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Contributions of trees dispersed in pastures to livestock farms in Costa Rica

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Abstract

Livestock production systems and the tree component within them were characterised in La Fortuna, San Carlos, Costa Rica. Three types of production systems were observed: mixed (dairy and agriculture), dairy, and dual purpose (milk and meat). Milk productivity (kg ha^{-1}) was highest for dairy farms. The area of pasture with trees was greater in dual purpose systems (74% of total area), predominantly timber trees. The timber tree species laurel (*Cordia alliodora*) was predominant in the pastures, although its density was low (11 trees ha^{-1}). In specialised milk systems, a significantly high density of shade trees was found compared to the other systems, protecting exotic animal breeds from direct sun. No significant differences were observed between the systems in live fence tree species and the fence lengths covered per ha of pasture. The dual purpose system presented the greatest abundance of laurel with small diameters, assuring a sustainable natural regeneration of this species, and the greatest merchantable volume of laurel (2.21 m^3 ha^{-1}). The greater abundance of laurel in the dual purpose system may be related to the fact that these livestock farmers try to reduce risk by diversifying farm production. The highest net present value (US$ 256.18 ha^{-1}) was found in the dual purpose systems. The average income from milk production in all three systems contributed the most to the total gross income (49.8%), while the average income from wood only made a small contribution (1.02%). In the future the tree component could play a more important role in the cattle production systems of the region.

Key words: *Cordia alliodora*, cattle farms, financial viability, La Fortuna, San Carlos, shade trees, timber trees

1. Introduction

Trees dispersed or isolated in pastures are considered a type of silvopastoral system, when the grazing systems in which trees are present play an interactive role in animal production (for example, by providing shade to animals, promoting pasture growth, and providing tree fodder or other tree products) (Pezo and Ibrahim, 1996; Pezo et al., 1999).

In Costa Rica, dispersed trees are found in more than 90% of cattle farms (Leeuwen and Hofstede, 1995; Ibrahim et al., 1998) and they may be arranged as single trees that are generally widely spaced and/ or as group of clustered trees referred to as tree units (Guevara et al., 1998).

In northern Costa Rica cattle farming is one of the main activities. The traditional cattle systems in Costa Rica are confronted with the serious problems of reduction in the price for their products and also with the degradation of the environment (Pomareda et al., 1997). On the other hand, forest products have shown less price variability in recent years. In this context, timber trees could be an important alternative for restoring degraded areas and for diversifying cattle farms in regions where wood production has great importance due to its commercial value (Howard, 1995; Marlats et al., 1995).

Some studies have reported the beneficial effects of isolated trees in pastures for the conservation of biodiversity (Guevara et al., 1998; Harvey and Haber, 1999). Yet, there have been few systematic surveys on isolated trees in pastures, to study such matters as density and arrangement of these trees in paddock landscapes, the variation of the tree component according to different animal production systems and financial analysis of silvopastoral systems. This information is important in understanding the role these trees play in the financial viability of cattle farms and would enable the possibility of recommendations for reliable alternatives for improving the use of pasture trees according to their role in the different cattle farming systems.

In the present study the role of dispersed pasture trees in enhancing the income of cattle farming systems was examined. In addition, the volume and growth dynamics of the two main tree species dispersed in pastures of the region were analysed to understand their future financial contribution to the different cattle systems. This information provides a basis for assessing the importance of trees for the sustainability of cattle farming systems and their potential for producing future profits for the farmers.

2. Materials and methods

The study was conducted in La Fortuna, San Carlos, in the northern humid tropical region of Costa Rica (10° 28'N Lat.; 84° 39'W Long.; 250 m a.s.l.; 3000-3500 mm mean annual precipitation; 26° C mean annual temperature; 80% average relative humidity; volcanic soils – Andisols associated with Inceptisols) (MAG, 1998).

In May 1999, a survey using a structured-interview was applied to thirty-five livestock farms that were chosen randomly from nine zones of the study area (n= 71 livestock farms), to obtain information on the animal production systems, silvopastoral systems and socio-economic data. A canonical discriminant analysis (SAS Institute Inc., 1985) was performed on the data base of cattle surveys to identify farm typologies. Three different types of livestock systems were identified according to the main activity: 1) mixed (milk and crop production); 2) specialised milk production; and 3) dual purpose (milk and meat production). From the first original 35 farms, 5 farms were discarded, because their characteristics were different from those of the groups.

In September 1999 a case study was conducted to make an evaluation of the silvopastoral systems and a financial analysis of farms selected from the three farm typology identified in the area. For this case study four farms for the mixed system and three farms each for the specialised dairy and dual purpose systems were selected from the 30 farms surveyed (Souza de Abreu, 2002).

The case study consisted of: a) A detailed inventory of trees in pastures to identify the species that were present, their abundance, origin, distribution (Souza de Abreu et al, 2000 a ,b) and the regeneration dynamics and volume of laurel (*Cordia alliodora*) and cedro (*Cedrela odorata*) (Souza de Abreu, 2002); b) Collection of production and socio-economic data (Souza de Abreu, 2002).

In order to understand the regeneration dynamics and consequently ascertain the sustainability of the most common and valuable tree species in the pasture systems of the region, abundance (n ha^{-1}) of laurel and cedro was estimated according to diametric classes in each of the three different animal production systems. In addition, dbh (stem diameter at 1.30 m breast height), total height (ht) and the commercial height (hc) of the timber these species were taken in order to determine the total volume of laurel (Somarriba and Beer,1986), the merchantable volume of laurel (McCaffrey, 1972) and volume of cedro (Ford, 1979) of the different cattle farm systems.

Interviews using questionnaire surveys were applied on the 10 farms and were focused mainly on the costs and benefits (financial analysis) of the different animal production (milk, meat and crop combined with wood production). Financial analyses were made for a period of one year (October 1998 to September 1999) (Souza de Abreu, 2002). The following indicators were used for the financial evaluation of the systems: Net present value (NPV) (i= 2.68%) and Benefit-cost ratio (BCR) (Gittinger, 1982).

3. Results and discussion

Characteristics of animal production systems

Mean farm size and area covered by pastures of dual purpose farms were around seven times (6.95 and 6.70 respectively) greater than those of the other systems, with these differences being significant ($p < 0.001$). Dual purpose farms had a significantly ($p < 0.001$) greater percentage of pastures characterised with trees (74%) compared with mixed (16%) and specialised dairy farms (27%). Mean daily milk production per ha was greater on specialised milk (14.2 kg) and mixed farms (12.6 kg) than on dual purpose farms (4.3 kg) (Table 1).

Table 1. Characteristics of the cattle production systems. La Fortuna, San Carlos, 1999 (n = 30 farms)

System	Farm size (ha)	Pasture area (ha)	Area of pasture with trees (%)	Stocking rate (AU ha^{-1})	Milk yield / area (kg $ha^{-1}day^{-1}$)
Mixed (n=13)	44.0 b* (± 33.5)	35.0 b (± 26.6)	16.0 b	1.8 a (± 0.7)	12.6 a (± 8.3)
Specialised milk production (n= 9)	50.0 b (± 38.4)	46.0 b (± 37.3)	27.0 b	2.2 a (± 1.1)	14.2 a (± 11.2)
Dual purpose (n=8)	327.0 a (± 133.8)	273.0 a (± 123.1)	74.0 a	0.6 b (± 0.3)	4.3 b (± 2.4)

* Means with the same letter within each column are not significantly different ($p <0.05$)
± Standard deviation
AU = Animal Unit (400 kg live weight)

Tree surveys

Although the pastures in La Fortuna had many tree species, there was a predominance of timber species, mainly laurel and to some extent cedro in all the cattle production systems, which originated from natural regeneration and were randomly distributed in the pastures. The density of trees (n ha^{-1}) was greater in specialised milk production and dual purpose systems. However dual purpose farms had pastures that were characterised with a higher timber tree density (n ha^{-1}) (17.96 vs. 16.11 vs. 10.47) and a higher proportion of timber trees species in pastures (87.73 vs. 84.03 vs. 72.83) compared to specialised dairy and mixed farms respectively (Table 2), indicating that dual purpose farmers had a greater interest to diversify production by increasing timber production. This will help to buffer negative changes in price of milk and meat which affects profitability of livestock farming (Somarriba and Beer, 1987; Holmann et al., 1992). A lower percentage of pastures characterised with timber trees in mixed farms may be associated to the fact that these farmers have a keen interest in intensive management of grass pastures to ensure a good supply of forage (Casasola et al., 2001).

Table 2. Abundance of trees (average number of trees ha^{-1}) according to type of cattle production system. La Fortuna, San Carlos, 1999

Trees	Mixed (n =4)	Specialised in milk production (n =3)	Dual purpose (n=3)
Laurel	7.33 b[1]	10.34 b	16.08 a
Cedro	0.63 a	1.44 a	0.62 a
Other timber trees[2]	2.51 a	4.33 a	1.26 a
Non-timber trees[3]	1.99 b	6.00 a	2.51 b
Total	12.46 a	22.11 b	20.47 b

[1] Values with the same letter in the same row are not significantly different ($p < 0.05$)
[2] Lagarto (*Zanthoxylum belizense*), surá (*Terminalia oblonga*), gavilán (*Pentaclethra macroloba*) and poró (*Erythrina spp.*)
[3] Limón dulce (*Citrus limetta*), naranja (*Citrus sinensis*), guayaba (*Psidium guajava*), guava (Inga *sp.*) and higuerón (*Ficus spp.*) (fruit and shade trees)

Compared to the dual purpose and mixed systems, the specialised milk production system presented a greater abundance of non-timber tree species (Table 2) that are characterised with a larger crown cover than laurel and cedro. This could be explained by the fact that such farms have pure exotic milk breeds (e.g., Holstein and Jersey) that have high shade requirements to minimise heat stress (Gregory, 1995; McArthur, 1991; Souza de Abreu et al., 1999). Recent studies conducted in this study area showed that dairy cows which had access to shade trees had an average of 13.3% higher milk yields in the dry season compared to cows which did not had access to shade but differences in the rainy season was not significant (Souza de Abreu, 2002). Timber extracted by all farmers in the three cattle systems was mainly used for their own consumption and then for sale. The average harvesting frequency was around once every three years. No silvicultural techniques were used to improve tree form and vigour.

Tree regeneration dynamics

According to Lamprecht (1990), to assure the sustainable natural regeneration of a tree species, the system is expected to have many trees with small diameters to replace the trees of greater diameters that are going to be extracted (diametric distribution in reversed “J” form). Excluding the diameter class 10.0-14.9 cm, where all systems showed a relatively low abundance of laurel, in the present study the dual purpose system was the only one that follows the diametric distribution in form of a reversed “J”. The other two animal husbandry systems showed an irregular distribution of trees according to the diameter classes (Figure 1).

The maintenance of high quality pastures was very important for the mixed and specialised milk systems, and this did not permit a normal natural regeneration of laurel and cedro. Farmers eliminated trees from the pastures, fearing that the grass would be shaded and consequently pasture growth would be compromised. Harvey and Haber (1999) similarly found that shade management appeared to be a key factor influencing farmers' decisions to eliminate trees from pastures. Farmers in the three systems also removed trees for timber for personal use and for sale, although this use was sporadic and unplanned and may not endanger natural regeneration of laurel and cedro in the same way that elimination due to shade management would.

In relation to cedro trees, no animal production system had a diametric distribution (reversed “J” form) required to ensure the sustainability of this species in the system. Cedro trees in the three cattle systems will tend to disappear in the future, because the number of small trees in pastures (dbh<35 cm) (Table 3) is insufficient to ensure their natural capacity for a sustainable regeneration.

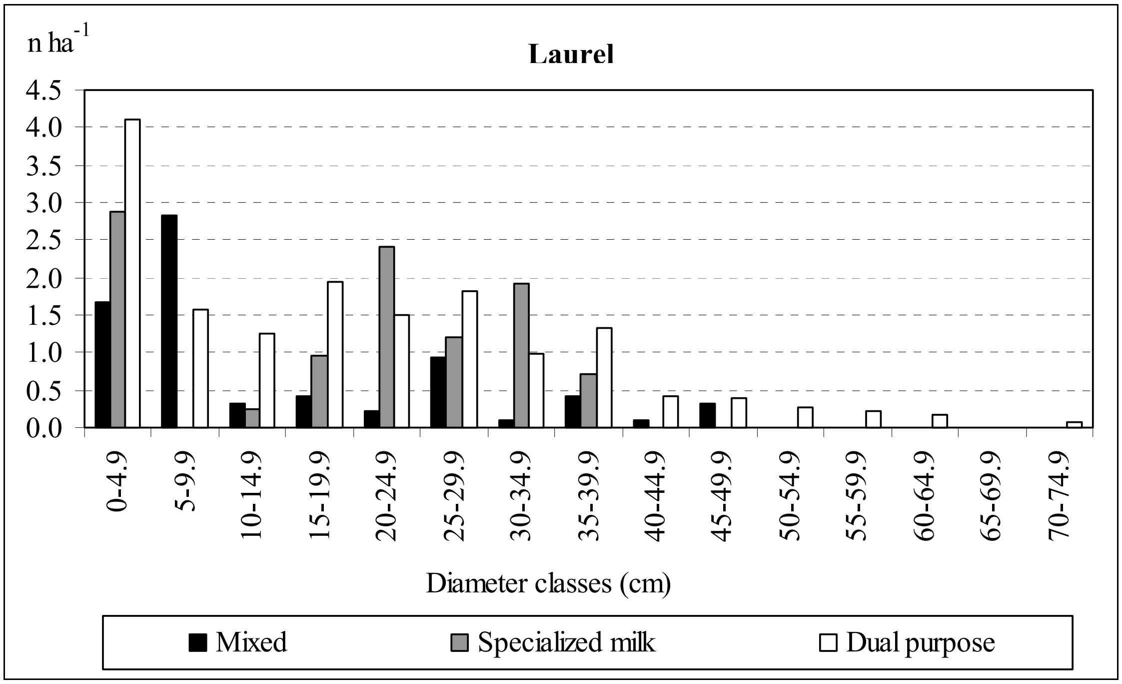

Figure 1. Abundance of laurel (n ha^{-1}), according to diametric classes, in the three cattle production systems. La Fortuna, San Carlos, 1999

Tree volumes

The dual purpose system presented a significantly ($p < 0.05$) greater merchantable volume of laurel than the mixed and specialised milk systems (Table 3).

Table 3. Average merchantable and non-merchantable volume of laurel and cedro (m^3 ha^{-1}), according to type of production system. La Fortuna, San Carlos, 1999

Tree species / Type of system	Total sample size (ha)	Merchantable volume (dbh ≥35 cm) [m^3 ha^{-1}]	Non-merchantable volume (dbh <35 cm) [m^3 ha^{-1}]
Laurel			
Mixed (n= 4)	9.55	0.54 ± 0.12 b	0.87 ± 0.13 b
Specialised milk (n= 3)	4.16	0.41 ± 0.08 b	3.47 ± 0.71 a
Dual purpose (n= 3)	28.67	2.21 ± 0.45 a	2.28 ± 0.37 a
Cedro			
Mixed (n= 4)	9.55	1.56 ± 0.45 a	0.03 ± 0.01 a
Specialised milk (n= 3)	4.16	0.00 ± 0.00 a	0.18 ± 0.04 a
Dual purpose (n= 3)	28.67	1.18 ± 0.24 a	0.01 ± 0.00 a

Within each tree specie, means with the same letter within each column are not significantly different ($p < 0.05$)
± = standard deviation

The results of an assessment of timber production in traditional agroforestry systems in the Atlantic Region of Costa Rica showed a good performance of naturally regenerated *C. alliodora* growing in combination with pastures (Rosero and Gewald, 1979). Their findings were: laurel with ages of 25-30 years, 200 trees per ha, a mean dbh of 37 cm, and standing volume of 380 m^3 ha^{-1}. Somarriba and Beer (1987) found dbh of 24, 26 and 36 cm for laurel associated with pastures in permanent sample plots in two humid regions of Costa Rica. The present study found: laurel of different ages, mean abundance of 11.25 trees per ha (Souza de Abreu et al., 2000a, b); mean dbh of 19.9 cm (range from 14.3 to 23.1 cm); and mean merchantable volume of 1.05 m^3 ha^{-1}. The lower results of the present study might be due to the low abundance of laurel in the pasture, site characteristics and lack of silvicultural techniques.

Financial analysis

Considering the total variable and fixed costs of the three systems, the specialised milk system showed greater costs than the mixed and dual purpose systems, mainly due to the variable costs associated with animal nutrition, maintenance costs of the animals and general costs. These high costs were due to the rearing of pure milk breeds such as Holstein and Jersey, which require better nutrition for maintaining high production. The dual purpose system had the lowest costs for supplementary feeding due to the rearing of cross breeds for dual purpose (milk and meat). The mixed system showed higher fixed costs than the other two systems due to the need for employment of external labour during harvest time (permanent labour) (Table 4).

The average annual gross income (US\$ ha^{-1}) of the milk production was higher in the specialised milk system than in the mixed and dual purpose systems, but was not high enough to cover these high total costs. The gross income from specialised milk systems could cover the total variable costs and part of the fixed costs. This is considered within agricultural enterprise as a rational (operable) financial behaviour and is considered a frequently and cyclic situation related to the behaviour of market prices of inputs and outputs (Manuel Gomez, pers. comm., 2002). The contribution of income from wood to the total income was 1.2% for mixed systems, 1.0% for specialised milk systems and 0.9% for dual purpose systems, showing that the exploitation of wood is still a secondary activity for the farmers (Table 4).

Table 4. Financial analysis of three different animal production systems. La Fortuna, San Carlos, 1999 (n= 9 farms)

AVERAGE ANNUAL COSTS (US$ ha^{-1})	Animal production system		
	Mixed	Spec. milk	Dual purpose
Total variable costs	**1,008.06**	**1,494.22**	**349.98**
Total fixed costs	**1,327.79**	**1,201.72**	**459.31**
Total variable and fixed costs	**2,355.85**	**2,695.94**	**809.29**
AVERAGE ANNUAL GROSS INCOME (US$ ha^{-1})			
Milk production	1,197.15	1,531.79	389.17
Crop production	93.34	0.00	3.83
Meat production	146.07	156.93	251.50
Citrus production	4.43	0.00	0.00
Sundry jobs	159.47	5.24	6.49
Posts	3.59	0.00	0.00
Wood utilisation	28.97	23.70	9.57
Animal stock	483.87	504.20	364.91
Self-consumption products	341.76	147.75	53.73
Total gross income	**2,458.64**	**2,369.61**	**1,079.20**

1 US$= 279.64 colones (average from Oct. 1998 to Sept. 1999 according to Central Bank of CR)

With regards to the resulting NPV (i= 2.68%), only the mixed and dual purpose systems were able to cover the total costs and had a positive NPV, although the NPV of the mixed system was low (Table 5). The negative NPV of the specialised milk system shows that the higher milk production was not able to cover the high animal costs. Although the specialised pure milk breeds should produce more milk when they receive appropriated feeding, the animals did not reach 100% of their potential production. This could be explained by the negative effect of the climatic conditions of the region on the specialised milk breeds, causing heat stress which prevents an optimal milk production (Souza de Abreu et al., 2002). The mixed and dual purpose systems showed BCRs greater than 1, while the specialised milk system had a BCR lower than 1.

Table 5. Financial indicators of the three different animal production systems. La Fortuna, San Carlos, 1999 (n= 9 farms)

Financial indicator	Animal production system		
	Mixed	Specialised milk	Dual purpose
NPV (i = 2.68%) US$ ha^{-1}	97.57 (-701.76 – 567.48)*	-309.73 (-509.41 – - 108.69)	256.18 (203.28 – 294.23)
Benefit cost ratio (BCR)	1.09 (0.75 – 1.33)	0.88 (0.84 – 0.92)	1.36 (1.21 – 1.51)

* Data range

The results of Marlats et al (1995) using a discount rate of 8%, showed that an increased diversification of a silvopastoral system using timber trees leads to an improved NPV. The site characteristics of the region which are suitable for the natural regeneration of laurel in pastures could be better used by increasing the use of this timber resource in the three systems. In the present study the dual purpose system presents the best opportunity to exploit the potential of a more regular use of timber for sale in the future due to a greater abundance of laurel with small diameters. Therefore the benefits derived from this type of silvopastoral system could be increased. The financial results of the present study shows that the importance of the use of timber from the natural regeneration of trees in the region to improve farm income is still small and the farmers' adoption and exploitation of trees depends on their level of preference for animal production activities.

5. Conclusions

Laurel associated with pasture represents a considerable timber reserve. This justifies recommending silvicultural techniques in order to minimise current commercial wood losses and encouraging large-scale natural regeneration which would be beneficial to farmers in the region. It is clear that trees dispersed in pastures of La Fortuna, San Carlos could contribute to the sustainability of the silvopastoral system as a whole, producing additional income, providing shade to limit heat stress in cattle, and also helping to conserve biodiversity. At the farm level, efforts should be made to encourage cattle farmers to preserve pasture trees in the region and to use silvicultural techniques, showing them the associated benefits to the sustainability of the farm as a whole.

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