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ACTIVITY BASED COSTING OF THE NUCLEATION TECHNIQUES IMPLEMENTED IN FOREST CLEARINGS DUE TO OIL EXPLORATION IN THE CENTRAL AMAZON

CUSTEIO DAS ATIVIDADES DAS TÉCNICAS DE NUCLEAÇÃO IMPLANTADAS NAS CLAREIRAS ABERTAS PELA EXPLORAÇÃO PETROLÍFERA NA AMAZÔNIA CENTRAL

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ABSTRACT

The objective of this work is to present the costs of nucleation techniques in environment restoration from damaged areas due to oil exploration at the Geologist Pedro de Moura Operation Base – BOGPM, identified by Petrobras as LUC 15, JAZ 104 and JAZ 94. Three nucleation techniques were used: topsoil, artificial perches and dead wood/sticks. Nucleation consists in forming propagation nuclei in small strategic points of the area to be restored. The technique takes advantage of existing natural resources in the area, which reduces the cost of restoration. We registered the time of execution from each activity, the manpower and the input used. The data was analyzed by the method of Activity-Based Costing (ABC). For the three techniques, we found that cleaning of the damaged area was the activity that consumed more resources. For the topsoil technique, the activity of collection and transportation of the forest floor were also identified. The use of topsoil was the most costly technique, followed by the activities of dead woods/sticks and artificial perches respectively. We suggest the use of nucleation techniques to promote soil recovery to increase the number of propagule seedlings, to attract wildlife, and to act strategically in the landscapes, while minimizing erosion and costs.

Key words: restoration cost, Activity Based Costing (ABC), nucleation, oil exploration.

RESUMO

O objetivo deste trabalho é apresentar o custo das técnicas de Nucleação na recuperação ambiental das áreas degradadas pela exploração petrolífera na Base de Operação Geólogo Pedro de Moura – BOGPM, identificadas pela Petrobras como LUC 15, JAZ 104 e JAZ 94. Foram utilizadas três técnicas de Nucleação: *topsoil*, poleiros artificiais e galhada. A nucleação consiste em formar núcleos de propagação em pequenos pontos estratégicos da área a ser restaurada. A técnica aproveita os recursos naturais existentes na área, o que reduz o custo da restauração. Coletou-se dados sobre o tempo da execução de cada atividade, da mão-de-obra empregada e de insumos utilizados. Os dados foram contabilizados pelo método do Custeio Baseado em Atividades (ABC). Para as três técnicas, identificou-se que a limpeza da área degradada foi a atividade que consumiu mais recursos. Para a técnica de *topsoil*, identificou-se também a atividade de coleta e transporte de solo da floresta. A utilização da técnica de *topsoil* foi a que apresentou o custo mais elevado, seguida das atividades da galhada e dos poleiros artificiais, respectivamente. Sugere-se a utilização das técnicas de nucleação para se promover o reconhecimento do solo, aumentar o número de propágulos de plântulas, atrair a fauna silvestre e atuar estrategicamente na paisagem, enquanto se minimiza a erosão laminar e os custos.

Palavras-chave: custo de restauração, Custeio Baseado em Atividades (ABC), nucleação, exploração petrolífera.

INTRODUCTION

The analysis of the restoration costs of degraded areas in Central Amazon is strategic and decisive in the choice and implementation of techniques to use. These techniques are applied in degraded areas caused by mining, clearings opened for natural gas and oil prospecting and exploration.

The clearings (areas of oil and natural gas prospecting) and the deposits (lending areas or deposit of work refuse) are the most impacted areas at the Geologist Pedro de Moura Operation Base – BOGPM in Coari, state of Amazonas, Brazil. Restoring the clearings and deposits is a challenge for researchers and subcontracted companies hired by the company Petróleo Brasileiro S.A. – Petrobras. In these areas there are removal and/or inversion of soil horizons, elimination of the seed bank and seedlings, difficulty in the resumption of environmental resilience and facilitating erosion soil process by the exposure to adverse weather (Calvi, 2008).

The characteristics altered in landscapes and adverse weather conditions (high rainfall and temperature) (Instituto Nacional de Meteorologia [INMET], 2010), the distance from urban centers (650 km from Manaus, capital city of the state of Amazonas, Brazil) and the complexity of activities involved in the operations of restoration of these impacted areas make the environmental restoration technique that uses the minimal inputs and costs decisive.

One technique to restore degraded areas that can be developed "*in situ*" is nucleation (Reis *et al.*, 2003a). Nucleation is understood as the capacity of species to provide significant improvement in environmental quality, increasing the probability of occupation of this environment by other species (Yarranton and Morrison, 1974; Reis *et al.,* 2010).

Nucleation uses small strategic points of the area to be restored for the installation of different nucleation techniques (constituting small mosaics) (Corbin and Karen, 2012). Then, the formation of islands of diversity with different life forms and ecological niches serve as shelter, food, reproduction and establishment for other species (Reis *et al.*, 2003b). This technique takes advantage of local resources using minimal external inputs, which lead to decreasing restoration costs of the degraded area (Kinyua *et al.*, 2010). This aspect is important to be evaluated and contribute to cost accounting analysis.

The cost method used in this exploratory research was the Activity Based Costing – ABC (Cooper and Kaplan, 1988; Kaplan and Anderson, 2007; Schulze *et al.*, 2011), which aims to identify the activities, the resources consumed by these activities and the costs of these resources (Nakagawa, 1994; Carmo and Padovani, 2012). The ABC method is based on the registry and on the accumulation of costs of the environment's basic activities, Cost Management System – CMS (Berliner and Brinson, 1991; Benjamin *et al.*, 2009). The purpose of this study is to present the cost per square meter of nucleation techniques in environment restoration from damaged areas due to oil exploration at the BOGPM/Petrobras in experimental scale.

From a methodological point of view, this paper consists in a case study conducted at the Geologist Pedro de Moura Operation Base – BOGPM, in three clearings denominated LUC 15, JAZ 94 and JAZ 104. The contribution of the study consists in presenting through a practice of costing the process of adaptation of the ABC method in a specific activity of environmental restoration. As seen, the analysis of recovery cost becomes strategic and decisive for the selection and the implementation of the technique to be used.

The paper is structured in five sections. The next section of the paper presents the Activity-Based Costing method, the process of adaptation of the activities and costs, and discusses the techniques of nucleation implemented. The following section features the characterization of the area studied and the analysis of the main activities. The two final sections show the main results and the final conclusions.

ADAPTATION TO THE ACTIVITY BASED COSTING (ABC) METHOD

The Cost Accounting changed from an assist in stock assessment and profits to a major tool of control and management decisions. Such changes in cost accounting functions are an important source of management data for the information within organizations (Martins, 2001; Benjamin *et al.*, 2009; Grondskis and Sapkauskiene, 2011).

According to Cardinaels *et al.* (2004) and Chea (2011), Cost Accounting provides a range of information that allows managers to position themselves as to the efficiency and the effectiveness of the production process and its ability to maintain the continuity of the enterprise – or activity – profits with the information for control and decision making.

ABC was originally proposed by Robin Cooper in the 1980s and during the 1990s. The ABC still motivates debates and controversies about its methodology. Emerged with the aim of solving the problems of apportionment criteria, ABC is a costing method that "seek(s) to substantially reduce the distortions caused by arbitrary apportionment of indirect costs" (Martins, 2001; Balakrishnan *et al.*, 2012).

ABC, according to Cooper and Kaplan (1988), is an economic map of the expenses of the organization's profitability based on organizational activities. A system of activity-based costing provides businesses with an economic map of its operations, emphasizing the cost of existing and projected activities and business process which, in contrast, explains the cost and profitability of each product, service, customer and operational unit (Cokins *et al.*, 2011). Even the method having a significant visibility in scientific publications and conferences, it appears that the effective use of the method of costing activities by firms is much lower in proportion (Anthony, 2004).

The ABC method considers that costs are generated by the execution of activities when those activities require resources. ABC identifies and traces the causes of costs when placing products or services eliminating the apportionment criteria (Martins, 2001; Anderson and Dekker, 2009).

In this study, three nucleation techniques for the restoration of clearings as topsoil, dead wood/sticks and artificial perches were evaluated. The topsoil consists in moving a layer of the forest soil, rich in seeds and soil biota to the impacted area (Akintorinwa and Adesoji, 2009; Hooper *et al.*, 2004).

The dead wood/sticks technique consist in forming a bunch of dead wood/sticks in the impacted area by brushwood and woods collected in the adjacent forest (Schmidt, 2008). The dead wood/sticks technique aims to accommodate small animals such as amphibians, rodents, lizards and birds. The dead wood/sticks also attract wood degrading insects, releasing more carbon into the soil in the decomposition process, which has fundamental importance in early stages of soil formation and colonization by microorganisms and plant species (Bechara, 2006).

The Artificial perches consist of small trees (up to 7m tall), cut and transferred to degraded areas in order to attract fauna birds, serving as perches during the flight. The feces deposited in the area are rich in seeds of the forest fragments of the region, increasing the probability of colonization, mainly of grass, lianas, herbs and shrubs (Bechara, 2006).

To understand the production chain of nucleation techniques (Heelemann *et al.*, 2012), the scope of the processes involved (Figure 1) was developed. To know the problem under study, a flowchart of the main activities involved in the

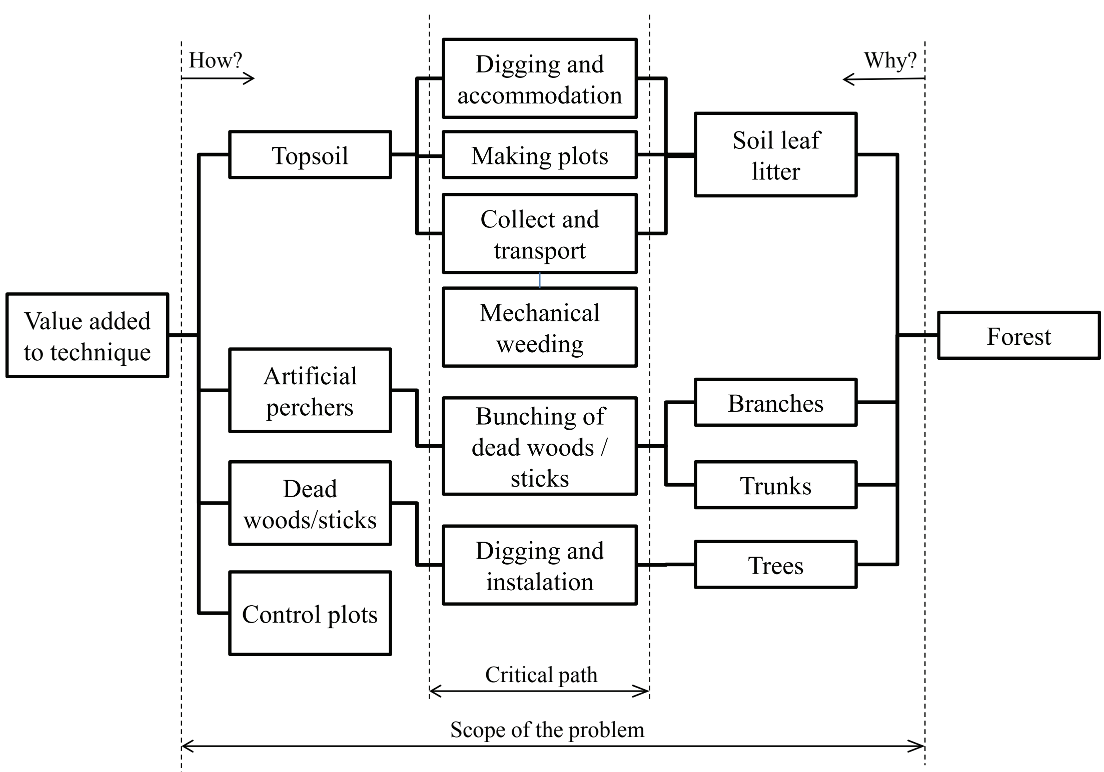

Figure 1. *Production Chain of nucleation techniques.*

Source: adapted from Kaufman (1990).

deployment of the technique was elaborated, highlighting the resources required to the development of the necessary activities to obtain the products (Figure 2).

The ABC method assumes that there are activities that consume the resources, and the products and services consume the activities (Nakagawa, 1994). In Figure 3, there is a division of the resources in categories and their respective activity centers. By the analysis of Cost Drivers we can understand the dynamics of resource consumption and how products consume activities.

The data presented was provided by Calvi (2008) for the development of this research, which was tabulated and adapted to the Activity Based Costs method (Figures 2 and 3). The data generated in the used infrastructure at the BOGPM for deployment of the technique was added to the original data.

METHODOLOGY

This section shows briefly the principal items of the Geologist Pedro de Moura Operation Base – BOGPM case study, the location of the clearings restored and the conduction of the activity analysis and costs.

LOCALIZATION OF THE STUDY AREA

The study was conducted at the Geologist Pedro de Moura Operation Base – BOGPM, in Coari, state of Amazonas, Brazil, located at coordinates 04°53'S and 65° 11'W

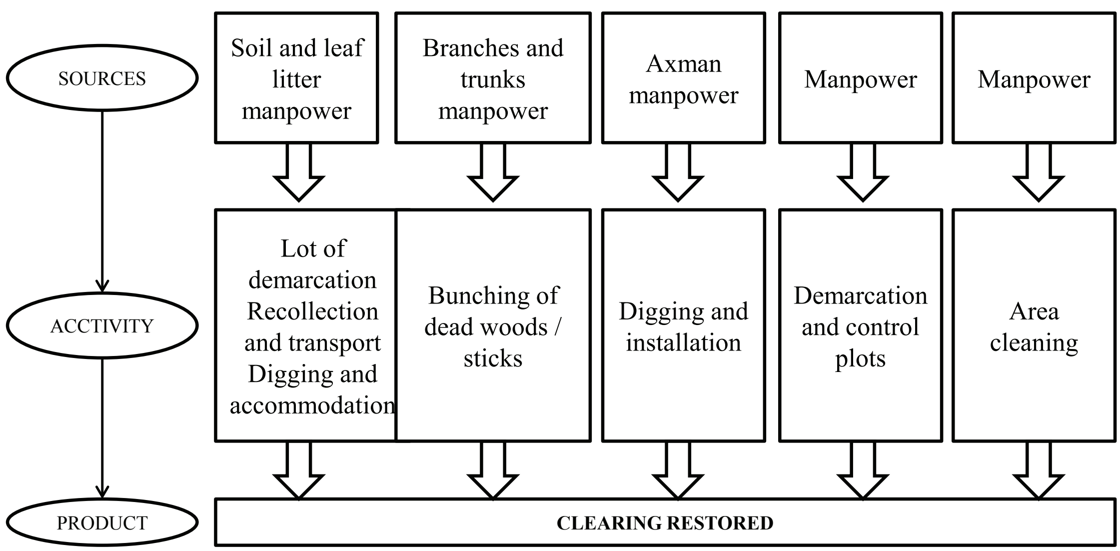

Figure 2. *Flowchart of the activities.*

Source: adapted from Nakagawa (2000).

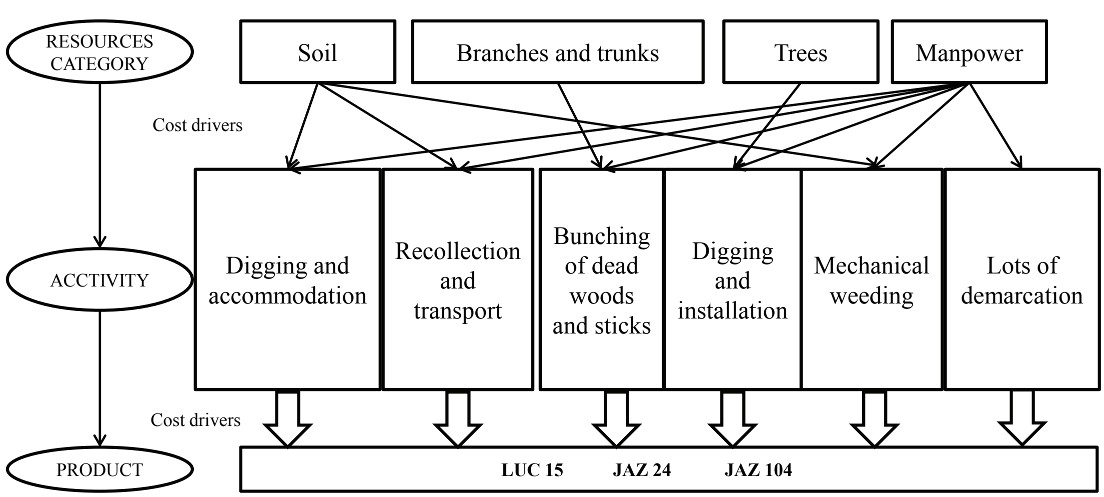

Figure 3. *Systematic allocation of resources and activities.*

Source: adapted from Brinker (1980) and Nakagawa (2000).

(Figure 4). The region is comprised of Rain Forest ombrophilous in dystrophic Ultisol, with closed canopy and dense predominantly fine trees (10–20 cm DAP), straight trunks, large globe-shaped treetops, with low diversity of epiphytes and lianas (Whitmore, 1990; Lima-Filho *et al.*, 2001). The climate is "Afi" (Koppen, 1948), equatorial hot and humid with abundant rainfalls from September to April and dry from May to August, with annual rainfall average superior to 250mm and annual temperature average of 26° Celsius (Oliveira *et al.*, 2008).

The experiment was set up in December 2007 in open areas due to oil exploration. Each forest clearing was divided into four quadrants and the nucleation techniques were implemented: topsoil (1m x 1m x 10cm), artificial perches (trees up to 7 meters), dead wood/sticks (1m^3) and control plots (1m x 1m). Further details from deployment of nucleation techniques may be checked in Calvi (2008).

The opened clearings at the BOGPM are normally released for restoration without the surface soil horizons. The exposed soil presents dense structure, low porosity, imperfect drainage, poorly drained and high density (Martins *et al.*, 2008). This region with heavy precipitation, annual average of 2,069.20mm, exposes these poor, loamy and unstructured soils to serious erosion processes (Leal Filho *et al.*, 2008; INMET, 2010). To avoid the weathering process in widening the clearing, the rapid soil cover has fundamental importance. For nucleation techniques serving to this purpose it is necessary to have a larger number of plots located in clearings, targeting the larger covering of ground in a short period of time.

DELIMITATION OF STUDY

The costs of labor supervising at the BOGPM were estimated to simulate a reality in the field. Estimated value of supervision costs assumes a team of a Forester, a Safety Technician, an Agronomist, an Administrative Assistant and a Production Supervisor.

The subcontracted company hired by Petrobras was considered direct labor. The information on taxes, fees and charges related to the labor used in the experiment were collected with the authorization of this company.

The incurred costs in manpower recruited at the BOGPM, as food, housing, transportation and laundry, were called, in this work, Permanence Costs. A market survey was conducted in the city of Manaus, the capital of the state of Amazonas, Brazil. Other variables related to permanence at the BOGPM such as attendance safety, personal training, health, entertainment and leisure were not considered.

The currency used was the Brazilian one (REAL), and to present costs, the reference is April 2010 and the devaluation of the currency in the period of analysis was not considered, considering the short period of analysis.

ANALYSIS OF THE ACTIVITIES

The deployment of Nucleation techniques for the restoration of forest clearings due to oil exploration at the BOGPM was carried out by Calvi (2008). The field data recorded by Calvi provided the basis for the calculation used in the costs accounting of this work. The time spent performing each activity, the number of men who worked and the input used during 12 days of work – time of execution of data collection – were recorded.

Figure 4. *Location of clearings.*

Mechanical weeding is an activity used in all the forest clearings. It consists in cutting the grass before the deployment of nucleation techniques. In this work, this activity was called Cleaning the Area. The control plots of 1 meter x 10 meters ($10m^2$) were set up as witnesses of nucleation, to check and verify the potential of other techniques deployed.

The topsoil technique consists of three activities: (i) demarcation of the plots (ii) collecting and transporting, and (iii) excavating and accommodating. The demarcation of the plots encompasses the planning activity and the demarcation of plots. The activities of collecting and transporting correspond to collecting soil with forest leaf litter and transporting this material into the clearing to be restored. Excavating and accommodating consisted of opening 10 cm deep ditches in 1 meter x 1 meter plots.

The dead wood/sticks is the activity of bunching dead wood/sticks, in other words, forming a pile of branches and trunks of $1m^3$ in the clearing. For the purpose of calculating costs, the activities of cutting, collecting and transporting trunks or branches to form dead wood/sticks were grouped in only one activity, in function of the complexity of measurement and relevance of values involved.

The Artificial perches technique embodies the activity of armhole excavation and installation, considered everything from the collection of material in the forest to its installation.

The costs of mechanized weeding and control plots for the Topsoil, dead wood/sticks and artificial perches nucleation techniques were distributed. The final calculation, purpose of this work, was obtained dividing the costs calculated in each restoration technique by the area of their experiments.

MANPOWER COSTS

Each activity identified by the nucleation techniques was timed from start until the conclusion. Three men were the manpower used to carry out this experiment. The supervision of technicians (Forester, Safety Technician, Agronomist, Administrative Secretary and Production Supervisor) was necessary for accrediting the work quality.

The labor in the deployment of nucleation techniques was classified as Direct Manpower, corresponding to people who worked directly in obtaining the product. The time spent and the number of people performing the work were registered. The supervised manpower was classified as Indirect Manpower (Martins, 2001) and their respective values were estimated.

In the cost estimation the time of Direct Labor Costs stopped due to imposition of weather conditions (rain or insolation) was considered. These values were considered as "non-productive time", in other words, a loss in the process. The payroll, related to the production staff is called Fixed Cost (Martins, 2001; Viceconti and Neves, 2003). All the expenses related to topsoil, dead wood/sticks and artificial perches production that are not classified as Direct Material or Direct Labor were called Indirect Manufacturing Costs (Martins, 2001; Viceconti and Neves, 2003).

At the BOGPM, a monthly working time corresponds to 14 days of effective work and 14 days off, considering up to two days for boarding and landing. The substitute worker, called "back", will complete the month with more 14 days of effective work. Therefore, workers work 28 days effectively in a month and 341 days in a year. The monthly costs of manpower were calculated considering, therefore, two workers. Both workers performed the same work to complete the monthly working time. The companies Conspizza Environment Solutions and Parente Andrade Ltda (PA) provided the data and values for social and labor charges.

The social charge consists in mandatory taxes by the labor law instituted by Brazilian Constitution (1988), in Labor Laws and collective bargaining agreements applicable on the payroll (PARAOBRAS, 2010). In the estimation of manpower costs, the federal taxes involved were also considered: Tax Over Services (*ISS*); Social Integration (*PIS*); Contribution for the Financing of Social Security (*COFINS*); Income Tax (*IR*); Social Contribution Over Net Profit (*CSLL*). To compose the manpower costs the administrative and financial taxes and the profit of the outsourced company were taken into account.

COST OF INFRASTRUCTURE, LOGISTICS, EQUIPMENT AND PERMANENCE

The cost of infrastructure, logistics, equipment and permanence are necessary for a suitable manpower to deploy restoration techniques in degraded areas. These activities refer to food, transportation, laundry and lodging provided by Petrobras and not by outsourced companies. This cost covers the labor of each day at the BOGPM.

To estimate the Permanence Costs at the BOGPM, a market survey was elaborated in the city of Manaus, between January and February, 2010. In this research, the same type of facilities, standards of infrastructure and services at the BOGPM were considered. A budget in different companies, like airlines, hostels, restaurants and laundries was calculated.

DEPRECIATION COST

To calculate the depreciation cost the straight line method was adopted. This method consists in dividing the initial value of assets – less the residual value – by the number of probable years of duration (Oliveira, 2000).

The costs for the vehicle depreciation and the mower used during the implementation of the nucleation techniques were calculated. Other goods used in the implementation of the techniques that have a short life cycle of less than one year and that cost less than R$ 326,61 are exempt from fixed asset, they are not subject to depreciation (Receita Federal do Brasil, 2010; Santos, 2009). The useful life of equipments was available in the website of the Secretariat of the Federal Revenue of Brazil (2010). A residual value of 15% of the initial value of goods was adopted (Koury, 2007).

DIRECT AND INDIRECT MATERIAL OF NUCLEATION TECHNIQUES

The direct materials of the nucleation techniques were identified at the time of implementation of the experiment in the degraded area. Materials are directly applied to obtain the final product (Santos, 2009). In the particular case of nucleation, the natural resources (soil with leaf litter, branches, trunks, trees) compose the direct materials and do not have reference values to be considered in this study as direct material cost.

The indirect material and the costs that complement indirectly the activity benefiting all goods and services produced (Santos, 2009) were identified. The necessary supplies for obtaining the final product that do not hold any direct relationship with the product are: hoe, machete, shovel, wheelbarrow, pliers, wire brush cutter, gasoline, natural gas, among others. To form the costs of indirect material, the prices were estimated in specialized shops of building and gardening in the city of Manaus, Amazonas state.

RESULTS AND DISCUSSION

The ABC method allowed a better understanding of the activities developed in the BOGPM clearings and a better approach to the nucleation techniques in relation to activities cost. The cost evaluation based on activities contributes to highlight the most important activities (consumers of the financial resources), as well as the less significant activities (with costs that do not justify a detailed appraisal). This kind of information provides the basis for the strategic planning of restoration projects that include nucleation techniques.

MAIN ACTIVITIES OF NUCLEATION AND THEIR COST DRIVERS

As the nucleation technique is composed of specific activities developed in the moment of implementation of the technique, the identification and gathering of information for the purpose of costs estimating are easily undertaken. However, knowledge about estimating costs methodology is required in order to allocate, identify and segment the activities for the purposes of collecting data of concerning values (Nakagawa, 2000). We identified two cost drivers in the implementation of activities associated to the nucleation techniques: the quantity and the area (Table 1).

ACTIVITIES COSTS OF NUCLEATION TECHNIQUES

Two main activities were identified as highly consuming resources in cost analysis: the cleaning area activity and the gathering and transporting activity, among the activities associated with the topsoil technique (Figure 5 and Tables 2 and 3).

The costs distribution was done for the activities of Area Cleaning and Lots Demarcation for the areas of topsoil, dead wood/sticks and artificial perches. One of the reasons for the costs distribution of the Control Lots to others lots of nucleation techniques is the application of an experimental scale.

Table 1. *Size of clearings and the quantity established of plots.*

Clearing	Size	Topsoil		Artificial Perches		Dead wood/sticks		Control Plot	
	ha	qt	qt/ha	qt	qt/ha	qt	qt/ha	qt	qt/ha
LUC-15	0,72	56	80	12	20	20	30	8	12
JAZ-94	0.60	48	80	12	20	16	30	8	12
JAZ-104	0,20	16	80	4	20	8	40	4	12

Source Calvi (2008)

Technique	Activity	Cost drivers
Topsoil	Lots of demarcation	Quantity
	Recollection and transport	
	Digging and accommodation	
Artificial perches	Digging and installation	Quantity
Dead wood/sticks	Bunching od dead wood/sticks	Quantity
	Demarcation of the control lots	
	Area cleaning	Area

Figure 5. *Main activities of nucleation techniques and their costs drivers.*

Table 2. *Activity costs of nucleation techniques for restoring clearing LUC 15*

	Activity	Labor DL	Labor IL	Indirect materials	Depreciation	Total
		R$	R$	R$	hours	R$
Topsoil	Demarcation of the lots	419,45	76,09	47,98	14,63	558,14
	Gathering and transport	792,29	143,73	90,62	27,63	1.054,26
	Digging and accomodation	396,14	71,86	45,31	13,81	527,13
Dead wood / sticks	Bunching of dead wood/sticks	512,55	93,00	58,64	17,88	682,17
Perches	Digging and installation	419,45	76,09	47,98	14,63	558,14
Control lots	Parcels demarcation	30,76	5,58	17,99	1,07	55.40
Mechanical Weeding	Cleaning área	1.491,36	270,54	123,95	53,56	1.939,41

Table 3. *Activity costs of nucleation techniques for restoring clearing JAZ 94.*

	Activity	Labor DL	Labor IL	Indirect materials	Depreciation	Total
		R$	R$	R$	hours	R$
Topsoil	Demarcation of the lots	139,82	25,36	15,99	4,88	186,05
	Gathering and transport	838,89	152,18	95,96	29,25	1.116,28
	Digging and accomodation	240,48	43,63	27,25	8,39	320,00
Dead wood / sticks	Bunching of dead wood/sticks	652,47	118,36	74,63	22,75	868,21
Perches	Digging and installation	466,05	84,55	53,31	16,25	620,15
Control lots	Parcels demarcation	46,41	8,45	27,26	1,63	83,94
Mechanical Weeding	Cleaning area	2.982,72	541,09	247,89	107,11	3.878,81

The cost of weeding to the clearing JAZ 94 is proportionally greater than others. This is due to double days and hours worked to cut the invasive grass, which had grown more than expected for that clearing (2–2.5 meters tall).

Note that mechanical weeding has a significant participation in the costs formation, followed by activities of topsoil, dead wood/sticks and artificial perches. As expected, control parcels have an insignificant participation compared with the others.

When nucleation techniques are used in large-scale production, the control parcels are not used because there is no coherence in leaving 102 plots exposed, when the intention is to occupy the area and protect the soil quickly. The dimension of incidence of the costs in the clearings study is observed on Table 4.

The cost analysis in this work allows noticing the variations of costs due to the implementation of the techniques in different clearings at the BOGPM. It allowed to measure the incidence of direct and indirect labor costs in the execution of the activities and to identify the environmental factors (natural conditions found in the clearing) that interfere in the costs formation.

The topsoil technique tended to be the most costly one for the implementation in the clearings studied followed by the dead wood/sticks technique and the artificial perches one. However, the topsoil technique proved to have the best result in environmental terms, with a contribution of up to 120 seedlings per square meter after 4 months of experiment evaluation (Calvi, 2008).

Through the field observations, it is suggested that the topsoil lots, instead of using the pickets to mark the parcels (now the intention is in a commercial scale), these would be laid on the ground around the plot, to protect the soil and serve as a barrier against water. Calvi (2008) collected the equivalent of 10cm depth of soil with forest leaf litter. Based on the results of Leal Filho *et al.* (2006), it is suggested racking up in the superficial layers of soil as deep as six inches deep, for the purpose of economy and the regeneration potential of soils in the Urucu Region, state of Amazonas.

The dead wood/sticks technique was the second most costly technique implemented in the clearings studied. The environmental results expected, which is the introduction of new seedlings in the areas, were not significant for the technique (Calvi, 2008). However, one great advantage of this technique is the addition of organic matter due to the decomposition of trunks as a source of carbon, energy and nutrients for the microorganisms (Bayer and Mielniczuk, 1999). Another important aspect observed in the field refers to the usefulness of dead wood/sticks not only because of their nucleation function, but also because they create a barrier to rainwater. It is suggested allocating the portions of dead wood/sticks at strategic points in the degraded area serving as intended barriers against runoff water.

It is suggested improving the artificial perches as the results were not as expected by Calvi (2008). These would be attractive to birds such as mirrors and lianas or vines entangled on the stem of the dead tree. The perches would be like "Tower of Liana" (Bechara *et al.*, 2005) initially performing the function of dried perches and then with the growth of the tangle of liana or vines, it would make excellent shelter for birds and bats.

The costs of these new ideas have no influence on the increase of nucleation techniques values. The costs would be concentrated on activities achieved through an economic analysis conducted in this study to topsoil, dead wood/sticks and artificial perches nucleation techniques.

The implementation of nucleation techniques has some advantages that are reflected in lower operation costs. One of them is the reduced infrastructure required. All activities are developed in the field at the time of the deployment of the technique. This way, the need for physical space for storage, facilities, building constructions and machinery is reduced. The cost of fixed assets, in this case, does not burden the total costs because the nucleation technique does not require a specific physical structure.

Therefore, the environmental responses to the approached nucleation technique and the identification of the resource consumer activities presented by the economic

Table 4. *Activity costs of nucleation techniques for restoring clearing JAZ 104.*

	Activity	Labor DL	Labor IL	Indirect materials	Depreciation	Total
		R$	R$	R$	hours	R$
Topsoil	Demarcation of the lots	46,61	8,45	5,33	1,63	62,02
	Gathering and transport	279,63	50,73	31,99	9,75	372,09
	Digging and accomodation	139,82	25,36	15,99	4,88	186,05
Dead wood / sticks	Bunching of dead wood/sticks	326,24	59,18	37,32	8,13	430,86
Perches	Digging and installation	233,03	42,27	26,65	11,38	313,33
Control lots	Parcels demarcation	46,61	8,45	27,26	1,63	83.94
Mechanical Weeding	Cleaning area	1.491,36	270,54	123,95	53,56	1.939,41

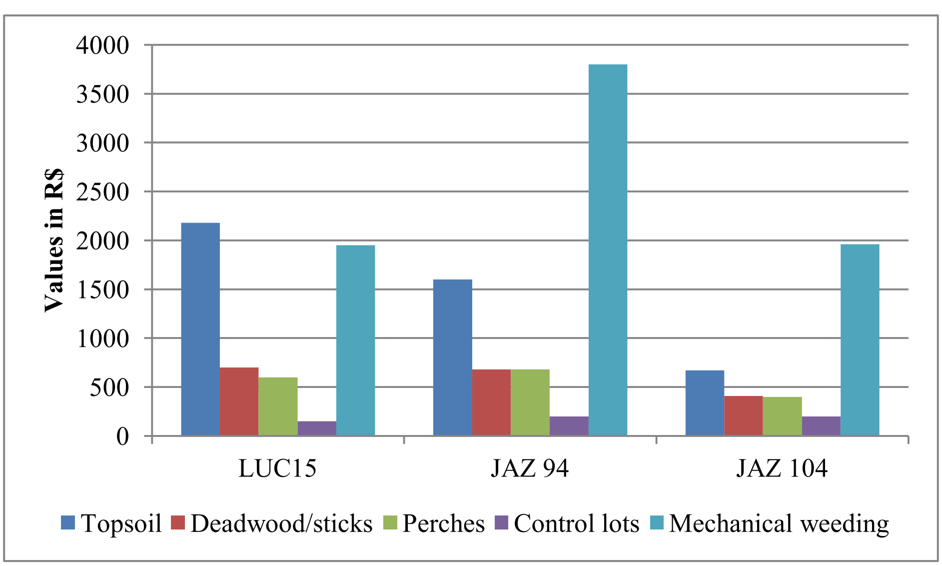

Figure 6. *Implantation costs of nucleation techniques and mechanical weeding.*

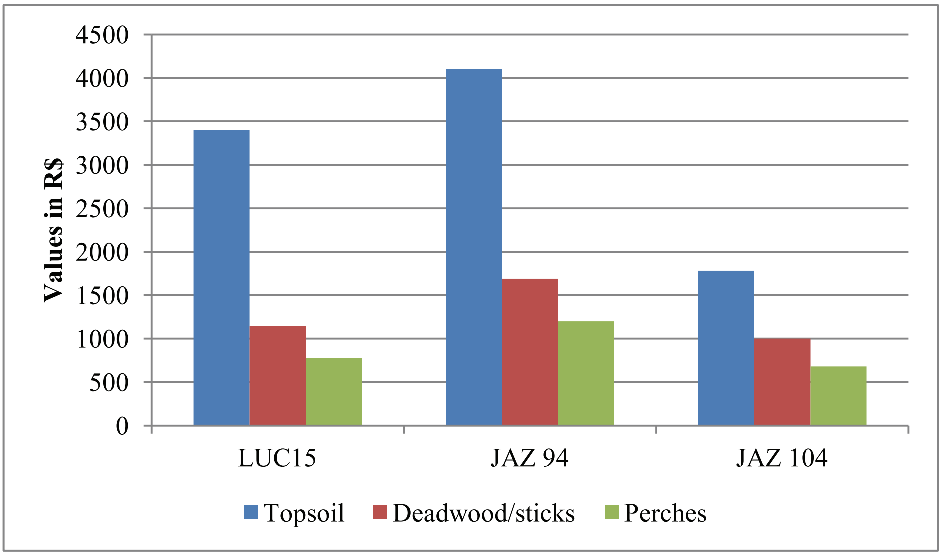

Figure 7. *Total cost of implementing the nucleation techniques.*

Table 5. *Total cost by hectare of nucleation techniques.*

Nucleation technique	LUC 15	JAZ 94	JAZ 104
Topsoil	4.734,66	6.875,19	8.881,76
Dead wood/sticks	1.577,13	2.837.46	5.044,78
Artificial perches	1.153,00	2.076.42	3.011,88
Total	**7.464,78**	**11.789,07**	**16.938,42**

analysis carried out in this study may serve as a reference for further work aimed at restoring degraded areas.

The use of nucleation techniques is not recent in the Amazon. Since 1979, the mining company Rio do Norte S/A implements in its program of rehabilitation and reforestation the replacement of the topsoil layer of 15cm. The operation cost along with the subsoiling and the planting of 92 species of forest seedlings is around US$ 2,500.00 (Toy *et al.*, 2001).

In comparison, Bechara (2006) estimated the average costs of nucleation techniques deployment in Demonstrative Units in the Brazilian "Cerrado" and in the Semi deciduous Seasonal Forest in R$ 3,652.50 per hectare (year 2006), considering six days of work for a team of five workers. To establish this cost, the cost man-hour was R$ 9.53 and included techniques and other activities of nucleation, besides the ones shown in this work.

The values found by Bechara (2006) were inferior compared to those obtained in the implantation of topsoil, dead wood/sticks and artificial perches at the BOGPM. The variation is explained by the variable cost analysis, the region of deployment and the use of available natural resources. The incidence of costs on the Direct Manpower at the BOGPM is at least three times the one used by Bechara (2006). The branches or trees trunks used for the windrowing of dead wood/sticks and artificial perches were made of Eucalyptus, different from the natural resources used at the BOGPM.

Langa (2010) provided cost data of nucleation techniques deployed in the area of Battistella Forest Company in the state of Santa Catarina, Brazil. The value obtained per hectare corresponded to R$ 1,983.44 for the topsoil, R$ 2,303.00 for the artificial perches, and R$ 500.00 for the dead wood/sticks. The material for the topsoil technique was collected as far as 50km away from the implanted area. Even this operation was cheaper when compared with areas at the BOGPM.

Langa (2010) used ringed trees of *Pinus sp* and armed bamboo like artificial perches reaching the values of implantation of the techniques at the BOGPM (R$ 1,153.00 for LUC 15, R$ 2,076.42 for JAZ 94, and R$ 3,011.88 for JAZ 104). The values obtained by the Battistella Company for the artificial perches correspond to a different reality from the one applied at the BOGPM due to the use of different natural resources. For the construction of dead wood/sticks, it is believed that the use of branches or trunks of *Pinus sp* (abundant in the area) led to cheaper operations.

CONCLUSION

The implementation of nucleation techniques occurred in three different clearings at the BOGPM contributing to cost analysis in diverse conditions, where it was possible to observe different variables acting on the composing costs. The values found in the economic analysis show that the characteristics of each clearing (as a slope of the land, available natural resources around the degraded area and the size of the grass) can influence the costs of the restored areas at the BOGPM.

Despite the fact that Pinã-Rodrigues *et al.* (1997) have highlighted the importance in using topsoil transference for reestablishment of colonizing vegetation in impacted areas due to mining impact, there is no individualized study of cost for nucleation technique applied for this type of companies.

The ABC method provided a better understanding and an approach to the nucleation techniques implanted in clearings LUC 15, JAZ 94 and JAZ 104. The cost analysis identified the causes of cost variations occurred between the clearings in study, highlighting the main interference in the formation of costs, availability of natural resources inside the forest, slope of the land around the clearing and the size of the grass in the degraded area.

Among the three clearings studied, JAZ 104 was the one that used more financial resources for the implementation of nucleation techniques per hectare, followed by JAZ 94 and LUC 15. JAZ 104 presented the lowest availability of natural resources and parts of the clearings were slopes. These geographic factors interfere in the development of the activities, increasing the number of hours spent, influencing the highest costs with Direct Labor and Indirect Labor in this clearing.

JAZ 94 also presented difficulties in the collection of branches or trees and soil with *forest litter*. The costs were higher due to the consumption of time with the Direct Labor in development activities. The costs distribution of the activity Cleaning the area contributed to an increase in the costs of nucleation techniques in the area even more.

LUC 15 presented better field conditions and larger availability of natural resources enabling the implementation of activities in less time. It used less hours of Direct Labor to complete the activities, making it less difficult in terms of costs as verified for topsoil, dead wood/sticks and artificial perches techniques.

Among the studied nucleation techniques, topsoil was the one that consumed more financial resources, followed by dead wood/sticks and artificial perches. The costs are related to the amount of parcels installed, the Direct Labor and Indirect Labor hours consumed, the time using materials and equipment, the availability of natural resources in the studied clearing and the land slope.

The implementation costs of nucleation techniques per hectare correspond to R$ 7,464.78 for LUC 15, R$ 11,789.07 for JAZ 94 and R$ 16,938.42 for JAZ 104. The costs related to the development of nucleation techniques in the methodology applied in other areas of Brazil do not apply to the Central Amazon, assumption made with the experience observed in field. The number and the size of the lots, mainly the topsoil and dead wood/sticks ones, and climate conditions of the BOGPM region are insufficient to promote rapid soil coverage.

It is suggested increasing the number of topsoil, dead wood/sticks and artificial perches parcels for the studied clearings and other areas at the BOGPM where nucleation techniques were applied. The increase of the occupied area by parcels would promote a larger soil coverage that would increase the number of propagule and would attract wildlife, and also it could act strategically in the landscape minimizing laminar erosion. Also it is suggested using, for subsequent studies, the cost analysis performed in this work as a reference for future projects of restoration of degraded areas that employ the nucleation techniques.

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