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Multi-criteria Assessment of Ecosystems and Biodiversity: New Dimensions and Stakeholders in the South of France

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This paper summarises research undertaken to develop a methodology for multi-criteria assessment of biodiversity which takes into account a multitude of criteria and stakeholder perspectives. The proposed methodology will be of particular value for developing countries, where conflicts of interest regarding ecosystems and biodiversity are numerous and often involve businesses, government, local residents, and other stakeholders. The article reviews the state of the art in the field of multi-criteria methods and assessment of ecosystems and biodiversity. It presents the results of analytical work undertaken on the basis of interviews carried out in the Provence–Alpes–Côte d'Azur (PACA) region of France, focusing on biodiversity in the Réserve Naturelle Coussouls de Crau.

The paper addresses three main issues: selection of the multi-criteria assessment method, selection of the assessment criteria, and a comparison of stakeholder interests in the context of biodiversity analysis. Identification of potential decision criteria was based on a survey of key stakeholders, namely Management of the Réserve Naturelle Coussouls de Crau; Muséum National d'Histoire Naturelle, a national biodiversity research institution; the Laissez-faire Association, protecting the interests of the agricultural community; CDC Biodiversité (a branch of Caisse des Dépôts), a group carrying out long-term investments in the public interest; and Direction regionale de l'environnement Provence–Alpes–Côte d'Azur (DIREN-PACA).

Based on these interviews, 14 ecological, nine economic, and 12 social criteria were identified. Further analysis revealed very few points of overlap among the interests of the stakeholders, which complicates the case for consensus building.

Not accepting the idea that the value of ecosystems and biodiversity can be expressed in monetary terms, the author suggests an alternative, more inclusive approach, focusing on multiple social, economic, and ecological dimensions of ecosystem value, and illustrates the existence of divergent interests among the stakeholders. This experience would be particularly useful in situations where local communities have to defend their right to a clean environment and preserve important virgin ecosystems for the future generations.

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1. Introduction

Ecosystems can be seen as a scarce common-pool resource with a multitude of characteristics, which are seen by potential users from differing perspectives (Ostrom et al., 1999; Adams et al., 2003; Lant et al., 2008; Ostrom, 2008). According to the Millennium Ecosystem Assessment, "over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth" (MEA, 2005). There is a need to be able to make decisions on the future of ecosystems and have clear methodologies in place for classifying ecosystems into valuable ecosystems that should be protected, areas that should be restored, and areas that could be developed. The instrument of mitigation banking could be a good tool to manage the complex resource under study and help to reduce fragmentation of ecosystems and improve their quality. The key question when setting up a mitigation banking system becomes how to classify or value ecosystems, how to determine the unit of value (if any), and how to find an area of equal value to compensate for the development of an ecosystem within the mitigation banking mechanism.

Ecosystems are multifunctional, complex systems, described by a multitude of characteristics from the point of view of multiple criteria. How to compare objects with multiple characteristics has been the focus of Multi-Criteria Decision Aid (MCDA). Methods of multi-criteria analysis have been developed to address the problem of incommensurable values. These methods seek to account for the social, economic, and environmental dimensions of decisions. This paper presents a review of methods and applications of multi-criteria analysis in the context of ecosystems and biodiversity assessment; offers a selection of the most appropriate tools among the MCDA methods; and identifies a set of criteria relevant to a case study in southern France. A discussion on the diversity of interests and ways of mitigating conflict will follow.

Recently, at regional, corporate, and local levels, decisions regarding the use of natural resources, investments, and other forward-looking strategies have been guided by monetary methods, notably cost–benefit analysis. Following Kapp (Kapp, 1970), O'Neil (O'Neil, 1997), Foster (Foster, 1997), and Martinez-Alier et al. (Martinez-Alier et al., 1998) demonstrated the role that incommensurability of values plays in decision-making problems, illustrated the inherent limitations of cost–benefit analysis, and identified multi-criteria methods as viable alternatives. Sustainability problems usually imply relatively low levels of substitutability among criteria to be satisfied, given the urgency and complexity of the problems that we are facing: loss of biodiversity, climate change, deterioration of public health, and poverty. We need to understand multiple dimensions of the decisions that are taken today, and the linkages among these dimensions (Shmelev and Shmeleva, 2009). In making decisions, it is necessary to assess likely multiple consequences of these decisions in the future and work on the innovative strategies that would

satisfy multiple criteria to the best possible extent. New multi-criteria methods, when applied at the local, regional, and corporate levels would stimulate a shift of the development pattern towards sustainability.

2. PACA case study

The Nature Reserve of Crau is situated in the south of France, south-east of Arles. The region is bordered in the south by the Mediterranean Sea, in the east by Étang de Berre, and in the west by the river Rhone. The region is well described in a paper by Buisson (Buisson and Dutoit 2006). Figure 1 depicts the physical geography of the region of Crau. The Nature Reserve of Crau is embedded within a complex network of environmentally sensitive and protected territories. In the west it is bordered by a large Ramsar site. The PACA region is covered by a few larger and smaller National and Regional Nature Reserves. The region is also neatly covered by a network of marine and land-based Zones Naturelles d'Intérêt Ecologique Faunistique et Floristique (ZNIEFF). In addition, parts of the Crau region are covered by the system of Reserves de Biosphere. The Crau region does not have any Reserves Biologiques, or Arretes de Protection de Biotope, neither does it have any Parcs Nationaux. However, it is adjoined by the Parc Naturel Regional of Camargue. The system of Natura 2000 territories,[2] largely different from the types mentioned above, is extremely diverse and covers a considerable proportion of the region.

[2] Natura 2000 is an EU-wide network of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). Special Protection Areas (SPAs) are created by applying an EU directive requiring the protection of wild birds (79/409/EEC, 1979). The Department of Ecology of each country designates these areas, and potential management is planned locally (France: 103 SPA; 8000 km^2). The SPA Crau sèche was designated in 1990 and covers 11816 ha. Special Conservation Areas are designated by applying Annex II (animal and plant species of community interest) of the EU directive, requiring the protection of natural habitats (92/43/EEC, 1992). Annex I plans for the establishment of a consistent network of SCAs within which SPAs are automatically integrated: NATURA 2000. The SCA Crau centrale—Crau sèche was designated in 1996 and covers 31,458 ha. (Buisson and Dutoit, 2006).

Figure 1. Nature Reserve of Crau

If we look more closely at the Crau region, the patchiness and multiple designations of the same small territories become apparent. It is often the case that a small piece of land is designated simultaneously as a Reserve Naturelle National and as a Parc National Regional, or a Parc Naturelle Regional can be part of a Ramsar site. The full structure of multiplicity of designations in the Crau Region is depicted in Table 1. It should be noted that the value of each individual site to be assessed with the help of MCDA would increase if it fell into several designation categories.

The general problem that decision makers are facing in the region is the comparison of 60–70 sites within or next to a Nature Reserve, and deciding which sites should be incorporated into the Nature Reserve and which given to developers for such projects as a gas pipeline.

	National Nature Reserves (RNN)	Regional Nature Reserves (RNR)	Nature Parks (PN)	Regional Nature Parks (PNR)	ZNIEFF Sea	ZNIEFF Land	Biosphere Reserves (RBS)	Ramsar Sites	Natura 2000 Birds	Natura 2000 Habitats
National Nature Reserves (RNN)				X		X	X	X	X	X
Regional Nature Reserves (RNR)				X		X	X	X	X	X
Nature Parks (PN)										
Regional Nature Parks (PNR)	X	X			X	X	X	X	X	X
ZNIEFF Sea				X			X	X	X	X
ZNIEFF Land	X	X		X			X	X	X	X
Biosphere Reserves (RBS)	X	X		X	X	X		X	X	X
Ramsar Sites	X	X		X	X	X	X		X	X
Natura 2000 Birds	X	X		X	X	X	X	X		X
Natura 2000 Habitats	X	X		X	X	X	X	X	X	

Table 1. Multiple designations in the Crau Region

In cases when there is only one criterion and an infinite number of alternatives, single-criterion optimization is usually the most appropriate tool; when the number of alternatives is infinite and the number of criteria is greater than one, an apparatus of multi-criteria optimization could be applied. In cases where the number of criteria is greater than one and the number of objects to be compared is finite, MCDA proves to be a viable tool for the development of robust scientific assessment methodology, which can be replicated. Alternative approaches, namely citizens' juries, can be considered, but they are not practical because of the relatively high number of alternatives (60–70), and also given the existing time constraints and budget limitations. However, the Delphi method of using the expertise of stakeholders and interacting with them will be applied in this study. The paper will focus on three main issues: identification of the assessment criteria, selection of the multi-criteria assessment method, and comparison of stakeholder interests in the context of ecosystem and biodiversity assessment.

3. Integrating socio-economic information in conservation planning: a multi-criteria framework

Multi-criteria evaluation of biodiversity for the purposes of ecological compensation and mitigation banking[3] presents a methodological challenge as well as a practical challenge. Multi-criteria decision tools allow simultaneous consideration of a wide range of criteria, representing different dimensions of sustainability. These may include poverty; governance; health; education; demographics; natural hazards; atmosphere; land; oceans, seas, and coasts; freshwater, biodiversity, economic development, global economic partnership, consumption and production patterns (United Nations, 2007) or the social, environmental, and economic dimensions of sustainability in the

[3] Mitigation banking is a tool that emerged in the USA in the 1970s to diminish the loss of wetland caused by development projects, as required by the federal Clean Water Act of 1972. The main function of a mitigation bank is to compensate for adverse impacts on natural resources by providing for the conservation of a similar resource in another location.

previous edition of the United Nations Guidelines. The latest edition of the UN Guidelines on indicators of sustainable development (United Nations, 2007) emphasizes the linkages among different dimensions of sustainability: e.g. the indicator "Percentage of trees damaged by defoliation" is related to the key thematic area "Land", as well as Biodiversity, and Consumption and Production Patterns. "Fragmentation of habitat" is related to the key thematic area "Biodiversity", as well as to Governance, Land, and Consumption and Production Patterns.

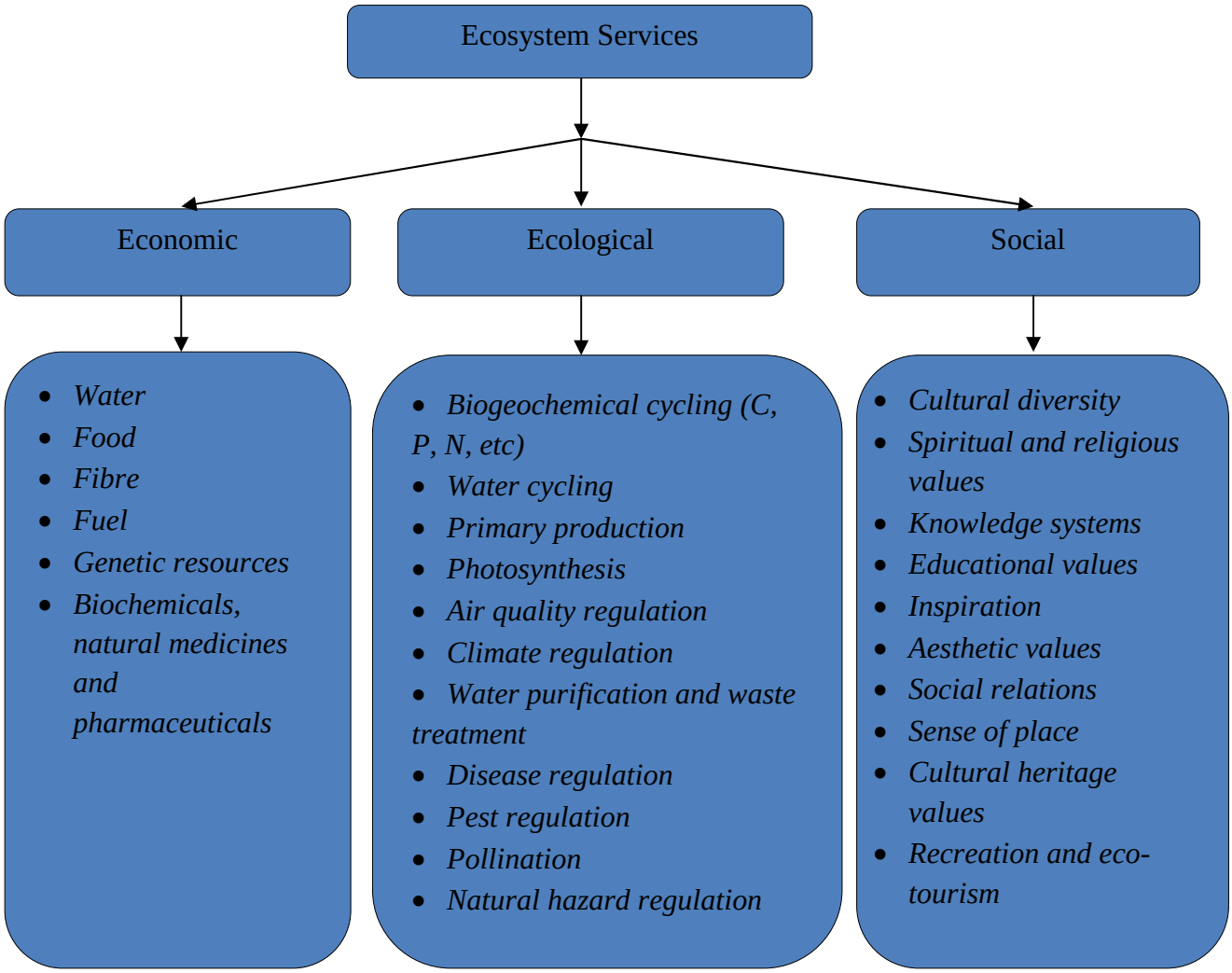

Figure 2. Classification of ecosystem services (adapted from the Millennium Ecosystem Assessment, 2004)

In the ecological (or, more broadly, natural science) domain, recent research in earth-systems science and complexity by V. G. Gorshkov et al. (Gorshkov et al., 2000), J. Lovelock, (Lovelock, 1992), and S. Harding (Harding, 2004) shows how the complexity of ecosystems and the ecological web and the biosphere in general can determine the climatic stability and resilience of the surrounding region or the global system. Recent research by Robert Costanza (Costanza, 2008) contributes to the debate on the evaluation of a multitude of ecosystem services. Thus modern science reveals the increasing importance of cross-disciplinary feedback loops.

Regan et al. (Regan et al., 2007) present a coherent set of environmental criteria for evaluating biodiversity. Moffet (Alexander Moffett, 2006) offers an extensive overview of existing applications of multi-criteria methods to the problem of biodiversity evaluation. It is interesting to

note that the majority of studies reviewed in this paper have been carried out with the help of the Multiple Attribute Value Theory and Analytic Hierarchy Process, or goal-programming methods. It should also be noted that the use of social criteria has been particularly rare in multi-criteria evaluation of biodiversity.

In the economic domain, in the spirit of Pearce and Moran (1994) and Costanza et al. (Costanza et al.,1997), increasing efforts have been devoted to attempts to estimate, in economic terms, the value of ecosystem services and biodiversity, with two major aims: to focus public attention on the problem of ecosystem services (which it succeeded in doing), and to provide the basis for decision making (in which it was not so successful). Methods of assessing the economic value of biodiversity have been reviewed by Jeroen van den Bergh and Paola Nunes (Nunes and van den Bergh, 2001), who concluded that the empirical literature fails to apply economic valuation to the entire range of biodiversity benefits. Therefore, available economic valuation estimates should generally be regarded as providing a very incomplete perspective on, and at best a lower limit to, the unknown value of biodiversity changes. The attempt to assess the value of ecosystem services and biodiversity using a single criterion of money is clearly a simplification greater than the world ecosystems could bear. In our case, incommensurability of certain aspects of value, which is essentially a multidimensional concept, plays a crucial role. This means that the value of ecosystems and biodiversity should be considered using multi-criteria methods, which correspond nicely to the multiple dimensions of the ecosystem value (see Figure 2).

In the social domain, several studies have identified the following socio-political criteria for biodiversity assessments: economic cost, recreational value, human population, future economic value, scenic beauty, cultural heritage, and educational value (Alexander Moffett, 2006). The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2004) describes the following cultural services provided by ecosystems: cultural diversity, spiritual and religious values, knowledge systems (traditional and formal), educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism (Figure 2).

The social and cultural aspects of biodiversity conservation, ecosystem health, and landscape quality have been addressed in a veritable cornucopia of literature (Tubbs and Blackwood, 1971; Peterson., 1974; Gehlbach, 1975; Wright, 1977; Inhaber 1977; Van der Ploeg, 1978; Zube et al. 1982). The diversity of the landscape has been proved to be an important feature in providing visual comfort to humans: in a series of seminal papers Ulrich (Ulrich, 1979; Ulrich, 1986) showed how important trees and vegetation in general are for the health and well-being of an individual. Modern research in the public evaluation of landscapes (Nijnik, et al., 2008; Tveit et al., 2006; Ode et al., 2009) shows how a multitude of approaches can be applied to the analysis of stakeholders' social preferences for different scenarios relating to biodiversity and natural ecosystems. Diversity of the landscape is often reported as an important factor for the visual satisfaction that humans derive from observing and experiencing scenery. Fragmentation has been identified by Taylor (Taylor, 2002) as an important issue in the field of landscape research and planning, which should be looked at from different points of view: ecological, socio-cultural, and anthropological. Lausch and Herzog (Lausch and Herzog, 2002), and Li and Wu (Li and Wu, 2004) discuss a range of landscape metrics used for the study of regional environmental change, data availability, and analytical procedures for landscape research. Other integrative attempts to evaluate the quality of landscapes include Antrop and Van Eetvelde, 2000; Arriaza et al., 2004; Coeterier 2002; de Groot and van den Born, 2003; de la Fuente de Val et al., 2006; Dramstad et al., 2006). The environmental psychology school has also made interesting contributions to this field: Hagerhall, 2001; Han, 2007; Lothian, 1999; Hartig et al., 2003; Van Den Berg, 1998).

The following approach may be productive when addressing the ecological, economic, and social aspects of biodiversity evaluation: identification of all relevant stakeholders in the region, design of the questionnaire, identification of potential social, economic, and environmental criteria, and presentation of the questionnaire to all stakeholders, with a request to assess on a scale (e.g.

from 1 to 10) the relative importance of various criteria for this particular region. Stakeholder responses could be used as a starting point to identify priorities. Then, using diverse GIS datasets, depicting various types of protected territory, species richness, information on the centres of population density, number of tourists, etc., further analysis could be conducted with the aim of integrating social preferences with ecological data.

4. Trade-offs between economic and ecological outcomes in biodiversity-offset decisions

In terms of biodiversity evaluation, the past 20 years have been very productive. Anselin et al. (Anselin et al., 1989) developed one of the first overviews of how multi-criteria methods may be applied to biodiversity assessment. Margules and Usher (Margules and Usher, 1981) summarised the criteria most often used in evaluation: diversity, rarity, naturalness, area, threat of human interference, representativeness, research and educational value, recorded history and potential value, etc. Goldsmith (Goldsmith, 1983) proposed a distinction between "ecological criteria" such as size, diversity, or richness and rarity, which can be more or less measured objectively, and "conservation criteria", such as potential value and intrinsic appeal (Van Den Berg et al., 1998), which are more appropriate to the category of value judgements. Margules and Usher (Margules and Usher, 1984) suggested a further separation of criteria, concluding that, for small sites, ecological fragility, threat, and both species and habitat were the most important criteria, while representativeness, size, naturalness, and position in an ecological/geographical unit were most important for large sites.

5. Multi-Criteria Decision Aid for ecological compensation

The field of multi-criteria decision aiding (MCDA) has developed since the 1960s. Methodological work focused on discrete methods has been carried out by Roy (Roy and Vincke, 1981; Roy 1985; Roy 1991), who pioneered the use of multi-criteria assessment with the ELECTRE family of methods. Brans (Brans et al., 1986) created the PROMETHEE method. Hinloopen and Nijkamp (Hinloopen and Nijkamp, 1990) developed a REGIME method, while Janssen developed the DEFINITE package (Janssen, 1993). Hovanov (Hovanov 1996) designed a method based on randomized preferences called ASPID. Munda (Munda 1995, Munda 1996, Munda 2005a, Munda 2005b) developed the NAIADE method. A survey of multi-criteria analysis methods is presented in Figueira et al,. 2005.

MCDA has been applied to a range of regional issues, e.g. industrial development (Nijkamp and van Delft, 1977), waste management (Shmelev, 2003; Shmelev and Powell, 2006), renewable energy (Madlener and Stagl, 2005; Gamboa and Munda, 2007) and environmental policy (Omann, 2000). MCDA methods have also been used to analyse sustainability problems in general (Munda, 2005a; Shmelev and Rodriguez-Labajos, 2009).

An extensive survey of MCDA methods has been offered by Guitouni and Martel (Guitouni and Martel, 1998), and a review of several MCDA sustainability applications was undertaken by De Montis et al. (2004). The paper by Moffet and Sarkar (Alexander Moffett, 2006) presents a good overview of existing approaches to multi-criteria evaluation of biodiversity in conservation planning.

MCDA presents a new paradigm which differs from the classical goal of finding an optimal solution subject to a set of constraints, which is so characteristic of operations research. Within the MCDA paradigm, the primary purpose of analysis becomes a search for a compromise solution that satisfies the decision maker, rather than some illusory optimum (Guitouni and Martel 1998).

The MCDA methodological procedure can be described as a non-linear recursive process involving four steps (Guitouni and Martel 1998): (i) structuring the decision problem, (ii) articulating and modelling preferences, (iii) aggregating the alternative evaluations (preferences), and (iv) making recommendations.

Roy (Roy 2005) identifies the following basic steps in the MCDA procedure: (i) identification of alternatives; (ii) selection of the family of criteria; and (iii) the choice of the "problematic", which may be reformulated as clarification of the type of problem, the form of results, and selection of the most appropriate procedure to guide the investigation. The following types of problematic are distinguished (Roy and Bouyssou, 1993):

- The choice problematic (P.α): the decision aid is oriented towards the selection of a small number of "good" actions in such a way that a single alternative may finally be chosen.
- The sorting problematic (P.β): the aid is oriented towards the assignment of each action to one category (judged the most appropriate) among those of a family of predefined categories.
- The ranking problematic (P.γ): the aid is oriented towards a complete or partial pre-order on A, which can be regarded as an appropriate instrument for comparing actions between each other.
- The description problematic (P. δ): the aid is oriented towards description in the appropriate language of the actions and their consequences.

A discrete multi-criteria problem can be described in general terms using the following terminology (Munda, 1995):

A is a finite set of *n* feasible actions (or alternatives);

m is the number of different points of view or evaluation criteria g_i (i=1, 2, …, m) considered relevant in a decision problem,

where g_i: $A \rightarrow R$ (i=1, 2, …, m) is a real valued function representing the i^{-th} criterion according to a non-decreasing preference,

while the action *a* is evaluated to be better than action *b* according to the i^{-th} point of view if-and-only-if $g_i(a) > g_i(b)$.

Therefore a decision problem may be represented in a tabular or matrix form. Given the sets *A* (of alternatives) and *G* (of evaluation criteria), and assuming the existence of n alternatives and m criteria, it is possible to build an $n*m$ matrix *P*, called an evaluation or impact matrix, whose typical element p_{ij} (i=1, 2, …, m; j=1, 2, …, n) represents the evaluation of the j-th alternative by means of the i-th criterion. The impact matrix may include quantitative, qualitative, or both types of information.

According to Roy (Roy 2005), the most frequently used decision-aiding methods are based on mathematically explicit multi-criteria aggregation procedures (MCAP). By definition, an MCAP is a procedure which, for any given pair of potential actions, gives a clear answer to the aggregation problem. This implies:

1) various inter-criteria parameters, such as weights, scaling constants, veto, aspiration levels, rejection levels, etc., which allow us to define the specific role that each criterion can play with respect to others;
2) a logic of aggregation, which usually takes into account:
    - the possible types of dependence that we might want to bring into play concerning criteria;

- the conditions under which we accept or refuse compensation between "good" and "bad" performances.[4]

Roy emphasizes the significance of the logic of aggregation of the MCAP. He differentiates three types of MCAP approach:

1) Incomparability is not allowed, and the rule (aggregation function) is explicitly stated. An aggregation function could be a weighted sum, additive, multiplicative, or lexicographic.
2) Incomparability is accepted, and instead of an aggregation rule, a set of tests, which focus on the conditions that must be verified for the outranking, is specified. In Electre methods, such a set uses the concepts of concordance and discordance.
3) Primary importance is given to local judgements without considering any explicit rules of aggregation. This approach uses a formal protocol, organizing the interaction between the decision maker and the analyst in a logical way.

When assessing the relative importance of particular sites for the purposes of biodiversity compensation (or mitigation banking), the problematic β is the most relevant. In this case each site could be assigned to a predefined quality class, e.g. from extremely valuable to not at all valuable, with 5–7 classes[5] in between. Therefore, a decision could be made about which quality class a particular site belongs to, and which other sites belonging to a similar class could be used as compensation (i.e. as an offset), should it be necessary to use the first site for development purposes. The MCDA method ELECTRE TRI, designed to address the problematic β,[6] focused on assignment of objects to one of several predefined classes, and developed at University Paris Dauphine, could be a good candidate for such an application. The method requires explicitly defined boundaries in each criterion for each class under consideration. Other alternative methods could be considered, but a decision should be made about which level of compensation among criteria is appropriate for biodiversity-evaluation schemes, with more compensation implying weaker sustainability, and less compensation implying stronger sustainability solutions. The general distinction between weak and strong sustainability is understood in the following way: more compensation among sustainability dimensions or more substitution of factors is acceptable in the case of weak sustainability, and less compensation among various sustainability dimensions or less substitution of factors is possible in the case of strong sustainability. It should be noted that each of the MCDA methods requires careful tuning, with the help of a range of parameters, such as threshold levels, priorities, etc. Robustness of recommendations in this context is usually assessed by use of the sensitivity analysis.

[4] The term "performance" is used to refer to the value of $g_i(a)$, emphasizing the fact that some of the $g_j(a)$ may not have cardinal interpretations and might be defined on a purely ordinal scale. When it is useful to emphasize the quantitative nature of $g_i(a)$, the term "performance" is replaced by "valuation" (when a criterion is a gradation) or "utility" (when the criterion is a measure).

[5] The standard Likert scale is much used in various fields of research and usually comprises from four to nine points. The use of a seven to nine point scale will allow necessary quality differentiation, at the same time keeping the number of categories of value manageable.

[6] Alternative methods, such as IRIS, PREFDIS, ORCLASS, and TOMASO, addressing problematique β, could also be considered.

Table 2. Potential evaluation criteria, revealed by the stakeholder interviews

	Criteria/Organization	Reserve Naturelle	Museum National d'Histoire Naturelle	DIREN -PACA	Laissez-faire Association	CDC Bio-diversité (Caisse des Dépôts)
	Ecological Criteria					
1	Ecological habitat	V		V		
2	Presence of species	V		V		
3	Connectivity of the ecosystem	V				
4	Grass cover		V			
5	Primary production		V			
6	Soil structure and the soil biosphere		V			
	Biophysical Indicators					
7	Slope, hydrostatic behaviour of the river		V			
	Biological					
8	Specialization of communities		V			
9	Complexity of the trophic web		V			
10	Special community index		V			
11	Bird Index		V			
12	Terrestrial Trophic Index		V			
13	Leaf Index		V			
14	Soil free of diseases				V	
	Economic Criteria					
15	Production of lamb meat	V				
16	Benefit of agriculture		V			
17	Benefit of tourism		V	V		
18	Financial value of the land				V	V

19	Interest from business (e.g. solar panels).				V	
20	Value of the hay of Crau					V
21	Sure valuation of the land due to infrastructure activities					V
22	Costs of rehabilitation of Coussoul					V
23	Value and quality of groundwater			V		
	Social Criteria					
24	Social value placed on the landscape by the agricultural community		V			
25	Social value placed on the landscape by the non-agricultural community		V			
26	Conflict between tree farmers and sheep farmers				V	
27	Interest in the space				V	
28	Social value of the proposed infrastructure					V
29	Patrimony value					V
30	Access to the reserve			V		
31	Participatory aspect of work and decision making			V		
32	Compliance with Government objectives of protection of biodiversity			V		
33	Preservation of pastoral activities			V		
34	Urgency to act			V		
35	Quality of the management (management plan)			V		

6. Stakeholder interviews

In order to reveal the web of stakeholder interests regarding the Nature Reserve of Crau, and to create a basis for discussion of the decision criteria, several Delphi-type[7] interviews were arranged with key stakeholders involved in the consultation process regarding the management of the Crau, and supervised by the Ministry of the Environment. Stakeholders involved in this process represent a range of organizations and have different goals and priorities regarding the conservation of biodiversity in the region but share an interest in the Nature Reserve of Crau. The following stakeholders were approached for this survey: Government of Provence–Alpes–Côte d'Azur (Deputy Chef de Mission), Muséum National d'Histore Naturelle (Scientific Researcher), CDC Biodiversité, Caisse des Dépôts (Chef de projet Sud-Est), Réserve Naturelle Coussouls de Crau (Manager of the Reserve Naturelle), Laissez-faire Farmers' Association (Director). The composition of the stakeholders is justified by the fact that they represent the key interest groups with a stake in the future of the Crau region. It was only recently that these stakeholders were gathered at the same table under the auspices of the Ministry of the Environment and were able to negotiate important issues related to the collaborative management of the Crau region. The local residents in the area are mostly farmers, and they are represented by the Laissez-faire Farmers' Association. It would of course be beneficial to conduct additional interviews with the farmers directly, but the budget and time constraints did not allow us to do so.

Each stakeholder was asked the same basic questions, plus some additional questions unique to each stakeholder. The basic set of questions was the following:

1) What does the Crau Nature Reserve mean for you?

2) Which criteria do you think are the most important for evaluation of different small pieces of land (social, economic, environmental)?

3) How do you think your interests regarding the nature reserve differ from the interests of other stakeholders?

Based on the stakeholder responses, a structured list of 35 economic, social, and environmental criteria was compiled (Table 1A of the Annex). In Table 1A each of the criteria was marked according to whether it was mentioned by the stakeholder or fell within the spectrum of its interests. Development of such a set of criteria is a useful first step towards a full-scale MCDA of the sites in the region. It should be noted that an individual scale should be developed for each of the criteria identified. This could be a quantitative or qualitative scale, with a particular method of assessment or measurement.

Results

Figure 3 depicts in graphical form the areas of intersection among the interests of various stakeholders. It is interesting to note that, although 35 different criteria for assessment were expressed by the stakeholders, no single criterion was suggested by all stakeholders. The management of the Reserve Naturelle and the management of DIREN-PACA share an interest in preservation of the ecological habitat (1) and protection of species (2). Museum National d'Histoire Naturelle expresses an interest in the benefit of tourism (17). Laissez-faire and the Caisse des Dépôts share an interest in the financial value of land (18). The value of

[7] Delphi method, Delphi technique: a method of using questionnaires to arrive at consensual judgements (Shorter Oxford English Dictionary). The Delphi method was developed in the USA during the 1950s–1960s by Project RAND (Olaf Helmer, Norman Dalkey, and Nicholas Rescher).

undertaking a full-scale multi-criteria evaluation of biodiversity would be to account for the whole spectrum of stakeholder interests.

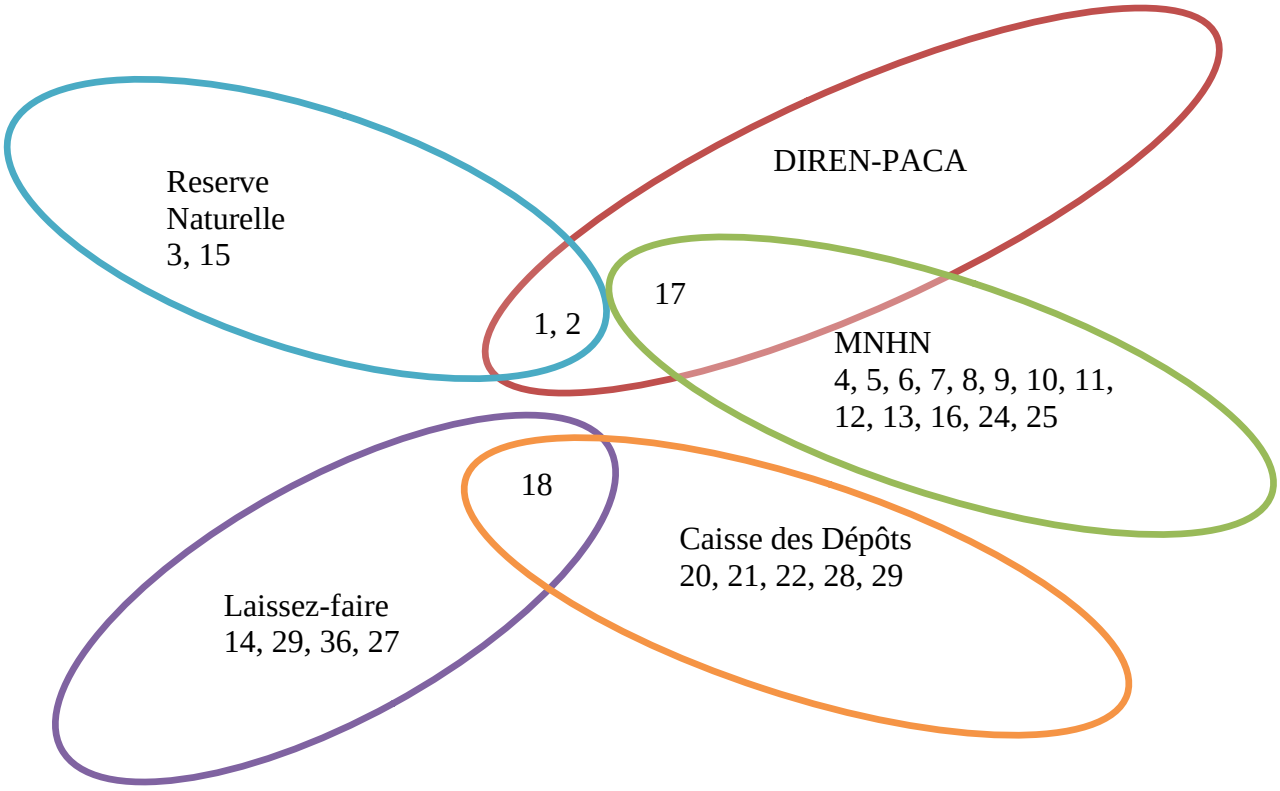

Figure 3. Intersection of the sets of stakeholder interests

7. Discussion and suggestions for further research

The analysis undertaken within this project has shown that it is possible to develop a holistic methodology which would integrate economic, social, and environmental information within a multi-criteria decision-aid framework to reflect the different values of particular plots of land for the purposes of ecological compensation or mitigation banking. The crucial elements of this approach are the following:

- identification of a minimal coherent set of criteria to be taken into account (extensive stakeholder consultations are required to reach consensus on which criteria should be included, and the total number of criteria);
- identification of alternatives to be compared (GIS maps of the various plots of land to be evaluated need to be developed, e.g. by using satellite imagery);
- selection of the multi-criteria aggregation procedure: we suggest the ELECTRE TRI method or its analogues, because it is capable of assigning a range of objects (e.g. plots of land) to predefined quality classes.

Once a decision on the criteria, alternatives, and aggregation procedure has been made, a multi-criteria evaluation can be undertaken, with due attention to the sensitivity of the parameters used in the procedure (e.g. threshold levels and other parameters). Full-scale

application of ELECTRE TRI and similar methods to the case of the Nature Reserve of Crau remains a task for future research.

Such an evaluation approach could be part of a wider system of adaptive governance which is being created around the Nature Reserve. Following Ostrom (2008), such a system should comply with the following five principles, which have been identified on the basis of interdisciplinary studies of failed and successful common-pool resource-governance systems:

1) *Achieving accurate and relevant information*: the use of GIS and modern technologies, as well as building collaborations between local users, public officials, and scientific experts, are indicated as key elements here (the first steps in this direction have already been taken in the Crau).

2) *Dealing with conflict*: Ostrom highlights the idea that the possibility of conflict, which in the case of the Crau is present due to very different sets of interests among stakeholders (Figure 3), should not be underestimated.

3) *Enhancing rule compliance*: formal rules may become effective when participants see them as legitimate, fair, enforced, and likely to achieve intended purposes. This principle illustrates the need for extensive consultations with the stakeholders, which could ensure that the evaluation method is effective.

4) *Providing infrastructure*: particular attention should be paid to the existing farmers' property rights over parts of the Crau.

5) *Encourage adaptation and change* (the stakeholders should be open to negotiations, be ready to adapt, and be ready to legitimize change which emerges out of friendly collaboration).

One would hope that, using the principles outlined above, it should be possible to develop an effective governance system that will be capable of dealing with contradictions highlighted in this paper.

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ANNEX A. Results of Stakeholder Interviews Conducted in the PACA Region regarding the Reserve Naturelle de Crau.

Table 1. Detailed exposure of the opinions of the stakeholders on the main role of their organization regarding the Nature Reserve, the meaning of the nature reserve for their organization, the most important criteria to be taken into account in the valuation process and the differences with other stakeholders.

Organisation	Main Role	What does Reserve Naturelle Means for organisation	Criteria	Differences with other stakeholders
Nature Reserve	1) **Buy land** (own 500 ha in the region) 2) Protection of interesting areas through **passing conservation agreements with the owners**	Speciality of La Crau because of the **Natura 2000 status**, unique in France and in Europe because of the **vegetation and bird species and insects**; At the same time Crau has been the site of the large **waste dump of Marseille, military base and a dynamite factory**. Difficulty to persuade that the it was a unique ecosystem.	Ecological: **habitat** and **species presence**. Habitat – coussoul has been untouched for thousands of years. Animal community is unique, including birds and insects: Calandre lark, Little Bustard, Oscillated Lizard, Crau Jewel Beetle, and Crau Grasshopper. Would include types of species present, the presence or absence of the typical vegetation of the coussoul **Connectivity of the system**: crau steppe is very fragmented	Local interest in the protection of the coussoul: dilemma of factories and peach orchids vs protected territory. Farmers have acknowledged the importance of the protection of the coussoul. The Agricultural Chamber is now playing a central role and acknowledges that the coussoul needs to be protected. Peach farmers may have slightly different interests. But everyone's interests are taken into account through discussion groups. Yes, multiplicity of different types of designation can be confusing for local people (farmers, hunters), they sometimes mix natural reserve and Natura 2000.

Musee Histoire Naturelle	1) Scientific research for the Ministry of the Environment on measurement and quantify the ecosystem functioning 2) Development of indicators to quantify the ecosystem functions and to quantify the optimal value of the ecosystem functioning and the resilience value	Reserve Naturelle means a **protected area** where there is a **limited impact of human development on nature**. Personally, Reserve Naturelle de la Crau means that there's **sheep everywhere** and there's very few people, and only agriculture	The **economic criteria**, I think, will be the easier thing to do, through the **benefit of agriculture and tourism**; The social value will be **how agriculture values this landscape**, but not only as a job case, and also non-agricultural people, how they value it; Functioning of an ecosystem, so it is a grass ecosystem, there is a huge **importance of grass cover**, and of **primary production** and as the soil is very specific in this region, the **soil structure and the soil biosphere**. **Biophysical indicators**, which can be the **slope, hydrostatic behaviour of the river** in different kinds of patches; Purely **biological criteria**, which can be the **specialization of communities**, which means there are more general species or more specialist species, and also, the **complexity of the trophic web;** this ecosystem is not a real natural ecosystem, but it is a result of the historical development, therefore the importance of historical status of the ecosystem. Two major types of indicator: 1) response of an ecosystem to a perturbation, 2) measurement of the real effect of one function of an ecosystem **E.g. special community index**, reveals a fragmented area, which is a perturbation **Bird index**, which is a bird specialisation index, because the ratio between the specialists and generalists reflects the fragmentation of the habitat and biotic homogenization; this specialization index, we also try to calculate this on **mammals and amphibians (reptiles),** but this will take a few more months. Like the Marine Trophic index, designed by Poli et al 1998 we are trying to build with birds data the **terrestrial**	MHN is a research organisation, so we are interested in ecological research. From the ecological point of view I think that we have the same interest and the same preoccupation like the people from the reserve and the people from the university in the south of France, but we do not value coussoul for the same reason as agriculturalists or economists because we are interested in the species that live there, but not in what can the humans do with it. A non-utilitarian approach, exactly. In the Reserve Naturelle the focus is on species that need to be preserved and that is a very important part of ecology, but you cannot focus on every species, you have to focus on one special species. And as a research organism, MNHN can have a more theoretical approaches which can integrate more species and the functional aspects, which are not integrated by specific measures on this or this species.

			trophic index on the trophic levels of birds, and these two indicators are only available right now. However they lack some information about bacteria, about maybe hydrology and geophysics criteria. **Leaf index**, which can be calculated through satellites, and this is an indicator of primary production and plant density. Potentially indicators of diversity in rivers and other aquatic living species. What is the minimum scale, minimum patch of land these indicators could be applied to? Thinking about that. We have the national dataset and we need to complete this dataset to assess the small patches, but we don't know yet the scale limits of these indicators, we are trying to develop this further.	
Laissez-faire Association	1) intervention in the land-tenure transactions with a view of securing the durability of the site 2) protection of the environment; 3) protection of the agricultural sector: choice of whom to sell the land	Reserve Naturelle is a link in the cycle of the pasture. For all the humid Crau, that is a meadow, the 4th shoot growth of grass (September, October, November, etc and until the 15th of February), this grass that grows is not cut and it is eaten by the sheep. That what is called "the 4th cut" and that is used as pasture. When the sheep that come down	The thought about the **financial valorisation of the land in Euros**. The Crau is an important stake as in the 1980's several tree farmers came and implanted the **"drop by drop" irrigation technique**. They implemented fruit tree farms in a desert. And it as very interesting economically because the coussoul was not expensive so they created fruit tree farms with a land that did not cost much (because quite dry) and also because they could create very well-structured and large units on a **soil that was free of disease** like the bacteriose in the Drome region. Several hectares of fruit tree were developed. Today **prices are more stable as there is no more possibility to implement fruit tree farms in the Crau**. Fruit tree farmers know it and they do not make any application anymore. Stabilisation at 4500-5000 Euros. That is that if the value and the becoming can be managed. **If the**	For the protection-side, other stakeholders are: **NGOs**, **"The Conservatoire"**, **DIREN**, **Departmental (as in the French context of Department) Agricultural Administration**, who is very motivated about the protection and also very concerned about preserving the state of equilibrium and the space so the sheep can get out of meadows. Because if the sheep stay in the meadows they eat the "first growth of grass". So the sheep need to go somewhere else so that this first grass can grow, be cut and

	to.	from the mountain in September-October they go to the Crau to eat. And the Crau create the join after and before the sheep herds go to the mountains. The sheet herds are very important for the richness of the meadow. So it is a cycle in Provence that is important. So if the Crau was not protected there would be some economical problems if the sheep were going to stay in the meadow. So this is an aspect purely economic.	**coussoul can be restored then the price could be much higher** (reflecting the potentiality of what could be done). If you can irrigate you can grow things on these pieces of lands. Today in the Crau there is **no real market**. The only buyer in the Crau today, when it is not possible to restore, are conservation and environmental organisations who have a goal of natural reserve. So it is not really a free market anymore. People that want to buy in the Crau for raising sheep, there are none. As the only agricultural use is sheep farming, less and less people will want to but some land. The only potential buyers will gradually be organisations of nature protection, who anyway will put sheep farming o n the land. So in this quite limited territory the market is collapsing. It is also interesting because it quietens the market and a real development of the reserve will be possible and limit a pressure on land prices. Everybody is trying to avoid this pressure. Lasafaire tries to be as soon as possible involved in the sale of a piece of land (of coussoul) to avoid the parcel being sold to somebody who has the project to disturb the coussoul (as not all of it is in the reserve) and to transform it in something else. So they try to be proactive and present. That is what happened for the compensatory measure of "Gertegas" and "Sages" where they manage to negotiate in amicable terms with the owners of a piece of land that was situated at the exit of a motorway, between the industrial zone of "claie sud" and the motorway and that potentially could have been given a higher value for somebody who would not have been associated with the reserve. So there would have been some additional motorways sections built, or it	sold as hay. Lots of people have some interests in protecting this equilibrium. So all the stakeholders cited previously and **the farmers**. The **sheep farming sector** wants to protect the coussoul but the tree farming sector prefer to turn the coussoul (disturb it). There are some contradictory interests. So the piece of land of coussoul that they bought ("Gertegas (???)" and "Sages (???)" see above) could have been used very easily for non-agricultural activities**, industrialisation**. Now some reserves have been implemented, the land zoning plans of each "communes" classified this piece of land for protection. But such land zoning plans can be changed. There are pressures from the industrial sector to get this piece of land because it is very flat and clean. Generally it is always supermarkets and never micro-scale activities. So when you discuss with one person you could have 70 or 80 hectares. Today there is one risk which is to implement **photovoltaic**

			could have been transformed in an industrial area, given the proximity of the "claie sud" industrial zone. So they try to occupy the land and try not to let people dream about the transformations of the coussoul. In Provence, there is as well a cultural aspect and the notion of space. There is space for all activities and there is **a need for space**.	**activities**. Some people, and it might be a transitory phenomenon, who look for vast space of land to put solar panels. They do not dare so far come in the Crau because there is a real desire to protect the Crau. But there is some tries because it is quite easy to install solar panel as there is no uneven level. There is a will from the elected people to preserve this Crau but sometimes opportunities create a situation where there is less attention paid. So there is always this pending danger. It is a fight.
CDC Bio-diversité (Caisse des Dépôts)	Management of innovative collaborative projects in the region.	Pre-exiting structure that, since its creation, has a favourable action of biodiversity of the territory. Because of co-management by naturalists (conservatoire national des especes naturelles de Provence Alpes Cotes d'Azur de Sete) and by the chamber of agriculture	The term value has different meanings - in economic terms, **value is associated with financial transactions** (buying selling). Economic value linked to the kind of use the piece of land is used for. Historically, the coussoul had a pastoral use then in the 1980s it was more used for fruit trees. Agriculture is also a use of the coussoul (e.g. vegetable growing, market gardening). Value depending of the productivity of the systems. For a small piece of land, the economic value per hectare associated with pastoral activities is one to four-times lower than if it is used for growing fruit trees (fully productive). - **Co-existence of different land uses in the Reserve Naturelle** some are used for grazing. (only talking about	The actions that they have when considering the reserve are two-fold: i) an action of conservation that complies with the requirement of the "reserve naturelle" status in terms of preservation of natural landscapes and ii) inclusion of agricultural activities because of the necessity of having pastoral activities for the management practices of these landscapes. So the reserve naturelle is both conservation and valorisation of

		(des bouches du rhone), the reserve is original in terms of its actions not only regionally but also nationally. Not a lot of example of natural reserve with a co-management system. Reserve Naturelle de la Crau is a partner in one of their project: action “cosur”. This project aims at converting an abandoned fruit tree commercial area into a pastoral area with a great legacy value from a public perspective.	the dry Crau, not the humid Crau where the quality-certified hay is grown) The culture of **the hay of Crau** has an added value compared to pastoral land (as the hay has a quality-certified status and is sold both nationally and internationally). Also not other animal feed in France that has this status So economic value associated with the land is variable and this depends on the practices used on the piece of land Also projects and infrastructures (existing and planned) in the area will progressively reduce this area and will reduce some of its capacities (e.g. agricultural production). This can cause a “sur-evaluation” of the price of the piece of land. When there are other factors on these pieces of land than agricultural activities, prices become higher. - The other value is the **ecological one**. Particularly, for the dry Crau that encompasses the coussoul, the **patrimony value** is very important at European scale. And so when one talks about value, in this case there are very strong implications. To date this ecological value is not precisely quantified in economic terms but this will be possible in the future, through for example the rehabilitation operation that they are going to undertake; then they will have an idea of costs associated with the rehabilitation of the site (in this particular case of starting from an industrial fruit production area and converting the area into a steppic landscape and pastoral). This conversion is undertaken with an ecological vision in mind that after some time could lead to the **establishment of the coussoul.** It is clear that it will take some time for the coussoul to	different practices on a same piece of land (especially agriculture). Regarding the conservation and agricultural aspects their activities are totally aligned with the status of reserve naturelle. Their project is situated not directly in the reserve naturelle but is surrounded by the reserve naturelle. The main aim is to re-connect different land pieces to support biodiversity, as at present these pieces of land used originally for industrial fruit production fragmented the landscape. Their activities are therefore totally in phase with the management of the reserve naturelle

			establish itself, as generally it takes about **2000 years**. The type of pastoral activities on the coussoul use the same practices as the Romans used. The restoration project does not intend to restore the coussoul but it participates in the restoration of a landscape that could lead to the formation of coussoul. So this will give an idea of **costs associated with the rehabilitation of the coussoul** or a landscape close to the coussoul. - After these values, one can also add other values. Values can also be associated with the ecosystem provision of goods and services, linked for example with water management, air quality management. Up to date there is no particular study undertaken at their level.	
DIREN-PACA	The DIREN represents the regional directorate of the environment (or Direction regionale de l'environnement in French), related to the French government. DIREN has for mission to preserve biodiversity	The DIREN has a very special role as it is the instructor of the creation of the natural reserves. The Environment ministry instigates the creation of the natural reserve but it is the DIREN that manages projects in the natural reserve at regional scale, under the authority of the "préfet". So the DIREN has a role of instructor, so it is totally involved in	For the CRAU, in the speaker's personal point of view, the CRAU is a natural reserve that is unique. The reserve is open to the world as everybody can have **access to the reserve**. In Camargue, the public can't access the natural reserve and as such it seems that it would be easier to preserve a reserve if the public can't have access. But one still needs to comply with the regulations. In the CRAU, the managers do not really manage anything: the sheep and shepherds do. The managers of the natural reserve in the CRAU, are evaluating activities, facilitating communications and are responsible for trainings but the main managers of the reserve are the sheep, shepherds, hunters, hikers, "ravers" (participating to rave parties). So it is very complicated. So the important criteria when it comes to valuation, is the fact that any work **should be done collectively**. All the actors concerned should be brought together and	In France, there are too many tools available for Nature's protection and this is applicable to the designation of the different areas of protection. Different attempts have been made to **simplify the system** but nothing has been implemented yet. Different organisations have different designations for the protection areas they cover and all these are not harmonised. It is a problem. These designations have different properties that are not comprehensive and this is why

	and landscape at regional scale and to get to know and contribute to the building of knowledge about this biodiversity and landscapes and the patrimony value that they represent.	natural reserves. The natural reserve is a strong protection tool, a very heavy procedure to set up (14'07-14'27 in the recording: the speaker explained a bit how a natural reserve is set up under French legislation, but explanations are a bit confusing). It is a tool that the DIREN do not wish to see being made as commonplace as there can not be 10 000 of natural reserves in France. At the moment 160 natural reserves in France (covers about 0.2 or 0.3 % of national territory). So these territories, classified as natural reserve are precious. For the Crau too, the set-up of the natural reserve status was a heavy procedure but even more so than it	that is the role of the "comité consultatif". Information and pedagogy are needed but firmness and rigor are also needed. There are regulations that need to be complied to. The managers of the reserve have the power to enforce these regulations (but not the DIREN). The manager in that respect can be helped by existing police forces. So on one hand, rigour and firmness are needed to enforce the natural reserve regulations but on the other hand working together with all the stakeholders to avoid misunderstandings is necessary. And there are lots of stakeholders involved: elected people, hunters, shepherds and so on. So it is complicated and an on-going work. The DIREN is a bit far from the ground but relies on firmness for the surveillance of the site, good will to work hand in hand with all the stakeholders and the DIREN is particularly attentive to the managers of the reserve, who are representing the natural reserve on the ground (with the outfit, the logo, car, the regulation enforcement power and the means, both financial and human, to have the regulations enforced). So the work of the managers is very important. The last point is the **management plan**. To manage the reserve properly it is important to have a multi-annual management plan. The document is being written by the managers of the reserve as the interview took place and it will be reviewed through a strict evaluation process at national, regional and local levels. The document being written will expose the five-year management plan for the reserve. A very long-term management is decided and only what is going to be done over the next five years is indicated and will be implemented and re-evaluated.	it is important to have the different designations to cover all the different aspects of protections. For example the status of Natura 2000 or other contract-based tools are not sufficient and the accumulation of the different designations is needed to cover all aspects of nature protection. The last point is the protection by zones, but it is also insufficient. At the date of today all these perimeters of protection help in nature protection but need to be **harmonised** and this is extremely difficult to achieve.

		was politically complicated by diverse oppositions. People see the reserve as a constraint because when the status of natural reserve is given to an area, one cannot do what one wants in the area. So the DIREN is totally involved in the Crau natural reserve and even more so that it is financing the natural reserves' managers and it is doing so democratically. So the DIREN, under the control of the "préfet", establishes a management committee: the "comité consultatif de la réserve" that is chaired by the "préfet", and sometimes the DIREN (when the "préfet" delegates his/her role) and that involves all the actors of the	This management plan applies to the natural reserve (7500 ha) but this logic of management plan also should apply to the Natura 2000 site, in its "document of objectives". The "document of objectives" fro Natura 2000 sites serves the same principles as the management plan for the reserve but is not as binding and non-compulsory. To sum up: police, constant exchange with all the stakeholders so that the natural reserve is not perceived as a protection zone but is integrated in the local economic community and understood by the stakeholders, are necessary. In the reserve, the signs/presentation boards on the walking path are strategically placed to open the reserve to all the stakeholders. Financial support is needed to manage the reserve. Without financial means, nothing is possible. And finally a long-term management plan is needed. In the management plan of the natural reserve there are several indicators, i.e. value per ha of the natural reserve, biodiversity criteria, number of rare species of birds, etc. So these are indicators, where the DIREN has information on the initial state. The DIREN implements protection and information campaigns in order to have protected or restored areas. For the DIREN, the natural reserve has one objective: the protection of the biodiversity. It is the priority. So if additionally, the natural reserve is an asset for the local tourism industry, the shepherds and so on it is a bonus. But for the speaker's point of view the biodiversity is the priority, so the main criterion is the biodiversity **(e.g. species of birds, coussoul**). There are indicators to assess the biodiversity criteria. The DIREN assesses the biodiversity of the reserve every five years and see if any	

		natural reserve (that comprise elected people, NGOs, residents and users of the reserve, etc). This committee meets once or twice and is facilitated by the DIREN and the "préfet". The "préfet" nominates a manager, whose for the CRAU are the CEP and the agricultural chamber. It is original and unique in France to have two bodies acting as co-managers of the natural reserve as normally there is only one body. In the case of the CRAU there are two: one agricultural and one biodiversity-related. It is original because of the geographical setting and requirements of the CRAU. The DIREN finances yearly 100% of the CRAU natural reserve	changes occurred. So for the speaker, the main criterion is the protection of the biodiversity even if it is impeding other areas of activities such as tourism. [*Another speaker talked from here*]. For the second speaker, in terms of valuation, **the tourism is important** but there is also the pastoral activity. There is a systemic link for this area between biodiversity and pastoral activities. This link is a benefit but is also a weakness as it is depending on external regulations (i.e. agricultural), which can affect the link (e.g. agricultural policies from Brussels). In the CRAU there is also **groundwater**, which has an indirect value. **The groundwater is protected** by the agriculture and the reserve status and should other activities be implemented in the CRAU, the groundwater could disappear. Eighty percent of the groundwater table is fed through the humid Crau (not the coussoul). So there is an indirect benefit for the areas external to the reserve as these areas extract water from the groundwater table found in the CRAU reserve (e.g. Fosse, Miramas). [*First speaker again*] This national natural reserve has the main objective of protecting the biodiversity. Up to date there is a fragile equilibrium that depends on agricultural practices. It worked up to today. But it still remains fragile and external factors can jeopardise this fragile equilibrium. If that happens, solutions should be found. The main objective is to **preserve the biodiversity and the agriculture in the reserve is a mean to protect this biodiversity.** If the agriculture should become a problem for the protection of the biodiversity, alternative solutions should be found. If better solutions than sheep are better to maintain the biodiversity then they should	

		at the moment, or about 200 000 Euros, that is used to pay people involved in the management of the reserve, surveillance, pay the cars, etc. So the DIREN is really involved in the management of the CRAU natural reserve. As it stands to date, the DIREN has a permanent obligation, on a yearly basis to finance the natural reserve. And for now the DIREN manages to have the budget to finance the natural reserve. So the DIREN is an important actor of the natural reserve because it is its financial and administrative missions, under the authority of the Préfet.	be implemented (but that would not go easy politically). This is a complex, subtle and difficult ecosystem. Another criterion is the fact that the natural reserve status helped the CRAU to be known as an area and to take a strong identity, where the area was un-known. The natural reserve is young (2002 or 2004) and where the CRAU used to be destroyed, it is now protected and restored. It is a great shift.	
Ministry of the Environment				

Table 2. Evaluation Criteria, revealed through stakeholder interviews.

	Criteria/Organization	Reserve	Museum National d'Histoire Naturelle	DIREN-PACA	Ministry of the Environment	Laissez-faire Association	CDC Bio-diversité (Caisse des Dépôts)
	Ecological Criteria						
1	Ecological Habitat	V		V			
2	Presence of species	V		V			
3	Connectivity of the Ecosystem	V					
4	Grass cover		V				
5	Primary production		V				
6	Soil structure and the soil biosphere		V				
	Biophysical Indicators						
7	Slope, hydrostatic behaviour of the river		V				
	Biological						
8	Specialization of communities		V				
9	Complexity of the trophic web		V				
10	Special community index		**V**				
11	Bird Index		**V**				
12	Terrestrial Trophic Index		**V**				
13	Leaf Index		**V**				
14	Soil free of diseases					V	
	Economic Criteria						
15	Production of lamb meat	V					
16	Benefit of agriculture		V				
17	Benefit of tourism		V	V			
18	Financial value of the land					V	V
19	Interest from the business (e.g. solar panels).					V	
20	Value of the Hay of Crau						V
21	Surevaluation of the land due to infrastructure activities						V

22	Costs of rehabilitation of coussoul						V
23	Value and quality of groundwater			V			
	Social Criteria						
24	Social value placed on the landscape by agricultural community		V				
25	Social value placed on the landscape by the non-agricultural community		V				
26	Conflict between tree farmers and sheep farmers					V	
27	Interest in the space					V	
28	Social value of the proposed infrastructure						V
29	Patrimony value						V
30	Access to the reserve			V			
31	Participatory aspect of work and decision making			V			
32	Compliance with the Government objectives of protection of biodiversity			V			
33	Preservation of the pastoral activities			V			
34	Urgency to act			V			
35	Quality of the management (management plan)			V			