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Economic Feasibility of an Eucalyptus Agroforestry System in Brazil

Álvaro Nogueira de Souza, Humberto Ângelo, Maísa Santos Joaquim, Sandro Nogueira de Souza and John Edward Belknap
Universidade de Brasília
Brasil

1. Introduction

Agroforestry systems consist of cultivation practices, which combine arboreal species with either annual or perennial crops in a manner which seeks the optimal use of land together with the maximum return per unit area. Macelo (1992) considered that agroforestry systems could be used for the recovery of degraded soils and for fragmented pastures under agropastoral activities, in both cases the factors of production are insufficient for the natural recovery of the land's productive potential.

Hoeflich (1995) believed that these agroforestry systems are forms of land use, which offers a sustainable return in which management activities combine with the cultivation patterns of the local population, thus creating greater diversity and sustainability. For Franco (2000), these agroforestry systems help to control soil erosion and replace nutrients lost to the soil by intensive use. Such overuse, often not viable from an economic point of view, given the price of fertilizer, can be substituted by agroforestry, with the decomposition of plant material, which remains in the soil.

a. The use of legumes in agroforestry systems

A principal reason for the use of legumes in an agroforestry system is for the benefits offered by green fertilizer. Atmospheric nitrogen is captured by bacteria present in the legume roots and incorporated in the soil composition (Ferreira, 1994). According to Malavolta (1981), the guandu bean is a legume capable of fixing 50 to 150 kg of nitrogen per ha per year. This same observation was made by Mielnickzuk (1988). Evaluating various cultivation systems, Mielnickzuk (1988) observed that when the systems included legumes, the quantities of nitrogen in the soil increased significantly with emphasis on guandu bean, which after three years presented an increase in total nitrogen of 900 kg per ha.

b. Presence of animals in agroforestry systems

The silvopastoral system is an association of species of trees and grazing, with or without the presence of crops. In this type of system, one can encounter commercial timber stands with the presence of cattle or pasture as a complementary factor to subsistence agriculture.

Tree varieties can include recent reforestation pastures, lumber grade trees, fruit trees, forage trees, windbreaks, pastureland, shade trees, and trees to provide conservation and soil improvement in pastures (Santos, 1990).

The problem of soil compaction in silvopastoral systems cannot be neglected. According to Silva (1999), the physical conditions of the soil are affected principally in the upper surface layers by animal trampling.

1.1 The use of eucalyptus in agroforestry systems

When one considers agroforestry cultivation with eucalyptus, the protection of the soil is especially important because, the wet period is when the soil is exposed, as a result of the soil preparation for planting annual crops.

The *Eucalyptus grandis* has been one of the most utilized varieties in agroforestry systems. The most common combination is with legumes, cited in the works of Passos (1990), Passos et al. (1993) and Ferreira Neto (1994). The association of reforestation with crops and pasture reduces substantially the costs of planting and maintaining of stands of eucalyptus, it augments the productivity of the site besides minimizing erosion and other negative environmental impacts (Dube et al., 2002).

Silva (1999) evaluated the possibility of combinations of *Eucalyptus grandis* with the grasses *Braquiária decumbens* and *Melinis minutiflora*, in steep land. Four spacings were tested for Eucalyptus: 3x2m, 4x2m, 5x2m, and 6x2m. The control was Eucalyptus alone with a spacing of 3x2m. The results showed a smaller diameter tree, with a reduction of the useful area per plant. The best treatment was at 3x2m combined with *Braquiaria*. This test plot reached a volume 55.2% greater than the control. With respect to lumber quality and quantity of grass biomass, the best spacing was 6x2m, which produced less volume, however, the timber had commercial use as lumber. The *Braquiária* produced 2.45 times with this spacing in relation to the 3x2m spacing. *Milinis minutiflora* disappeared after two years, demonstrating its lack of suitability for the conditions of this study.

Since the start of agricultural and pastoral activities on Brazilian savanna soils, which presented a principal barrier to cultivation in the high acidity level, varied cultivation practices have been tried. Among the crops are rice, soy, corn, coffee, sugar cane, eucalyptus and pastoral activities, in which cattle were raised exclusively.

In the beginning of the decade of 1990, agro-silvopastroral systems were started in commercial scale in regions of savanna soils in the South East Region of the State of Minas Gerais, Brazil. In the studied case, the system developed according to these stages: In December 1999, the project began with the planting of rice and eucalyptus (Figure 1).

The Eucalyptus seedlings were clones adapted to the North East Region of Minas Gerais. The area was prepared by one deep tilling and two grader levelings, as well as the application of calcium zincal MMA 85% with PRNT, at a rate of 2.5 tons per hectare. The eucalyptus seedlings were planted in lines east/west, in order to permit greater solar exposure to the combined crops. The space between eucalyptus rows was planted with rice, (*Orizza sativa*, cultivar Guarany) with a spacing of 0.45 meters.

Soy (*Glycine max (L), Merril*, cultivar Conquista), at a spacing of 0.45m was the crop introduced at the end of the first year. At this time, the eucalyptus had one year of growth (Figure 2).

Planting of pastures began at the end of the second year / start of the third year, with planting of *Brachiaria brizantha* (Figure 3).

Fig. 1. Cultivation of rice (*Orizza sativa*, cultivar Guarany) with eucalyptus (natural hybrid of *Eucalyptus urophylla x Eucalyptus camaldulensis*) in a spacing of 10 x 4m in the first year.

Fig. 2. Soy crop (*Glycine max (L), Merril*, cultivar Conquista) in place of rice in year 2 of an associated system of eucalyptus (natural hybrid of *Eucalyptus urophylla x Eucalyptus camaldulensis*) before the first pruning.

Fig. 3. Formation of pasture (*Brachiaria brizantha*) in year 3 of agroforestry association with eucalyptus (natural hybrid of *Eucalyptus urophylla x Eucalyptus camaldulensis*) after the second pruning of trees.

In the fourth year of eucalyptus growth, nitrogen fertilizer was applied (300 kg/ha) to the pasture grass. At this time, yearling steers were placed in the pasture to fatten and the cattle used the eucalyptus for shade and rest areas (Figure 4).

The forest eucalyptus stands had three prunings. At 2.5 years after planting, the first pruning was done with loppers and saw cutting of all the branches to a height of 2 meters. At 3.5 years of growth, pruning with saws was done to cut all branches to the height of 4 meters. At 4.5 years, pruning was done to a height of 6 meters, leaving a tree trunk free of all knots (Figure 5).

The trees were sold standing in the market for pole logs, used as utility posts in rural electrification. The demand for this product was stimulated by a Federal Government program, called "Light for All" which sought to bring electricity to all those living in rural communities.

Prior to this use for utility poles, the wood from agroforestry plantings was used to make pallets, or, for unusable wood, converted to charcoal for use in steel mills. These uses did not have a high market value, but were profitable for the landowning companies. This study is reported in Souza et al. (2007).

Given the new alternative use of wood in agroforest systems, a new economic analysis was completed and the results are compared with those found in Souza et al.

Fig. 4. Yearling cattle in the shade of eucalyptus trees at the start of year 4 of tree growth.

Fig. 5. Trees in the system with six meters of knot free trunk, allowing for a higher use of lumber.

Fig. 6. Logs stacked on ground already cut to dimension for utility poles.

2. Characteristics of the area of cultivation in the agroforestry study

The area of study belongs to a large forestry enterprise, active in the savannas of the State of Minas Gerais, located in the Municipality of Vazante, in the Northeast Region of the State. The latitude is 17º 36′ 09″ S and the longitude is 46º 42′ 02″ West of Greenwich. It is at an altitude of 550 meters, with a climate Aw, that is, tropical humid savanna, dry winters, rainy summers, according to the classification of Köppen (Antunes, 1986). The average temperature is 24º C, with an average precipitation of 1,450 mm.

The items of study included seedlings of clones of a natural hybrid of *Eucalyptus urophylla x Eucalyptus camaldulensis*, planted in association with rice, soy, and pasturage with a spacing of 10 x 4m (Figures 1-6). The initial objective was to produce wood for a lumber mill and for energy and after a few years, the forestry component could provide timber for sale as utility poles for the rural electrification program.

3. Structure of costs

Table 1 shows the costs of diverse activities related to the agroforestry system. For eucalyptus, the costs considered were planting, annual maintenance, and timber sold standing. In the case of soy and rice, the costs summed all of the expenses from panting until harvest, since these activities have a production cycle of less than one year. For cattle ranching, the costs were itemized according to the time period of occurrence, since these are spread over several years. Cattle density was 1.5 steer per hectare, and the yearlings are acquired at 8.25@ (1 @ is equal to 15kg). Each animal should gain 5.5@ per year, which results in a weight gain of 8.25@ per hectare per year. The cost of land was calculated as the interest on the land value.

Itemized costs	Year	Value[1]
- Creation and installation of plan (R$/ha)	0	1,956.78
- Rice cultivation (R$/ha)	0	690.40
- Eucalyptus maintenance (R$/ha)	1	299.24
- Soy cultivation (R$/ha)	1	856.91
- Eucalyptus maintenance (R$/ha)	2	263.81
- Pasture seeding (R$/ha)	2	323.42
- Eucalyptus maintenance (R$/ha)	3	237.08
- Cattle infra-structure (R$/ha)	3	171.31
- Eucalyptus maintenance (R$/ha)	4 a n-1	144.17
- Eucalyptus maintenance (R$/ha)	n[2]	188.31
- Cattle inputs (R$/ha)	3 a n	64.03
- Cattlemen (R$/ha)	3 a n	17.69
- Depreciation of goods related to cattle raising (R$/ha)[1]	3 a n	2.49
- Acquisition of yearling cattle for fattening (R$/ha)	3 a n	519.75
- Administration (R$/ha)	1 a n	99.24
- Land (R$/ha)	1 a n	90.00
- Harvest (R$/m^3)	n	11.54

[1] The goods related to cattle ranching are: housing for ranch hands, barns and sheds, corral, electric fence, water and salt supply, riding tack, and service horses. The value of depreciation of those goods related to other activities has been added to their costs.
[2] n is the age of eucalyptus, to be defined based on economic criteria.

Table 1. Costs of the diverse activities of the agroforestry system.

4. Structure of income

Table 2 shows the prices, quantities produced, and income received from the sale of agricultural products and fattened cattle. In the case of forestry products, the wood is sold standing. Only forestry price is reported since the quantity produced and income vary with the age of felling to be determined by economic analysis.

Itemization	Year	Unit	Price (R$un)	Quantity/ha	Income (R$/ha)
- Rice	0	Sc	26.00	20.16	524.16
- Soy	1	Sc	29.00	21.60	626.40
- Fatten Steer	3 a n	@	57.00	16.50	940.50
Timber standing	n	m^3	190.00		

n: rotation of trees defined by economic analysis.

Table 2. Prices, quantities and income from products of the Agroforestry System.

5. Determination of the economic cutting of eucalyptus

The economic rotation of eucalyptus plantings was determined with respect to profit maximization according to the methods of economic analysis adopted in this study.

An estimate of the volume of wood in logs was realized by a system of production forecasting whose equations are available in Souza (2005). Table 3 presents the volumes forecast at various ages.

Age in years	Volume based on forecasts in m^3/ha
5	100
6	120
7	140
8	160
9	180
10	195
11	203
12	208
13	212
14	215

Table 3. Volume of timber logs for poles of diverse ages from forestry logging.

The economic analysis used the methods of Net Present Value (NPV), Internal Rate of Return (IRR) and Equivalent Periodic Benefit (BPE), taking the alternative interest rate in the market of 10% per year. This is the rate of return required by the investors of this company for their investments, however, one expects a return above 10% per year, so that the system could be seen as a more profitable investment. According to Rezende & Oliveira (2008), the NPV, IRR and BPE can be calculated with the following formulae.

$$NPV = \sum_{j=0}^{n} R_j (1+i)^{-j} - \sum_{j=0}^{n} C_j (1+i)^{-j} \quad (1)$$

$$0 = \sum_{j=0}^{n} R_j (1+IRR)^{-j} - \sum_{j=0}^{n} C_j (1+IRR)^{-j} \quad (2)$$

$$BPE = \frac{NPV\left[(1+i)^{t} - 1\right](1+i)^{nt}}{\left[(1+i)^{nt} - 1\right]} \quad (3)$$

where;

R_j = receipts at end of year j;
C_j = costs at end of year j;
n = age of eucalyptus cutting corresponding to the end of the cycle in the system;
i = alternative market rate of interest;
t = number of periods of calculation;

6. Market options for timber from the agroforestry system

The original proposal

The market conditions changed after the implantation of this agroforestry system in 1999. Originally, wood from the forestry plantation would be sold to sawmills and for firewood. The results of the original proposal are stated in Table 4, in which one can observe the analytic conditions for the most productive segment.

	Sale of logs		Sale of milled lumber (product 1 and charcoal)		Sale of milled lumber (product 2 and charcoal)	
	NPV (R$/ha)	BPE (R$/ha)	NPV (R$/ha)	BPE (R$/ha)	NPV (R$/ha)	BPE (R$/ha)
5	717.49	189.27	1.246,72	328.88	1,322.01	348.74
6	1,502.83	345.06	2.139,15	491.16	2,229.67	511.95
7	1,270.91	261.05	1.874,90	385.12	1,960.82	402.76
8	1,020.59	191.30	1.589,77	297.99	1,670.75	313.17
9	747.12	129.73	1.278,38	221.98	1,353.95	235.10
10	478.63	77.89	972,68	158.30	1,042.97	169.74
11	229.95	35.40	689,55	106.16	754.93	116.23
12	-1.13	-0.17	426,46	62.59	487.28	71.52

Source: Souza et al.,2007.

Table 4. NPV and BPE based on the sale of timber logs, milled lumber and charcoal, from diverse years of cutting.

The results indicate an optimal age for cutting at six years, with a maximum annual profit of R$511.95, derived from the sale of half the volume of timber for the production of charcoal and the other half from the production of milled lumber for a product of greater total value. However profitable, the system does not become more interesting than other eucalyptus plantings purely for the production of charcoal.

7. The actual market situation

The new market possibilities allowed the company to seek alternatives for the principal product of the system, timber. The timber of the agroforestry system do not attain sufficient diimensions for the use as poles for rural electrification until seven years of age. Thus, beginning with the eigth year, 30% of the timber can be used for poles and the remaining 70% sold as firewood.

At nine years, 60% of timber was sold for poles and 40% for firewood; in the 10^{th} year 90% was sold for poles and 10% for firewood, in years 11 and 12 all the timber was sold for poles.

Table 5 shows the values of cash flow with the net value occuring between yerars 6 and 12.

The values presented in Table 5 represent the cash flow from the installation of the agroforestry system, beginning with a value of –R$ 2,181.08/ha until the final value when the income from the sale of timber is calculated. One notes that from the third year, the cash flow sign changes from negative (-R$ 776.47/ha) to positive (R$ 324.66/ha). The sale of soy and rice merely reduce the costs in the initial years; note that the cash flow becomes positive beginning with the sale of fattened cattle.

Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
-2,181.08	-2,181.08	-2,181.08	-2,181.08	-2,181.08	-2,181.08	-2,181.08
-408.59	-408.59	-408.59	-408.59	-408.59	-408.59	-408.59
-776.47	-776.47	-776.47	-776.47	-776.47	-776.47	-776.47
324.66	324.66	324.66	324.66	324.66	324.66	324.66
716.94	716.94	716.94	716.94	716.94	716.94	716.94
716.94	716.94	716.94	716.94	716.94	716.94	716.94
6,664.74	716.94	716.94	716.94	716.94	716.94	716.94
	6,934.74	716.94	716.94	716.94	716.94	716.94
		10,480.74	716.94	716.94	716.94	716.94
			14,145.54	716.94	716.94	716.94
				17,937.24	716.94	716.94
					19,528.74	716.94
						19,972.74

Table 5. Cash flow considering income and costs between years 6 and 12 after implantation of the Agroforestry System.

An analysis of investment viability used in this cash flow within the methods of VPL, BPE, and TIR, in order to determine the age of timber cutting which mazimized profits is shown in Table 6.

Year	NPV (R$/ha)	BPE (R$/ha.yr)	IRR (%)
6	1,746.59	401.03	20
7	1,947.83	400.09	20
8	3,646.46	683.50	24
9	5,090.67	883.94	25
10	6,311.21	1,027.12	26
11	6,516.74	1,003.33	25
12	6,287.25	922.73	24

Table 6. Values of NPV, BPE and IRR between the years 6 and 12 in the Agroforestry System.

Analyzing individually the columns of data in Figure 6, it seems that the major Net Present Value (NPV) occurs at 11 years with a value of R$6,516.74 / ha. The values of NPV increase according to the forecast increase in tree volume in every age. When this volume begins to increase at a diminishing rate, the NPV diminishes the rate of increase in value, reaching a maximum at 11 years and decreasing in year 12 to a value of R$6,287.25 / ha. Thus, based solely on the NPV, the age for the final cutting of the system to maximize profit is at 11 years.

When one looks at the Equivalente Periodic Benefit (BPE) column, the same dynamic is present; an increase in value until a point of maximum value followed by a soft decline. From the point of investment analysis with the use of BPE, the optimal moment for timber felling and the end of the cycle of the agroforestry system is at 10 years of growth. This represents a net annual profit of R$1,027.12 /ha.

8. Conclusion

In decision making between projects which have different time horizons, the Equivalent Periodic Benefits (BPE) method has priority over the Net Present Value (NPV). Thus, considering that each different age represents an alternative project with different planning horizons, the alternative with a greater BPE must be chosen. In this case, the project with cutting at 10 years is given more economic viability with respect to an annual return on capital invested of 26% (Internal Rate of Return, IRR), followed by the project with cutting at 11 years.

Comparing the results of the original proposl and the actual proposal, there is an increase in annual net profit for a hectare of the agroforestry system from R$511.95 up to R$1,027.12. In addition, actual market conditions allowed a useful life of 10 years to the project as opposed to the 6 years in the earlier circumstances where the wood was destined for the construction of pallets and charcoal.

Agroforestry systems have gained support among development agencies in agricultural activities and with institutions of learning and research. As a result, many rural producers in the savanna regions of Brazil dedicate part of their land to the activity which offers the better use of land as a factor of production.

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