Revista da Gestão Costeira Integrada 13(2):215-227 (2013)
*Journal of Integrated Coastal Zone Management* 13(2):215-227 (2013)

ASSOCIAÇÃO PORTUGUESA DOS RECURSOS HÍDRICOS · UNIVALI · GESTÃO COSTEIRA INTEGRADA · *Journal of Integrated Coastal Zone Management* · CIMA · Labomar

http://www.aprh.pt/rgci/pdf/rgci-341_Souza.pdf | DOI:10.5894/rgci341

# Avaliação de metodologias para valoração de recursos naturais e danos ambientais em ecossistemas costeiros: Estudo de Caso de uma área do Banhado da Palhocinha, Garopaba, Santa catarina, Brasil *

## *Assessing Methodologies for Valuating Natural Resources and Environmental Damages in Coastal Ecosystems: A Case Study in an Area of Palhocinha Marsh, Garopaba, Santa Catarina State, Brazil*

Fernando Basquiroto de Souza [@, 1], Carlyle Torres Bezerra de Menezes [2]

**RESUMO**

A valoração ambiental é uma técnica utilizada para mensurar o valor monetário de um recurso natural ou de um dano ambiental, normalmente empregada com o intuito de preservar um recurso ambiental ou em processos administrativos e judiciais visando ações indenizatórias. Várias são as metodologias utilizadas, sendo que a Metodologia do Fator Ambiental, do DEPRN e do Cardoso, são objeto deste trabalho, por terem maior afinidade com o ramo da engenharia e serem propensas a valorar o dano ambiental em questão, o aterramento de um banhado por um empreendimento imobiliário no município de Garopaba, Santa Catarina. A estimativa de custos para a recuperação do passivo ambiental foi realizada considerando a remoção do aterro, sua disposição final, a adubação e plantio de mudas em uma área de 10 hectares, resultando no valor de US$ 1.101.057,02. Por meio das metodologias de valoração do Fator Ambiental, do DEPRN e do Cardoso, obteve-se, respectivamente, os valores US$ 2.202.114,04; US$ 17.616.912,36 e US$ 33.031.694,00. Entre as metodologias aplicadas, todas não fornecem um valor diário, sendo que a do Fator Ambiental demonstrou ser a mais simples, não abordando especificamente os danos ambientais; a do Cardoso, em relação ao dano, somente considera a duração do mesmo, não levando em conta a frequência ou extensão; e a do DEPRN, mostrou ser a mais detalhada, não deixando margens para ambiguidade. Tais metodologias agregadas a técnicas de avaliação de impactos ambientais são importantes para a gestão pública dos recursos naturais.

**Palavras Chaves**: Ecossistemas Costeiros, Valoração Ambiental, Metodologia do DEPRN, Metodologia do Fator Ambiental, Metodologia do Cardoso.

*@ - Corresponding author*
*1 - Universidade do Extremo Sul Catarinense (UNESC). Rua Quintino Rizzieri, nº 525, CEP: 88804-210. Criciúma, Santa Catarina, Brasil. e-mail: fbs@unesc.net*
*2 - Universidade do Extremo Sul Catarinense (UNESC) – Avenida Universitária, nº 1105 – Caixa Postal 3167 - CEP: 88806-000. Criciúma, Santa Catarina, Brasil. e-mail: cbm@unesc.net*

** Submission: June 21, 2012; Evaluation: July 18, 2012; Reception of revised manuscript: October 05, 2012; Accepted: November 12, 2012; Available on-line: November 30, 2012*

***ABSTRACT***

*Environmental valuation is a technique used to measure the monetary value of a natural resource or an environmental damage, usually used for the purpose of environmental resource protection or in administrative or judicial lawsuits aiming a monetary compensation. Various methodologies are used, but Environment Factor, Departamento Estadual de Proteção de Recursos Naturais (DEPRN - State Department of Natural Resources Protection) and Cardoso Methodologies are the objects of this work, as they have more affinity with the engineering field and are likely to valuate the environmental damage in question, the fill of a marsh by a real estate enterprise in the town of Garopaba, Santa Catarina State in Brazil. The cost estimation for the recovery of environmental liability was carried out considering fill removal, its final disposal, manuring and planting seedlings in 10 hectares, resulting in the value of US$1,101,057.02. According to valuation methodologies such as Environment Factor, DEPRN and Cardoso, it was obtained, respectively, the values of US$2,202,114.04, US$17,616,912.36, and US$33,031,694.00. Among the applied methodologies, the Environment Factor demonstrated to be the simplest, not specifically approaching environmental damages; Cardoso, in relation to the damage, only considers its duration, not taking into account its frequency or extent; and DEPRN showed to be the most suitable. These methodologies, along with the assessment of environmental impacts, are important tools for public management of natural resources.*

***Keywords:*** *Coastal ecosystems, Environmental valuation, DEPRN methodology, Environmental factor methodology, Cardoso methodology.*

## 1. INTRODUCTION

In economics, value may be defined as the price that individuals are willing to pay in order to obtain a service or good, thus environmental valuation aims to measure natural resources and environmental damage values, present or not on the markets (Lipton, 1995). The task of environmental goods valuation consists in assessing if the population welfare will get better or worse as changes occur in the quality of the natural resources and services (Motta, 1997). This may be a polemic issue, but it is important that these relatively new studies share their results and experiences in order to converge to a consensus (Merico, 1996; Vo *et al.*, 2012).

Environmental valuation works with services and goods that the environment provides to humans, such as food supply, flood risk reduction, decomposition of waste, prevention of diseases, building materials, medicines and many others. It is important to stress that there is an increasing difficulty in valuing intangible goods (which are not actually present in the market) and it relies on the available information, knowledge of the ecosystem and assumptions made. It is used as a tool for creation and improvement of macroeconomic indicators, improvement of fines, and assessment of projects and policies (Matos *et al.*, 2010; Merico, 1996; CAVSARTE-NRC, 2004). Environmental valuation is also used in those situations where the goal is to preserve an environmental resource or to obtain indemnification in lawsuits.

Environmental services and goods are often overlooked in the process of policy decision-making, creating conflicts between different policies, for example, between environmental and land occupation use policies. Due to these conditions, their values must be estimated in order to support the decision-making process (CAVSARTE-NRC, 2004; Vo *et al.*, 2012).

In order to protect the coastal zone, which in Brazil is considered as national patrimony by the Constituição Federal (Brazilian Constitution), article 222 paragraph 4, coastal management must be accomplished, ensuring conservation of natural resources and population welfare.

A lot of studies carried out in the last two decades recognize the relationship between environmental functions and human welfare (Vo *et al.*, 2012) and many organizations acknowledge that in marine and coastal ecosystems it is important to make of the valuation process an important tool for coastal zone management (Remoundou *et al.*, 2009).

According to Upadhyay et al. (2002), 34% of coastal ecosystems in the world are under potential threat of degradation; and less than half of mangrove forests remain non-degraded in tropical and subtropical countries; and in the United States it is estimated that from the time of the European settlement to 1950 more than a half of the wetlands were converted for other uses (CAVSARTE-NRC, 2004).

In the south of Santa Catarina (SC) State, Brazil, a great number of environmental impacts have affected aquatic and coastal ecosystems, such as ponds, mangroves, water springs**,** dunes, marshes, and green areas. In this context, the monetary valuation is claimed for the survey of costs for any compensation. But what is the right method to be used to valuate these ecosystems? How much must be paid for those who had their rights violated and benefits limited? Are the methodologies applied nowadays capable of valuating these environmental damages?

Others studies valuated coastal ecosystems, as Luisetti *et al.* (2011) that estimated the value of a salt marsh in United Kingdom (UK), under different scenarios, reaching values of 6,347 £ / year (for 81.3 hectares and a scenario where economic growth is combined with environmental protection) and 8,348 £ / year (for 2,404.1 hectares and a scenario where environmental protection has priority over economic growth). Also Alongi (2002) valued a mangrove and estimated the mean monetary value in US$ 9,990 / ha.year; and Tong *et al.* (2007) estimated the potential value of degraded permanent river wetland in China in 55,332 yuan / ha.year. In addition Alier (2007) presented an overview of mangrove occupation conflict with shrimp aquaculture, providing an excerpt of a Greenpeace Report which estimated the mangrove ecosystem value in the order of US$13,000 / ha.year; and Ramalho and Pimenta (2010) valued with DEPRN (State Department of Natural Resources Protection) method damage caused by the illegal extraction of orchids in Natal (Rio Grande do Norte State, Brazil), their valuation reached BRL$ 9,555,200.00. Grasso and Novelli

(1999) valued, through different methods, the services and goods of a mangrove in São Paulo, Brazil, reaching a value of US$ 4,751 /ha.year.

Also Vo *et al*. (2012) presented studies valuing mangrove ecosystems under different approaches; Remoundou *et al*. (2009) showed some studies that estimated the values of some environmental resources in the Mediterranean Sea and Black Sea. Maltchik (2003) and Soares and Dominguez (2012) pointed out some limitations of studies on wetlands in Brazil due to the lack of terms to classify these ecosystems.

## 2. CASE STUDY

The town of Garopaba lies in the coastal zone of Santa Catarina State in Brazil, it is defined, according to the Law no. 7.661 of May 16th, 1988, as a region where there is interaction between air, soil and the sea, including the natural resources and involving a land area and maritime strip. The definition of what is considered a coastal area is conflicting as Marroni & Asmus (2005) have demonstrated when pointed out that the number of cities / countries in the coastal area provided by different official bodies are different one from the other.

The present work was accomplished having as boundary of the case study an area of Palhocinha Marsh, in Garopaba, Santa Catarina State (SC), Brazil, where 10 hectares of wetlands were filled for future use in the real estate market. It is important to say that a lawsuit was filed in the District of Garopaba, where they granted an injunction warning that the environmental damage could be irreversible, resulting in losses to the collectivity.

Using the environmental valuation methodologies, which has the purpose to measure the monetary value of a natural resource, it is intended, as an illustrative exercise, to compare and assess the validity of these methodologies in lawsuits and decision-making processes. This is accomplished by estimating the value of the damage caused by the fill in the 10 hectares of wetlands that is, based on Brazilian law (Law no. 12.651/2012), an Area of Permanent Preservation (APP) once the government declared it as an area of social interest, that is, when it has functions such as prevention of landslides and erosion, protection of flora and fauna and of species under threat of extinction, wetlands protection, among other services. The same law also considers native forests and other vegetation as national assets and has as one of its principles the creation and mobilization of economic incentives to promote sustainable development and protection of natural resources.

This area also lies on the boundary between two conservation units (Law no. 9.985/2000), Parque Estadual da Serra do Tabuleiro (State Park of Tabuleiro Mountain Range) and Área de Proteção Ambiental da Baleia Franca (Southern Right Whale (Eubalaena australis) Environmental Protection Area).

The aim of this study is to evaluate the application of valuation methodologies of environmental resources and damages, widespread in Brazilian literature, with emphasis on coastal ecosystems, using and comparing the Environmental Factor, Departamento Estadual de Proteção de Recursos Naturais (DEPRN - State Department of Natural Resources Protection) and Cardoso methodologies. These methodologies were chosen due to their affinity with the environmental engineering field and will more likely valuate the damage done to the wetland area chosen for this study.

This study takes into consideration: i) the principle of polluter payer, which determines that the one who degrades the environment, besides the obligation to restore the damage done, must pay for the losses caused to the environment and the collectivity; ii) the principle of precaution, which ensures against potential risks that cannot be predicted as a result of the current state of scientific knowledge; and, iii) the fragility of coastal ecosystems as well as its classification as a Brazilian natural heritage, along with the necessity to improve the application of pecuniary sanctions and penalties on account of environmental damages.

## 3. MATERIALS AND METHODS

Three different methods were applied to value the damage to a wetland situated in Garopaba (SC, Brazil). Also, a local expedition occurred in order to collect data to evaluate the damage. Detailed information about the methods and the local expedition is provided hereafter.

### 3.1. Environmental Factor Methodology (EFM)

Elma Romanó, creator of the method, is an agricultural engineer, has a master's degree in soil science and has published a paper (Neto, 2005) on monetary valuation of the environment.

According to Neto (2005), the EFM begins by calculating the price to restore the degraded environment, and then the resulting value is used in the equation 1:

$$AV = \sum x + FA \qquad (1)$$

where AV is the Environmental Damage Valuation; $\sum x$ is the sum of the costs to restore the environment (calculated in the former steps of the method) and FA, which is the Environment Factor, is the same value as $\sum x$, that is, the environmental damage is the restoration costs doubled.

### 3.2. DEPRN methodology

Developed by Departamento Estadual de Proteção de Recursos Naturais (DEPRN – State Department of Natural Resources Protection), the method works with two tables, the first one (Table 1) shows a division of the environment in its medium, such as air, water, soil and subsoil, flora, fauna and landscape, and for each medium, it has various harms which weighs the damage with indexes (the complete list of indexes can be found in Almeida *et al*. (2000) or Neto (2005)). The sum of the indexes is compared to the second table (Table 2) that provides a multiplication factor for each medium, then these multiplication factors are added together in order to be used in Equation 2:

$$\text{Environment Value} = (\sum \text{Multiplication Factors}) \times \text{Restoration Costs} \qquad (2)$$

**Table 1.** Division of the environmental medium and their harms.
***Tabela 1.*** *Divisão do meio ambiente e seus agravos.*

| Environmental Aspect | Atmosphere | | Water | | Soil and Subsoil | |
|---|---|---|---|---|---|---|
| **Kind of harms** | Impact caused by emission of gases, particles, biological agents, energy. | Impact on Atmospheric Dynamics (x 1,5). | Impact caused by chemical, physical and/ or biological compounds and energy. | Impact on Hydrodynamics (x 1,5). | Impact caused by chemical, physical and/or biological compounds and energy | Impact on Soil and/ or Subsoil Dynamics (x 1,5). |
| **Description and qualification of harms** | Toxicity of Emissions | Death or damage to animal species | Toxicity of Emissions | Death or damage to animal species | Toxicity of Emissions | Death or damage to animal species |
| | Close to Urban Centers | Death or damage to plant species | Groundwater (aquifer) impairment | Death or damage to plant species | Impairment of the aquifer | Death and Damage to plant species |
| | Protected Areas | Air quality change | Protected Areas | Classification Change of the Water Body | Protected Areas | Change of the land use capacity |
| | Groundwater (aquifer) impairment | Prediction of Equilibrium Recovery | Damage to soil and/or subsoil | Change of water's flow/ volume | Aggradation of water bodies | Damage to terrain relief |
| | Death or Damage to plant species | | Death or damage to plant species | Prediction of Equilibrium Recovery | Death or damage to plant species | Prediction of Equilibrium Recovery |
| | Death or damage to animal species | | Death or damage to animal species | | Death or damage to animal species | |
| | Damage to heritage or natural monuments | | Damage to heritage or natural monuments | | Damage to heritage or natural monuments | |
| | | | | | Commercialization purpose | |
| **Environmental Aspect** | **Flora** | | **Fauna** | | **Landscape** | |
| **Kind of harms** | Damage to individuals. | Impact on the Community Dynamics (x 1,5) | Damage to individuals | Impact on the Community Dynamics (x 1,5). | Damage to the landscape | Damage to heritage, cultural, historical heritage, touristic monuments (x 1,5). |
| **Description and qualification of harms** | Protected Areas | Death or damage to fauna | Protected Areas | Relative Importance | Protected Areas | Close to Urban Centers |
| | Endangered Species | Relative importance | Endangered Species | Death or damage to plant species | Close to urban centers | Damage Reversion |
| | Endemic Species | Change in the ecological niches | Endemic Species | Change in the ecological niches | Damage Reversion | Groundwater (aquifer) Impairment |
| | Favoring erosion | Prediction of Equilibrium Recovery | Females | Prediction of Equilibrium Recovery | Groundwater (aquifer) Impairment | Impairment of the soil / subsoil |
| | Damage to heritage or natural monument | | Commercialization purpose | | Impairment of the soil / subsoil | Death or damage to plant species |
| | Commercialization Purpose | | | | Death or damage to plant species | Death or damage to animal species |
| | | | | | Death or damage to animal species | |
| | | | | | Damage to heritage or natural monument | |

Source: Adapted from Almeida *et al.* (2000); Neto, (2005).

**Table 2.** Indexes to the qualification of harms.
***Tabela 2.*** *Indices para qualificação dos agravos.*

| Environmental Domain | Maximum values of numerical indexes corresponding harm classification (maximum values allowed). | | | | |
|---|---|---|---|---|---|
| Air | 6,0 | 12,0 | 18,0 | 24,0 | 30,0 |
| Water | 7,0 | 14,4 | 21,6 | 28,8 | 36,0 |
| Soil-Subsoil | 7,5 | 15,0 | 22,5 | 30,0 | 37,5 |
| Fauna | 6,4 | 12,8 | 19,2 | 25,6 | 32,0 |
| Flora | 6,6 | 13,2 | 19,8 | 26,4 | 33,0 |
| Landscape | 8,0 | 16,0 | 24,0 | 32,0 | 40,0 |
| Multiplication Factor | 1,6 | 3,2 | 6,4 | 12,8 | 25,6 |

Source: Almeida *et al*. (2000).

**Table 3.** Survey of intangible environmental damages.
***Tabela 3.*** *Levantamento de danos ambientais intangiveis.*

| | | | Environmental Impact | | | | |
|---|---|---|---|---|---|---|---|
| Environment | | in | 0 | 1 | 2 | 3 | 4 |
| Physical | Air | i1 | | | | | |
| | Water | i2 | | | | | |
| | Soil / Sediment | i3 | | | | | |
| Biotic | Bacterias e cyanobacterias | i4 | | | | | |
| | Protozoa | i5 | | | | | |
| | Mushrooms | i6 | | | | | |
| | Invertebrates | i7 | | | | | |
| | Vertebrates | i8 | | | | | |
| | Higher plants | i9 | | | | | |
| | Intermediate plants | i10 | | | | | |
| | Lower plants | i11 | | | | | |
| Anthropic | Social | i12 | | | | | |
| | Landscape | i13 | | | | | |
| | Economic Losses | i14 | | | | | |
| | Welfare | i15 | | | | | |
| Sum of the environmental impacts | | | | | | | |

Source: Adapted from Cardoso (2003).

## 3.3. Cardoso Methodology

Arthur Renato Albeche Cardoso is a sanitary chemist, toxicology expert and environmental adviser of the Ministério Público do Rio Grande do Sul (Public Ministry of Rio Grande do Sul State). He has written a book on environmental damage and their monetary valuation where he presents a methodology to valuate these damages. This method is here called Cardoso Methodology. For further information see Cardoso (2003).

Cardoso method begins with two variables, the first one is called Q that represents tangible values, such as costs to restore the degraded area, values that were not spend to prevent the damage, environmental license taxes, and others. The second is called I that represents intangible values, such as death of microorganisms, biodiversity, and others.

For these intangible values, Cardoso (2003) provides a table, showed here as table 3, in which for each environmental medium a number between 0 and 4 is given. The medium with 0 values has not suffered an impact, with 1 values has suffered a short-term impact, with 2 values has suffered a medium-term impact, 3 values has suffered a long-term impact, and with 4 values the medium has suffered an extremely long-term impact ranging from a month to years. For impact values between 1 and 3 the length of time is counted in days.

After surveying the values, they are used in the following equation (3):

$$VERD = \sum Q \times \sum I \qquad (3)$$

in which, VERD is the monetary value of the environmental damage, $\sum Q$ is the sum of the tangible values and $\sum I$ the sum of intangible values provided by table 3.

### 3.4. Local Expedition

These methods were applied in the fill of Palhocinha Marsh, Garopaba, SC, Brazil, which created a tension between society and the real estate enterprise, resulting in the lawsuit. The geographic coordinates for the fill are 28º 03' 0.28" S – 48º 37' 59.42" O (Figure 1, in which the circle is a partial area of the marsh, and the dot inside it is the place where the fill occurred).


**Figure 1**. Location of the area of the case study in Garopaba, (SC, Brazil).
***Figura 1.*** *Localização da área de estudo na cidade de Garopaba, (SC, Brasil).*
Source: Adapted from i3geo, Mapa Interativo de Santa Catarina and Google Maps.

A local expedition was made to examine the environmental damage and to know the local environment. In this expedition, we have noticed some streams that feed the marsh and that also feed a tourist pond, Encantada Pond, and we have also noticed some areas of the marsh that were previously occupied by houses and shops. Moreover, the marsh is part of the lowlands of the local watershed basin.

After visiting the place, a budget estimation was elaborated to restore the degraded environment, the base price was September's values of Sistema Nacional de Pesquisa de Custos e Índices da Construção Civil (SINAPI - National System of Construction Costs Survey and Indexes). The result was used with the methodologies previously mentioned, all of them use the same value for the variable that represents the costs to restore the environment.

With these values in hand, they were put together in the equations, provided by the authors earlier cited, and the results were compared and the evaluation was made.

## 4. RESULTS AND DISCUSSION

The cost to restore the degraded environment was elaborated with the considerations presented on table 4, besides the values of the inputs. All values were converted into American dollars at the end of the calculations, considering the average value of dollar of the last months (late 2011 and early 2012), in other words, one U.S. dollar is equal to 1.8 (one real and eighty centavos) Brazilian reais.

**Table 4.** Summary of inputs used for calculating the costs of restoration.
***Tabela 4.*** *Resumo dos custos para o calculo dos custos de restauração.*

| *SINAPI's code* | *Input* | *Value (BRL$)* | *Unit* |
|---|---|---|---|
| 00001139 | Dump Truck (8 m³/ 16 Ton) | 45.42 | Hour |
| 00010800 | Hydraulic Excavator (2 m³) | 163.00 | Hour |
| 00007626 | Bulldozer | 81.00 | Hour |
| 00000365 | Shrub Seedlings | 3.68 | Unit |
| 00007253 | Vegetable Soil | 5.60 | Cubic meter |
| 00000159 | Cattle Manure | 81.00 | Cubic meter |

The estimation considered only the values of local restoration services, not considering the costs involved to elaborate the restoration project, neither the professionals who will coordinate it.

For the removal of the fill dumped in the marsh it will be necessary, to transport it, the work of a dump truck, and to load that truck, a hydraulic excavator will be needed, and to loosen the densely-compacted material of the fill, a bulldozer.

For the restoration of the native vegetation it will be necessary to use shrub seedlings, vegetable soil and cattle manure, the last two will be used to improve and to ensure the growing of the seedlings by providing them nutrients.

Considering the removal of 01 meter deep of the fill in the 10 hectares occupied, it will result in 100,000 cubic meters of fill to be removed and disposed in another place. In this case for budget estimations and disregarding the impacts in the disposal area, the place from where it was initially removed, which is 4.4 kilometers away from the area to be restored, resulting in 8.8 kilometers to be traveled in following route: Rodovia (Highway) SC 434, Rua (Street) Vinte e Três , Rua (Street) GRP 250 and Rua (Street) GRP 471.

To calculate the number of trips it was divided the volume of fill to be removed by the capacity of the dump truck, in other words, 100,000 $m^3$ / 8 $m^3$ = 12,500 trips.

The total distance to be traveled by the dump truck to remove all the fill is given by the multiplication of the distance of the round trip times the number of trips, 8.8 km x 12,500 travels = 110,000 kilometers.

Considering that the average speed of the dump truck is 40 km/h, the total travel time is found by dividing the total distance of the travel by the average speed, 110,000 km / 40 km/h = 2,750 hours, but, using 2 dump trucks, this values is reduced to half, 2,750 / 2 = 1,375 hours.

In order to calculate the time the hydraulic excavator will take to fill the dump truck, we have the capacity of the dump truck divided by the capacity of the excavator's bucket, 8 $m^3$ / 2 $m^3$ = 4 buckets. Considering 5 minutes to fill up the truck, we multiply the number of trips by the time to fill up the truck, 12,500 trips x 5 minutes = 625,000 minutes = 1,042 hours. Using 2 hydraulic excavators, this value is divided by 2, so 1,042 / 2 = 521 hours.

The time spent to remove the fill is the result of the sum of the values previously presented, 1,375 hours + 521 hours = 1,896 hours.

The final price of the dump truck is given by the multiplication of its value (BRL$45.42) and 2, as there will be 2 trucks, and the time spent to remove all the fill, 1,896 hours x 45.42 Brazilian reais x 2 = 172,232.64 Brazilian reais.

The final price of the hydraulic excavator is given by the multiplication of its value (BRL$ 163.00) and 2 because of the use of 2 excavators, and the time spent to remove all the fill, 1,896 hours x 163.00 Brazilian reais x 2 = 618,092 Brazilian reais.

The total price of the bulldozer is given by the multiplication of its value by the number of hours worked, considering that it will work during all the removal of the fill, 1,896 hours x 81.00 Brazilian reais = 153,578.00 Brazilian reais.

For the restoration of the local vegetation, considering a distance of 2 meters between the seedlings, we will have the following calculations ($\sqrt{100.000\ m^2}$ / 2) x ($\sqrt{100.000\ m^2}$ / 2) in order to get the results, which is 25,000 seedlings to restore the 10 hectares degraded. The depth of the new organic layer of the soil will be 15 centimeters, in which 5 centimeters are cattle manure and 10 centimeters are vegetable soil. Multiplying the depth of these inputs the result is the quantity to be used, 0.1 meters x 100,000 m² = 10,000 m³ of vegetable soil; 0.05 meters x 100,000 m³ = 5,000 m³ of cattle manure.

The final price of the shrub seedlings is the multiplication of the number of seedlings used by its price, 25,000 seedlings x 3.68 Brazilian reais = 92,000.00 Brazilian reais. The final price of the vegetable soil and cattle manure are given by the multiplication of their prices by the volume used to restore the area, respectively, 10,000 m³ x 51.60 Brazilian reais = 516,000 Brazilian reais and 5,000 m³ x 86.00 Brazilian reais = 430,000.00 Brazilian reais.

The sum of all prices results in the value to restore the degraded environment, in this case the marsh that suffered a fill, the sum is 172,232.64 + 618,092 + 153,578 + 92,000 + 516,000 + 430,000 = 1,981,902.64 Brazilian reais, converted into American dollars, we have US$ 1,101,057.02 (One million, one hundred and one thousand, fifty-seven dollars and two cents).

## 4.1. Cardoso Methodology

After the local expedition it was possible to establish the relationship of the environmental impacts to the marsh fill, listing them in table 5 provided by Cardoso (2003).

Among the impacts that reached the maximum values, we have: a) Water, as the fill changed the local water system because of the soil impermeability and because it prevents the water from flowing and then feeding other bodies of water; b) Soil/Sediment, because the soil that suffered the fill was changed (alteration of its chemical, physical and biological composition) and consequently there is the transport of sediments to downstream bodies of water and the loss of nutrients and biodiversity; c) and Landscape, as it has been changed and the return to the original state is slow and expensive.

Among the impacts which scored a median value, we have: a) Invertebrates and Vertebrates whose ecological niches have been changed; b) Higher, intermediate and lower plants that were suppressed to give place to the new enterprise, completely modifying the ecosystem; c) Social and Welfare, because the disposal of fill resulted in particles suspended in the air causing discomfort to the neighbors of the enterprise, besides the intense traffic of heavy vehicles that generated discomfort caused by their noise.

Among the impacts that scored lower points, we have air, due to the presence of particulate materials, but the restoration of the original conditions of the atmosphere will occur with the end of real estate enterprise works.

**Table 5.** Environmental Impacts expected on Palhocinha Marsh.
***Tabela 5.*** *Impactos ambientais previstos no Banhado da Palhocinha.*

| | | | Environmental Impact | | | | |
|---|---|---|---|---|---|---|---|
| **Environment** | | **in** | **0** | **1** | **2** | **3** | **4** |
| **Physical** | Air | i1 | | X | | | |
| | Water | i2 | | | | | X |
| | Soil/Sediments | i3 | | | | | X |
| **Biotic** | Bacteria and cyanobacteria | i4 | X | | | | |
| | Protozoa | i5 | X | | | | |
| | Mushrooms | i6 | X | | | | |
| | Invertebrates | i7 | | | X | | |
| | Vertebrates | i8 | | | X | | |
| | Higher Plants | i9 | | | X | | |
| | Intermediate Plants | i10 | | | X | | |
| | Lower Plants | i11 | | | X | | |
| **Anthropic** | Social | i12 | | | | X | |
| | Landscape | i13 | | | | | X |
| | Economic Loss | i14 | X | | | | |
| | Welfare | i15 | | | X | | |
| **Sum of the environmental impacts** | | 30 | | | | | |

Source: Adapted from Cardoso (2003).

The values that did not score are Bacteria and Cyanobacteria, Protozoa, mushrooms and economical loss. These aspects were not considered in that study due to the lack of information about them, nevertheless in future studies, they must be included.

The value of the environmental damage, calculated with Cardoso Method, is the result of the multiplication between the value to restore the environment and the sum of the environmental impacts of table 5, 1,981,902.64 Brazilian reais x 30 = 59,457,049.20 Brazilian reais, converting this value into American dollars, we have US$ 33,031,694.00 (Thirty-three million, thirty-one thousand, six hundred and ninety-four dollars).

### 4.2. DEPRN Methodology

Using the list of harms provided by Almeida *et al*. (2000), the items that are related to the damages observed during the local visit were selected; they appear in the third column in the tables 6, 7, 8, 9 and 10. After each item of harms a reason is given to explain why it was chosen.

In brief, the sum of each environmental aspect is: Atmosphere: 4; Water: 14.5; Soil/Sediment: 11.5; Flora: 5.5; and Landscape: 9. Comparing these values with the indexes shown in Table 03, we obtain the following numbers: 1.6 for Air (atmosphere), 6.4 for Water, 3.2 for Soil/Sediment, 1.6 for Flora, and 3.2 for Landscape.

Based on the sum of these indexes/factors (result of Table 03) multiplied by the value to restore the environment, we have the value of the environmental damage, BRL$(1.6 + 6.4 + 3.2 + 1.6 + 3.2) x 1,981,902.64 Brazilian reais = BRL$ 31,710,442.24 Brazilian reais, which converted into US dollars is US$ 17,616,912.36 (Seventeen million, six hundred and sixteen thousand, nine hundred and twelve dollars and thirty-six cents).

### 4.3. EFM

Considering that the environmental factor is equal to the value to restore the degraded environment, as Neto (2005) has explained, the value of the damage will be the sum of these two variables, in other words, 1,981,902.64 Brazilian reais + 1,981,902.64 Brazilian reais = 3,963,805.28 Brazilian reais. And by converting it into American dollars we have US$ 2,202,114.04 (Two million, two hundred and two thousand, one hundred and fourteen dollars and four cents).

### 4.4. Comparison of the Methodologies

By comparing the results of the methods it is verified a variation of values for the same damage. This happens because each methodology has a different process to establish a "multiplication factor", which represents the intangible values.

EFM results show the lowest values because this method works with only one addition, adding the cost of restoring the environment to its own value, so it does not consider the importance of the ecosystem, their services, goods and its complexity.

The methods of DEPRN and Cardoso work with multiplication, and Cardoso method resulted in the highest value because the sum of environmental impacts directly multiply the costs to restore the environment. On the other hand DEPRN method, after the sum of the environmental aspects, obtains a value and such value goes through a table which generates multiplication factors, in other words, the values are previously filtered to be multiplied by the restoration costs.

**Table 6.** Summary of atmospheric harms, reason for item selection, and sum of values.
***Tabela 6.*** *Resumo dos agravos à atmosfera, motivação da seleção e somatória dos valores.*

**Environmental Aspect: Atmosphere**

| Harm | Items | Selected Item |
|---|---|---|
| (01) Location concerning Environmental Protection Areas | i) Inside the area = 2<br>ii) Under influence = 1 | ii) Under influence = 1 |
| Reason: The area of the enterprise is located between two Conservation Units, Parque Estadual da Serra do Tabuleiro (State Park of Tabuleiro Mountain Range) and Área de Proteção Ambiental da Baleia Franca (Southern Right Whale (Eubalaena australis) Environmental Protection Area), although it does not belong to them, the enterprise is located in its area of influence. | | |
| (02) Change of air quality (x 1,5) | i) Emergency state = 3<br>ii) Alert state = 2<br>iii) Attention state or Bad = 1 | iii) Attention state or Bad = 1 |
| Reason: The disposal of fill throughout the enterprise resulted in the transport of particles of the material by the wind, although they were not toxic, such particles cause discomfort to neighbors of the enterprise. | | |
| (03) Natural equilibrium forecast (x 1,5): | i) Short-term = 1<br>ii) Medium-term = 2<br>iii)Long-term = 3 | i) Short-term = 1 |
| Reason: Equilibrium forecast of natural conditions of air pollution is short-term, because as soon as the activities of the enterprise stop, the emissions will also cease. | | |
| **Sum of the chosen items: 4 points.** | | |

**Table 7.** Summary of water harms, reason for item selection, and sum of values.
***Tabela 7.*** *Resumo dos agravos à água, motivação da seleção e somatória dos valores.*

**Environmental Aspect: Water**

| Harm | Items | Selected Item |
|---|---|---|
| (04) Emission Toxicity | i)Verified = 3<br>ii) Strong Indications = 2<br>iii) Presumed = 1 | iii) Presumed = 1 |
| Reason: The transport of particles, originated by the fill, change turbidity levels and accelerate aggradation processes in the bodies of water that receive them, and can even transport the organic charge of the sewage of future houses. | | |
| (05) Damage to the Aquifer | i) Verified = 3<br>ii) Strong Indications = 2<br>iii) Presumed = 1 | i) Verified =3 |
| Reason: The fill in the area of the marsh for the construction of the enterprise resulted in the reduction of permeable areas, consequently, decreasing aquifer water supply. | | |
| (06) Location concerning protected areas | i) Inside = 3<br>ii) In the same watershed upstream = 2<br>iii) In the same watershed downstream = 1 | ii) In the same watershed upstream = 2 |
| Reason: Although the enterprise is found in the same watershed downstream Parque Estadual da Serra do Tabuleiro (State Park of Tabuleiro Mountain Range), we selected the upstream option, because in relation to Área de Proteção Ambiental da Baleia Franca (Southern Right Whale (Eubalaena australis) Environmental Protection Area), this is its position. | | |
| (07) Damage to historical, cultural, artistic, archaeological, touristic heritage and/or natural monuments caused by the damage in the water | i) Verified = 2<br>ii) Presumed = 1 | ii) Presumed = 1 |
| Reason: It is known that Palhocinha Marsh feeds Encantada Pond, which is a sightseeing tour of the region. There are indications that the fill can damage it through aggradation, because the materials of the fill can be transported by water and reach the sightseeing area. | | |
| (08) Alteration on flow and volume of water (x 1,5) | i) Significant = 2<br>ii) Not Significant = 1 | i) Significant = 2 |
| Reason: The fill of a part of the marsh will change the flow and volume of water in it, because it will reduce the amount of spaces through which water can flow. | | |
| (09) Forecast to restore balance of the natural condition (x 1,5) | i) Short-term = 1<br>ii)Medium-term = 2<br>iii) Long-term = 3 | iii) Long-term = 3 |
| Reason: The forecast to restore balance is long-term because after the activities of the enterprise cease the marsh will still be filled and will continue to transport particles and degrading bodies of water downstream. | | |
| **Sum of the chosen items: 14.5 points.** | | |

**Table 8.** Summary of soil and sediment harms, reason for item selection, and sum of the values.
***Tabela 8.*** *Resumo dos agravos ao solo e sedimentos, motivação da seleção e somatória dos valores.*

Environmental Aspect: Soil and Sediments

| Harm | Items | Selected Item |
|---|---|---|
| (10) Aggradation of bodies of water | i) High Intensity = 3<br>ii) Medium Intensity = 2<br>iii) Low Intensity = 1 | i) High Intensity = 3 |
| Reason: When a body of water is filled, there will consequently be aggradation of the bodies of water downstream, because particles of materials that were thrown will be carried by water. | | |
| (11) Death or injury to animal species due to damage to soil or subsoil (x 1.5) | i) Verified = 2<br>ii) Presumed = 1 | ii) Presumed = 1 |
| Reason: In order to perform the fill operation, soil conditions will be altered, thus changing ecological niches, and consequently resulting in fauna damage. | | |
| (12) Aiming commercialization | i) Main or secondary activity = 1 | i) Main or secondary activity = 1 |
| Reason: Since the enterprise that has done the fill is a real estate enterprise, as soon as the work finishes, there will be the commercialization of the land. | | |
| (13) Damage to terrain relief (x 1.5) | i) Verified = 3<br>ii) High risk = 2<br>iii) Low risk = 1 | iii) Low Risk = 1 |
| Reason: Since the area of the marsh is flat, there is a low risk of damage to terrain relief because there is no risk of landslides (and others), but there is the probability of future flooding. | | |
| (14) Forecast to restore balance of the natural condition (x 1.5) | i) Short-term = 1<br>ii) Medium-term = 2<br>iii) Long-term = 3 | iii) Long-term = 3 |
| Reason: The forecast of balance is classified as long-term, because to return to the original condition of the soil, it would be necessary to remove the fill, and in natural conditions, this process would be very slow. | | |
| Sum of the chosen items: 11.5 points. | | |

**Table 9.** Summary of flora harms, reason for item selection, and sum of the values.
***Tabela 9.*** *Resumo dos agravos à flora, motivação da seleção e somatória dos valores.*

Environmental Aspect: Flora

| Harm | Items | Selected Item |
|---|---|---|
| (15) Aiming commercialization | i) Main activity = 2<br>ii) Secondary activity = 1 | ii) Secondary activity = 1 |
| Reason: It is known that the reason for the removal of flora is the sale of lands, so the damage to plant species is classified as a secondary activity. | | |
| (16) Balance forecast (x 1,5) | i) Long-term = 3<br>ii) Medium-term = 2<br>iii) Short-term = 1 | i) Long-term = 3 |
| Reason: For the vegetation to reach the successional stage as it once was, considering it is a slow process, the forecast for equilibrium will be long-term. | | |
| Sum of the chosen items: 5.5 points. | | |

**Table 10.** Summary of landscape harms, reason for item selection, and sum of the values.
***Tabela 10.*** *Resumo dos agravos ao relevo, motivação da seleção e somatória dos valores.*

Environmental Aspect: Landscape

| Harm | Items | Selected Item |
|---|---|---|
| (17) Reversing environmental damage | i) High cost = 3<br>ii) Medium cost = 2<br>iii) Low cost = 1 | i) High cost = 3 |
| Reason: Considering the values already seen to restore the marsh, there is a high cost to restore this degraded environment. | | |
| (18) Damage to the aquifer | i) Directly related = 2<br>ii) Not directly related = 1 | i) Directly related = 2 |
| Reason: The fill of the soil altered the characteristics of the already consolidated soil, reducing the aquifer recharge and, depending on the pollutant, degrading it. | | |
| Damage to soil or subsoil | i) Directly related = 2<br>ii) Not directly related = 1 | i) Directly related = 2 |
| Reason: The fill of the soil altered the characteristics of the already consolidated soil, in other words, degrading it. | | |
| Death or damage to plant species. | i) Directly related = 2<br>ii) Not directly related = 1 | i) Directly related = 2 |
| Reason: The vegetation was suppressed, altering the landscape. | | |
| Sum of the chosen items: 9 points. | | |

## 5. CONCLUSIONS

The final values do not reflect, in its totality, the reality, because it is a simulation for academic purposes and we did not have access to the information of the lawsuit previously cited, which contains the reports of experts and government agencies. However, the methodologies of environmental valuation have validity and can be used as models for valuation processes in similar situations.

The environmental valuation demonstrated to be a favorable way to support lawsuits in order to contribute to assemble more suitable values to the environmental resources that aim to prevent damaging actions to the environment through a higher fine. This study also contributes to better choose valuation methodologies, because these methods will more likely valuate environmental damages.

Analyzing the methods used, we noticed that Cardoso method was the one that resulted in the highest values, because this methodology is not very detailed, assessing the environmental impact only in terms of duration, not dealing with other characteristics of the damage, such as frequency, magnitude, extent, among others.

DEPRN method showed to be the most recommended for raising the monetary value of the environment, the reason is that the methodology presents a detailed list of criteria for the qualification of harms, along with a table to obtain the multiplication factor. Among the three methods analyzed, this is the one that is closer to an ideal condition for assessing environmental damages to intangible goods. However, for the best use of this method, it is necessary to have access to a lot of information, sometimes not available, such as the occurrence of endemic species, the sphere of action of the fauna, historical and cultural heritage, and others.

Environmental Factor Methodology has shown to be the simplest one, but it reached the lowest value. This happened because the method just doubles the restoration costs. It does not consider the services provided by the environment, that is, non-use values (climate regulation, flood mitigation, etc) are not completely weighed (unless the appraiser includes them into the restoration costs), involving a monetary devaluation of the environmental damage. Such methodology is easy to use and it must be used when the professional does not have any information about the environment and about the bonds between humans and nature.

Also, the methodologies do not provide a monetary value for a period of time (for example, US$ / year), complicating the comparison with other studies of similar areas and making the assessment of these relatively new methods difficult.

Despite the efficiency of the methods, there are limitations to the valuation of intangible goods, considering that an ideal valuation condition would happen if a complete environmental service framework of the ecosystem is available, but in real conditions, where such information is not available and potential risks to the environment and human health exists, the principle of precaution principle must prevail.

## REFERENCES

Alier, J.M. (2007) – *O Ecologismo dos Pobres.* 379p., Editora Contexto, São Paulo, Brasil. ISBN: 978-8572443586.

Almeida, J.R.; Panno, M.; Oliveira, S.G. (2000) - *Perícia Ambiental*. 286p., Thex, Rio de Janeiro, Brasil. ISBN: 978-8528606980.

Alongi, D.M. (2002) – Present State and Future of the World's Mangrove Forests. *Environmental Conservation* (ISSN: 0376-8929), 29(3):331-349. doi:10.1017/S0376892902000231

CAIXA (s/d) - *Sistema Nacional de Pesquisa de Custos e Índices da Construção Civil (SINAPI)*. CAIXA, Brasil. https://webp.caixa.gov.br/casa/sinapi/index.asp?menu=0.

Cardoso, A.R.A. (2003) - *A Degradação Ambiental e seus Valores Econômicos Associados*. 96p., Sergio Antonio Fabris Editor, Porto Alegre, RS, Brasil. ISBN: 8575252267.

Centro de Informática e Automação do Estado de Santa Catarina (s/d) - *Mapa Interativo de Santa Catarina*. Centro de Informática e Automação do Estado de Santa Catarina, SC, Brasil. Disponível em http://www.mapainterativo.ciasc.gov.br.

Committee on Assessing and Valuing the the Services of Aquatic and Related Terrestrial Ecosystems (CAVSARTE); National Research Council (NRC). (2004) - *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. The National Academies Press, Washington DC, USA. ISBN: 978-0309093187.

Grasso, M.; Novelli, Y.S. (1999) - Economic Valuation of Mangrove Ecosystem. *In*: May, P.H. (ed.), *Natural resource valuation and policy in Brazil*, pp.113-136, Columbia University Press, New York, USA. ISBN: 978-0231108270.

Lipton, D. W.; Wellman, K.; Sheifer, I.C.; Weiher, R.F. (1995) - *Economic Valuation of Natural Resources: A Handbook for Coastal Resource Policymakers*. 131p., US Department of Commerce. Maryland, USA. Disponível em http://www.mdsg.umd.edu/Extension/valuation/handbook.htm

Luisetti, T.; Turner, R.K.; Bateman, I.J.; Morse-Jones, S.; Adams, C.; Fonseca, L. (2011) - Coastal and marine ecosystem services valuation for policy and management: Managed realignment case studies in England. *Ocean & Coastal Management*, 54(3):212-224. doi:10.1016/j.ocecoaman.2010.11.003

Maltchik, L. (2003) - Three new wetlands inventories in Brazil, *Interciencia* (ISSN: 0378-1844), 28(7):421-423, Caracas, Venezuela. Disponivel em http://www.scielo.org.ve/scielo.php?script=sci_arttext&pid=S0378-18442003000700011&lng=es&nrm=iso

Marroni, E.V.; Asmus, M.L. (2005) – *Gerenciamento Costeiro: Uma proposta para o fortalecimento comunitário na gestão ambiental*. 149p., Editora da União Sul-Americana de Estudos da Biodiversidade – USEB, Pelotas, Brasil. ISBN: 8589985067.

Massachusetts Institute of Technology (2002) – *Brazilian Constitution of 1988*. Massachusetts Institute of Technology, Massachusetts, USA. Disponível em http://web.mit.edu/12.000/www/m2006/teams/willr3/const.htm

Matos, A.; Ribeiro, I.; Fernandes, A.; Cabo, P. (2010) - *Análise crítica dos métodos de valoração economica dos bens e recursos ambientais*. 14p., Universidade da Extremadura, Estremadura, Espanha. Disponível em http://hdl.handle.net/10198/2699

Merico, L. F. (1996) - *Introdução à economia ecológica.* 160p., Ed. da FURB, Blumenau, SC, Brasil. ISBN: 8571140537.

Ministério do Meio Ambiente (s/d) - *i3geo: Free Software to create interactive maps and geoprocessing*. Ministério do Meio Ambiente, Brasilia, Brasil. Disponível em http://mapas.mma.gov.br/i3geo/.

Motta, R.S. (1997) - *Manual para Valoração Econômica de Recursos Ambientais*. 242p. IPEA / MMA / PNUD / CNPq, Brasilia, Brasil. Disponível em http://www.em.ufop.br/ceamb/petamb/cariboost_files/manual_20serroa_20motta.pdf

Neto, G K. (2005) - *Apostila de Perícia Ambiental*. 229p., Rui Juliano Perícias, Rio Grande do Sul, Brasil. Disponível em http://iemhub.org/resources/574

Presidência da República (s/d) - *Lei nº 12.651 of 25 may 2012*. Presidência da República, Brasilia, Brasil. Disponível em http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Lei/L12651.htm

Presidência da República (s/d) - *Lei nº 7661 of 16 may 1988*. Presidência da República, Brasilia, Brasil. Disponível em http://www.planalto.gov.br/ccivil_03/leis/l7661.htm

Presidência da República (s/d) - *Lei nº 9.985 of 18 july 2000*. Presidência da República, Brasilia, Brasil. Disponível em http://www.planalto.gov.br/ccivil_03/leis/L9985.htm

Ramalho, A.M.Z.; Pimenta, H.C.D. (2010) – Valoração Econômica do Dano Ambiental Ocasionado pela Extração Ilegal da Orquídea Cattleya granulosa no Parque Natural Dom Novaldo Monte, Natal/RN, *Holos* (ISSN: 1807-1600), 26(1):62-82, Rio Grande do Norte, Brasil. Disponível em http://www2.ifrn.edu.br/ojs/index.php/HOLOS/article/view/333

Remoundou, K.; Koundouri, P.; Kontogianni, A.; Nunes, P.A.L.D.; Skourtos, M. (2009) – Valuation of Natural Marine Ecosystems: An Economic Perspective, *Environmental Science and Policy* (ISSN: 1462-9011), 12(7):1040-1051. doi:10.1016/j.envsci.2009.06.006

Soares, G.S.; Dominguez, J.M.L. (2012) - Zonas úmidas na planície costeira do rio Itapicuru, litoral norte do estado da Bahia, Brasil: classificação e controles ambientais. *Journal of Integrated Coastal Zone Management*, 12(2):223-237. doi:10.5894/rgci324

Tong, C.; Feagin, R.A.; Lu, J.; Zhang, X.; Zhu, X.; Weng, W.; He, W. (2007) - Ecosystem service values and restoration in urban Sanyang wetland of Wenzhou, China. *Ecological Engineering,* 29(3):249-258. doi:10.1016/j.ecoleng.2006.03.002

Upadhyay, V.P.; Ranjan, R.; Singh, J.S. (2002) – Human-Mangrove Conflict: The Way Out. *Current Science* (ISSN: 0011-3891), 83(11):1328-1336. Disponível em http://www.iisc.ernet.in/currsci/dec102002/1328.pdf

Vo, Q.T.; Kuenzer, C.; Vo, Q.M.; Moder, F.; Oppelt, N. (2012) – Review of valuation methods for mangrove ecosystem services. *Ecological Indicators*, 23:431-446. doi:10.1016/j.ecolind.2012.04.022