ECONOMIC VIABILITY OF CERRADO VEGETATION MANAGEMENT UNDER CONDITIONS OF RISK

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ABSTRACT: Cerrado vegetation is Brazil's second largest biome, comprising about 388 municipalities in Minas Gerais state alone and serving as an important source of natural resources. A large share of the wood charcoal produced in Minas Gerais is sourced from Cerrado vegetation. The objective of this work is to assess the economic viability of Cerrado vegetation management for wood charcoal production, under conditions of risk. The study site is a fragment of Cerrado subjected to five levels of intervention as to basal area removal. For risk analysis, the Monte Carlo method was applied, using charcoal price, interest rate and land value as input variables, and using Net Present Value as output variable over an infinite planning horizon. It was concluded that introducing risk in the economic analysis of the various Cerrado management regimes helped provide additional information to that obtained by deterministic analysis, improving understanding and ensuring safety in decision-making about the economic viability of such regimes. For all treatments, the probability of VPL being negative increases with increasing cutting cycle lengths. For all treatments, the optimal cutting cycle is ten years. Treatments where a larger volume of wood was removed proved less prone to risks of economic inviability since they secure more revenue than treatments where less wood was removed.

Key words: Monte Carlo simulation, forest economics, risk analysis, Cerrado vegetation.

VIABILIDADE ECONÔMICA DO MANEJO DO CERRADO EM CONDIÇÕES DE RISCO

RESUMO: *O Cerrado é o segundo maior bioma do Brasil. Em Minas Gerais, ele abrange cerca de 388 municípios, sendo uma importante fonte de recursos naturais. Uma grande parcela do carvão vegetal produzido no Estado é proveniente da vegetação do cerrado. Objetivou-se, com este trabalho, analisar a viabilidade econômica do manejo da vegetação do cerrado para a produção de madeira para carvão vegetal em condição de risco. A área de estudo foi um fragmento de cerrado submetido a cinco níveis de intervenção em relação a retirada de área basal. Para a análise de risco, utilizou-se o método de Monte Carlo, tendo como variáveis de entrada, o preço do carvão, a taxa de juros e o valor da terra, e, como variável de saída, o Valor Presente Líquido para horizonte infinito. Concluiu-se que a introdução do risco na análise econômica dos diversos regimes de manejo da vegetação do cerrado propiciou a obtenção de informações adicionais às obtidas pela análise determinística, o que melhorou a compreensão e aumentou a segurança para a tomada de decisão em relação à viabilidade econômica desses regimes. Para todos os tratamentos estudados, a probabilidade do VPL ser negativo aumenta com o aumento do ciclo de corte. Para todos os tratamentos, o ciclo de corte ótimo foi de dez anos. Os tratamentos em que se retirou maior volume de madeira mostraram-se menos susceptíveis a riscos de inviabilidade econômica por propiciarem a obtenção de mais renda que os tratamentos em que se retirou menos madeira.*

Palavras-chave: Simulação de Monte Carlo, Economia Florestal, análise de risco, vegetação de cerrado.

1 INTRODUCTION

The Brazilian Cerrado covers an area of roughly two million km^2, equivalent to 23% of the Brazilian territory. It is the country's second largest biome, second only to the Amazon Forest, extending from marginal areas of the Amazon Forest down to Paraná state. In other parts of South America, the Cerrado is also present in Bolivia, Paraguay and Venezuela (RATTER et al., 1997).

In Minas Gerais alone, the Cerrado covers an area of 384,366 km^2 and embraces 388 municipalities (PEREIRA et al., 1997). Minas Gerais state is the largest producer and consumer of wood charcoal for the steel industry, having consumed 21.17 million meters of charcoal in 2008 (ASSOCIAÇÃO MINEIRA DE SILVICULTURA - AMS, 2009).

The Cerrado was the first supplier of wood for charcoal production to assist the steel industry of Minas

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Gerais state. In 1980, 85.8% of the total charcoal input consumed in Brazil was sourced from native forests. This percentage decreased in the following years, reaching 24.6% in 1997 (REZENDE et al., 2002). However, the supply of charcoal sourced from nonnative forests failed to meet the increase in demand by steel plants. Thus, in 2008, 36.2% of the charcoal consumed in Minas Gerais was sourced from native forests (AMS, 2009).

Several authors have analyzed the economic viability of using wood from Cerrado vegetation to manufacture charcoal for the steel industry, including Oliveira et al. (1998, 2002) and Rezende et al. (1986). In these studies, economic analysis followed a deterministic approach based on classic methods of investment analysis that include Net Present Value (VPL) and Internal Rate of Return (TIR).

Actual reality may nevertheless be poorly captured by these economic indicators (BRUNI et al., 1998). There is no certainty that expected project estimates will match reality, since there is not enough ability to predict every factor affecting the future, whether favorably or unfavorably. Thus, acceptance of a project with a positive VPL also entails uncertainty because it is based on a cash flow which in turn relies on uncertain estimates (LAPPONI, 2007).

Globalization and the complexity of reality cause uncertainties and market risks to hinder assessment of project efficiency. According to Securato (2007), risk is the probability of events occurring that will generate loss or uncertainty.

Within this context, risk measurement and analysis techniques provide not only additional information to VPL or TIR results but also a perception of the intrinsic characteristic of a project and the impact of likely future events on the decision of accepting the project (LAPPONI, 2007).

Moore and Weatherford (2005) argue that the Monte Carlo method can be used as an alternative method for project assessment whereby risks involved are plainly expressed and easy to understand so as to help decision-making. Indicators thus go from being deterministic to becoming stochastic or probabilistic.

This work aims to assess the economic viability of Cerrado vegetation management for charcoal production, under conditions of risk.

2 MATERIAL AND METHODS

2.1 Database

The study site is a fragment of Fazenda Vitória, an estate owned by V&M Florestal and located in the municipality of Coração de Jesus, Minas Gerais state.

The above fragment falls into the 'Cerrado sensu stricto' vegetation category, having been subjected to exploration in past decades, though the intensity of intervention is unknown. The area lies in the northern part of Minas Gerais state, 490 km away from Belo Horizonte, at an a altitude of 800 m, having flat relief.

According to Köppen classification, the study region falls into the 'Aw' group: dry tropical climate, average annual precipitation of 820 mm and average annual temperature of 25°C.

In 1986, the State Forest Institute (IEF) set up an experiment in the above study site consisting of six treatments, with 50%, 70%, 80%, 90% and 100% removal of the total basal area, besides a control treatment (no intervention). The experiment covered an area of 30 hectares and treatments were distributed randomly in five blocks, to a total of 30 plots 1 ha each.

2.2 Investment analysis under condition of risk

Project investments presuppose the existence of economic, financial, technological, administrative, legal and natural risks. Risks presuppose the possibility of something going wrong within an estimated probability distribution (COELHO JUNIOR et al., 2008).

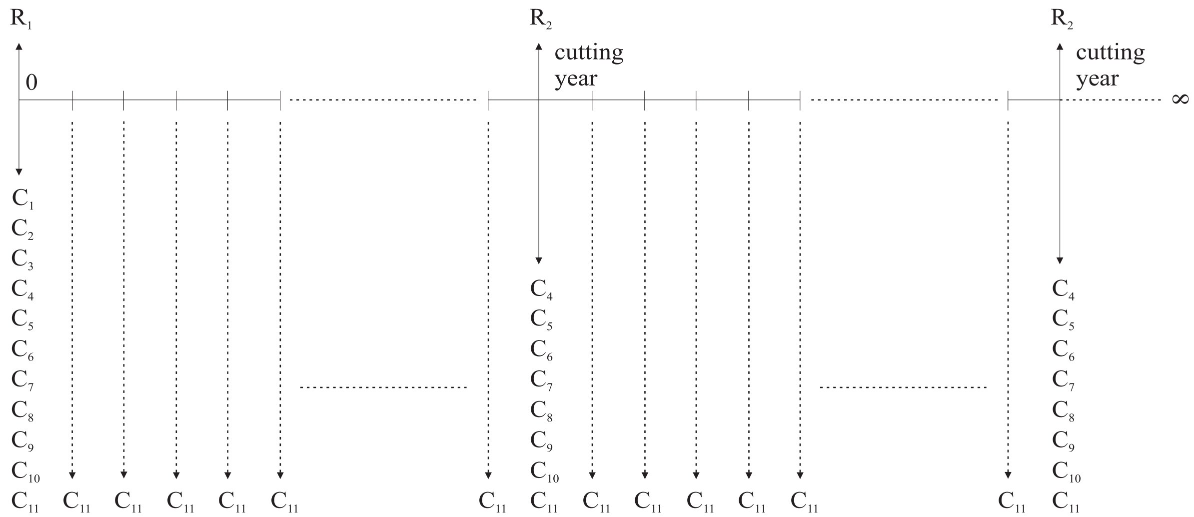
According to the above authors, due to its ease of use, the Monte Carlo method provides several estimation alternatives for the probability distribution prior to decision-making, offering advantages over other simulation theories.

The risk analysis using the Monte Carlo simulation technique is presented in four stages, as follows.

2.2.1 Model development

In order to assess investment, taking into account the relevant risks and uncertainties, the following cash flow was used, as provided in Figure 1.

Table 1 provides the volume of removed timber in m^3/ha at the moment of intervention in 1986, in inventories (1996, 1998 and 2004) and for prognoses (October 2010, December 2016, February 2023 and April 2029).



C1: Topographic survey; C2: Inventory and management plan preparation; C3: Road and firebreak construction; C4: Tree marking for harvesting; C5: Road and firebreak maintenance; C6: Felling, limbing, bucking and stacking; C7: Log hauling; C8: Transportation to charcoal kiln; C9: Carbonization; C10: Freight to plant; C11: Annual cost of land; R1: Revenue year 0; R2: Revenue cutting cycle year.
Source: Oliveira (2006).

Figure 1 – Cash flow for Cerrado vegetation management.

Figura 1 – *Fluxo de caixa para o manejo da vegetação do cerrado.*

Table 1 – Volumes of removed timber (RET) for each treatment and cutting cycle.

Tabela 1 – *Volumes de madeira removidos (RET) nos tratamentos e ciclos de corte.*

Month/Year	Treatments				
	50% RET	70% RET	80% RET	90% RET	100% RET
1986	10.81	15.13	17.29	19.45	21.61
Feb/1996	16.76	22.97	21.48	24.30	36.70
Jun/1998	18.90	24.68	26.10	29.68	44.18
Aug/2004	20.72	27.08	29.32	33.78	50.75
Oct/2010	26.18	32.91	39.52	41.99	60.92
Dec/2016	28.24	34.03	43.57	44.65	64.34
Feb/2023	30.17	35.00	47.11	47.30	67.18
Apr/2029	31.93	35.86	50.05	49.90	69.43

Source: Oliveira (2006)

Table 2 presents costs involved in charcoal production using wood from Cerrado vegetation in northern Minas Gerais.

2.2.2 Identification of risks and uncertainties

To conduct the analysis it is necessary to identify opportunities and threats influencing the relevant project variables. Independent variables considered as input variables (inputs) included value of land, charcoal price and interest rate. To measure input uncertainties, a triangular distribution was used attributing maximum, minimum and most likely values to these variables (Table 3).

2.2.3 Identification of analysis variables or output variables

The net present value method over an infinite planning horizon (VPL_∞) was used in order to define the optimal economic cutting cycle and to assess the different Cerrado management regimes, under deterministic conditions. The formula used for VPL_∞ calculation was developed by Oliveira (2006), as follows:

$$VPL_\infty = VPL + \frac{VFL}{(1+i)^n - 1} + PT$$

where:
VPL = Net present value;
VFL = Net final value;
PT = Price of land;
i = Annual interest rate;
n = Cutting cycle duration, in years.

Table 2 – Costs involved in charcoal production.

***Tabela 2** – Custos de produção do carvão vegetal.*

Items	Unit	Year of occurrence	Value (R$)
Implementation			
Topographic survey	ha	0	4.00
Inventory and management plan preparation	ha	0	15.00
Road and firebreak construction	ha	0	54.00
Harvest			
Tree marking for harvesting	ha	Cutting years	12.00
Road and firebreak maintenance	ha	Cutting years	10.63
Tree felling, limbing, bucking and stacking	m^3	Cutting years	6.60
Log hauling to roadside	m^3	Cutting years	2.20
Transportation to charcoal kiln	m^3	Cutting years	4.40
Carbonization	mdc	Cutting years	8.00
Freight to plant	mdc	Cutting years	14.50
Cost of land			
Value of land	ha	-	400.00
Cost of land – (i = 6% p.a.) - [400,00 x i]	ha	Annual	24.00

Factor (m^3/mdc) = 1.3636
mdc* = cubic meter of charcoal
Source: Oliveira (2006)

Table 3 – Price of land and charcoal and interest rate.

***Tabela 3** – Preço da terra e do carvão e taxa de juros.*

Items	Unit	Minimum value	Most likely value	Maximum value
Value of Land	R$/ha	0.00	400.00	1,000.00
Charcoal Price	R$/ha	60.67	72.80	101.92
Interest Rate	%	2	6	10

The VPL is given by the difference between the value of revenues and costs occurring in the year when treatments were implemented (1986 = year 0) and the VFL is given by the difference between the value of revenues and costs occurring in the base year defining the cutting cycle (1996 = 10-year cutting cycle = year 10; 1998 = 12-year cutting cycle = year 12; ...; 2029 = 43-year cutting cycle = year 43).

The VPL_∞ of different management regimes was considered an output variable (outputs).

2.2.4 Simulation and model analysis

For the risk analysis, @Risk software was used (PALISADE CORPORATION, 1995). According to Bentes-Gama (2003), this program enables applying the Monte Carlo method to simulate values of random and independent variables (revenue and cost) and, as a result, to obtain values of the profit variable.

After assembling the cash flow, 10,000 simulations were run for the input variable (VPL_∞), using pseudorandom numbers, in other words, a series of values was generated for this variable so as to obtain its simple and cumulative frequency distribution.

3 RESULTS AND DISCUSSION

Table 4 provides results of economic analysis, as conducted by Oliveira (2006), without taking risks into account (deterministic analysis). Higher VPL_∞ values were obtained when shorter cutting cycles were used, regardless of treatment. For a given cutting cycle, the higher the level of basal area intervention, the higher profitability is, as expressed by VPL_∞.

Table 5 provides results of simulations run in order to obtain VPL_∞ occurrence probabilities for each treatment and cutting cycle being studied, while Figure 2 provides simple and cumulative frequency distributions of this indicator for the 10-year cutting cycle. The treatment in which 50% of basal area is removal, in the 10-year cutting cycle, 5% of VPL_∞ values are above R$1,134.29. In the 43-year cutting cycle, 5% of VPL_∞ values are above R$ 244.36. The same trend is observed in the remaining situations.

Table 4 – VPL_∞ for each treatment and cutting cycle.

Tabela 4 *– VPL_∞ para os tratamentos e ciclos de corte.*

Cutting Cycle	Treatments / VPL_∞ (R$/ha)				
	50%	70%	80%	90%	100%
10	233.82	522.15	528.69	664.32	1,086.89
12	180.38	417.97	502.37	637.32	1,027.81
18	12.91	196.48	276.26	384.40	652.35
24	-43.59	111.02	213.54	283.90	482.13
30	-103.31	27.93	126.73	183.29	332.79
37	-148.94	-31.63	57.10	108.86	221.69
43	-174.35	-63.74	17.30	68.15	160.43

Source: Oliveira (2006)

Table 5 – VPL_∞ probabilities (R$/ha) for each treatment and cutting cycle.

Tabela 5 *– Probabilidades do VPL_∞ (R$/ha) para os tratamentos e ciclos de corte.*

Probabilities	Cutting cycle (years)						
	10	12	18	24	30	37	43
	50% Treatment						
5%	-205.79	-249.79	-389.54	-441.47	-493.37	-535.98	-560.61
15%	-32.18	-83.32	-237.69	-291.54	-348.61	-392.43	-419.98
25%	87.78	34.36	-131.13	-189.92	-252.05	-301.51	-327.50
35%	184.23	127.86	-47.13	-107.74	-171.96	-221.61	-250.24
45%	273.55	213.65	26.46	-34.92	-103.32	-156.11	-185.59
55%	364.10	300.06	100.68	34.57	-37.79	-92.22	-123.76
65%	465.25	396.37	180.14	108.37	33.19	-26.56	-59.59
75%	589.92	514.89	272.29	195.99	113.34	47.36	10.47
85%	774.43	683.20	400.57	315.00	216.49	141.32	100.26
95%	1134.29	1020.74	642.65	533.73	400.20	298.39	244.36
	70% Treatment						
5%	33.61	-50.12	-223.80	-298.88	-367.10	-419.56	-449.86
15%	228.04	136.09	-62.36	-140.89	-213.37	-268.19	-299.23
25%	363.12	265.02	56.73	-27.89	-111.60	-173.31	-206.67
35%	481.92	375.10	149.13	60.12	-28.06	-91.20	-125.93
45%	593.34	476.89	232.37	138.93	47.30	-22.17	-59.33
55%	711.15	585.88	318.94	217.37	119.03	46.50	7.32
65%	841.27	701.69	412.12	304.52	195.84	118.37	75.24
75%	1002.61	849.62	526.60	406.25	285.94	199.86	154.35
85%	1249.48	1072.62	686.51	547.47	409.05	304.86	250.80
95%	1753.92	1528.71	1009.33	831.08	635.12	489.38	415.70

Continua...

To be continued...

Tabela 2 – Continua…

***Table 2** – Continued…*

Probabilities	Cutting cycle (years)						
	10	12	18	24	30	37	43
	80% Treatment						
5%	45.62	22.85	-155.50	-207.93	-278.22	-335.15	-371.52
15%	240.76	216.61	14.34	-43.71	-122.34	-181.98	-217.79
25%	374.95	347.53	137.44	74.74	-8.17	-79.19	-117.91
35%	493.10	464.25	232.77	168.12	79.48	6.35	-35.05
45%	602.32	573.34	323.00	253.52	159.15	82.04	36.47
55%	717.97	686.72	413.23	340.41	236.33	155.63	107.62
65%	845.48	811.65	513.69	436.30	325.44	233.94	184.82
75%	1003.14	967.10	636.90	554.12	428.23	326.69	269.16
85%	1236.29	1200.99	814.35	722.72	570.43	452.61	383.88
95%	1720.72	1687.07	1163.47	1061.37	857.71	687.71	589.55
	90% Treatment						
5%	154.90	128.64	-68.21	-147.06	-224.88	-286.45	-321.63
15%	358.69	332.71	114.07	22.88	-67.92	-129.76	-166.81
25%	503.51	475.87	241.61	146.95	49.86	-22.99	-64.19
35%	631.94	601.99	346.22	242.35	141.47	62.91	20.34
45%	753.84	722.50	443.56	333.64	222.27	140.89	93.54
55%	880.36	848.54	542.62	423.42	304.45	215.84	166.61
65%	1024.60	988.90	654.65	525.90	395.96	296.94	242.87
75%	1197.46	1163.46	790.65	650.03	501.24	391.27	332.02
85%	1462.32	1429.64	996.12	832.76	651.12	522.14	452.38
95%	2008.82	1975.00	1400.79	1194.06	949.47	765.73	663.37
	100% Treatment						
5%	449.43	399.06	130.73	4.06	-109.74	-191.81	-238.81
15%	705.99	650.67	339.36	196.48	68.68	-28.32	-79.98
25%	891.20	830.72	484.33	326.29	193.74	91.86	33.70
35%	1054.46	991.69	613.91	441.90	294.44	183.27	121.40
45%	1219.32	1152.03	736.95	549.80	390.29	268.44	202.28
55%	1390.99	1319.65	866.80	666.50	485.79	353.32	280.92
65%	1593.27	1519.13	1015.62	791.45	594.55	450.38	368.26
75%	1845.94	1768.77	1203.63	950.98	729.74	562.78	469.71
85%	2216.04	2131.94	1484.11	1200.22	931.64	727.63	610.78
95%	3022.61	2931.19	2081.61	1721.09	1360.75	1061.58	892.27

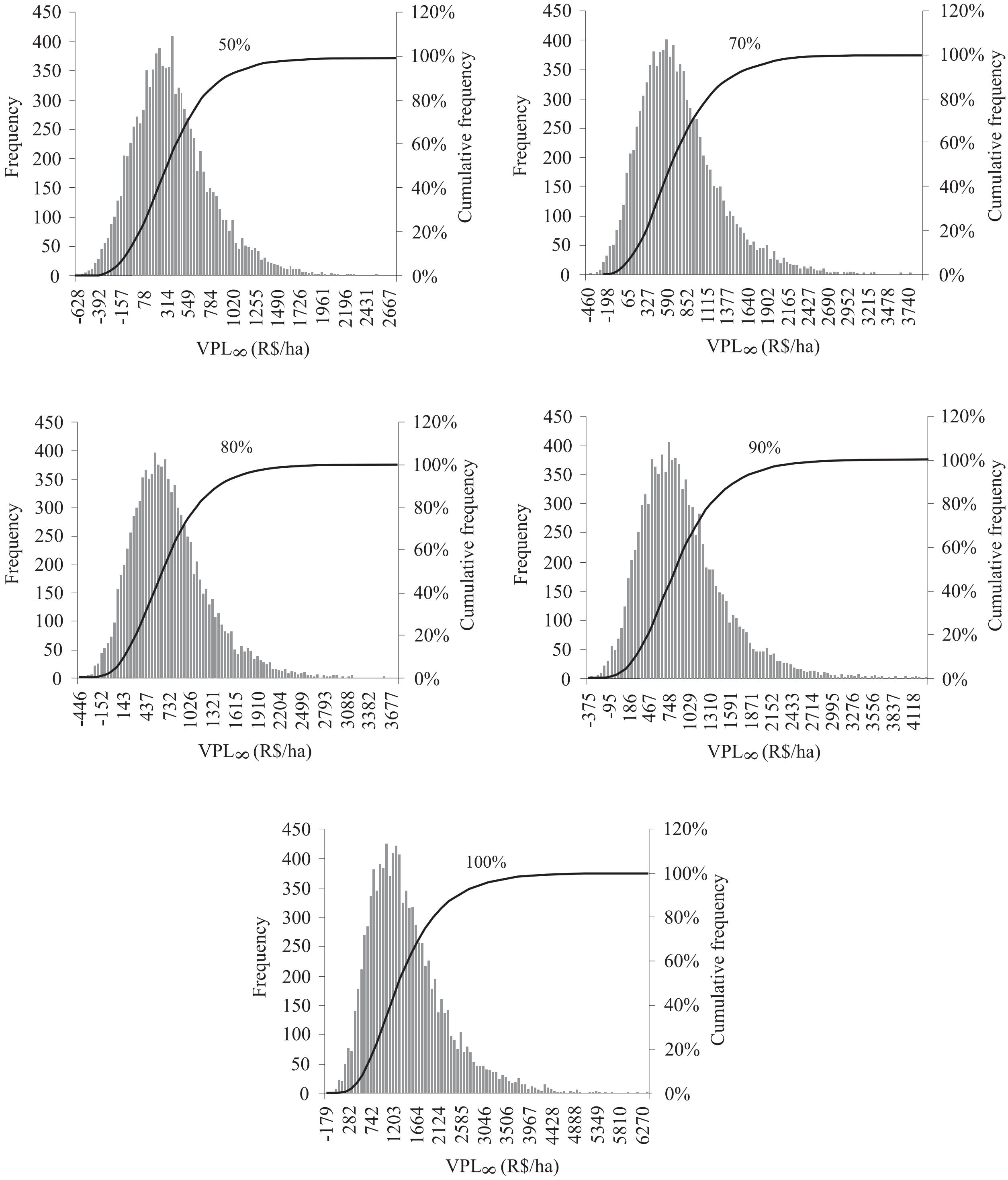


Figure 2 – VPL_∞ value histograms for each treatment, in the 10-year cutting cycle.

Figura 2 – *Histogramas dos valores de* VPL_∞ *para os tratamentos, no ciclo de corte de 10 anos.*

Table 6 provides probabilities of VPL_∞ being below zero, indicating economic inviability of the relevant treatment. The 50% treatment shows higher occurrence probabilities of a negative VPL_∞. The probability ranges from 17.80% in the 10-year cycle to 73.49% in the 43-year cycle, indicating that Cerrado management following this prescription entails high risk. The clear cutting treatment (100% of vegetation removed), on the other hand, entails low risk even in a 24-year cutting cycle (4.83%).

The above check can also be done through analysis of numerical data in Table 7. In the 50% treatment, the expected VPL_∞ value (or mean value) is R$369.46, and its standard deviation is R$ 412.87. Thus, with a little less than one standard deviation a zero VPL_∞ is attained. As for the 100% treatment, 1.8 standard deviations are necessary for a negative VPL_∞. Additionally, the coefficient of variation of the 50% treatment (111.74%) shows higher risk than the coefficient of the 100% treatment (55.74%).

The mean VPL_∞, or expected VPL_∞ value, whose calculation is risk based (Table 7) is invariably higher than the VPL_∞ whose calculation is based on deterministic analysis (Table 4). Take for instance the 80% treatment, with risks being computed, the mean VPL_∞ is R$735.91. In the deterministic analysis, the VPL_∞ is R$ 528.69.

The probability of VPL_∞ being below values calculated by Oliveira (2006) was also assessed without computing risks. Probabilities in Table 8 indicate that in the 100% treatment, 10-year cutting cycle, the VPL_∞ calculated with risks being computed has a 36.77% chance of being lower than the VPL_∞ shown in Table 4 (R$1,086.89), where risks were not computed.

Table 6 – Probabilities of VPL_∞ being negative for each treatment and cutting cycle.

Tabela 6 – *Probabilidades de o VPL_∞ ser negativo para os tratamentos e ciclos de corte.*

Cutting Cycle	Treatments				
	50%	70%	80%	90%	100%
10	17.80	3.92	3.51	1.68	0.09
12	21.80	7.22	4.21	2.03	0.17
18	41.32	20.00	13.88	7.93	2.00
24	50.21	27.99	18.66	13.18	4.83
30	60.41	39.01	25.80	20.41	10.34
37	68.49	48.24	34.14	27.25	17.06
43	73.49	53.99	39.99	32.24	21.85

Table 7 – A descriptive statistic of VPL_∞ for each treatment, in the 10-year cutting cycle.

Tabela 7 – *Estatística descritiva do VPL_∞ para os tratamentos, no ciclo de corte de 10 anos.*

Statistics	Treatments /VPL_∞ (R$/ha)				
	50%	70%	80%	90%	100%
Minimum value	-627.53	-460.24	-446.09	-375.34	-179.15
Maximum value	2,734.04	3,915.06	3,760.95	4,305.28	6,402.05
Mean (expected value)	369.46	734.95	735.91	907.38	1,457.84
Standard deviation	412.87	536.26	518.23	576.68	812.59
Variance	170,459.60	287,579.40	268,567.00	332,564.00	660,309.60
Coefficient of variation (%)	111.74	72.97	70.42	63.56	55.74

Table 8 – Probability of the VPL_∞ of risk analysis being lower than the VPL_∞ of deterministic analysis.

Tabela 8 – *Probabilidade de o VPL_∞ da análise de risco situar-se abaixo do VPL_∞ da análise determinística.*

Cutting Cycles	Treatments				
	50%	70%	80%	90%	100%
10	40.47	38.65	38.16	37.58	36.77
12	41.18	39.18	38.51	37.82	37.13
18	43.08	40.76	39.92	39.00	38.05
24	43.90	41.55	40.45	39.66	38.67
30	45.00	42.43	41.10	40.41	39.16
37	46.17	43.52	41.89	41.19	39.55
43	47.07	44.34	42.31	41.68	40.13

4 CONCLUSIONS

The introduction of risk in the economic analysis of several Cerrado management regimes helped obtain additional information to that obtained by deterministic analysis, improving understanding and ensuring safety for decision-making about the economic viability of such regimes.

For all treatments being studied, the probability of VPL being negative increases with increasing cutting cycle lengths.

Treatments with larger volumes of wood being removed proved less prone to risks of economic inviability than treatments with less wood being removed, for the reason that they secure more revenue.

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