A Data Envelopment Analysis Approach to the Assessment of Natural Parks' Economic Efficiency and Sustainability. The Case of Italian National Parks

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Summary

Wilderness protection is a growing necessity for modern societies, and this is particularly true for areas where population density is extremely high, as for example Europe. Conservation, however, implies very high opportunity costs. It is thus crucial to create incentives to efficient management practices, to promote benchmarking and to improve conservation management. In the present paper we propose a methodology based on Data Envelopment Analysis, DEA, a non parametric benchmarking technique specifically developed to assess the relative efficiency of decision-making units. In particular, the objective of the discussed methodology is to assess the relative efficiency of the management units of the protected area and to indicate how it could be improved, by providing a set of guidelines. The main advantage of this methodology is that it allows to assess the efficiency of natural parks' management not only internally (comparing the performance of the park to itself in time) but also by external benchmarking, thus providing new and different perspectives on potential improvements. Although the proposed methodology is fairly general, we have applied it to the context of Italian National Parks in order to produce a representative case study. Specifically, the choice of adequate cost and benefit indicators is a very important and delicate phase of any benchmark analysis. For this purpose, a questionnaire was used to investigate the opinions of Italian National Parks managers and stakeholders and to define the relevant indicators for the analysis. Finally, relevant policy implications for the case study are given.

Keywords: Data envelopment analysis, Natural park management

JEL Classification: Q01, Q26, Q56

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Introduction

Since ancient eras, the idea of protecting portions of the land has appeared as a necessity. The reasons for this have intrinsically changed over time, going from the mere necessity of preserving hunting areas to the idea of biological conservation, which remains one of today's driving causes. Although in different times and places, and motivated by different concerns, this idea has led to the same result: the conservation of ecosystems that would otherwise have disappeared. Indeed, if on the one hand the first example of a modern National Park is quite recent (Yellowstone, Wyoming, instituted in 1872), on the other hand, examples of protected areas can be traced back to game reserves. The first example, which can be dated back to 7.500-7000 B.C., shows the existence of hunting areas in archaeological sites in South-west Iran. During the history of Indo-European civilizations, the aristocracy used to create game preserves in forests with the effect of conserving wide pristine areas which solely a very restricted number of individuals could make use of. This was also the case for Italy where many areas which are still protected today, were originally game preserves. The preservation of wilderness is also linked to religious activities, for example the holy woods of Mediterranean cultures. During the Middle Ages, almost all of the forests surrounding monasteries were turned into preserves and the population was forbidden to harvest these areas. In Italy, the Apennine forest of Abetone and the "Foreste Casentinesi" National Park have been preserved to the present day thanks to the presence of eremitical places (Massa, 1999). However, the origins of the concept of 'holy forests' can be traced back to the Etruscan and Greek civilizations, when natural areas surrounding towns were consecrated to divinities and any human activity was forbidden.

The modern idea of protected areas, which underpinned the Yellowstone Park institution, was based on the recognition of the value of wilderness amenity and of the recreational services it produces.

The American “Protection Ethics” sprung from the ideas of three naturalists: Ralph Waldo Emerson, Henry David Thoreau and John Muir. In their interpretation, for the first time wilderness was as important as religion. Nature could not be exploited for purely economic reasons. Moreover, the beauty of Nature had to be safeguarded in that its contemplation was recognized as a basic need for human beings; this ‘use value’, mainly centered on human needs, was at the foundation of this early protection ethic.

At the beginning of the twentieth century, a new idea took shape: that of Gifford Pinchot. He based his thought on the philosophical outlook of John Stuart Mill and believed that preserving nature has first of all an economic rationale behind it.

It was only around the 1950s that along with these different interpretations of nature’s conservation, essentially based on an anthropocentric perspective, a new thought emerged: that of Aldo Leopold. It was based on the recognition of the intrinsic value of the existence of nature and it constituted, in subsequent years, the foundation of modern evolutionary ecology.

During the twentieth century, particularly in Europe, the erosion of territory, hence of ecosystems, due to human activities was dramatically increasing. This led to a growing concern for wilderness conservation issues, tracing back from the first meetings in Paris (1902) and London (1937), up to the 1987 report “Our Common Future”, prepared as a discussion basis for the Earth Summit held in Rio de Janeiro in

1992. During these subsequent meetings, the concept of a preserved natural area, the ‘natural park’, has undergone several successive transformations, until a new interpretation emerged. Natural parks should be government- managed territories, where development and preservation forces are kept in balance. Management should not only be concerned with environmental issues, but more broadly with the socio-economic features of the territory. Indeed, in a dynamic perspective, it might turn out more appropriate for conservation purposes, to open a protected area to some human activities, rather than to close it completely, preventing any development, even under a pure non-anthropocentric ethic of conservation. Indeed, it is now widely recognized that untouchable territories are bound to slowly disappear, because of land scarcity, and this is particularly true for highly populated areas as Europe. Therefore, in a long-term perspective, the involvement and sustainable development of human activities within protected areas may prove to be a win-win strategy.

Within this enlarged vision, natural areas’ management entails the dynamic assessment of environmental quality indicators as well as the sustainability level of management activities, thus increasing the need for comprehensive indicators. Qualitative and quantitative indicators may support the decision- maker in comparing different realities, in evaluating the environmental and economic performance of its management’s policies, and in trying to forecast the effectiveness of potential changes in management strategies.

There is a long tradition of benchmarking methodologies, however most of them are commonly restrained to cover an internal perspective and do not investigate how the analysed protected area is performing when compared to others.

The main objective of the present paper is the external benchmarking of protected areas. To this aim, it is necessary to introduce a common benchmarking methodology, capable of taking into account specific features of different realities. Data Envelopment Analysis (DEA) is an extremely flexible and useful methodology, which provides an indicator of the relative efficiency for each different analysed decision-making unit (in our case National Park Management offices), where efficiency is a measure of different features related to the environmental as well as to the economic or social impacts of the protected area.

In this paper we present and discuss the application of DEA to the case of Italian National Parks. In order to create a common set of indicators, a preliminary questionnaire was administered to investigate the opinion of parks' managers and other stakeholders at a qualitative level. A follow-up questionnaire was subsequently carried out in order to collect intertemporal quantitative data for all the indicators that were considered more relevant by managers and stakeholders. DEA analysis was carried out on the data set.

The paper is organized as follows. Section 1 provides a brief literature review. In Section 2 a brief description of the DEA methodology is given, while in Section 3 the data set and the data collection methodology are discussed, together with the types of DEA analysis performed. Section 4 is a description of the main results and Section 5 concludes with a summary of the main findings along with the final remarks and future extensions.

1 DEA and the environment

DEA is a multivariate technique for monitoring productivity and providing insights on the possible directions of improvement of the status quo, when inefficient. It is a non-parametric technique, i.e. it can compare input/output data, making no prior assumptions about the probability distribution under study. The origin of non-parametric programming methodology, with respect to the relative efficiency measurement, lies in the work of Charnes *et al*. (1978, 1979, 1981).

DEA has been applied to several benchmarking studies and to the performance analysis of public institutions, such as schools (Charnes *et al*., 1981), hospitals (Nyman and Bricker, 1989), but also of private ones, such as banks (Charnes *et al*., 1990). An exhaustive analysis of its underlying theory and main applications can be found in Charnes *et al*. (1993), while a comprehensive literature review in Tavaresa (2002).

Applications to environmental and resource management problems are less frequent. An interesting overview of the role of DEA in environmental valuation can be found in Kortelainen and Kuosmanen (2004), while a survey of indicators of firm's environmental behavior can be found in Tyteca (1996). We briefly report some application studies in the following.

Application	**Author**
Measure ecological efficiency	Dyckhoff and Allen, (2001)
Measure environmental impacts of different production technology	De Koeijer, et al. (2002)
Measure different systems of waste management	Sarkis and Weinrach (2001)
Measure efficiency of environmental regulation schemes	Hernandez-Sancho et al. (2000)

2 Methodology

Although DEA is based on the concept of efficiency that approaches the idea of a classical production function, the latter is typically determined by a specific equation, while DEA is generated from the data set of observed operative units (Decision Making Units or DMUs). The DEA efficiency score of any DMU is derived from the comparison with the other DMUs that are included in the analysis, considering the maximum score of unity (or 100%) as a benchmark. The score is independent of the units in which outputs and inputs are measured, and this allows for a greater flexibility in the choice of inputs and outputs to be included in the study.

An important assumption of the DEA is that all DMUs face the same unspecified technology and operational characteristics, which defines the set of their production possibilities.

The idea of measuring the efficiency of DMUs with multiple inputs and outputs is specified as a linear fractional programming model. A commonly accepted measure of efficiency is given by the ratio of the weighted sum of outputs over the weighted sum of inputs. It is however necessary to assess a common set of weights and this may give rise to some problems. With DEA methodology each DMU can freely assess its own set of weights, that can be inferred through the process of maximizing the efficiency. Given a set of N DMUs, each producing J outputs from a set of I inputs, let us denote by y_{jn} and x_{in} the vectors representing the quantities of outputs and inputs relative to the m-th DMU, respectively. The efficiency of the m-th DMU can thus be calculated as:

$$e_m = \frac{\sum_{j=1}^{J} u_j y_{jm}}{\sum_{i=1}^{I} v_i x_{im}}, \qquad \begin{bmatrix} j = 1,.., J \\ i = 1,.., I \end{bmatrix} \tag{1}$$

where u_j and v_i are two vectors of weight that DMU m uses in order to measure the relative importance of the consumed and the produced factors. As mentioned, the set of weights, in DEA, is not given, but is calculated through the DMU's maximization problem, that is stated below for the *m*-th DMU.

$$\begin{aligned} &\max e_m \\ &s.t. \\ &\frac{\sum_{j=1}^{J} u_j y_{jn}}{\sum_{i=1}^{I} v_i x_{in}} \le 1 \quad \forall n = 1,., m,., N \\ &0 \le u_j \le 1 \\ &0 \le v_i \le 1 \end{aligned} \tag{2}$$

To simplify computations it is possible to scale the input prices so that the cost of the DMU m's inputs equals 1, thus transforming problem set in (2) in the ordinary linear programming problem stated below:

$$\begin{aligned} &\max h_m = \sum_{j=1}^{J} u_j y_{jm} \\ &s.t. \\ &\sum_{i=1}^{I} v_i x_{im} = 1 \\ &\sum_{j=1}^{J} u_j y_{jn} - \sum_{i=1}^{I} v_i x_{in} \le 0 \quad \forall n = 1,., m,., N \\ &\varepsilon \le u_j \le 1, \ \varepsilon \le v_i \le 1, \ \varepsilon \in \Re^+ \end{aligned} \tag{3}$$

In addition to the linearization constraint, weights have to be strictly positive in order to avoid the possibility that some inputs or outputs may be ignored in the process of determination of the efficiency of each DMU.

If the solution to the maximization problem gives a value of efficiency equal to 1, the corresponding DMU is considered to be efficient or non-dominated, if the efficiency value is inferior to 1 then the corresponding DMU is dominated, therefore does not lie on the efficiency frontier, which is defined by the efficient DMUs.

As for every linear programming problem, there is a dual formulation of the primal formulation of the maximization problem outlined in (3), which has an identical solution. While the primal problem can be interpreted as an output- oriented formulation (for a given level of input, DMUs maximizing output are preferred), the dual problem can be interpreted as an input- oriented formulation (for a given level of output, DMUs minimizing inputs are preferred).

Scale effects can be accounted for modifying the model as presented in (3), in order to account for variable returns to scale (we adopt the solution suggested in Banker *et al.*, 1984).

Finally, the dynamic analysis was performed using the window approach, first put forward by Charnes and others (Charnes *et al.*, 1978), in order to produce not only a static picture of efficiency, but also the evolution of efficiency of each municipality. The DEA is performed over time using a similar moving average procedure, where parks' performances in one year are compared with their performances in another year.

3 Data Collection and Analysis

To define environmental efficiency is a very challenging task; several different definitions of ecological efficiency exist in the literature. In the case of protected areas, the problem becomes even more complicated, because management and financial features have to be considered as well. As mentioned above, in a DEA study, the most crucial phase is indeed the choice of the representative benefit and cost indicators, which will be extremely influential in defining each DMU level of efficiency.

For this reason, the direct involvement of stakeholders is appropriate, if not fundamental. The managers of all the National Parks[1] in Italy were therefore interviewed through mail questionnaires in order to understand what they perceived as the most relevant indicators. In particular, for each proposed indicator, the respondent could choose among different qualitative definitions (very relevant, VR, relevant, R, not very relevant, NVR, and not relevant, NR). On the basis of the survey's results, which are summarized in Table 1, a second survey was designed in order to obtain quantitative definitions of each of the indicators (the final set of indicators used in the DEA analysis is reported in Table 2 divided in three models, see section 4).

On the output side, first the number of visitors to the park was considered as an indicator of its attractiveness, providing potential indirect benefit to the local economy. Second, the number of the parks' employees, as an indicator of the social and economic indirect and direct benefits. Third, the number of economic businesses which are directly linked empowered or created thanks to the presence of the park (e.g. parks

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[1] There are 21 National Parks in Italy. The analysis was performed on the 17 parks which were able to produce the required data, which are: Abruzzo, Lazio and Molise; Arcipelago la Maddalena; Arcipelago Toscano; Asinara; Aspromonte; Cilento and Vallo di Diano; Circeo; Monti Sibillini; Gargano; Dolomiti Bellunesi; Foreste Casentinesi; Gran Paradiso; Gran Sasso and Monti della Laga; Majella; Val Grande; Vesuvio.

certifying farmers producing within the protected area). Fourth, the number of protected species, which is a good proxy of the environmental quality and biodiversity of the park (in some models the inverse of this biodiversity indicator was included as an input). Finally, the number of students who visit the park for environmental education trips, as a proxy of the social and educational benefits deriving from the park.

On the input side, economic costs, computed aggregating management costs and variable costs and extraordinary expenses were considered. Moreover, the area extension was also considered as a proxy of fixed costs, which are assumed to be proportional to the area covered by the park.

4 Results

Three different models have been used to perform DEA analysis. The choice of using more than one model specification derives from the consideration that the DEA technique is extremely sensitive to the choice of indicators. Hence, coherent responses obtained by different models prove to be more reliable and robust, diminishing the degree of subjectivity of the efficiency scores produced. Moreover, each different model mimics the three main existing management strategies, namely a ‘pure socio-economic development oriented’ (Model 1), a ‘pure conservation oriented’ (Model 2) and an ‘in between’ strategy (Model 3).

In Table 3, results for Model 1, 2 and 3 (for the maximization of outputs approach, MAXOUTPUT) are shown, respectively. Parks scoring a 100% efficiency in Model 1 (as for example the National Park *Foreste Casentinesi*) are successfully promoting the development of the area. DMUs efficient according to Model 2 prove to have a high natural performance, in terms of biodiversity conservation, attractiveness and capacity of diffusing awareness among new generations (as for example the National Park *Gran Sasso and Monti della Laga*).

When a DMU is scoring maximum efficiency according to all three models, then one can argue the management has attained the sustainable development goal in a very broad sense. In the case of DMUs which are partially inefficient (as for example the National Park *Gran Paradiso*) it is possible to use the DEA analysis to obtain information concerning potential improvements of the management[2] (see Figure 1).

Finally, the total potential improvements, described in Figure 2, are defined by aggregating over all inefficient DMUs, in order to provide guidelines to properly allocate government incentives.

Conclusions

In recent years, a substantial re-interpretation of wilderness management objectives has occurred. According to this conceptual ‘revolution’, management strategies should aim at harmonizing human and nature’s interests, in the attempt of finding a balance between development and preservation, rather than a “put under a glass bell” approach. Nowadays a protected area has a new function: it is also a place where the concept of sustainable development can be put into practice and where traditional economic activities can be consistent with preservation needs.

This is the interpretation of nature protection, and specifically of Natural Parks, underpinning the design of environmental protection strategies.

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[2] *Parco Nazionale del Gargano*, *Parco del Vesuvio*, *Parco delle Foreste Casentinesi* and *Parco del Gran Sasso e dei Monti della Laga* compose the peer group for the *Parco Nazionale delle Dolomiti,* used to define the virtual efficient DMU, thus providing information on potential improvements, *P*.

Accordingly, it becomes increasingly important to monitor multi-objectives efficiency, a task which can be successfully accomplished by adopting benchmarking techniques (as for example DEA). These techniques provide information about efficiency, interpreted as a multi dimensional object, but also enable a detailed analysis of potential improvements.

The present study represents the first attempt to apply this methodology to this complex and experimental area. In particular, the methodology has been applied to the case of Italian National Parks; the resulting rankings and information to improve the management status have been provided as a feedback to their questionnaires to Parks' managers and to the Italian authority. The next step on the research agenda is the enlargement of the data set to include a broader variety of parks (for example national parks of other countries in Europe) in order to produce a more reliable and useful efficiency classification.

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Tables and Figures

	OUTPUT	**VR-R**	**NVR-NR**
a	Number of annual visitors	100%	0%
b	Number of historical buildings	100%	0%
c	Number of protected species	89%	11%
d	Number of students which visit the park for environmental education trips	88%	12%
e	Number of equipped areas	56%	44%
f	Area extension	56%	44%
g	Number of parks employees	56%	44%
h	Number of environmental illegal acts	55%	45%
i	Restored environmental area extension	45%	55%
l	Presence of a certification system with park labels	44%	56%
m	Gadget sale	22%	78%
n	Number of economic business directly linked, empowered or created thanks to the presence of the park	22%	78%
	INPUT	**VR-R**	**NVR-NR**
a	Management costs	100%	0%
b	Variable costs	89%	11%
c	Area extension	56%	44%

Table 1 - Results to questionnaire. The column VR-R presents the sum of the answers VR and R. The column NVR-NR presents the sum of the answers NVR and NR. (author)

	Output			Input			
Model 1	Visitors	Parks employees	Economic business created thanks to the park	Ind. of biodiversity	Management costs	Variable costs	
Model 2	Visitors	protected species	environmental education trips	Total costs	Area extension		
Model 3	Visitors	Parks employees	Economic business created thanks to the park	Ind. of biodiversity	Management costs	Variable costs	Area extension

Table 2 - Definition of input-output for the three models. Grey indicates input assumed as uncontrollable. (author)

DMU	MODEL 1	MODEL 2	MODEL 3
	Efficiency	Efficiency	Efficiency
Abruzzo, Lazio e Molise	100	100	100
Arcipelago la Maddalena	6,54	45,2	22,94
Arcipelago Toscano	54,82	100	100
Asinara	100	100	100
Aspromonte	7,3	51,77	21,81
Cilento Vallo di Diano	16,56	30,14	35,33
Circeo	93,27	100	100
Dolomiti Bellunesi	23,56	62,28	33,07
Foreste Casentinesi	100	68,07	100
Gargano	68,23	100	100
Gran Paradiso	58,62	48,16	65,62
Gran Sasso e Monti della Laga	34,02	42,94	100
Majella	100	100	100
Monti Sibillini	100	92,45	100
Val Grande	9,43	100	53,32
Vesuvio	100	100	100

Table 3 - Efficiency results for the three models. (author)

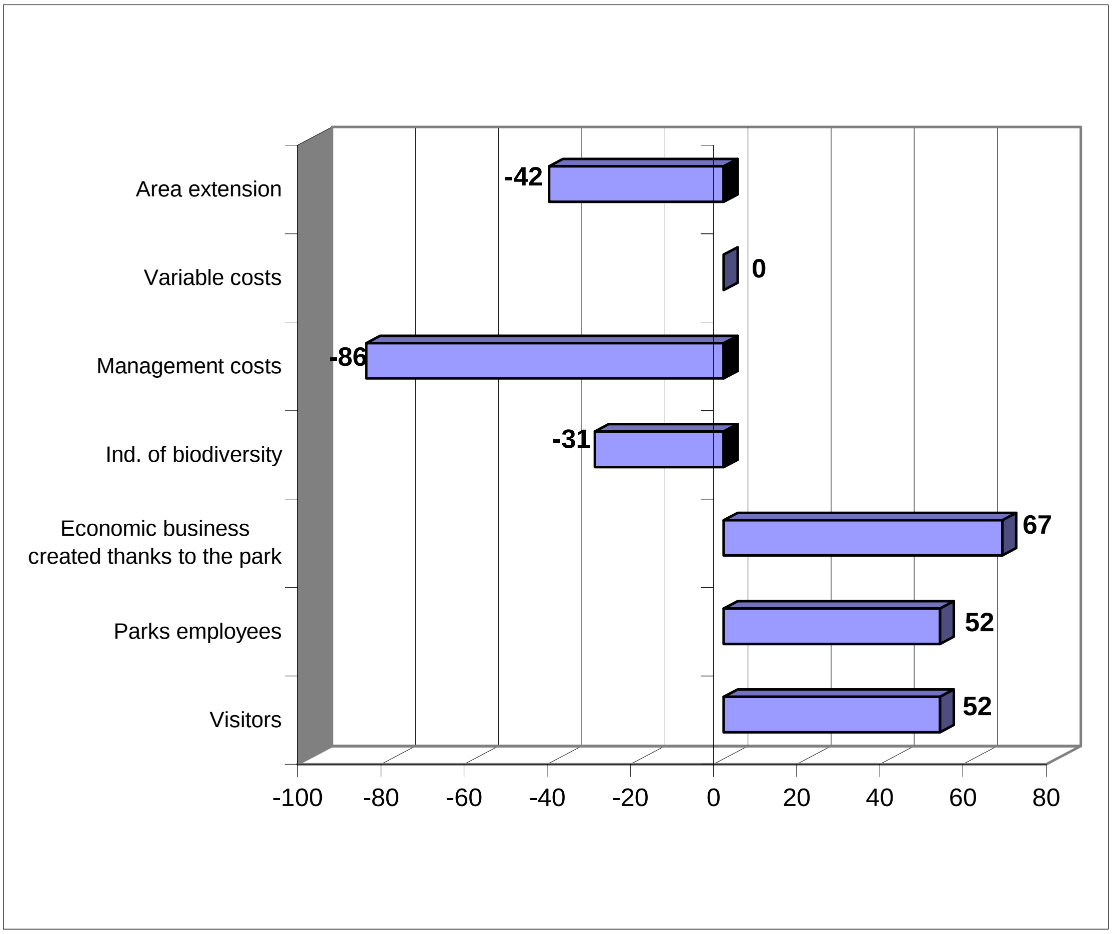

Figure 1 - Suggested potential improvements to obtain full efficiency. (author)

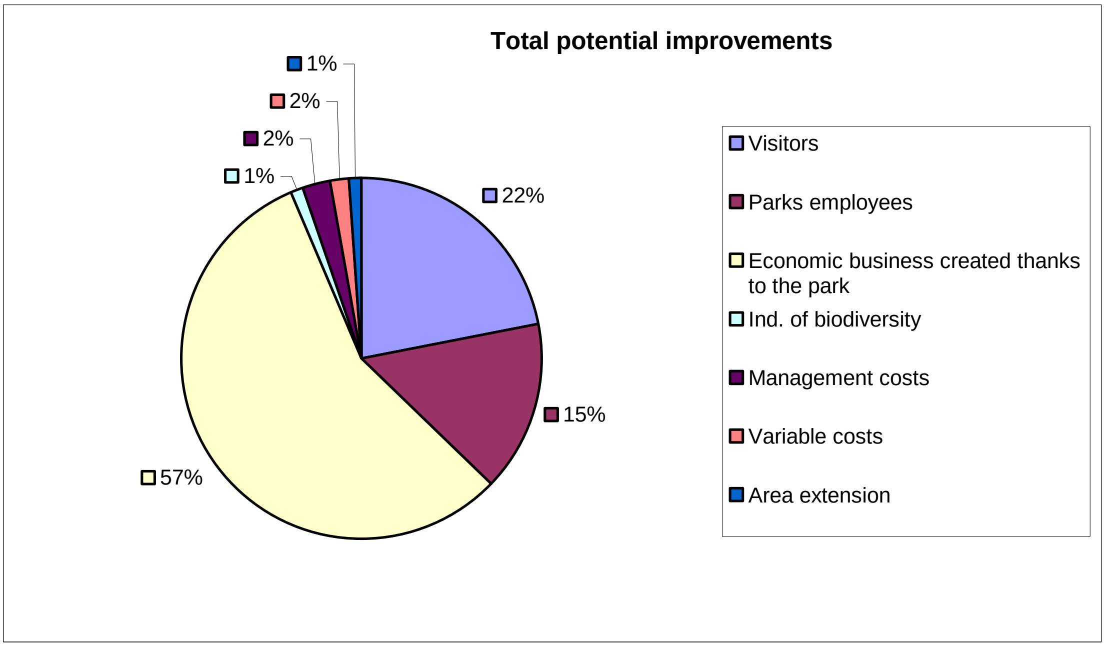

Figure 2 -Total potential improvements. (author)

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(lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003

(lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL) , Venice, August 28-29, 2003

(lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003

(lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003

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(lxx) This paper was presented at the 9th Coalition Theory Workshop on "Collective Decisions and Institutional Design" organised by the Universitat Autònoma de Barcelona and held in Barcelona, Spain, January 30-31, 2004

(lxxi) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications”, organised by Fondazione Eni Enrico Mattei and Consip and sponsored by the EU, Rome, September 23-25, 2004

(lxxii) This paper was presented at the 10th Coalition Theory Network Workshop held in Paris, France on 28-29 January 2005 and organised by EUREQua.

(lxxiii) This paper was presented at the 2nd Workshop on "Inclusive Wealth and Accounting Prices" held in Trieste, Italy on 13-15 April 2005 and organised by the Ecological and Environmental Economics - EEE Programme, a joint three-year programme of ICTP - The Abdus Salam International Centre for Theoretical Physics, FEEM - Fondazione Eni Enrico Mattei, and The Beijer International Institute of Ecological Economics.

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