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# DEFINITION OF THE INITIAL CAPITAL VALUE IN REFORESTATION PROCESSES WITH NEGATIVE $CO_2$ EMISSIONS

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**ABSTRACT**

Negative $CO_2$ emission processes are techniques that involve the definitive removal of excess $CO_2$ from the atmosphere. Advances in the method of carbon quantification in reforestation have allowed the accomplishment of mathematical-statistical modeling as a function of production and productivity in the carbon storage processes of structured reforestation programs. This work aimed to investigate a method that allows the quantification of the initial capital in a process of greenhouse effect mitigation through reforestation. The materials used consisted of the production and productivity equations in a productive structure under sustained yield management of *Mimosa scabrella Benthan*, commonly known as Bracatinga. The results show that the rate of capitalization or discount of natural values follows a sigmoidal form, not a non-geometric form. Interest rates must be derived and appropriated in the actual process or production effect. By obtaining the current present value of production and the variable interest rate, one can calculate the initial capital of the period considered. The possibility of calculating the variable interest rates also allows the same process to be applied in the management of native populations under a polycyclic sustainable income system.



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## INTRODUCTION

**Nature and background of the problem:** Processes with negative $CO_2$ emission are techniques that involve the definitive removal of excess $CO_2$ from the atmosphere. One way of enabling such processes is by means of reforestation, which is a scientifically established method (compatible with the effects of the natural entropy of the biosphere – Hosokawa, 2005) and is also economically viable. Advances in techniques for quantifying carbon in reforestation have allowed the use of mathematical-statistical modeling, such as production and productivity functions, in the processes of carbon sequestration in reforestation projects based on the production of wood biomass (Hosokawa *et al.,* 2002). However, this has hindered the economic analysis when considering carbon sequestration in forest stands as a value.

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The question first arose when Samuelson (Nobel Prize in Economics - 1976, 1983, 2001) demonstrated that the tools used for the economic analysis of the indirect benefits of the forest, except for the formula developed by Faustmann (Konig, 1813; Navarro, 2003; Faustmann, 1849 a,b), were all inadequate, as they led to absurd estimates in the long term. Similarly, Birdsall, Steer and Cline (World Bank economists - 1993) demonstrated that the capitalization or discount calculated with the classical Compound Interest Formula works only for financial values and not for natural values coming from the effects of biomass infrastructure, such as reforestation, which can mitigate climate changes caused by the greenhouse effect. Those authors emphasized that by capitalizing one dollar for a millennium, there would never be enough money to pay the final value. However, if the current real value is discounted for a millennium, the initial value is practically zero and hence supports the argument that there is no need to invest in indirect benefits. Nevertheless, macro-environmental damage, according to surveys conducted by the Munich Re Foundation, have grown from 20 billion dollars to

600 billion dollars just in the last five decades, thus demonstrating that human society must eventually invest in the environment. The exceeding financial resources generated periodically by society have never been enough to fully cover humanitarian deficiencies such as hunger, illiteracy, diseases and also environmental damage. This fact necessarily leads to priorities in investments whose decisions are based on the comparison of the return on investment from competing sectors. The benefits from investments in education, nourishment and health can be measured by compound interests and represent opportunity costs of capital added with measurable costs of risks. The indirect benefits of the environment are impossible to measure by compound interests due to the law of diminishing returns, as stated by Faustmann. Also, the factors that influence the production of indirect benefits are limited over time and space. In order to work around these issues, the concept of social rate of time preference has been adopted, which unfortunately does not represent the reality of nature in the long term for being drastically subjective. The case study "Dynamics of $CO_2$ assimilation by reforestation" (Hosokawa, 2000) has allowed the quantification of natural interest rates that vary over time and show sigmoidal shape, and not a unique exponential value as in the classic compound interest calculation. The application of this new concept solves the aforementioned deficiency. Its use allows the assessment of real interest over time, causing both the capitalization and the discount to calculate correct values. Also, by its use, the environment has its return on investment when based on unit values of capital. Interval interest can be calculated by the differences of successive integrals of a function that produces natural interest. However, the question still remains: how much is the initial capital worth for reforestation when the carbon storage value is added?

In the case of reforestation bases with continuous wood production, the initial investment is grouped as a "planting costs center". Its value is in principle the initial capital that, through the opportunity cost of capital, reaches the final value of rotation. When added with costs that occurred over time, it should be equal to the sum of income capitalized over time. In this context, the value aggregated due to carbon sequestration has the same initial capital as the wood production and, therefore, at the end of rotation is already paid by the income obtained from wood. Would it be unfair to charge for value-added carbon? Despite contributing to the removal of excess $CO_2$ from the atmosphere in the long term, the reforestation activity is one of the only significant processes of mitigation of low entropy emissions concerning to the global warming. Thus, it should be a remunerated activity (Hosokawa, 2006).

**Objectives:** We aim in this study to elucidate the aforementioned questions and also search for a method that allows the quantification of the initial capital amount in the process of mitigation of greenhouse gases by means of reforestation.

### LITERATURE REVIEW

Relevant bibliographic references concerning to the subject are still scarce, as we study new forms of valuing forestry activities. However, some classic methods are still applicable, such as:

**Cost-Benefit method:** This is the easiest method to apply, as long as the real benefit can be quantified. The cost is appropriate by means of inputs used in the production of the benefit. The biggest difference between the benefit and the cost is regarded as the appropriate value.

**Cost-Utility Method:** This method is used to verify the utility of several processes by means of qualitative assessments, which are treated with scale transformation and weighing in order to allow the selection of the most useful one. The cost corresponds to the most useful process or the one with the lowest cost.

**Cost-Efficiency Method:** In this method, the value is already set. It is used in order to find procedures that lead to the best cost-efficiency relationship.

Peripheral bibliography such as *Economia y MedioAmbiente*, *Preparación yEvaluación de Proyectos*, *Métodos Fundamentales de Economía Matemática*, and*Teoria de los Precios y Aplicaciones de Teoria Macro-Económica* are references that support the processes but do not specifically address the problem.

The Brazilian Ministry of the Environment presents some particular applications with case studies, as follows:

**Production Function:** It uses resources from marginal productivity and from substitute goods markets. The benefit or cost of the variation in the availability of environmental resources is given by the product of the varied amount of resources times its estimated economic value.

**Demand Function:** It is based on the market of complementary goods and on quota valuation. It assumes that the availability of natural resources alters the payment and estimates economic values based on demand.

**Substitute Goods Market:** It is used when there are no observable market prices or when these are burdensome to measure.

**Hedonistic Prices:** The basis of this method is the identification of attributes of a private compound product that are complementary to environmental goods or services. The price is determined by exclusion.

**Contingent Valuation:** This method is based on the concept of willingness to pay and accept. It uses mathematical-statistical features such as stochastic simulation and its efficiency depends on the level of knowledge of the attributes inherent to goods and services by those concerned.

## MATERIALS AND METHODS

We used the equations of production and productivity in a production structure under sustained yield management of *Mimosa scabrella Bentham*, commonly known as Bracatinga.

**Production Functions**

$$G = \frac{I^2}{0.2087239 - 0.0592329\, I + 0.053653208\, I^2}$$

$$TP = \frac{I^2}{0.039983 - 0.005509\, I + 0.005199 I^2}$$

$$B = \frac{I^2}{0.09499128 - 0.01393649\,I + 0.01302957 I^2}$$

$$GI = \frac{I^2}{0.024374 - 0.006340\,I + 0.001197 I^2}$$

$$C = \frac{I^2}{0.154397 - 0.011314\,I + 0.026268 I^2}$$

**Productivity Functions**

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$$C = \frac{I}{0.154397 - 0.011314\,I + 0.026268\,I^2}$$

Where:

I: Age in years
Basal Area (G): $m^2$ / hectare
Total Production (TP): $m^3$ / stere
Biomass (B): ton. / hectare
Carbon (C): per hectare

We also used the following methods:
Measurement of attribute values
Production and productivity functions
Capitalization and financial discount
Interval capitalization and discount for natural values (new method considering the laws of diminishing returns).

## RESULTS AND DISCUSSION

**Economic Value of the attributes:** The energy value that bracatinga offers is traditionally considered its biggest asset in a sustainable production structure. Bracatinga can be sold in form of firewood, with a diameter of at least 4 cm at the small end and 1 meter in length, for R$ 5.00 per stere. The revenue earned with its sustainable yield is represented by the price of the stere times the volume of wood per unit of production. In this study, the unit of production is in its fifth year – in a dynamic structure held from the first year of growth to the fifth year. That is, the fifth-year units are harvested annually and the harvested area is immediately prepared for regeneration. In the following year, the current fourth-year units will be the fifth-year units and will be ready for harvest, thus allowing a sustainable harvest for an undefined amount of time. This is considered the first direct benefit attribute of bracatinga. The commercialization of bracatinga in form of vertical props for formwork has drawn attention lately for being more profitable. The props are sold by the dozen and they must have a diameter of at least 7 cm at the small end and 4 meters in length. The revenue earned with its sustainable yield is represented by the price of the product, quoted at R$ 0.40 per unit, times the dozen produced by the unit of production in its fifth year. This is considered the second direct benefit attribute of bracatinga. Furthermore, due to the shortage of raw materials that has happened in the furniture industry, bracatinga has stood out as an option of lumber that can be used in furniture making. For commercialization, bracatinga posts must have a diameter of at least 15 cm at the small end and 3 meters in length, and are quoted at R$ 7.00 per stere. This is considered the third direct benefit attribute of bracatinga. As bracatinga trees can store the $CO^2$ that results from photosynthesis, we might consider the storage of tons of carbon in the units of production between the first and fourth years as an indirect benefit. Since the carbon market currently accepts 3.5 tons of carbon credits per ton of surplus diesel, and considering a value of R$ 2.00 per liter of diesel, following international standards, it is possible to obtain a value of R$ 7.00 per ton of carbon stored in the wood, as quoted at the Chicago stock market (Hosokawa *et al.,* 1997). We might consider this as the fourth attribute, but an indirect one. In order to quantify bracatinga products, such as firewood, posts and lumber, and now with the addition of the $CO^2$ storage as an indirect attribute, we have a *j* unit value of the tree $X_{i,}$ $P_{xij}$. These values are defined by an attribute vector $a_{ij}$, which results in $P_{xij} = P_{xi}$ ($a_{ij}1$, $a_{ij}2$, $a_j3$,+ $a_{ij}4$). The value for each unit of production from the first to the fifth year, considering the four attributes, is the sum of the value of each tree $S_j$( $P_{xij}$ ) = $S_j$( $P_{xi}$ ($a_{ij}1$, $a_{ij}2$, $a_{ij}3$,$a_{ij}4$ )). Production and productivity functions for the four attributes of bracatinga Considering *K* as the age of bracatinga production, we have $S_{JK}$ ($P_{xij}$) = $S_{JK}$ ($P_{Xi}$ ($a_{ij}1$, $a_{ij}2$, $a_{ij}3$, $a_{ij}4$)). Therefore, a sufficient number of sample enables us to model the production function $U_{sjk}$ = f (age). For instance, using Prodan's equation, we have as a function of production $U_{sjk} = K^2 / (k^* b0 + b1 + b2\ ^*k^2)$. If we divide this function by *K* (age), the result is a productivity function $UPs_{jk} = K / (k^* b0 + b1 + b2\ ^* K^2)$. If we derive this function, we obtain as the first derivative the maximum or minimum productivity age d UP $s_{jkdk}$ = d (K/b0 b1 + b2 + $K^{2*}$ k) dk, which is reached at the age K = $(b0/b2)^{1/2}$. The second derivative of the equation, $d^2$ (b2 * $K^2$ - b0) dk, demonstrates if the function attains a maximum or minimum.

**Capitalization rate and discount rate (Speidel 1972, 1984):** The capitalization of the financial assets is obtained by Cn = C0 $^*$ 1.0 $i^t$. Thus, the value of the initial capital for bracatinga is C0 = C5 / 1.0 $i^5$, where *i* can be obtained through the opportunity cost of capital.

**Capitalization and natural resources discount:** The capitalization or the discount of the production values that present direct and indirect benefits to the environment do not develop exponentially but as a classic sigmoidal growth curve. This happens because biomass production follows genetic planning, which includes growth stages such as the juvenile, mature and senescence stages, what induces the existence of an inflection point in which the growth rate changes from a progressive growth to a regressive growth, to posteriorly, based on the average maximum yield, achieve an asymptotic growth. However, environmental production factors are limited, what induces production subjected to the law of diminishing returns. For these reasons, one cannot only use one capitalization or discount rate. It is necessary to adopt different capitalization rates or discount rates during production. One of the criteria for determining the variable rates, including the various conditions of productivity, is to assume that a production value of 100% occurs at the optimal rotation age. The other criteria would derive as gradients of the variable rates of interest over time. Under these conditions, the initial capital value is considered as the capital at the beginning of each period, and the dynamics of capitalization are:

$Cn = Cn\text{-}1 * 1.0\ iv_n - (_{n-1})$.

Such dynamics can be used to estimate the initial capital value of the carbon stored in the reforestation process:

$Cn - 1 = Cn / 1.0\ iv_n - (_{n-1})$

Where:
$Cn\text{-}1 = C0\ (_{n\ -\ 1})$: Initial capital at the beginning of the considered period (n - 1).
Cn: Amount capitalized at the end of period *n*
$Iv_{n\ -}\ (_{n-1})$: Interest rate of the period (n-(n-1)).

**Selection of the payback period**

Normally, the optimal rotation age of the targeted product is selected as the payback period. We found the following ages for the parameters considered:

Basal Area = 2.0 years
Total production = 2.8 years
Biomass = 2.7 years
Gross Income = 4.5 years
Carbon = 2.4 years

We defined the payback period as 5 years based on the gross income, since it synthesizes the optimal production, considering the firewood, lumber, posts and carbon storage as added value. Bracatinga's phenology also determines 5 full years as the age of full seed yield in order to ensure the natural regeneration of the area from which the trees were cut down. Procedures for calculating the capitalization or discount rate and the initial capital value for a five-year continuous production structure of bracatinga. With the assist of the production function used to determine the gross income we estimated the initial and final values of the period and added the carbon storage value through the function of carbon storage and multiplied by the price of R$ 7.00.

The Variable Natural Rate of Interest is obtained by:

$iv = ((Cn – C0\ (_{n-1})\ ) / C0\ (_{n-1})\ )^{*}\ 100$ $\qquad iv = (1338 – 1093) / 1093\ ^{*}\ 100 = 22.42\ \%$

The Initial Capital of the considered period is calculated through the discount formula:

$C0\ (_{n-1}) = Cn / 1.0\ iv\ C0\ (_{n-1}) = 1338 / 1.2242 = 1093$

**Conclusion**

- The capitalization or discount rate has a sigmoid shape and not a geometric one as that of the financial or risk rate;
- The rates of interest must be derived and adequate to the production process;
- With the current production value and the variable interest rate, it is possible to calculate the initial capital of the considered period;
- The possibility of calculating the variable interest rate allows us to apply the same process in the sustainable yield of native plants under a polycyclic management;
- As society keeps consuming more and more and resources are increasingly scarcer, as well as the tendency of biomass productivity to decrease governed by the law of diminishing returns, the management of native forests will become proportionally more critical. This will result in the decrease of the use of the *Plenterwald* practice (polycyclic), and in the gradual increase of the use of the *Femelwald* practice (partial domestication). Reforestation under the *Normalwald* concept will also suffer restrictions due to its environmental impacts;
- The low wood value determines the need to apply the methods of economies of scale in forestry, but the existence of limitations on area availability added to high operating costs make any management structure in semi domesticated structures economically unviable;
- Such reasons are enough to show that society should pay for the indirect benefits of forests, such as carbon storage, that could lead to the decrease of the greenhouse effect that causes climate change, to the maintenance of biological diversity, to the maintenance of the hydrologic cycle for drinkable water production, to the protection of soil productivity for food production and so on;
- One should not forget that the effect of the forest infrastructure is an essential asset in the maintenance of indirect benefits, which are crucial for the existence of mankind;
- In order to obtain natural rates in several silviculture treatments, it is necessary to use data with minimal sampling errors and defined probabilities about sites, age, forest products market, effects of different infrastructure and other variables to model their production functions according to time;
- The interval variable rates can be calculated by their successive integrals with intervals defined by these functions. With these rates, one can easily obtain both the initial and final capital values. Further research is required due to the need for huge amount of data concerning to the nature and the socio-economic environment.

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