which areas species can be found is crossed with data given by a chart from the impact study showing the predicted evolution of the repartition of each type of area before and after the implementation of the infrastructure development plan. These data are then grouped into a table so as to calculate, depending on cover types used by each species, the total size of their available habitat on the pilot area.

Measure of the HSI indices: given the available data, we opt for the use of an existing HSI model. In this case, the most important step to change the output of a model into an HSI index consists in defining a standard of comparison to use in the following equation:

$$HSI = \frac{Existing\ model\ output\ for\ area\ of\ interest}{Defined\ standard\ of\ comparison}$$

Several types of model could be used depending on selected evaluation species as well as available data for these species. Our first idea was to use a model with defined output units, such as the model from Russell et al. [1980], using population density estimate as the only indicator of habitat quality. Unfortunately, the field data collected on the pilot area do not include the necessary data on population. We had to use information that was already available, we opted for species classification in various protection lists. The underlying hypothesis is: the weaker the population density of a species, the higher its level of protection. We are aware to be setting a very strong assumption here but we insist that our aim is focused on the methodology rather than on the result.

Thus, a numerical ranking based on the level of protection given to each evaluation species is used as an HSI model. We set the hypothesis that there is a positive and linear relationship between the population density of a species (represented here by its level of protection) and its capacity to supply ecosystem services. The chosen HSI model is:

$$HSI = \frac{Species\ rank\ in\ protection\ lists}{Maximum\ rank}$$

Baseline conditions in habitat units: the purpose of performing a baseline assessment is to calculate the number of habitat units at one point in time (before the implementation of the plan) for each evaluation species. The area of available habitat is multiplied by the HSI index of each evaluation species to determine the total amount of habitat units for that species on the pilot area. In our case sudy, the total amount of habitat units that can be allocated to the pilot area before the implementation of the plan is equal to 198.52 units.

2.1.3 Future conditions in habitat units

This stage consists in assessing the environmental impact of the plan by estimating, still for each evaluation species, the predicted size of its available habitat and the predicted HSI index for this habitat once the plan is implemented. It is thus necessary to give an estimation of the conditions that will prevail once the infrastructure created. The USFWS states that this stage can be simplified by selecting target years and annualizing the impacts. We choose, in our case study, not to use target years at this stage but to make a simple distinction between situations before (baseline conditions) and after the implementation of the plan (as described in the impact study).

Predicting future area of available habitat: once again, we use the chart from the impact study showing the evolution of the different area types repartition before and after the implementation of the plan. We obtain a table determining, depending on land covers used by each evaluation species, the predicted area of available habitat.

Predicting future HSI indices: the USFWS insists that the same model that was used to determine baseline HSI indices must be used to determine future HSI indices. In our case, it deals with population density represented by the level of species protection.

In our case study, most destroyed areas were made of cultivated lands, mainly used by wildlife species for feeding or mere passage rather than habitation. The impacts on other cover types are considered low enough for the species to be able to live normally on the remaining lands, with no impact on population densities. It is quite the same for flora species since, even if some of these species are indeed destroyed, it is not the population densities that would be modified but rather the area of available habitat. We are in a binary situation where species are either destroyed or conserved with the same level of quality.

Future conditions in habitat units: as for baseline conditions, the amount of habitat units that can be allocated to each species once the plan is implemented, is given by the multiplication of the predicted area of available habitat by the predicted HSI index for each species. In our case study, 141.5 units can be allocated to the pilot area in its future conditions.

Net impact: once the future conditions are measured in terms of habitat units, we can determine the net impact of the plan by substracting the remaining habitat units in the future conditions to the habitat units calculated for the pilot area baseline conditions: $198.5 - 141.5 = 57$ units. Thus, the "equivalent" compensatory mitigation measures should be able to create 57 habitat units.

2.2 "Ideal" compensatory mitigation measures

Compensatory mitigation measures are made of management actions allowing one to offset non-avoidable losses in habitat units deriving from the implementation of an infrastructure development plan. These measures are called "ideal" because they deal with hypothetical measures that would, if they were to be actually implemented, recreate the lost ecosystem services. Compensation is obtained through the implementation of specified management actions on a given habitat so as to obtain a net increase in habitat units that would equal the estimated net loss. The USFWS states that the same valuation method must be used twice in order to guarantee the equivalence between destroyed habitat units on the one hand and created habitat units on the other hand.

In the original methodology, the HEP method is run a second time to determine the size of the compensatory mitigation measures to be implemented so as to obtain, depending on the selected compensation area, the required rise in habitat units. We will run our "adapted" HEP method a second time as well to determine the size of the "ideal" compensatory mitigation measures for our case study. However, in our case, the "ideal" compensatory measures being used only to assess the environmental cost of the plan, the suggested management actions and compensation area remain hypothetical. They are thus not constrained by potential problems issuing from the compensation area or its environment, but the practical feasibility of their implementation is not guaranteed.

As for the first application of the "adapted" HEP method, we will follow as closely as possible the recommendations from the USFWS, highlighting the necessary modifications. The stages set by the USFWS are:

1. Identify losses for which compensation is desired.
2. Identify potential target species.
3. Define compensation goal.
4. Select candidate compensation area.
5. Calculate habitat units for target evaluation species at baseline conditions.
6. Calculate habitat units for future conditions without management.
7. Select management (action) alternative.
8. Calculate habitat units for future with management action.
9. Calculate the annualized benefits for compensation plan.
10. Determine the actual compensation efforts to approach goal.
11. Make recommendations.

2.2.1 Identification of losses, target species and compensation goal

Losses to offset correspond to the net environmental impact of the plan calculated with the first implementation of the "adapted" HEP method, *i.e.* 57 habitat units. Concerning the list of target species, it is not necessarily the same as the list of evaluation species used to measure the net impact of the plan. The selection of target species is guided by the chosen compensation goal. The USFWS distinguishes three possible objectives:

1. In kind, no trade-off: the list of target species must be identical to the list of negatively impacted species. The ideal compensation plan will provide, for each individual species, an increase in habitat units equal in magnitude to the habitat units losses.

2. Equal replacement, equal trade-off: a gain of one habitat unit for any target species can be used to offset the loss of one habitat unit for any evaluation species. The list of target species may or may not be identical to the list of impacted species.

3. Relative replacement, relative trade-off: a gain of one habitat unit for a target species is used to offset the loss of one habitat unit for an evaluation species at a differential rate depending on the species involved (*i.e.* not necessarily on a one-to-one basis).

Given the hypotheses set and the conceptual framework (based on ecosystem services) used in our "adapted" method, we do have the choice between these three options as well. We can either use target species different from evaluation species and which provide the same ecosystem services with the same magnitudes (equal replacement) or provide the same ecosystem services with different magnitudes by using a differential rate to take this gap into account (relative replacement).

Even though compensatory mitigation measures remain, in our case, hypothetical and our aim is mainly to identify the "ideal" compensatory measures, we do have to take into account that the creation of an identical natural system is technically impossible. We thus opt for the objective of equal replacement. Though we do keep the list of evaluation species as target species.

2.2.2 Selection of candidate compensation area

The area can be of any size but must be large enough to be a manageable unit for the target species. For the creation of habitat units to be possible, it is better for the compensation area to be of low ecological value. Furthermore, if it was not the case, we would then have to offset the compensatory measures. In practice, candidate areas must be as close as possible to impacted area, either from an ecological or a geographical point of view, so as to optimize the equivalence and the chances of sucess of the compensatory measures. In our case study, we opt for a candidate area made of meadows, cultivated lands and grassy fallows. They constitute the most impacted lands on the pilot area and present the lowest ecological values as well.

2.2.3 Habitat units for future conditions without management

The USFWS allows for the baseline data concerning individual species in the pilot area to be used if the candidate compensation area is similar in terms of HSI values. If it is not the case, additional field work to determine HSI indices will be necessary in the compensation area.

We set the hypothesis that the candidate compensation area is of equal quality as the pilot area and thus presents the same HSI indices. At this stage, the size of the candidate area is chosen arbitrarily. It is only during the last stage that we will be able to determine the optimal size of the compensatory mitigation measures. The size chosen at this stage for the candidate area will have no influence on the assessment of the optimal size in the end. We opt here for a candidate area of a size identical to the pilot area: 70 hectares (ha)[1] divided into 30 ha of cultivated lands, 20 ha of grassy fallows and 20 ha of meadows.

The candidate compensation area having been selected and the evaluation species list being kept as target species, we are able to determine the target secies that should be present on the candidate area and calculate, for each, the total size of their available habitat. We keep the HSI indices obtained in the first application of the "adapted" method and thus have all the necessary data to calculate the habitat units for the candidate compensation area whithout management: 107.5 units.

2.2.4 Selection of management alternative

Specify the management actions that will be used to increase the habitat units for target species in the candidate compensation area. These actions should lead to the creation of 57 habitat units. Our aim being to obtain an equivalence between compensatory mitigation measures and the net environmental impact of the plan, these management actions should lead to the creation of ecosystem services identical to those lost due to the plan. There are three types of compensatory measures: technical actions (restore or create functional natural areas), management or legal actions (protection of existing areas, creation of natural parcs) and monetary actions (the land planner gives an amount of money devoted to the implementation of ecological measures). Since "ideal" compensatory mitigation measures must necessarily lead to the creation of habitat units in order to completely offset the net environmental impact of the plan, only the technical actions are conceivable in our methodology. These actions were identified in two documents dealing with insertion and compensatory actions [Bloch et al., 2009, Cox, 2007] and through interviews conducted by Marthe Lucas and Caroline Thinus for the *Centre de Droit de l'Environment de Strasbourg*[2]

[1] 1 acre = 0.40 hectare.

[2] June the 5th 2009: interview with Mr Jean Pierre Vacher, BUFO.
May the 25th 2009: interview with Mr Christian Braun, LPO.
November the 14th 2008: interview with Mr Emmanuel Braun, DRDAF du Bas-Rhin.
October the 30th 2008: interview with Mrs Vanessa Garnero, CG67.

Compensatory mitigation measures must be selected so as to recreate, on the candidate compensation area, habitats which are favourable to target species. The candidate area being made of cultivated lands, grassy fallows and meadows, the required management actions should lead to the creation of groups of bushes and fruit trees and to an increase of meadows. Indeed, these are the most impacted lands, appart from the cultivated lands, and they are used as habitats for most of the evaluation species. The selected actions for our case study are: to plant hedges, bushy clumps and trees (including fruit trees), to transplant species (notably for meadow species) and to regroup lands (for cultivated lands).

2.2.5 Habitat units for future conditions with management action

Suppose that we only intervene on grassy fallows by creating 10 ha of additionnal meadows and 10 ha of groups of bushes and fruit trees. The 30 ha of cultivated lands would remain untouched. The objective is, in the end, to reach the same habitat quality as the one that existed on the pilot area before the implementation of the plan ("ideal" compensation). However, in practice, the success of the implemented compensatory measures remains uncertain. Furthermore, whatever the chosen actions, there will always be a certain lenght of time before the area will be able to provide ecosystem services of the same magnitude as those lost. We will take this time lag and uncertainty into account in the following stages of our methodology. However, some of the figures being chosen at random, the calculation is only made here as a demonstration for the application of the "adapted" method.

To take the time lag into account, benefits from the implementation of compensatory mitigation measures are supposed to have repercussions over several years, which requires their annualization. In that case, the USFWS advises, so as to simplifies the calculation, to select target years for which habitat conditions can be reasonably defined. At a minimum, target years should be selected for points in time when the rates of loss or gain in HSI or area are predicted to change (rates of loss or gain in HSI or area are assumed to occur linearly between target years).

There are several requirements for the selection of target years. First and foremost, the time analysis of habitat units must begin at a baseline year (TY-0). A baseline year is defined as a point in time before proposed changes in land and water use result in habitat alterations in the study area. In addition to a baseline year, there must always be a target year 1 and an ending target year which defines the future period of analysis. Target year 1 is the first year land and water use conditions are expected to deviate from baseline conditions.The habitat conditions (HSI and area) described for each target year are the expected conditions at the end of that year.

We state that 10 years will be necessary for the compensatory mitigation actions to allow the created natural areas to supply ecosystem services equivalent to those lost. The chosen target years are:

- Baseline year 0 (TY-0): defines the existing conditions before proposed changes.
- First year following the implementation of compensatory mitigation measures (TY-1), as requested by the USFWS.
- An intermediary year (for which we pose the hypothesis of an increase in the speed of recovery of the compensation area) arbitrary set at year 5 (TY-5).
- Final year, arbitrary set as well at year 10 (TY-10).

The total size of available habitat being known, only the HSI indices will change. Conditions for TY-0 correspond to the present conditions on the candidate compensation area. The habitat units for this area were calculated on the previous stage and are equal to 107.5 units. We assume that, without the proposed changes, the candidate area would keep its level of quality. We assume also that, at the end of the first target year, the quality of the created areas will only be half as good as the quality of the destroyed ones but that this quality will improve continuously until TY-5, and then even faster from TY-5 to TY-10 where it will reach its maximum level of ecosystem services supply. These hypotheses are represented in a grap, inspired by the ones used by the USFWS, presenting the evolution of changes in habitat units on the candidate compensation area for the conditions with and without the implementation of compensatory measures.

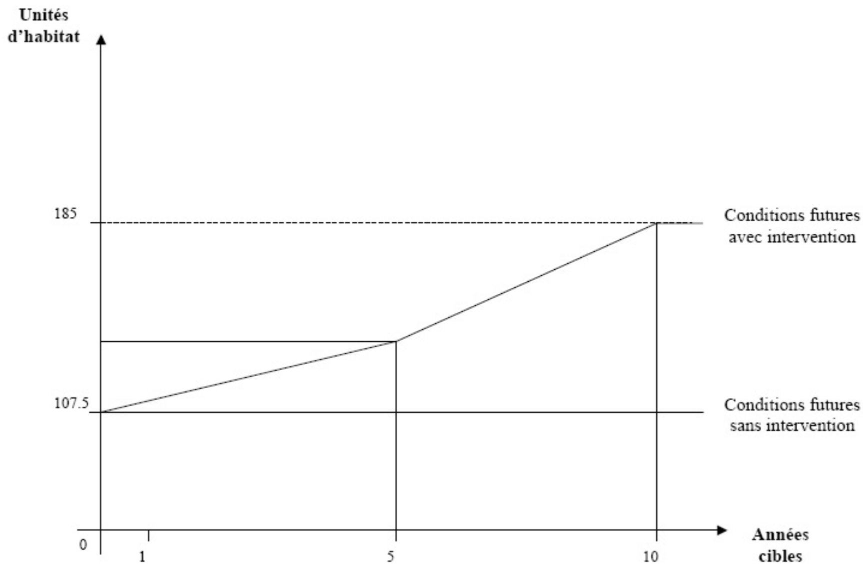

Figure 1: Changes in habitat units on the candidate compensation area for conditions with and without compensatory measures.

Gains in habitat units are changing depending on target years. According to the USFWS, these gains must be annualized by summing habitat units across all years in the period of analysis and dividing the total (cumulative habitat units) by the number of years in the life of the plan (here equal to the estimated time of recovery for the candidate area set at 10 years). When using target years, the cumulative habitat units are calculated with the following equation:

$$HUC \; = \; (T_2 - T_1 \left[\frac{A_1 \times H_1 + A_2 \times H_2}{3} + \frac{A_2 \times H_1 + A_1 \times H_2}{6} \right]$$

With T_1 = first target year of time interval,
T_2 = last target year of time interval,
A_1 = area of available habitat at beginning of time interval,
A_2 = area of available habitat at end of time interval,
H_1 = HSI at beginning of time interval,
H_2 = HSI at end of time interval,
3 and 6 = constants derived from integration of HSI times Area for the interval between any two target years.

This formula is applied to the time intervals between target years. Determining the net impact of a proposed action requires that two future analyses be performed and compared to one another: expected future conditions with the proposed action and the future without the proposed action. When comparing future conditions, the same baseline year and period of analysis must be used for each. We pose the hypothesis that without the proposed action the present conditions would remain the same. The habitat units corresponding to future conditions without the proposed action stay constant at 107.5 units. The total value of the candidate compensation area is then equal to the sum of cumulated habitat units for each species: 171.045 units. Which constitutes a net gain in habitat units equal to $171.045 - 107.5 = 63.545$ units.

2.2.6 Estimation of suitable area for the "ideal" compensatory mitigation measures

So far, we were considering a candidate compensation area which size was chosen arbitrarily. The last stage of our methodology, based on the obtained results, aims at determining the optimal size for the "ideal" compensation area. The formula used for the calculation of the optimal size in the case of an equal replacement is:

$$ZC = -A \left[\frac{\sum_{i=1}^{n} I_i}{\sum_{i=1}^{n} M_i} \right]$$

Where A = size of candidate compensation study area,
M_i = habitat units gained through compensation for a target species i,
I_i = habitat units losses for same species i,
n = the total number of identified species.

The application of this equation to our case study gives an optimal size of the "ideal" compensation area of about 63 ha. A compensation area originally divided into 27 ha of cultivated lands, 18 ha of grassy fallows and 18 ha of meadows (we keep the percentage of cover types that we had chosen for the candidate compensation area), will lead to the creation of 57 habitat units thanks to the creation of 8 ha of groups of bushes and fruit trees associated with an increase of meadows from 18 ha to 27 ha. 28 ha of cultivated lands would remain.

2.3 Estimating the environmental cost

In the original HEP method, once the method used to measure the net impact of the plan and then to determine the optimal size of the compensatory mitigation measures so as to create areas equivalent (in their size/quality ratio) to those lost, the monetary valuation is made directly on the market. Indeed, land planners who need to offset impacts generated by their plan only have to go and see a compensation bank in order to buy the requested amount of habitat units. The net environmental cost of their plan is then equal to the habitat unit market price multiplied by the number of habitat units to be bought.

At present, there is no such market in Europe. We can thus not rely on a potential market price of the habitat unit. As a consequence, we use, in our "adapted" method, the cost of the implementation of the estimated "ideal" compensatory mitigation measures as an assessment of the environmental cost of the plan. This cost is therefore based on present knowledge with respect to ecological engineering and on french, and even local, market prices.

The hypotheses and simplifications made during the application of our "adapted" method do not allow for a realistic monetary valuation of the compensatory action plan. The obtained figures are only used as an illustration of our monetary valuation method. Cost data are issued from a document aiming at giving a first indicative idea of the main compensatory actions [Bloch et al., 2009]. The study was conducted in the East of France, the listed prices are thus consistent with the context of our study located in Alsace (Eastern France).

The optimal size of the compensatory mitigation measure is 63 ha divided, before the implementation of these measures, into 27 ha of cultivated lands, 18 ha of grassy fallows and 18 ha of meadows. The selected management actions aim at transforming these areas so as to obtain 8 ha of groups of bushes and fruit trees, and to increase the area of meadow from 18 ha to 27 ha and the cultivated area of 1 additional hectare, through plantations (of hedges, bushy clumps and trees, including fruit trees), transplantation of species (notably for meadow species so as to introduce the species destroyed on the pilot area) and regrouping of lands. The detail of these actions is:

- Plantation of $50m \times 136m$ *i.e.* 6800 m^2 of bushy clumps.
- Plantation of 34 trees: we presume that about 8 meters must be kept between 2 trees, which allows us to plant 2 rows of trees on the area dedicated to that purpose.
- Transplantation of 9 ha of meadow, *i.e.* 9000 m^2.
- Regrouping of 1 ha of cultivated lands.

We use the prices indicated in the cited document giving, for each data, a price and an margin of variation. The first element of price to take into account is the acquisition of lands in order to guarantee the implementation of compensatory measures. The other items are made out of prices related to plantations and species transplantations. The total cost of the implementation of the compensatory measures amount to 883 360 euros contained in an interval ranging from 743 458 to 1 023 212 euros. For a full understanding of these figures, they must be compared to the expected benefits of the extension of the harbor in Lauterbourg, as well as to the result that could be obtained through the use of more traditional valuation methods.

3 Conclusion

Given that the law and the community institutions seem to support a complete integration of environmental and ecological damage, the need of complementary economic methods, in the specific case of land planning in sensitive environments, is getting greater. Included in the specific case of land planning in sensitive environment. In this paper, we propose to use the compensatory mitigation concept as an other way of assessing the damages induced by an infrastructure development plan. To this end, a procedure called Habitat Evaluation Procedure developed in the United States, seems particularly relevant to our methodology.

The original HEP method favors the use of an equivalence-based valuation focused on in-kind compensations of natural areas of the same type, quality and quantity as the damaged ones. The adaptation of the HEP method to our analytical framework requires some adjustment. Notably the introduction of the "ecosystem services" concept now appearing in discussions concerning the valuation of ecosystems and natural areas. Nevertheless, important needs in scientific data have already been identified (inventories, mapping, ecological equivalencies). Not all these data are yet available. This is why, while researches continue in this field and before they lead to additional knowledge, we consider that some kind of transfer from foreign studies and field analyses is possible. Indeed, unlike benefit transfer for contingent valuation or similar methods, the transfer of scientific data and results such as the equivalence between a newly created natural function and the loss of this natural function, is not bound to socio-economic data about the country or area under study. The validity of scientific data transfers relies on the ecological similarity between the considered areas. This is the reason why, beyond the problems raised by the uncertainties this kind of method can bring, a specific attention should be payed to the transferability of scientific results concerning in-kind equivalencies.

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