Cattle and Weedy Shrubs as Restoration Tools of Tropical Montane Rainforest

Juan M. Posada¹,² T. Mitchell Aide³ Jaime Cavelier⁴

Abstract

Over the last 150 years, a large proportion of forests in Latin America have been converted to pastures. When these pastures are abandoned, grasses may slow re-establishment of woody species and limit forest regeneration. In this study, we explored the use of cattle in facilitating the establishment of woody vegetation in Colombian montane pastures, dominated by the African grasses Pennisetum clandestinum (Kikuyo) and Melinis minutiflora (Yaraguá). First, we described woody and herbaceous vegetation in grazed and non-grazed pastures. Second, we tested the effect of grazing and seed addition on the establishment and growth of woody species. We also determined if the effect of grazing was different in P. clandestinum and M. minutiflora pastures. We found that low stocking density of cattle greatly increased density, number of branches per individual (a measure of “shrubiness”), and basal area of woody species, but also reduced woody plant species richness and diversity. In the grazed area, the shrubs Baccharis latifolia (Chilca) and Salvia sp. (Salvia) were the most abundant. The combined effect of grazing and shading from the shrubs reduced herbaceous vegetation by 52 to 92%. In the grazing/seed addition experiment, grazing increased establishment of woody seedlings, particularly of the shrub Verbesina arborea (camargo), but the largest effect was seed addition. Where grasses are an important barrier to regeneration, grazing can facilitate the establishment of shrubs that create a microhabitat more suitable for the establishment of montane forest tree species.

Key words: cattle, restoration, grazing, shrubs, montane pastures, tropics.

Introduction

In the neotropics, extensive areas of mid-altitude montane forest have been deforested for the establishment of agricultural lands (Houghton et al. 1991), particularly coffee plantations (Parsons 1979; Molano 1992). At high elevations, forests were used for the extraction of timber and charcoal and then converted to pastures for cattle grazing (Parsons 1975). These cattle pastures, dominated by introduced African grasses, have been maintained for decades by high density grazing, weeding of colonizing woody species, and the use of fire in areas where rainfall is strongly seasonal.

Once pastures are abandoned, the rate of forest recovery depends on the degree of site degradation (Aide & Cavelier 1994). Forest regeneration in areas subject to intense grazing, long-term use, and soil erosion, can be very slow or may never occur. Although many pastures are abandoned because of reduced productivity, economic and sociopolitical changes can result in the abandonment of highly productive pastures (Stonich & DeWalt 1996). In these sites, forest regeneration can also be inhibited because of competition with aggressive native and introduced grasses (Aide et al. 1995). The high above- and belowground biomass of these grass species can impede seed germination, survivorship, and growth of forest species as has been shown for abandoned Amazonian pastures (Buschbacher 1986; Nepstad et al. 1990).

To accelerate forest regeneration in these productive grasslands, competition from grasses needs to be reduced. Mechanical (machete) or chemical (herbicide) methods can reduce grass biomass. These techniques are effective for forest restoration at a small spatial scale, but they are costly to implement for large-scale projects. Although cattle ranching produced and helped maintain these grasslands (Faminow 1998), grazing animals are a potential tool for reducing grass biomass and facilitating the colonization of woody species (Zimmerman & NeuenSchwander 1984; Janzen 1986, 1988a; Archer 1994; Belsky & Blumenthal 1997). Even if grass biomass is reduced, forest regeneration can be limited by seed availability (Thébaud & Strasberg 1997). Although the majority of tropical tree species are animal dispersed (Howe & Smallwood 1982), initial colonization in the grasslands is dominated by wind-dispersed species (Cave-
lier & Aide, unpublished data). In these ecosystems, most wind-dispersed species are weedy shrubs or small trees in the Asteraceae that normally occur in frequently disturbed areas and are not the pioneer species in mature forest gaps. Direct planting of most forest species into the grasslands is likely to be unsuccessful, due to slow growth rate, competition with grasses, and physiological limitations (Cavelier & Aide, unpublished data). The establishment of these wind-dispersed species can enhance forest regeneration by shading the grass and creating a microclimate for the germination and establishment of forest species (Guimãres-Vieira et al. 1994; Lamb et al. 1997).

The goal of this project was to understand how grazing can be used to reduce grass biomass and enhance colonization of weedy shrub species in abandoned pastures. First, we described the biomass of herbaceous species, as well as abundance, species composition, and canopy structure of woody species in two pastures that had been abandoned for 3 years. One pasture was not grazed after abandonment, while the other was grazed at a very low density and did not receive any weed management. Second, we measured the density of woody plants occurring in neighboring farms that were managed to raise cattle. Finally, we experimentally tested the effect of grazing and seed addition on woody seedling establishment and growth.

Materials and Methods

Study Site

The study was carried out at La Sierra Ranch located in the municipality of Pijao, Department of Quindío, Colombia, at 2,000–2,200 m elevation. Average annual temperature at 2,100 m is 16.8°C, with an average annual maximum of 22.3°C and an average annual minimum of 11.2°C. Between 1991 and 1995, annual precipitation varied between 1,652 and 2,135 mm/yr. Periods of low precipitation occur from December to January and June to September. During the study period (1995–1997), we did not observe fires in the region.

The study area was deforested between 1920 and 1930 for the extraction of timber and charcoal production. Since then, the study site had been used mainly for cattle ranching until the early 1990s (R. Hernández 1994, personal communication). In 1991, the Regional Corporation for development and natural resources conservation of Quindío (CRQ) bought La Sierra ranch and an adjacent cattle ranch (La Cristalina) to protect the watershed of the Río Lejos and prevent large landslides and avalanches in the town of Pijao. Although the CRQ planted some exotic trees (Pinus patula [Pino Pátula]—34,000 individuals; Cupressus lusitanica [Ciprés]—25,000 individuals) and native trees (Juglans neotropica [Cedro Negro]—1,020 individuals; Alnus acuminata [Aliso]—279 individuals) in abandoned pastures, most pastures were abandoned and received no management. These pastures were dominated by the African grasses Pennisetum clandestinum (Kikuyo) and Melinis minutiflora (Yaraguá) that were originally introduced by ranchers to increase cattle productivity. P. clandestinum was found on flat areas, where soils had slightly higher fertility, while M. minutiflora was found on slopes with less fertile soils (Cavelier & Aide, unpublished data). Three years after abandonment, P. clandestinum had an average above-ground biomass (including stolon mat) of 18.8 tons/ha and an average productivity of 18.4 tons ha⁻¹ yr⁻¹. In contrast, M. minutiflora had an above-ground biomass of 11.5 tons/ha and a productivity of 7.5 tons ha⁻¹ yr⁻¹ (Cavelier & Aide, unpublished data). Aerial biomass was similar between the two grasses, while root biomass tended to be lower in M. minutiflora. The largest difference between the two grass types was the investment in stolon biomass (Fig. 1).

Natural Regeneration With or Without Grazers

Natural regeneration was described in two large (20–40 ha), adjacent pastures. Cattle were completely removed
from one pasture in September 1992, while in the other pasture a maximum of ten cows and seven horses and mules were allowed to graze. In this pasture, the grazer density was 0.4–0.7 individuals ha\(^{-1}\) yr\(^{-1}\), which is almost 10 times lower than what pastures can support in the region (3–6 individuals ha\(^{-1}\) yr\(^{-1}\); Cavelier & Aide, unpublished data). Both pastures had steep slopes dominated by \(M.\) minutiflora and a few scattered flat areas dominated by \(P.\) clandestinum. Other than grazing, neither pasture was subjected to any management practices that would reduce the colonization of woody plants (Figs. 2a & 2b).

In both pastures, woody vegetation was measured in transects 1\(\times\)30 m, placed perpendicular to the slope. In each transect, all woody plants higher than 1.3 m were identified and measured (height and diameter). Shrub branches, which originated below 0.5 m and also attained heights above 1.3 m, were measured individually. These branches were a measure of the size of the shrub canopy, which we refer to as plant “shrubiness.” Ferns higher than 1.3 m were also included in the censuses. Six transects were placed on each grass type (\(P.\) clandestinum and \(M.\) minutiflora) and in each pasture (grazed and not grazed), for a total of 24 transects.

In both pastures and both grass types, herbaceous vegetation was described in three 1\(\times\)1 m quadrants. In each plot, aboveground vegetation was cut and sorted into five categories: \(P.\) clandestinum, \(M.\) minutiflora, ferns, herbs, and other species of grass. After sorting, each sample was dried at 60°C and then weighed. Ferns higher than 1.3 m in height were excluded. Samples were collected in June 1995.

**Active Pastures**

Woody vegetation was described in pastures of neighboring farms that were managed for cattle. We refer to

Figure 2. Natural regeneration in abandoned cattle pastures. a) There was no grazing after abandonment in this site. Note the dominance of \(P.\) clandestinum in the flatter area and \(M.\) minutiflora on the slope. b) This pasture was abandoned at the same time, but was occasionally grazed at low densities and is now dominated by shrubs.
these pastures as active to distinguish them from non-Managed pastures. In each farm, we counted and identified all individuals of woody species greater than 10 cm in height in six 1 × 30 m transects (three in P. clandestinum, and three in M. minutiflora). This minimum height was much lower than in the transects done in the two non-Managed pastures (1.3 m; see above), because farmers frequently cut woody vegetation. Three farms were censused in July 1996 and three more were censused in November 1996.

Corral Experiment

To experimentally test the effect of grazing on the establishment of woody seedlings, twelve 20 × 20 m corrals were delimited in pastures that had not been grazed for 3 years. Six corrals were dominated by M. minutiflora and six were dominated by P. clandestinum. Within each grass type, three sites were assigned as controls and three sites as treatments. The treatment corrals were enclosed with a three stranded barbed wire fence, 1.5 m tall. From February to mid-April 1995, two heifers and two young bulls were rotated through the treatment corrals to reduce the grass biomass to levels similar to that in active pastures.

In mid-April 1995, we established at random 12 circular plots (1 m radius) in each corral to evaluate the effect of seed addition. Six plots were used as controls and six plots received seeds of five species. Each plot received seeds of Baccharis latifolia (Chilca; ~25,000 seeds), Verbesina arborea (Camargo; ~800 seeds), Weinmannia pubescens (Encenillo; ~2,500 seeds), Solanum ovalifolium (~3,000 seeds), and Leandra melanodesma (Nigüito; ~2,000 seeds). Seed weight ranged from 0.2 to 20 mg. In July 1995, an additional 1,000 seeds of V. arborea were added to each seed addition plot. From mid-April to December 1995, grazing intensity was halved by keeping only one pair of cattle. The number of individuals and species of woody seedlings were counted in all plots in September 1995. In January 1996, the number and height of V. arborea seedlings were determined for the seed addition plots. The herbaceous vegetation in the corrals was collected in 1 × 1 m quadrants, in June 1995. The vegetation was then sorted and weighed following the same procedure described above.

Data Analysis

Shannon’s diversity index, Pielou’s evenness index, and Sorensen’s similarity index were used to describe the woody vegetation in the grazed and ungrazed pastures. We used two-way analysis of variance models to analyze the data describing the structure of the woody vegetation, aboveground herbaceous biomass, and height and number of V. arborea seedlings. The numbers of woody seedlings in the corrals (treatment and controls) were analyzed with a split-split-plot design. In this model, block was considered a random effect, while grass species, grazing and seed addition were considered fixed treatment effects. Each block included two pairs of corral and control plots (one pair per grass species). The average number of days with cattle and carrying capacity (individuals ha⁻¹ yr⁻¹) of P. clandestinum and M. minutiflora pastures were compared with a t-test. A Wilcoxon-Mann-Whitney test was used to test for differences in density of woody individuals in P. clandestinum and M. minutiflora in the active pastures.

Results

When comparing the two large pastures, density of woody vegetation was higher in the grazed than in the non-grazed pasture (F = 6.14, p = 0.022; Fig. 3). With grazing, an average of 70% more individuals established in M. minutiflora and P. clandestinum, compared to the pasture without grazing. More individuals estab-
lished in *M. minutiflora* than in *P. clandestinum* (*F* = 6.94, *p* < 0.001), independently of the presence or absence of grazing animals (no significant interaction; *F* = 1.63, *p* = 0.217). Mean basal area of woody plants was higher in the pasture with grazing than in the non-grazed pasture (*F* = 14.23, *p* = 0.001; Fig. 3). Grazing increased basal area by 85% in *P. clandestinum* and by 250% in *M. minutiflora*. Basal area was higher in *M. minutiflora* than in *P. clandestinum* (*F* = 12.24, *p* = 0.002), but the effect also depended on the grazing treatment (significant interaction; *F* = 6.25, *p* = 0.021). The interaction was interpreted as basal area increasing more in *M. minutiflora* than *P. clandestinum*, with grazing (Fig. 3). The average number of branches per individual, a measure of “shrubnness,” was approximately two times greater in grazed versus non-grazed pastures (ln-transformed data; *F* = 10.30, *p* = 0.005; Fig. 3). Branching was not influenced by the grass species (*F* = 0.64, *p* = 0.4). The average height of woody vegetation > 1.3 m tall was 2 m, and there was no significant effect of grazing (*F* = 1.35, *p* = 0.26) or grass type (*F* = 0.5, *p* = 0.8; data not shown).

In summary, grazing caused an increase in density of woody individuals, basal area, and number of branches per individual, but had no effect on plant height. Density and basal area were higher in *M. minutiflora* than in *P. clandestinum* pastures, while height and number of branches per individual were the same.

The grazed and non-grazed pastures had relatively simple community composition (Table 1). Species richness of woody plants was lower in the pasture with grazing than in the pasture without grazing, despite the former having more individuals. Asteraceae was the family with most individuals, particularly in the grazed pasture where *Baccharis latifolia* and *Salvia* sp. represented about 90% of all individuals. We found no ferns (Polypodiaceae) taller than 1.3 m in the grazed pasture. Pastures of *M. minutiflora* had about twice the number of individuals of woody plants without grazing, and about three times more individuals when grazed, in comparison with areas dominated by *P. clandestinum*. The number of species of woody plants was the same in *P. clandestinum* and *M. minutiflora* in the pasture without grazing, but was higher in *M. minutiflora* when grazing occurred. Species diversity and evenness were lower in the grazed pasture, than in the pasture without grazing (Table 1). Diversity was higher in *M. minutiflora* than in *P. clandestinum* when grazing took place. In the non-grazed pasture, diversity and evenness were very similar in the two grass species. Sorensen’s index shows that the grazed and non-grazed pastures had only 17–

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<th>Table 1. Woody species in grazed and non-grazed pastures, dominated by <em>P. clandestinum</em> (Pc) or <em>M. minutiflora</em> (Mm) grasses.* Number of individuals, species richness, Shannon’s diversity index, and Pielou’s evenness index are reported.</th>
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* In each grass and grazing “treatment” we sampled 180 m², in six 1 × 30 m transects.
22% similarity (Table 2). Only *B. latifolia* was common to both pastures (Table 1). The species composition was most similar between *P. clandestinum* and *M. minutiflora* pastures that had experienced the same grazing treatment (no grazing—71%; grazing—57%; Table 2). These results suggest that grazing, and to a lesser extent the dominant grass species, were important factors influencing woody plant colonization.

Grazing significantly reduced the aboveground biomass of herbaceous vegetation (ln-transformed data; $F = 80.69, p < 0.001$; Fig. 4). There was no detectable difference between the two grass species ($F = 0.31, p = 0.591$), but there was an interaction between grazing and grass species ($F = 5.61, p = 0.045$). This interaction was interpreted as grazing reducing the aboveground biomass of *M. minutiflora* more (78% reduction) than the biomass of *P. clandestinum* (61% reduction; Fig. 4). In areas dominated by *P. clandestinum*, the percent biomass of this grass decreased from 91% in the non-grazed pasture to 59% in the grazed pasture (Fig. 4). The decrease in percent *P. clandestinum* was associated with an increase in the percentage of herbs and other grass species. In areas dominated by *M. minutiflora*, the percent biomass of this grass declined from 85 to 23% when grazed and there was a greater proportion of ferns and herbs.

In active pastures, the average density of woody individuals taller than 10 cm was 0.5 individual/m². There was a marginal difference between *M. minutiflora* and *P. clandestinum* pastures ($Z = -1.86, p = 0.064$; Wilcoxon-Mann-Whitney test with normal approximation), suggesting that more individuals established in *M. minutiflora* (Fig. 5). Between farms, density varied from 0.0 to 1.0 woody individual/m² in *P. clandestinum* and from 0.3 to 1.5 woody individual/m² in *M. minutiflora*. The large variance in density was due to the frequency of weeding woody vegetation (i.e., cutting, pulling, or herbicide). Some pastures were weeded twice per year and others only once every two years. Ferns were the most common individuals in both grass types, followed by others only once every two years. Ferns were the most common individuals in both grass types, followed by individuals of the family Asteraceae (Fig. 5). *Salvia* sp., *B. latifolia*, and *L. melanodesma*, the three most abundant species in the pasture with grazing (Table 1), were common in these active pastures.

In the corral experiment, a pair of young bulls or heifers was kept for twice the number of days in enclosures on *P. clandestinum* pastures (3.64 d/month ± 1.2), than in enclosures on pastures of *M. minutiflora* (1.73 ± 0.05; $t = 3.56, p = 0.023$). Similarly, carrying capacity was two times larger in *P. clandestinum* (6.7 individuals ha⁻¹ yr⁻¹ ± 1.2) than in *M. minutiflora* (3.3 individuals ha⁻¹ yr⁻¹ ± 0.2, $t = 3.56, p = 0.023$), showing that *P. clandestinum* pastures had higher productivity. After six months of grazing, aboveground herbaceous biomass was significantly reduced in comparison with the control corrals (ln-transformed data; $F = 29.25, p < 0.001$; Fig. 6). In both the control and treatment corrals, the aboveground biomass was greater in areas dominated by *P. clandestinum* in comparison with *M. minutiflora* ($F = 19.59, p = 0.002$) and each species responded differently to grazing (interaction; $F = 11.26, p = 0.010$). The interaction was interpreted as grazing having a larger negative impact on the biomass of *M. minutiflora* pastures (92% reduction), than on *P. clandestinum* pastures (52% reduction; Fig. 6). In both grass types, grazing increased the proportion of the dominant grass species (*P. clandestinum* 92% to 100%; *M. minutiflora* 63 to 67%) (Fig. 6).

Adding seeds to grazed and control corrals dramati-
cally increased the number of seedlings of woody species ($F = 57.64, p = 0.017$, log-transformed data; Fig. 7). There was no detectable effect of grazing ($F = 7.14, p = 0.116$) or grass species ($F = 0.68, p = 0.498$) on the number of established individuals. However, we found a significant interaction between seed addition and grazing ($F = 19.32, p = 0.048$), indicating that more seedlings established when seed were added to the grazing treatment, than when added to control plots (Fig. 7). At the end of the experiment, the most common species was the shrub *V. arborea*. The effect of grazing on the number of *V. arborea* seedlings was marginally significant (log-transformed data, $F = 5.26, p = 0.051$), suggesting that more individuals were present in the grazing treatment than in control plots (Fig. 8). More individuals survived in *M. minutiflora* than in *P. clandestinum* pastures ($F = 8.59, p = 0.019$), and there was no interaction between the type of pasture and grazing ($F = 2.17, p = 0.179$). *V. arborea* seedlings were taller in grazed corrals than in controls ($F = 35.92, p < 0.001$; Fig. 8), suggesting that grazed areas were more favorable for growth, than non-grazed areas. Height was not different between *P. clandestinum* and *M. minutiflora* pastures ($F = 0.51, p = 0.500$), but the interaction between grazing and grass species was significant ($F = 9.05, p = 0.020$). When grazing occurred, *V. arborea* seedlings were taller in *P. clandestinum* than in *M. minutiflora*, but the opposite happened when pastures were not grazed (Fig. 8).

**Discussion**

The colonization of woody species in abandoned pastures depends on previous land use practices, grazing systems, and the dominant grass species (e.g., Alzéreca-Angelo et al. 1998). Active pastures with low grass biomass due to heavy grazing are continuously colonized by many species of ferns and woody shrubs (e.g., *Salvia sp.*, *B. latifolia*, and *L. melanodesma*). Once these pastures are abandoned, the relative proportion of grasses and woody vegetation will depend on previous management practices. Pastures that were frequently weeded will result in grasslands with high grass biomass, while areas that have not been frequently weeded should quickly become dominated by weed shrub species and have lower grass biomass. Virtually all species that col-
onized the abandoned pastures in this study have small wind-dispersed seeds (Bartholomäus et al. 1990), which should facilitate dispersal not only to forest edges, but also to large pastures.

The differences in biomass between the two dominant grass species (P. clandestinum and M. minutiflora) also affected herbaceous and woody plant colonization. Ferns, herbs, and other grasses were less common in areas dominated by P. clandestinum. Density and basal area of woody species were lower in P. clandestinum than in M. minutiflora, while height and number of branches per individual were the same. The lower density and basal area of woody plants in P. clandestinum in comparison with M. minutiflora was due to differences in biomass allocation. Thirty-five percent of aerial biomass of P. clandestinum was allocated to stolons (Fig. 1) creating a physical barrier that appears to inhibit seed germination and seedling establishment. Seedlings that germinated within the stolon mat rarely established due to low light and mechanical damage by fast growing grass shoots of P. clandestinum (Cavelier & Aide, unpublished data). Even wire flagging was twisted and disappeared under the grass within a few weeks. In contrast, M. minutiflora allocated much less biomass to stolons. We observed more open spaces at the soil surface in M. minutiflora, which should have permitted greater colonization of non-grass species. The greater allocation to stolons may explain why aboveground biomass of P. clandestinum was less affected by grazing in comparison with M. minutiflora (i.e., statistical interactions between grazing and grass species).

Many studies have reported decreases in grass biomass and changes in the composition and density of colonizing woody species with the presence of livestock grazing (Smith 1967; Zimmerman & Neuenschwander 1984; Janzen 1988b; Archer 1994; Belsky & Blumenthal 1997). After reviewing the available studies, Archer (1994) concluded that selective grazing by livestock was the major factor favoring the establishment of unpalatable woody species over graminoids in western temperate grasslands of North America. Similarly, Belsky and Blumenthal (1997) concluded that livestock grazing was a central factor in favoring the establishment of woody species over grasses in open coniferous forests of the western United States. The same pattern was observed in this study, when comparing the grazed and non-grazed pastures. In both P. clandestinum and M. minutiflora, grazing reduced grass biomass by more than 50%
and increased the number of woody plants, herbs and other grass species. These changes were greater in *M. miniatiflora*, probably due to the lower productivity and greater sensitivity of this species to grazing. The establishment of weedy shrub species in the low density grazed pasture also contributed to the decrease in grass biomass possibly because of an increased “shrubiness” leading to greater shading. Although the dominant grass species had an important effect on woody species colonization, the species composition of a pasture was mainly determined by the presence or absence of grazing. The density of woody species was much greater in the grazed pasture, but the diversity was much lower. The low-density grazed area was dominated by *B. latifolia* and *Salvia* sp., two species that were also present in the active pastures. These species have strongly aromatic leaves, and species of both genera are known to have secondary compounds that might be toxic for grazing animals (Idrobo 1992; Viola et al. 1997; Rizzo et al. 1997).

Although grazing increases the establishment of woody species, the corral experiment demonstrated that increased seed availability might be a more important limiting factor for forest recovery. Although weedy shrubs, like *V. arborea*, are wind dispersed and seeds are produced in great numbers, seed addition of these species could accelerate woody plant establishment. Once these shrub species are established in the abandoned pastures, they will act as perches for small birds that can increase seed dispersion, as has been shown for the shrub *Cordia multispicata* in Amazonian pastures (Guimaraes-Vieira et al. 1994) and large isolated trees in lowland pastures of Mexico (Guevara et al. 1986). In addition to attracting dispersers, these shrubs shade out the herbaceous vegetation creating a microhabitat that can enhance the survivorship of forest species. For example, seedlings of *Billia columbiana* (Hippocrateaceae) and *Pouteria* sp. (Sapotaceae) planted in open pastures produced symptoms of photoinhibition and water deficit within a few weeks, but individuals planted under the partial shade of *Baccharis latifolia* or *Leandra melanodesma* showed no symptoms (Cavelier & Aide, unpublished data).

**Conclusions/Implications**

The complete elimination of grazing in highly productive grasslands can result in areas of high grass biomass that inhibit the colonization of woody species. Grazing, even at low density, can reduce grass biomass, facilitating the establishment of weedy shrubs that can further reduce grass biomass by shading and create a microclimate suitable for the germination and establishment of forest tree species. This process can be accelerated by adding large quantities of seeds of shrub species. Seed addition will be most successful when grass biomass is low, immediately after abandonment or during a grazing treatment. By combining the use of cattle and weedy shrubs it might be possible to reduce the main barrier for forest regeneration in these highly productive grasslands. Once shrubs are established, seed rain of forest species may increase due to increased occurrence of seed dispersers as has been reported in shrubby pastures in Amazonia (Silva et al. 1996; Guimãres-Vieira et al. 1994). For many forest species, direct seeding or planting will be necessary (Lamb et al. 1997) since dispersal from the parent tree, particularly for large-seeded species, is usually a limiting factor for colonizing open sites (Wunderle 1997). The site preparation to the shrub phase can be accomplished on a large spatial scale with few resources. In contrast, much effort must be invested in collecting, germinating, and growing large quantities of many tree species to restore a high diversity montane forest.

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**LITERATURE CITED**


