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Secondary Tropical Dry Forests Are Important to Cattle Ranchers in Northwestern Costa Rica

Bosques tropicales estacionalmente secos son importantes para ganaderos en el noroeste costarricense

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Abstract

[**Introduction]:** In the dry regions of Central America, forests in cattle ranches are used as a refuge for cattle during the dry season, and there is no much information about this practice. [**Objective**]: to determine the frequency of this practice and how it fits in farm management. [**Methodology**]: We conducted semi-structured interviews with cattle ranchers in 43 farms in Liberia County, Guanacaste, Costa Rica. [**Results**]: Cattle farmers suffered from the loss of profitability due to droughts, fire, and cattle theft. Cattle browsing in the forest was used by 70 % of farms, mostly between March and May. No type of farm or feeding strategy was associated with forest browsing. The high variability in farm management did not provide a distinct classification of feeding strategies. We found a difference in farm structure and feed types between ranches in the plains and mountain slopes. The decision to use forests for browsing seemed to rely on a trade-off between animal welfare and ease of management. Traditional knowledge about cattle behavior in forests was variable and often limited to forest edges and pastures. [**Conclusions**]: This research shows that forests should be taken into consideration when analyzing cattle ranching in dry regions of Central America. We recommend a further study on feeding strategies and the impact of cattle on forest integrity to determine if agricultural policymakers should foster these low-costs alternatives.

Keywords: Browsing; Cattle ranching; Ecosystem-based adaptation; Mesoamerican Dry Corridor; Seasonally dry tropical forests.

Resumen

[**Introducción]:** En las regiones secas de Centroamérica, los ganaderos llevan su hato a los bosques de sus fincas durante la temporada seca, pero se sabe poco sobre esta práctica. [**Objetivo]:** Determinar la frecuencia de esta práctica, y cómo se ajusta al manejo de fincas. [**Metodología]:** Se administraron 43 entrevistas semiestructuradas a ganaderos del cantón de Liberia, Guanacaste, Costa Rica. [**Resultados]:** Los ganaderos padecían de la pérdida de rentabilidad de la ganadería debido a sequias, incendios y robo de ganado. El ramoneo en bosques se usaba en el 70 % de las fincas, mayormente entre marzo y mayo. No se pudo asociar esta práctica con un tipo específico de finca o estrategias de alimentación. La alta variabilidad en manejo de finca impidió explicar las diferencias en prácticas de alimentación. Se encontraron diferencias en la estructura y tipos de alimentación entre fincas de bajura y en las pendientes de montañas. La decisión de usar el bosque para ramoneo parecía basarse en un *trade-off* entre

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bienestar animal y facilidad de manejo. El conocimiento de los finqueros sobre el comportamiento del ganado en bosques era variable y limitado a los márgenes del bosque y pasturas. **[Conclusiones]:** Se destaca que los bosques se deben considerar cuando se estudia la ganadería en regiones secas de Centroamérica. Recomendamos estudios de seguimiento sobre estrategias de alimentación y sobre el impacto del ganado sobre la integridad ecológica de los bosques secos, para determinar si los decisores de política deben fomentar este tipo de alternativas de bajo costo.

Palabras claves: Adaptación basada en ecosistemas; bosque seco tropical; corredor seco mesoamericano; ganadería; ramoneo.

1. Introduction

Human development and cattle ranching in Latin America have made of the seasonally dry tropical forests (SDTF) one of the most endangered ecosystems today (Miles et al., 2006). However, the biophysical environment of those dry regions provides the context for a situation where forests are of critical use to cattle ranchers in those months when the dry season progresses, temperature rises and rainfall is close to zero (Sánchez-Azofeifa, Calvo-Alvarado, Marcos do Espírito-Santo, Fernandes, & Powers, 2013). Pastures dry out and those ranchers with no forest within their farm have three options: either selling part or all of their herd at low prices, increasing expenditures in alternative feeds, transporting cattle to non-seasonal areas or letting the herd go through the dry season with no assistance with the risk of losing part of the herd due to drought. On the other hand, farmers having a forest on a farm can use those as a refuge for cattle during the dry season, where the tree cover and cooler temperatures relieve cattle from heat stress and where the last green leaves and fruits from deciduous trees, shrubs, and herbaceous vegetation can improve animals' diet (Ascencio-Rojas, Valles-de la Mora, & Ibrahim, 2013; Betancourt, Ibrahim, Harvey, & Vargas, 2003; Vásquez, Mora, & Aguilar-støen, 2014). Cattle can then spend most of the dryer months in the forests.

In the Americas, only few studies were found that reported and discussed cattle behavior in the forest and its impact on it. Browse in general has been studied worldwide in the context of silvopastoral systems (Barrientos-Ramírez, Vargas-Radillo, Segura-Nieto, Manríquez-González, & López-Dellamary Toral, 2015; Pérez Almario, Ibrahim, Villanueva, Skarpe, & Guerin, 2013), and as a source of supplementation in the arid lands of Africa for subsistence farmers (Aganga & Tshwenyane, 2003; Franzel, Carsan, Lukuyu, Sinja, & Wambugu, 2014; Le Houerou, 1980). However, most of those papers pay little attention to the role of forests as a source of browse for cattle. Sporadic research on cattle in forests has been found in the United States, Venezuela, the Argentinian Chaco, Brazil and Mexico (Ascencio-Rojas *et al.*, 2013; Belsky & Blumenthal, 1997; Simón, Ibrahim, Finegan, & Pezo, 1998; Vieira, Scariot, & Holl, 2006). In Central America, research on cattle ranching practices has also left out forests from analysis; most of the work performed on the characterization of farm management in dry areas of the subcontinent ignores the use of forests, and the few mentions of this practice are scattered through documents broadly treating of farm management in Central America (Cabrera, 2007).

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This lack of interest in forests could simply mean that this practice is very marginal nowadays. It is true that this practice dates back to the colonial times and does not seem to fit within today's farm management intensification strategies, demanding a tighter control of cattle rather than extensive practices. However, it is possible that cattle browsing in forests is at the crossroad between two disciplines and their different priorities regarding livestock management and landscape conservation and restoration, which makes this topic far from being a priority study interest for agronomists and conservationists alike. However, in a world where climate change is now a reality, and where Central American seasonally dry regions are projected to experience longer and more intense droughts and a shorter rainy season (Fung *et al*., 2017), it is of prime importance to characterize the local practices that farmers use to cope with climatic hardship. A multidisciplinary approach to this subject is thus necessary.

In recent years, the concept of Ecosystem-based Adaptation (EbA) was created, with the aim to focus on local ecological conditions and livelihoods to increase climate change resilience (Andrade Pérez, Herrera Fernández, & Cazzolla Gatti, 2010). In the framework of this concept, this paper is one of the first to explore the practice of dry season browsing in SDTF by bovine cattle and its importance for local livelihoods. We decided to turn to farmers of those regions to probe the extent of the traditional knowledge on the topic. We interviewed farmers of the Liberia CountyCounty, Guanacaste, Costa Rica, with the aim to (i) determine the frequency and intensity of the dry season forest browse practice, (ii) gather traditional knowledge about cattle browsing preference and behavior while in seasonally dry forests and (iii) understand the feeding and management factors that influence farmers´ decisions to put their cattle in the forest or not during the dry season.

2. Methodology

2.1 Study Area

The study took place in Liberia County, Guanacaste Province, in northwestern Costa Rica, ranging from 10° 25' 6" N to 10° 57' 54" N, and 85° 17' 31" W to 85° 49' 34" W (**Figure 1**). Of the 650 farms of the county, 295 were dedicated to cattle ranching in 2014, with an average of approximately 89 animals per farm, compared to the national average of 35 animals per farm (Instituto Nacional de Estadísticas y Censos [INEC], 2014). Ranching in the Guanacaste Province is traditionally built on a "latifundio" model, with vast extents of land belonging to one owner or family and all personnel living on the farm (Cabrera, 2007; INEC, 2014). However, this model is crumbling due to fragmentation; for example, the biggest farm in the area, which used to span more than 34 000 ha in 1937 (Cabrera, 2007), today is reduced to a couple thousand hectares, and the average farm size for the Guanacaste Province is 54.6 ha, while remaining the highest average in the country.

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The county is mostly composed of flat to mildly hilly lowlands, with more marked slopes in the foothills of the Guanacaste Volcanic Cordillera to the East. Liberia County has a dry season (< 100 mm of precipitation per month) from December through May (Instituto Meteorológico Nacional [IMN], 2013). Most of the county's lowlands have a very warm tropical dry sub-humid climate with a period of "light to moderate excess of precipitation." The average rainfall is 1 600 mm per year, September being the rainiest month (346 mm) and January the driest (1.3 mm). Temperatures range from 19.2 °C to 37.7 °C in April and from 18.9 °C to 33.4 °C in November, with a mean annual temperature of 27.2 °C and a relative humidity ranging from 60.5 % to 86.1 % in March and October respectively (IMN, 2013). Soils are mostly Inceptisols over a shallow layer of brittle volcanic rock in the plains, among which are interspersed many patches of deep clayey soils with low water absorption capacity, locally named "sonzocuites" (Bergoeing, 2017).

Forests of Liberia County are SDTF as defined by Sánchez-Azofeifa *et al*., (2005), with a high proportion of dry season-deciduous species and Fabaceae (Kalacska *et al*., 2004; Murphy & Lugo, 1995), as it is the case for most tropical dry forests (Gei *et al*., 2018). However, forests with dominance of *Quercus oleoides* can be found in the flatlands surrounding Liberia and the slopes of Guanacaste Volcanic Cordillera (Klemens, Deacon, & Cavender-Bares, 2011). Classified by the Holdridge life zone system as a tropical dry forest, the vegetation on the slopes of the Guanacaste Cordillera transitions rapidly to premontane wet forest and lower montane rainforest at the county's maximum altitude of 1 916 m a.s.l. Most of the county is within the Central American Dry Forest ecoregion defined by Olson *et al*., (2001) as an ecosystem-based unit for conservation planning.

A wave of deforestation took place in Guanacaste Province during the second half of the 20th century with the fast development of extensive cattle ranching, boosted by national development incentives and international meat prices (Stan & Sanchez-Azofeifa, 2019). The Costa Rican golden age of beef cattle ended late in the 1970 decade, with a drop in meat prices and the end of those incentives, triggering the regeneration of forests on the least productive cleared areas. As a consequence, most dry forests today in Guanacaste Province and Liberia County are relatively young secondary forests (Stan & Sanchez-Azofeifa, 2019).

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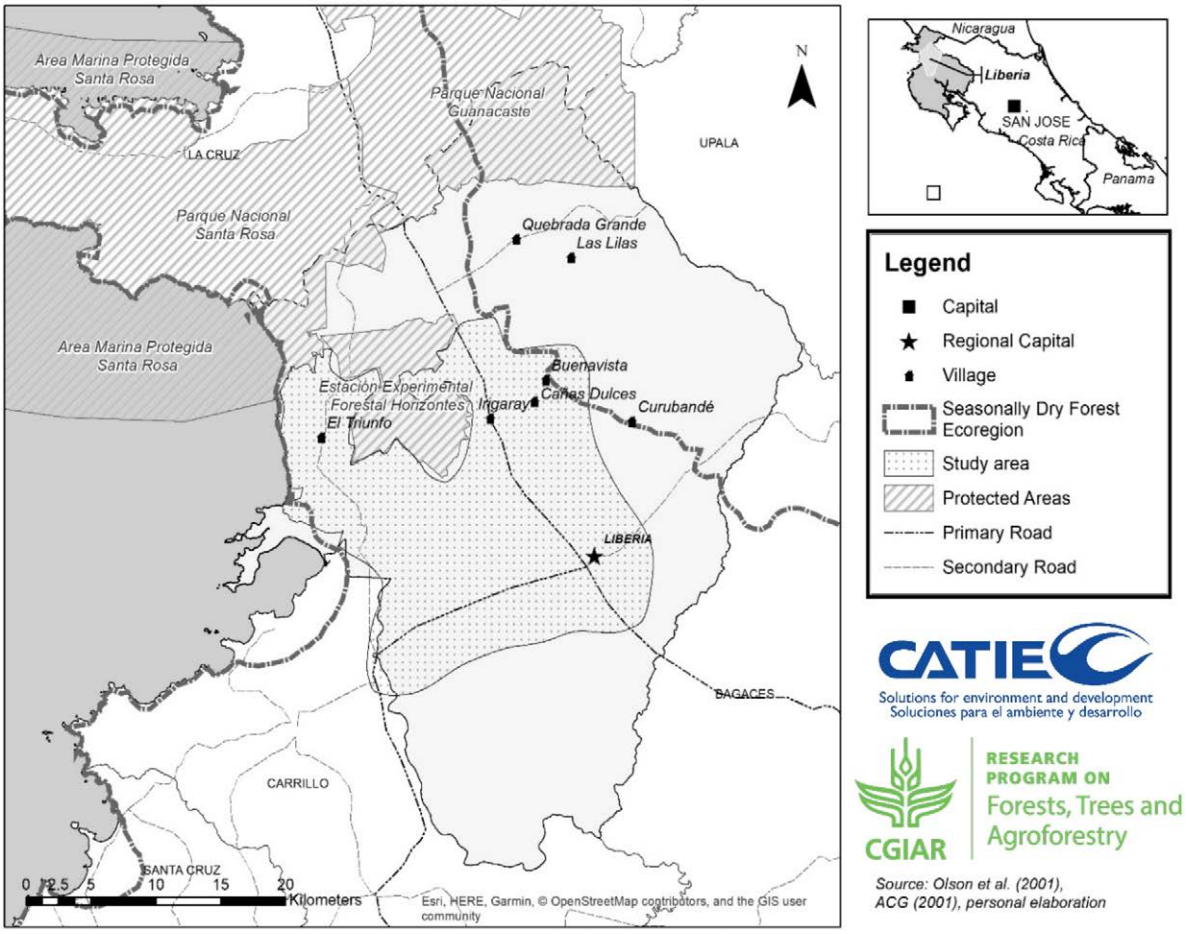

Figure 1. Map of Liberia County. The study area is shown as the approximate area covered by farms where interviews were performed.
Figura 1. *Mapa del cantón de Liberia. El área de estudio está representada como el área aproximada cubierta por las fincas donde se hicieron las entrevistas.*

2.2 Data Collection and Analysis

Between November and December 2018, semi-structured interviews were conducted in 43 cattle farms of Liberia County. The interview consisted of 13 open-ended questions with follow-up topics, some inquiring about farmer perceptions or opinions, and others requiring a concise answer or a list of items (**Appendix 1**). The questionnaire focused on dry season farm management practices, cattle management and behavior in forests, forest structure, age and composition, fire history, and reasons for putting or not cattle within forests. Interviews were recorded, and backup notes were taken to ensure minimum loss of information.

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Interviewees could be either farm owners or administrators. As cattle in forest was the object of this study, selected farms should have a patch of forest and a relatively important livestock density indicating an active herd management. For example, a farm of 250 ha with a herd of only five animals was not selected for the interview. Whether or not forests were used for cattle browse was not a selection criterion. Farms had to be within the limits of the Olson *et al.*, (2001) WWF Central American Dry Forest (CADF) ecoregion. For the sake of this study, the definition of cattle browse in forests was taken in a broad sense. The selected definition of forest was "an area with dense tree cover and an understory layer, where the main forage for cattle are trees, shrubs and native herbaceous vegetation." Hence, tree plantations and forests where cattle browsed on understory vegetation were included, but forests and plantations where the understory had been cleared to plant improved pastures were not. To avoid a repeated use of "browse and graze" the term "browse" will be used throughout this paper as the action of cattle feeding both from woody and herbaceous vegetation that are not domesticated pastures, within cattle's reach, i.e. between 0 and 2 m of height.

The interview was set up to leave many questions open-ended, and several items that were not meant to be specifically inquired about were mentioned spontaneously by farmers. Some other times, farmers did not know the answer to a question, or the question did not apply. In those cases, proportions will be presented as a percentage of farmers that responded on the matter, with the total number of respondent farmers, e.g.: *"24% (n=25)"*, when the number of interviews "n" differed from the total of 43 interviews.

Farmers were not randomly selected in terms of spatial distribution or farm size, as no exhaustive georeferenced map of cattle farms was available. Interviews were performed following a combination of a chain of recommendations or "snowball sampling," a list of addresses and contacts provided by the local governmental institutions. As an extensive list of possible interviewees was gradually compiled, the selection of the next farmers to meet was made to include a wide range of different farm sizes, occupations and locations, to embrace the highest possible combination of situations and managements. Interviews focused on three main population centers: El Triunfo, Liberia, and Cañas Dulces, but interviews were conducted on farms in different locations. The highest altitude registered for an interviewed farmer was 338 m a.s.l., in Buena Vista de Cañas Dulces, still within the CADF ecoregion.

Statistical analyses on feed data and farm structure used in this paper were performed using the statistical software Infostat (Di Rienzo *et al.*, 2018), using a simple T-test or an analysis of variance (ANOVA) when needed, with a Fisher's LSD test for comparing means, with a statistical significance fixed at $p<0.10$.

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3. Results and Discussion

3.1 General Considerations

Demographics of the 43 interviewees were quite homogenous. Only two interviewees were female. Sixty-three percent of the interviewees were farm owners, the other 37 % were administrators. Two of the interviewees had a primary occupation unrelated to cattle ranching, despite owning cattle and actively managing their farm. Farm size ranged between 7 ha and 1 200 ha (Med = 112.5, Q1 = 35, Q3 = 350), and herd size ranged between 9 and 500 heads of cattle (Med = 79.0, Q1 = 29, Q3 = 170).

Farmers described cattle ranching as an industry generating little profits due to low meat prices and increasing costs, particularly for feed and supplements. While the lowlands of Liberia County used to belong to immense ranches, farms have undergone a progressive fragmentation process due to the reduction of cattle herds, splitting of the land between successors, cost of land maintenance, and the lack of liquidity in times of financial hardship. For example, farms around Liberia have been progressively disappearing due to urban development; therefore, few farmers were interviewed in the immediate vicinity of LiberiaCounty.

3.2 Farmland and Cattle Herd Management

The following production types were encountered throughout this study, often combined, and are briefly defined below:

Beef cattle farms were split between cow-calf, growing and fattening farms. Cow-calf farms are dedicated to cattle breeding, selling calves at weaning. Growing farms raise cattle up to a certain weight or age; then, they sell the animals to fattening/finishing farms. Cow-calf and growing farms were the most common, representing 72 % of interviewed farmers, with farms often combining both activities. Those farms adapted their management to cope with the dry season, 35 % of them working with seasonal breeding to avoid having lactating cows during the driest month of the year, where the scarcity of feed resources, combined with the additional physiological demands of lactation, could put their lives in jeopardy. Only four farms were part of an artificial insemination program. As seasonal breeding requires a more intricate management plan and higher personnel costs, only 9 % of the farms with <150 ha had implemented it, compared to 55 % of the farms with >150 ha. In those farms, cows were mated so the calves could be born after the first rains of May. Weaning was done at 5 to 8 months of age, and most calves and heifers were thus sold before the start of the dry season. For farms that did not implement seasonal breeding, cows with calves were usually not allowed to enter the forest and were supplemented separately from the rest of the herd, to ensure a proper nutrition and avoid the smaller calves to be prey to coyotes, big cats and thieves. In those farms, the animals entering the forests were thus pregnant cows, bulls, and weaned calves and heifers.

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Beef fattening/finishing farms buy adult cattle and raise those up to slaughter weight. Some fattening farms were present (6 farms, 14 % of farms), but they were not a preferred type of cattle production, as the weight loss during the dry season usually would nullify all the weight gained during the rainy season. Consequently, cattle fattening is usually done as a side activity to complement other beef production modalities. As fattening allows some flexibility, cattle can be bought from auction markets when green pastures are available and sold for a profit at the beginning of the dry season. Hence, half of the farms dedicated to fattening drastically reduced their herd size as soon as the rains stop, leaving only a small number of cattle for pasture maintenance. Farms that kept fattening cattle during the dry season usually keep animals in pens and are heavily supplemented when pastures are dry. Only one of those farms purposefully brought cattle under a high tree cover.

Dairy farms focused on milk production, usually raising the heifers for replacement of older cows. Dairy farms were few (5 farms, 12 % of all farms), and only two of them sold milk to the national market through Dos Pinos, the main Costa Rican dairy farmers' cooperative. Both farms have a strong supplementation program to maintain milk production during the dry season and did not allow cows to go into the forest due to the demanding logistics of milking twice a day. Alternative feeding strategies were also capital in dairy farms due to the necessity of maintaining cows in lactation, forcing the farmers to let cows give birth at the peak of the dry season. Dairy cows were not of a dominant breed, but rather of *Bos indicus* dairy breeds (Gyr/Guzerat), *Chumeca* (Jersey x Holstein) and *Bos taurus* x *B. indicus* crossbreeds.

Dual-purpose farms were dedicated both to milk and meat production. Those farms had cross-bred dairy x beef cattle to provide a good value for the carcass when cows are slaughtered, but with lower milk production than specialized dairy cows.

Not even two farms were the same in terms of management, structure and feeding strategies. However, farms on the slopes of the volcanic cordillera, and particularly around the village of Cañas Dulces, were smaller than farms in the plains of Liberia County, had a larger proportion of pastures, and fewer forests on the farm (**Table 1**). In addition, almost all farms in Cañas Dulces managed a small area of crops for self-consumption or local markets, while crop areas in the plains were dedicated mostly to commercial production of sugar cane, rice, or corn. This difference could be explained by some historical and cultural background. As a farmer from the village explained, Cañas Dulces was founded by rural families looking for a piece of land to settle and live from subsistence agriculture. Historical literature confirms this claim. As explained by Cabrera (2007)**,** the set of land laws "*Leyes de Cabezas de Familia*" (laws for Heads of Families), promulgated at the beginning of the 20th century, that allowed citizens to occupy and claim public land gave rise to the idea that any uncultivated land was claimable. In addition, the poorly defined limits of big farms created some confusion in determining which area belonged to whom. As a result, many families settled on the least used areas of big farms, on the mountain slopes, giving birth to violent land conflicts between farms and squatters over the years (Cabrera, 2007)**.**

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Cañas Dulces' farmers, hence, come from a subsistence agriculture background and directly live and depend on their farms. This is a harshly different context from El Triunfo in the plains, where farms are bigger and belong to old ranching families. Most villagers of El Triunfo are farm workers and administrators, while people of Cañas Dulces own their land. Seventy-five percent of interviewees in Cañas Dulces were owners, living in or close to their farms, while only 48 % of interviewees in El Triunfo were owners. There are small farms around El Triunfo; however, those originated mostly from the more recent fragmentation of large farms, and few owners of those farms have cattle ranching as their only source of income. The social tissue in Cañas Dulces was also denser, and the local producers' association had managed to implement a community irrigation system for cattle and crops. In addition, while the herd in most beef farms in the plains were almost exclusively Brahman or Nellore cattle, only in five farms on the slopes of the volcanoes the animals were purebred Brahman. Other herds were composed of a mix of zebu cattle and dual-purpose cows.

Table 1. Comparison between mountain farms on the slopes of the Rincon de la Vieja volcano (Upland), Liberia farms (Peri-Urban) and farms in the plains of Liberia County in terms of mean farm size, proportion of pasture areas on the farm (Ppasture), proportion of forest (Pforest) and herd size. Other minoritarian uses (plantations, crops, and so forth) are not represented.
Cuadro 1. *Comparación entre fincas en las pendientes del volcán Rincón de la Vieja (Upland), fincas en Liberia (Peri-Urban) y fincas en las llanuras del cantón de Liberia por tamaño de finca, proporción de pastos en la finca (Ppastures), proporción de bosque (Pforest) y tamaño del hato. Otros usos minoritarios (plantaciones, cultivos…) no están representados.*

Location	n	Farm size (SE)	Ppastures (SE)	Pforest (SE)	Herd size (SE)
Upland	13	116.19 (90.01)b	0.78 (0.07)a	0.11 (0.06)b	121 (46.05)a
Peri-Urban	5	126.2 (145.14)ab	0.50 (0.10)b	0.30 (0.10)a	78 (74.26)a
Plains-Countryside	24	387.5 (66.25)a	0.60 (0.05)b	0.28 (0.04)a	156.42 (33.89)a
P-value		**0.0392**	**0.0375**	**0.0673**	**0.5873**

*Note.*Values in the same column with same letters are not statistically different (p>0.1). SE= Standard Error.

Small farms in any location experienced the same space challenges: in a small portion of land, one must be able to stock a herd big enough to support a family's financial needs, forcing farmers to maximize the number of animals per hectare, and, hence, the amount of pasture space. Therefore, small farms had either a significantly smaller proportion of forests, or managed forests to increase the forage output by either replacing the understory layer with improved pastures or selecting the understory vegetation to only leave plants edible by cattle in 12 % of farms.

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3.3 Dry Season Season Feeding Strategies and Cattle in Forests

3.3.1 Pasture management

Pastures remain the main source of feed for cattle in the dry season, although supplementation is needed to make up for the decrease in pasture availability and quality. Not all pastures were equal in terms of drought resistance once the dry season started. Jaragua grass (*Hyparrhenia rufa*) has been the preferred pasture in the region since its introduction in the 1920s when it replaced native grasses in the Guanacaste landscape (Janzen & Hallwachs, 2016). This tall savanna grass has poor nutritive value and low palatability when dried, and requires heavy grazing and a short pasture rotation cycle to maintain an acceptable condition for grazing (FAO, 2016). Jaragua dries early in the dry season, and without appropriate management becomes both an unpalatable pasture and a highly flammable fuel, which tempts farmers to use fire to trigger resprouts. Although still heavily present in the landscape, jaragua is disappearing, being dominant in only 11 farms (**Table 2**). It is progressively being replaced by improved pastures, and mostly by *Brachiaria* species, in particular *B. brizantha* (dominant in 21 farms), as well as *Andropogon gayanus,* a more nutritive and drought resistant cousin of jaragua, (FAO, 2016). *B. brizantha* was often mixed in pastures with other *Brachiaria* species.

Many other pasture types were found in the farms, some as farmers' tryouts of promising pastures varieties and combinations, some others as horse pasture in small areas (*Digitaria eriantha cv. Transvala, Dichanthium aristatum)*, and some others for hay production (e.g., *Brachiaria* sp., *Digitaria eriantha cv. Transvala)*.

Table 2. Presence and dominance of pastures in farms. All results add to more than 100 %, as several pastures could be present in farms, and that dominant pastures were often mixed in paddocks or several pastures represented a high cover of pasture areas.
Cuadro 2. *Presencia y dominancia de pasturas en fincas. Los resultados llegan a más de 100 %, ya que varias pasturas podían encontrarse en fincas, y que las pasturas dominantes a menudos estaban mezcladas en potreros, o que varias pasturas representaban una alta cobertura del área de pastos.*

Common name	Scientific name	Present (%)	Dominant (%)
Andropogon	*Andropogon gayanus kunth*	33	12
Angleton	*Dichanthium aristatum*	16	7
Brachiaria brizantha	*Brachiaria brizantha*	72	49
Brachiaria decumbens	*Brachiaria decumbens*	23	16
Brachiaria dictyoneura	*Brachiaria dictyoneura*	5	2
Brachiaria humidicola	*Brachiaria humidicola*	2	2
Brachipara	*Brachiaria hybrid (B.arrecta x B.mutica)*	2	0
Caiman	*Brachiaria hybrid cv. CIAT BR 02/1752*	2	2
Desmodium	*Desmodium spp.*	2	0
Estrella africana	*Cynodon spp.*	5	0

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Common name	Scientific name	Present (%)	Dominant (%)
Guinea	*Panicum maximum*	2	2
Guinea Masai	*Panicum maximum cv. Masai*	2	0
Guinea Mombasa	*Panicum maximum cv. Mombasa*	19	12
Jaragua	*Hyparrhenia rufa*	40	26
Kudzu tropical	*Pueraria phaseoloides*	2	0
Mulato	*Brachiaria hybrid 36061 cv. Mulato*	7	5
Stylosanthes	*Stylosanthes spp.*	2	0
Swazi	*Digitaría swazilandensis*	5	0
Transvala	*Digitaria eriantha cv. Transvala*	12	0

Improved pastures tend to dry later in the dry season, according to farmers and available literature (FAO, 2016), and their higher nutritive value and palatability was said to reduce the necessity for supplementation, including browsing in forests. However, even though improved pastures tend to be more drought resistant, the proportion of farms with improved pastures, which also allowed cattle to enter the forests, was similar to the rest of farms. The month of cattle entry in the forest followed the seasonal pattern of pastures drying, independently of their resistance to drought, as shown in **Figure 2.**

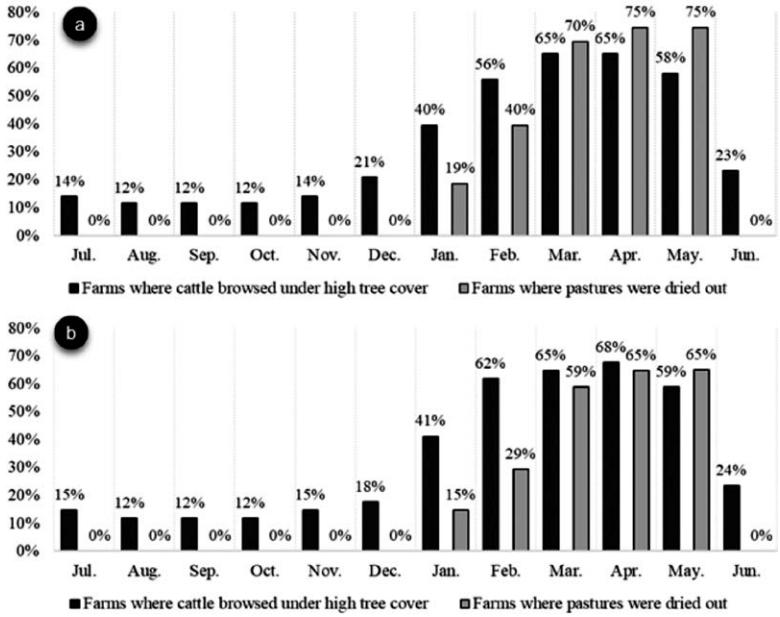

Figure 2. Chronological relationship between the proportion of farms allowing cattle to enter forests and the proportion of farms with dried-out pastures, for all farms (a) and farms with improved pastures (b).
Figura 2. *Relación cronológica entre proporción de fincas dejando su ganado entrar al bosque y proporción de fincas con pasturas completamente secas, para todas las fincas (a) y fincas con pasturas mejoradas (b).*

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However, improved pastures were sometimes used as a management strategy to avoid having to put cattle in the forests for survival. One farmer declared: "The idea for [our] farm is to have pastures that are good enough, so we do not have to bring our herd into the forest." Twenty-five percent of farmers declared that their pastures did not fully dry during the dry season, but the decrease in pasture's availability impacted sufficiently cow nutritional input to justify entering the forest. The months from March to May were the most critical, regardless of the type of pasture. In the last months of the dry season, two farmers stated that cows had to be removed from the forest to be supplemented, as the forest did not provide enough feed to maintain cattle in a healthy state, and walking long distances in search of feed depleted the energy of the cows. In total, 70 % of farms did bring cattle into the forest as a feed supplementation strategy, but in the critical months of March to May, only 65 % of farms had their cattle in forests for the reasons mentioned previously. On the contrary, others preferred to wait one month or two after the first rains before restarting a fully pasture-based diet, and let cows return from the forest, to allow for pastures to regrow.

Eight farms had implemented a rotational grazing system where small paddocks were grazed under high stocking rates for one or two days, with a total rotation time of approximately 30 days. Seven of them used improved pastures. The two dairy farms that sold milk to the Dos Pinos cooperative had implemented this system. All other farms had either a longer rotation time (between two and three months for a complete rotation) with bigger paddocks or had a lower number of animals in few paddocks. However, five farmers mentioned their desire to implement a more intensive (shorter) rotation system to intensify pasture use and increase the stocking rates. Some said: "We want to manage a beef cattle farm like a dairy farm because, today, we need to produce more with less." Rotational grazing was stopped during the dry season because of the decline in pasture; hence, 21 farms opened all paddock gates at the beginning of the dry season to allow cattle to find food wherever it was available. This practice was independent of farm size. Farms with a shorter rotation interval tended to maintain the same rotation during the dry season, except two.

Forests in farms were often part of the pasture areas, with several paddocks including a small portion of forest. When the forest was part of the paddocks, cattle were free to enter the small portions of forests year-round; but, according to farmers, cattle only tended to enter those forests during the dry months of the year, preferring green pastures to wild vegetation and legumes during the rainy months, which is a widely demonstrated behavior (see Lascano, 2000), and being deterred from entering forests because of the dense understory vegetation sprouting with the first rains. When only part of the forest was included within pastures, cows were only allowed access to the parts of the forest within the paddocks. In two farms where the forest was part of the paddocks, farmers stated that cows would not enter the forest on their own will during the dry season because paddocks had a high density of fruit trees that provided both feed and shade, in addition to other kinds of feed. This is a strong argument for fostering the planting

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of dispersed trees in paddocks, as these appeared to be a sufficient substitute to forests for cattle, without the drawbacks of forests, although this substitution must be further researched.

When the forest was fenced away from the paddocks, there were diverse reasons for this separation. Some farmers had fenced their forests so cattle would not enter to protect the integrity of the forest, or springs and streams, but the most common reason for fencing was to prevent cows from entering the forest and getting lost or stolen, or disrupting the rotational grazing plan during the rainy months. However, during the dry season, farms that used forest browse either opened the paddock gates to the forest at the same time as they stopped regular rotation, or put cattle entirely in forest patches, enclosing them in forests as extensive separate paddocks.

3.3.2 Feeding strategies

A big part of farm work in the last months of the rainy season consisted in harvesting and stocking up on various types of feed resources to prepare an adequate feeding strategy for cattle during the dry season. The main feed types provided in the dry season were the following:

- All farmers used salt and minerals all year-round. This feed type was left aside from further analysis as the interview did not inquire about the type of minerals used.

- Sixty per cent of farmers used hay bales and were the most common type of feed aside from the use of forests for browsing. Smaller farms tended to buy or exchange bales, while bigger farms usually had a reserved area of pastures for haymaking, in specialized paddocks within the farm or in a separate area. The most common source of hay were rice straw or grasses such as *Digitaria eriantha cv. Transvala* or *Digitaria swazilandensis.*

- Twenty-three farmers used molasses by as a source of energy, often in combination with hay, to encourage cattle to eat it, although there was no pattern of association between both feed resources.

- Silage was used in seven farms, mostly in the upland area.

- Fodder banks (fodder trees and grasses for cut-and-carry purposefully planted for use by cattle) had been implemented in 14 farms, nine of them in the surroundings of Cañas Dulces. There was some overlap of farms using fodder banks and silage, as all or part of the fodder banks were used for silage in 43% of the farms having fodder banks. Other farms provided the fodder bank materials, whole or chopped.

- Cattle were fed with fruits and branches from trees in a similar modality to fodder banks in eight farms. The distinction with the previous category was that cattle feeding was not the primary purpose of the resources, but rather an opportunistic use of trees in paddocks or agricultural byproducts. Branches from trees in pastures or from the forest were pruned and used to feed cattle. Fruits were directly eaten by cows from fruit trees planted in pastures

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where cattle were brought purposefully (e.g., mangoes, fruits from the *Acrocomia aculeata* palm tree). Four farms provided citrus pulp brought from a nearby orange plantation.

- Six farms, located mostly in the plains, used poultry manure as a protein supplement, although the Costa Rican Ministry of Agriculture and Livestock (MAG) does not recommend this practice because of potential health risks (Oscar Alvarez, Pers. Comm.).

- Concentrates were used in seven farms. Three of them were dairy farms, and one was a dual purpose farm; they fed their cattle with concentrate to maintain milk production during the dry season. Other farms only provided concentrates to weaned animals, or to the weakest cows. The low number of farms using commercial concentrates might be due to the high prices of these products in the market, forcing farmers to adopt other strategies. One dairy farmer had successfully developed his own concentrate formula.

Farms could not be grouped into distinct types of feeding strategies because feeding practices were extremely variable and heavily dependent on each farm's structure, purpose, and owner's knowledge. All correlation analyses performed between feeding strategies and forest browsing were not significant. Moreover, as sometimes more than one production group was present in the farms, different feeding strategies were used based on cattle age, production purpose (i.e., beef or dairy), and physical condition. However, we could find a difference in feeding strategies between farms located in mountains and plains (**Figure 3**). Farms in the plains relied more on hay and molasses, while fodder banks and silage were more common in upland farms. No poultry manure was used as supplement in upland farms. This might be due to the difference in soil types (Bergoeing, 2017), where upland soils have greater aptitude for agriculture, the existence of a subsistence farming, irrigation, or the extent of technical support of the Ministry of Agriculture. In the Cañas Dulces area, MAG provides more assistance to small and subsistence farmers to help them implement good animal husbandry practices (Oscar Álvarez, MAG, Pers. Comm.).

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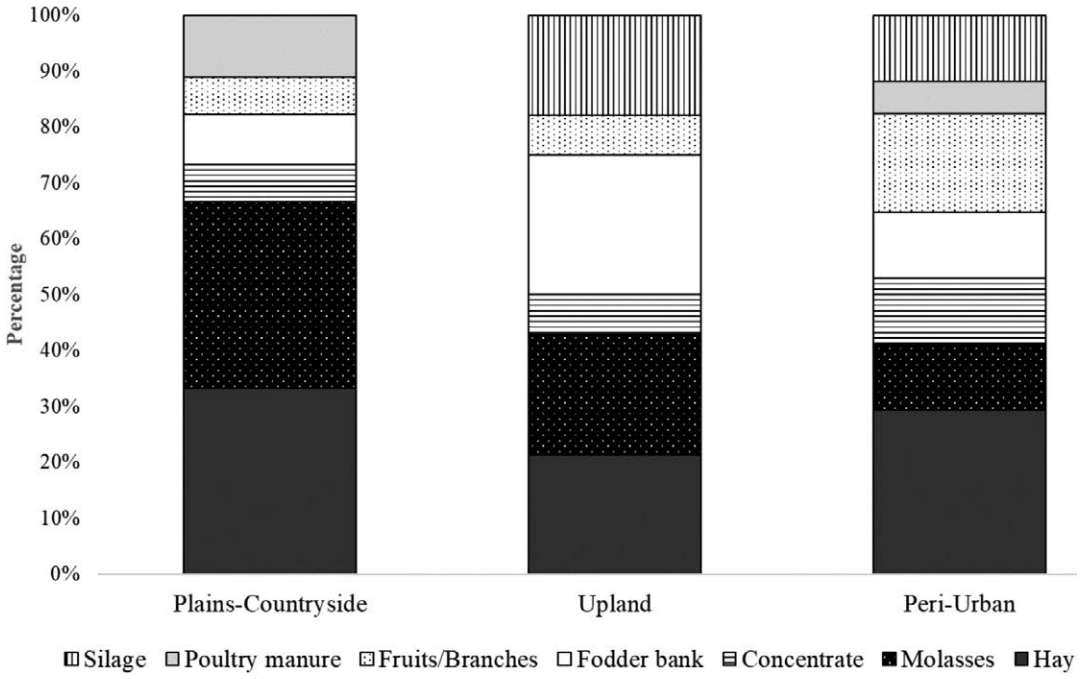

Figure 3. Proportion of each feed resource provided to cattle on farms for the three categories mentioned in **Table 1**.
Figura 3. *Proporción de cada tipo de alimentación dado al ganado en fincas de las tres categorías mencionadas en* ***Cuadro 1.***

The type of feeding strategy and amount of feed type used might have an impact on the need for cattle to benefit from another supplement, including the use of forests. For example, the feeding behavior of cattle in forests can be influenced by nutrient deficiencies, causing, in some cases, cows to eat wood, soil, plastic, and unpalatable or even toxic plants. One farmer mentioned that it is common in the area that cattle with nutrient deficiency would eat pieces of plastic or chew on posts. This behavior disorder is known as Pica or allotriophagia (Elshahawy & Aly, 2016). These considerations highlight the need for a more thorough analysis of the feeding strategy applied and the quantity of supplements provided to cattle by age and production systems in order to understand the need for using the forest as part of the dry-season feeding regimes.

3.4 Factors That Affect the Decision to Put Cattle in Forests

Farmers were asked about the benefits and drawbacks of using forest browsing by cattle as a dry season feeding strategy, as an open-ended question with multiple answers possible. Reasons given by farmers were classified into three categories: management, animal welfare, and ecological impacts (**Figure 4**).

Forest browse benefits were cited 77 times, while drawbacks were cited only 48 times, with a more diverse number of reasons. As expected, the value of forests as a source of food and shade

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were the most cited and most important benefits. The improvement in animal well-being overpowered the threats found in forests, such as wounds, parasites or animal attacks. One farmer said: "We have a contract with the jaguar; we give it one cow a year, this is better than having cows dying under the sun." However, in some cases farmers mentioned that the energy lost by cattle while walking to or within the forest canceled the positive effects of the forest browse. Most farmers preferred to maintain cows close to water and to feed them during dry season—even if it was scarce—rather than to put them in forest patches without a water source nearby.

Ecological impacts of browse were not usually considered as a factor of importance, with a few exceptions of interest. Forest browse is often cited as an efficient way to reduce fuels in the forest, making fire more manageable and ensuring that fires affect only the forest floor and do not affect the canopy of the forest, which we will call the fire control model. Fire is a prominent threat in Liberia County; it had affected 30 of the farms where interviews were held. Fires are started by criminal activity or arson for "recreation" (according to 33 % of farmers), agricultural burning (30 %), hunters (23 %), or various accidental reasons (28 %); as farmers provided more than one reason, the total is higher than 100 %. Hence, farmers considered cattle's work "cleaning the forest" as an important secondary benefit of this practice because it protects forests against wildfire, maintains firebreaks, and creates new ones as they make their path in the forest.

The fire control model has been criticized by some for the damages caused to tree regeneration (Stern, Quesada, & Stoner, 2002). Farmers were divided on this matter. Ten agreed that regeneration was impaired by browsing cattle. At the same time, seven sustained that, as cattle selected native grasses, other herbaceous plants, and strangling vines over saplings, tree regeneration was improved by the lack of competition**.** The negative impacts of the alleged forest degradation on farmers's decision were increased by the fact that three farms had forest patches registered in Payment for Ecosystem Services (PES), which forbids this practice in those forests for such reason. This disparity of opinions shows the complexity of a subject which has been little studied and might be depending on many factors such as the variation in browsing pressure related to animal stockings, and forest composition and structure, among other factors.

The factors of the strongest impacts on farmers' decision to keep their cattle away from the forest were related to herd and farm management. Even though the negative effect of cattle on regeneration was the most listed drawback, the risk of cattle theft and the difficulty of managing a cattle herd in a forest were strong deterrents for farmers, and were usually the principal reasons cited for not putting cattle in forests during the dry season. Cattle theft has become a real issue, affecting all cattle farms but mostly the ones close to cities and settlements. In total 26 % of farmers mentioned that they had been victims of cattle theft, and 4 out of 5 farms interviewed in peri-urban Liberia had to bring cattle into pens every night to avoid cattle theft. As described by farmers, cattle thieves usually kill and butcher cows on the spot, taking only the most valuable cuts with them. One of the interviewees mentioned that up to four cows were killed in one night. The Cattle Ranching Federation of Guanacaste (FCGG) has acknowledged the issue and gives classes and workshops on how to adapt farm management to avoid cattle theft.

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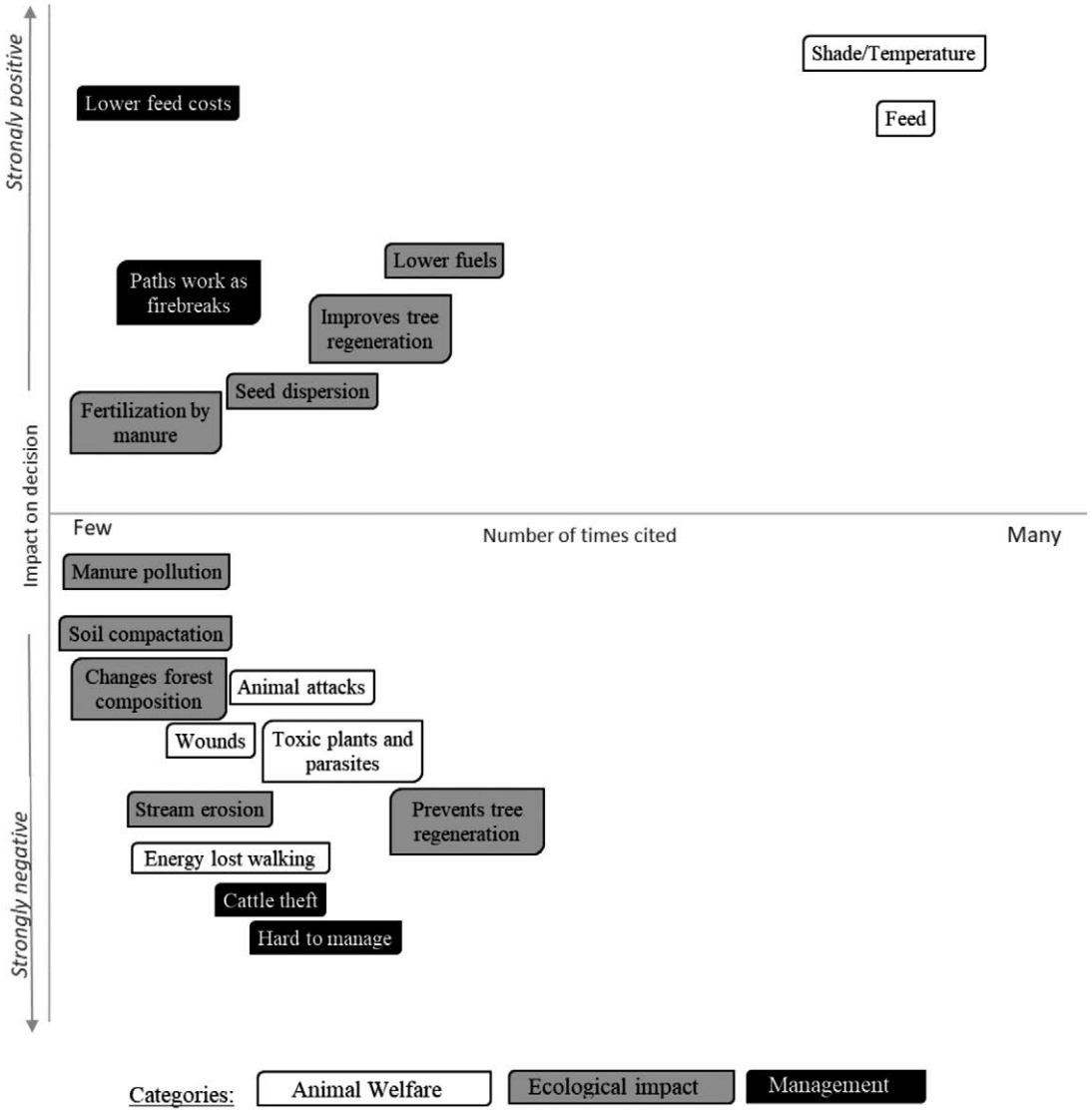

Figure 4. Benefits and drawbacks of dry season forest browsing according to farmers (n=43), and their relative impact on farmers' decision to implement or not this practice. Impact on decision was graded arbitrarily based on farmer's perception of each reason's importance in their decision making. A benefit or drawback that was cited by farmers as crucial would receive the highest score on a scale of 1 to 10, while one that did not matter at all for the farmer would receive a low score. Results were averaged and provided the placement on the Y axis.

Figura 4. *Ventajas e inconvenientes del ramoneo en bosques según los ganaderos (n=43), y su impacto relativo sobre la decisión de ganaderos de usar o no esta práctica. El impacto sobre la decisión fue graduado arbitrariamente, basado en la percepción del ganadero de la importancia de cada razón en su toma de decisión. Una ventaja o inconveniente citado como crucial por el ganadero fue calificado con el puntaje máximo en una escala de 1 a 10, y un puntaje bajo si no importaba. Los resultados se promediaron y se usaron para ubicar las razones en el eje Y.*

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Cattle in forests can easily escape or get lost. Feral cows are common in large forested areas where they can escape and sometimes live for several years in the forest before getting caught or killed. To avoid this situation, farmers either forbid cattle's entry in forests, or trained cows to come out of the forests by feeding them on the outer edges of the forest. Farmers also gathered cattle from a daily to fortnightly basis to check and count them, as well as to maintain them used to human contact. Only two farms had a cowboy who constantly stayed with the herd and followed them in the forest, while some farmers admitted to never enter the forest.

It seems that the decision to use or not the option of bringing cattle into forests could be due to a farmers' choice of to favor an efficient farm management over animal welfare or vice versa, based either on personal decision, familiarity with this practice, or farm management constraints. Browse in forests could help to reduce feeding costs but increase other management costs. Due to the intensification of farm management, forest browsing could be abandoned progressively to allow for more controlled practices, but more frequent droughts and increasing costs of dry season feeding strategies could also lead farmers to rely more heavily on low-cost alternatives like this practice. The farmer who mentioned his objective was to improve pastures as a means to avoid bringing his herd to the forest admitted in a further encounter that, after a difficult 2019 dry season, his cattle would not have survived without having access to the forest. These experiences show that climate change can delay the transition of farms to more intensive practices, and that cattle browse might stay a prominent way for farmers to deal with droughts in the region at a lower cost.

3.5 Cattle Behavior in Forests

3.5.3 Herd behavior and distribution of cattle in forest

When asked about how cattle behaved while in the forest, farmers provided most of the time a wide variety of answers, often contradictory and without a clear majority prevailing. We were unable to address most of these contradictions based solely on the farm management data collected through the semi-structured interviews, meaning that either cattle behavior was highly variable depending on ecological and structural factors proper to each forest that were outside of the scope of this study or farmer knowledge on cattle behavior in forest was quite rudimentary and based on a small number of personal observations.

Most farmers that allowed cows to enter the forest or had actively included forest browsing as a dry season feeding strategy (n=30) indicated that cows tended to use the complete extent of forest patches (80 %, n=25), while the rest indicated that cows only used the edges or parts of the forest, staying closer to rivers, drinking or feeding points. All farmers that expressed themselves (n=22) agreed that cows created "paths" between preferred spots, namely forest edge, rivers and streams, common resting places under high tree cover with low understory vegetation, and patches with predominance of fruit trees. In most farms, cows were said to regroup to ruminate

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and rest at a defined place in the forest common to all groups of cows. Cows did not always spend a whole day within a forest patch, preferring to enter during the hottest hours of the day, between noon and sunset time, as observed by Espinoza (2012) or Garcia-Cruz, Ibrahim, & Pezo (2013). Cattle were said to have a lasting memory of preferred spots in the forests and go back to the same spots year after year, reopening the same path as the years before, or using the man-made firebreaks. Of course, as preferred and most accessible fruit trees remain static through the years, cattle would be bound to find the same preferred areas every year, but this behavior can have implications on how cattle impacts are distributed in a forest, with the same parts of the forest receiving animal load every year, thereby, affecting the structure and composition of those areas only. Farmers had mixed responses regarding the size of cattle groups within the forest. The most common response was that once in the forest, the cattle herd would either split into several groups (61 %, n=23), stay as one herd (22 %, n=23), or behave as solitary individuals roaming the forest separately (17 %, n=23). This behavior was not dependent on the size of the herd or the size of the forest.

3.5.4 Plants preferred and avoided by cattle, cattle selectivity and impacts on the forest

Farmers cited 94 plant species that were either preferred, avoided, or harmful to cattle when eaten. The complete list of all plants identified is provided in **Appendix 2**. Despite the high number of plants identified, most of them were the trees traditionally associated with cattle ranching in dry regions of Costa Rica (**Table 3**). Most farms in Costa Rican Northwest include guácimo (*Guazuma ulmifolia*), guanacaste (*Enterolobium cyclocarpum*), and cenízaro (*Samanea saman*) trees in pastures, as it is of common knowledge that these trees provide nutritious fruits during the dry season. Farmers also mentioned "Madero negro" (*Gliciridia sepium*), a Fabaceae known worldwide for its value as forage and widely used as live fences in Costa Rica due to its capacity of resprouting from branches once planted as a post (Pezo & Ibrahim, 1998)**.** The "bejuco engordador" ("fattening vine", *Calopogonium mucunoides*) and "batatilla" (*Ipomoea* sp.*)* were the most cited non-woody plants, also growing in pastures and widely known as forage sources**.** Another poorly known key species for cattle nutrition is the oak (*Quercus oleoides*); only one of the farms that had a patch of oak forest moved cattle in it, where part of the herd was sustained solely on its acorns during the whole dry season.

Almost all cited plants could be found either in open pastures, forest edges or forest. Among the top, 20 plants (See **Table 3**) were also "domesticated" trees, such as *Mangifera indica* or *Gmelina arborea*, which were admittedly of importance for cattle nutrition in the dry season. Overall, plants that did not thrive outside of forest were little listed by ranchers. Forty-five plants were only cited once as eaten by or harmful to cattle. This points to the conclusion that there does not seem to be an extensive shared knowledge on edible forest plants by cattle, but rather a set of personal curiosity, observations and experience that vary a lot between farmers.

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Table 3. Twenty plant species most mentioned by farmers. Number of times mentioned are reported for parts of plants considered by farmers as eaten by cattle (E), avoided (A) or harmful to the animal (H).
Cuadro 3. *Veinte especies de plantas más mencionadas por ganaderos. El número de veces mencionado se reporta para plantas consideradas como Comida (E), Evitada (A) o Dañina (H) para el ganado.*

Common name	Scientific name	Life form	Part	E	A	H	Grows in
Guácimo	*Guazuma ulmifolia*	Tree	Fruit	33			Pastures/Forests
Guanacaste	*Enterolobium cyclocarpum*	Tree	Fruit	23		5	Forests/Pastures
Cenízaro	*Samanea saman*	Tree	Fruit	20		10	Forests/Pastures
Guácimo	*Guazuma ulmifolia*	Tree	Leaf	20	1		Pastures/Forests
Madero negro	*Gliricidia sepium*	Tree	Leaf	19	1		Pastures/Forests
Bejuco engordador	*Calopogonium mucunoides*	Liana	Leaf	16			Pastures/Forests edges
Josmeca/Ajillo	*Mansoa hymenaea*	Liana	Leaf	13		13	Forests
Escoba morada	*Melochia villosa*	Grass	Leaf	10		10	Pastures
Batatilla	*Ipomoea trifida*	Liana	Leaf	7			Pastures
Mango	*Mangifera indica*	Tree	Fruit	7		1	Domesticated
Coyol	*Acrocomia aculeata*	Palm	Fruit	6			Pastures/Scrubland/Forests
Encino	*Quercus oleoides*	Tree	Fruit	6			Pastures/Forests
Jobo	*Spondia mombin*	Tree	Fruit	6		1	Forests/Pastures
Escoba Amarilla	*Sida acuta*	Grass	Leaf	5	1		Pastures
Gmelina	*Gmelina arborea*	Tree	Fruit	5			Domesticated
Gmelina	*Gmelina arborea*	Tree	Leaf	5			Domesticated
Picapica	*Mucuna urens*	Liana	Leaf	5			Scrubland
Amapola	*Malvaviscus arboreus*	Shrub	Leaf	4			Forests/Scrubland
Aromo	*Acacia farnesiana*	Shrub	Leaf	4	1		Pastures/Scrubland
Cortez amarillo	*Handroanthus ochraceus*	Tree	Flower	4			Forests/Scrubland

Cattle were said to be little selective on which plant species to eat: 71 % of the farmers that put cattle in forests and expressed their opinion on the matter (n=24) estimated that "cattle would eat anything in their reach when they are hungry enough", and that animals would mostly eat shrubs, climbing plants and understory grasses, leaving the forest understory "clean." Few ranchers knew names of understory plants that were not trees. A common answer was, "Cows eat everything, but who knows the name of all those plants". The use of the word "charral" (scrubland) by farmers to describe understory in forests, which is the same word used with a negative connotation to describe abandoned pastures with woody regeneration, is a lexical hint of the little interest farmers give to this layer of the forest. Sixty-eight percent of farmers (n=25) said cattle ate leaf litter in forests, further contributing to reducing fire risk in those forests.

Some potentially harmful plants were identified. Again, many of those plants were marginal in forests, and were found mostly in pastures. *Mansoa hymenea* and *Petiveria alliacea,* which grow in forests, spoil cow's milk with a strong garlic smell and taste. The presence of

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these species was a deterrent for dairy producers to allow animals to enter the forest. Some producers cleared toxic plants by hand in the forests and pastures, but for most of them occurrence of cattle death following plant ingestion was too low to justify such demanding and costly management practice. *Samanea saman* and *Enterolobium cyclocarpum* seeds were widely mentioned as abortive, although less than expected; their abortifacient properties are part of the region's traditional knowledge. This is due to the facts that while cattle eat fallen fruits from those trees, few farmers had experienced cattle miscarriage following ingestion. As explained by two farmers who experienced said effect on their herd and subsequently avoided letting cattle browse in areas with high concentration of those species, those effects only appeared when excessive consumption happened, e.g., when a tree fell down, allowing cows to feed entirely on those seeds.

4. Conclusions

Farmers of Liberia County are facing a challenging situation as droughts and market pressure force them to find low-cost alternatives for cattle dry season feeding. Thus, browse in forests was the most common type of dry season feeding strategy in farms. The practice was mostly used in cow-calf and cattle growing ranches, but this paper did not find feeding profiles or particular types of feed associated with that practice. This highlights the complexity of cattle farm management in Liberia County and the dry regions of Central America in general, as well as the necessity for researchers to understand decisions taken in each farm based on resource availability and objectives. More detailed research, with a larger number of farms, is needed to understand the relationship between forest browsing and the role of other dry season feeding strategies applied.

The benefits of using forests for browse listed by farmers were mostly related to animal well-being. Farmers believe that this strategy contributes to improving cattle's ability to cope with heat stress and lack of feed during the dry season. Drawbacks associated with this practice were mostly the complications incurred in farm management.

A topic that remains unclear is the ecological impact of cattle on forests; this impact was deemed positive by some farmers, and negative by others. Farmers' knowledge about cattle's behavior in and their impact on forests is variable, and often restricted to behaviors observed at forest edges or in pastures. This subject is poorly covered in scientific literature and needs an ecological study to assess the cattle's impact on the structure, diversity, and composition of the secondary dry forest. If it is demonstrated that cattle browsing does not affect forests significantly, such practice would be a great example of ecosystem-based adaptation; it could also be improved and integrated by local policymakers into a local climate change adaptation plan for the years to come. In case the impact is deemed negative for the ecosystem services provided by the forests, better low-cost dry-season strategies need to be encouraged by local entities. Silage, fodder banks or an increased proportion of dispersed fodder/fruit trees in paddocks could be options for reducing farmers' dependence on forests, but the cost-effectiveness

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of such options needs to be assessed in any further research regarding farm management or climate change adaptation.

This study has shown that seasonally dry forests are an important component of cattle ranching in northwestern Costa Rica, despite being often ignored when studying farm management in the region. We recommend that all further studies on cattle ranching in seasonal areas must take on-farm forests into account.

5. Ethics and Conflict of Interest

The authors declare having fulfilled all relevant legal and ethical requirements during the study, as well as during the preparation of the manuscript. They also declare that there are no conflicts of interest of any nature, that all financial sources are fully and clearly mentioned in the acknowledgments section, and that they fully agree with the final edited version of the article.

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8. Appendices

Appendix 1. Interview questionnaire (Spanish).
Apéndice 1. *Cuestionario de entrevista.*

Nombre del encuestado: _____
Finca: _____
Fecha_____/_____/_____/
Contacto: _____

Buenos días. Mi nombre es Florent Godinot. Soy estudiante del CATIE de Turrialba y estoy aquí con el objetivo de entrevistarle, para conocer su finca, el bosque que tiene y su hato. Esta información me va a servir para mi tesis de maestría, que tiene como objetivo de conocer cómo se maneja el ganado aquí en verano, y como el bosque es parte o no del manejo. Para eso necesito saber cómo la gente de aquí maneja su ganado en verano, y como hace uso del bosque. Esta entrevista puede durar alrededor de 30 minutos. Su participación en esta conversación es totalmente voluntaria, si no desea participar o si existe alguna pregunta que no desea contestar puede decírmelo sin ningún problema. Si en algún momento se incomoda y no quiere continuar, por favor me lo hace saber. Su respuesta es anónima, esta será estudiada en conjunto y no se analizará en particular.
En caso de que mi pregunta no sea clara o desee una explicación adicional no dude en preguntarme. Durante la entrevista estaré tomando notas y fotografías para no perder la información y poder analizarla, quiero contar con su autorización. Quiero estar seguro de que ha quedado claro que está participando en esta entrevista de manera voluntaria.

1. Cuénteme la historia de su finca y descríbamela.
   a. ¿Cuántas hectáreas tiene esa finca?
   b. ¿A qué actividades se dedica la finca?
   c. ¿Cuántas hectáreas de pastura tiene la finca?
   d. ¿Qué tipo de pasto tiene?
   e. ¿Hay un pasto dominante?
   f. ¿Cuántas hectáreas de bosque tiene la finca?
   g. ¿Qué usos de la tierra tiene? ¿En qué superficie?

2. Descríbame su hato ganadero.
   a. ¿Cuánto ganado tiene?
   b. ¿De qué raza?
   c. ¿A qué tipo de producción sirve su ganado?

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d. ¿Cuántas vacas de cada categoría tiene? (vacas secas, en ordeno, novillas, etc…)
e. ¿Cuánto varía el hato en el ano?

3. ¿Como maneja su finca en el verano?
   a. ¿Cuáles estrategias utiliza usted en su finca para asegurar la disponibilidad de alimento de sus animales en época seca?
   b. ¿Como las pasturas satisfacen las necesidades de las vacas en verano?
   c. ¿De qué otra manera suplementa su ganado en verano?
   d. ¿Entra su ganado en el bosque de su finca?

4. ¿Si pone su ganado en el bosque, cuanto tiempo al año lo deja?
   a. ¿Lo pone cada año?
   b. ¿Queda siempre el mismo tiempo o depende del año?
   c. ¿Que hace que usted decida poner o no el ganado en el bosque?

5. ¿Como maneja su ganado en el bosque?
   a. ¿Cuánto tiempo al día lo deja?
   b. ¿Lo deja suelto o lo tiene en lotes de bosque con cercas?
   c. ¿Lo estabula a la noche?
   d. ¿Quién va al bosque con el ganado?

6. ¿Que come el ganado en el bosque?
   a. ¿Cuáles son las plantas preferidas del ganado?
   b. ¿Cuáles plantas evita?
   c. ¿Cuándo las come?
   d. ¿En el bosque, que come el ganado además de hojas verdes? (frutos, corteza, etc…)
   e. ¿Cuáles especies son malas para el ganado?

7. ¿Dónde se queda el ganado en el bosque?
   a. ¿Hay lugares preferidos por el ganado en el bosque?
   b. ¿Como se desplaza el ganado en el bosque?
   c. Explíqueme como se distribuye el hato en el bosque.

8. Descríbame y cuénteme la historia de su bosque que tiene en su finca
   a. ¿Qué edad tiene este bosque?
   b. ¿Se regenero solo o usted planto especies? ¿Cuales?
   c. ¿Qué especies se encuentran más?
   d. ¿Es un bosque de muchos árboles grandes o de arbustivas?

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9. Háble me de los otros animales se encuentran en el bosque.
   a. ¿Cuáles animales?
   b. ¿Cuáles son los que más hay y cuáles son los que hay menos?
   c. ¿Qué significan para usted y su finca estos animales?

10. ¿Qué otros usos se hacen del bosque?
   a. ¿Aprovecha madera? ¿Cuáles especies?
   b. ¿Busca frutas? ¿Cuáles especies?
   c. ¿Busca forraje para ganado? ¿Cuáles especies?
   d. ¿Busca leña? ¿Cuáles especies?

11. ¿Como manejan el fuego en su finca?
   a. ¿Usted usa el fuego en el manejo de su finca?
   b. ¿A qué época del año?
   c. ¿Con que objetivo?
   d. ¿Con que frecuencia y en cuantos lotes lo hace?
   e. ¿Cuál es el origen de los incendios no controlados?
   f. ¿Usa unas técnicas de control del fuego?
   g. ¿Ha sido incendiado su bosque en los últimos años?

12. ¿Qué piensa que son los lados positivos y negativos de meter su ganado al bosque, y como esas razones influyen en su decisión de hacerlo?

13. ¿Tiene alguna pregunta o algún comentario adicional que le gustaría hacer para que uno entienda mejor como maneja su ganado en temporada seca?

14. ¿A usted le gustaría que venga a hacer un muestreo en su bosque para mi proyecto? (detallar el muestreo)

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Appendix 2. Complete list of plants identified by farmers as Eaten (E), Avoided (A), or Harmful (H) to cattle. Scientific names associated by Roberto Espinoza, parataxonomist for the Área de Conservación Guanacaste (ACG).

Apéndice 2. *Lista completa de las plantas identificadas por ganaderos como Comidas (E) o Evitadas (A) por el ganado, o Dañinas (H) para él. Nombres científicos asociados por Roberto Espinoza, parataxónomo para el Área de Conservación Guanacaste (ACG).*

Common name	Scientific name	Life form	Part	E	A	H	Grows in
Abejón	*Senna pallida*	Weed	Leaf	1	2		Pastures
Almendro	*Andira inermis* or *Terminalia catapa*	Tree	Fruit		1		Forests/Domesticated
Amapola	*Malvaviscus arboreus*	Shrub	Leaf	4			Forests/Scrubland
Aromo	*Acacia farnesiana*	Shrub	Leaf	4	1		Pastures
Batatilla	*Ipomoea trífida*	Liana	Leaf	7			Pastures
Bejuco de fuego	*Desmodium sp.*	Liana	Leaf		1		Scrubland and open forests
Bejuco engordador	*Calopogonium mucunoides*	Liana	Leaf	16			Pastures/Forests edges
Cana silvestre	*Lasciasis sorghoidea*	Grass	Leaf	2			Scrubland and open forests
Canelo	*Ocotea Veraguense*	Tree	Leaf		1		Forests
Caoba	*Swietenia humilis/macrophylla*	Tree	Leaf	1			Forests
Carao	*Cassia grandis*	Tree	Fruit	1	2		Forests/Pastures
Casco de venado	*Bauhinia ungulata*	Shrub	Leaf		1		Pastures and open forests
Cedro amargo	*Cedrela odorata*	Tree	Leaf	1	1		Forests
Cenízaro	*Samanea saman*	Tree	Fruit	20		10	Forests/Pastures
Chaperno	*Lonchocarpus spp.*	Tree	Leaf	3			Forests and open areas
Cinco Negritos	*Lantana cámara*	Weed	Leaf	1		2	Pastures
Cocobolo	*Dalbergia retusa*	Tree	Leaf	1	1		Forests
Contenete	*Acacia tenuifolia*	Shrub	Leaf		1		Scrubland
Cornizuelo	*Vachellia collinsii*	Tree	Leaf		5		Forests/pastures
Cortez amarillo	*Handroanthus ochraceus*	Tree	Flower	4			Forests/Scrubland
Cortez amarillo	*Handroanthus ochraceus*	Tree	Leaf		1		Forests/Pastures
Cortez negro	*Handroanthus impetiginosus*	Tree	Leaf		1		Forests/scrubland
Coyol	*Acrocomia aculeata*	Palm	Fruit	6			Pastures/Scrubland/Forests
Cucharilla	*Amphilophium paniculatum*	Liana	Leaf	1	2		Pastures/Open forests
Cucharilla	*Amphilophium paniculatum*	Shrub	Fruit	1	2		Pastures/Open forests
Encino	*Quercus oleoides*	Tree	Fruit	6			Pastures/Forests
Encino	*Quercus oleoides*	Tree	Leaf		4		Forests/Pastures
Escoba Amarilla	*Sida acuta*	Weed	Leaf	5	1		Pastures
Escoba Lucia	*Sida rhombifolia*	Weed	Leaf	1			Pastures and scrubland
Escoba morada	*Melochia villosa*	Weed	Leaf	10		10	Pastures
Espavel	*Anacardium excelsum*	Tree	Leaf		1		Forests
Flor Amarilla	*Baltimora erecta*	Weed	Flower	1			Pastures and scrubland

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Common name	Scientific name	Life form	Part	E	A	H	Grows in
Fruta de pava	*Eugenia hiraefolia*	Tree	Fruit	2	1		Forests
Girasol silvestre	*Tithonia diversifolia*	Weed	Leaf	1			Semi-Domesticated/Open areas
Gmelina	*Gmelina arborea*	Tree	Fruit	5			Domesticated
Gmelina	*Gmelina arborea*	Tree	Leaf	5			Domesticated
Guácharo	*Semialiarium mexicanum*	Tree	Leaf		1		Forests/Scrubland/Pastures
Guachipelín	*Diphysa americana*	Tree	Leaf	2			Pastures and open areas
Guácimo	*Guazuma ulmifolia*	Tree	Fruit	33			Pastures/Forests
Guácimo	*Guazuma ulmifolia*	Tree	Leaf	20	1		Pastures/Forests
Guaitil	*Genipa americana*	Tree	Fruit	2	1		Pastures/Open forests
Guanacaste	*Enterolobium cyclocarpum*	Tree	Fruit	23		5	Forests/Pastures
Guanacaste	*Enterolobium cyclocarpum*	Tree	Leaf	3			Pastures/Forests
Guapinol	*Hymenea courbaril*	Tree	Leaf		1		Forests
Guayaba	*Psidium guajava*	Tree	Fruit	2			Domesticated
Guayacán real	*Guaiacum sanctum*	Tree	Leaf	1	1		Forests
Higuerilla	*Ricinus communis*	Liana	Leaf	1			River banks
Hoja ancha	*Piper sp.*	Weed	Leaf	1			Shaded forests
Hoja Chigua	*Tetracera volubilis*	Liana	Leaf		2	1	Forests/Pastures
Huesillo	*Casearia sp?*	Shrub	Leaf	1			Forests
Jícaro	*Crescentia sp.*	Tree	Fruit	3		1	Early succession/Pastures
Jícaro	*Crescentia sp.*	Tree	Leaf	4			Pastures/Domesticated
Jobo	*Spondia mombin*	Tree	Fruit	6		1	Forests/Pastures
Jocote	*Spondia purpurea*	Tree	Fruit	2			Domesticated/Wild var. in Forests/Pastures
Jozmeca/Ajillo	*Mansoa hymenaea*	Liana	Leaf	13		13	Forests/Pastures
Kudzu tropical	*Pueraria phaseoloides*	Weed	Leaf	1			Domesticated
Laurel	*Cordia alliodora*	Tree	Leaf	2	1		Forests/Pastures
Madero negro	*Gliricidia sepium*	Tree	Leaf	19	1		Pastures
Madroño	*Calycophyllum candidissimum*	Tree	Leaf		1		Forests/scrubland
Malacaguite	*Chomelia spinosa*	Shrub	Leaf	2			Forests/Open areas
Malva	*Unknown.*	?	Leaf		1		Pastures
Mangle salado/blanco	*Conocarpus erectus*	Tree	Leaf	1			Mangroves
Mango	*Mangifera indica*	Tree	Fruit	7		1	Domesticated
Mango	*Mangifera indica*	Tree	Leaf	2	1		Domesticated
Manteco	*Trichilia americana*	Tree	Leaf		1		Forests and open areas
Manzana Rosa	*Syzygium jambos*	Tree	Fruit	1			Domesticated
Marañón	*Anacardium occidentale*	Tree	Fruit	2			Domesticated
Matapalo	*Ficus sp.*	Tree	Leaf		1		Forests
Melón silvestre	*Agonandra macrocarpa*	Tree	Fruit	3			Forests

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Common name	Scientific name	Life form	Part	E	A	H	Grows in
Mora	*Maclura tinctoria*	Tree	Leaf		1		Open forests/Scrubland/Pastures
Moringa	*Moringa oleifera*	Tree	Leaf	2			Domesticated
Mostrenco	*Prosopis culiflora*	Tree	Leaf		1		Beaches
Mozote	*Triumfetta lappula*	Shrub	Leaf	2			Scrubland
Nance	*Byrsonima crassifolia*	Tree	Fruit	1			Pastures/Open forests
Nance	*Byrsonima crassifolia*	Tree	Leaf		1		Pastures/Open forests
Níspero	*Manilkara chicle*	Tree	Fruit	1			Forests
Ojo de buey	*Mucuna pruriens*	Liana	Leaf	1			Forests
Ojoche	*Brosimum alicastrum*	Tree	Fruit	4			Forests
Ortiga	*Urera baccifera*	Weed	Leaf		1		Pastures/scrubland/forests
Pansa de burro	*Oplismenus burmannii*	Grass	Leaf	1			Forests
Papa miel	*Combretum farinosum*	Shrub	Leaf	1			Pastures/Forests
Pata de venado	*Bauhinia ungulata*	Shrub	Leaf	4			Pastures and open forests
Picapica	*Mucuna urens*	Liana	Leaf	5			Scrubland
Pichi chivo	*Solanum candidum*	Weed	Fruit	1			Pastures/Forest edges
Piñuela	*Bromelia pinguin*	Bromeliaceae	Leaf	3	3	2	Open forests
Poroporo	*Cochlospermum vitifolium*	Tree	Leaf	2			Early succession, Pastures and Scrubland
Poroporo	*Cochlospermum vitifolium*	Tree	Flower	1			Pastures/Scrubland/Early succession
Quiebra machete	*Calliandra sp. or Combretum sp.*	?	Leaf		1		Pastures
Roble sabana	*Handroanthus rosea*	Tree	Flower	1			Pastures
Tamarindo	*Tamarindus indica*	Tree	Fruit	1			Domesticated
Teca	*Tectona grandis*	Tree	Fruit		1		Domesticated
Tempisque	*Sideroxylon capiri*	Tree	Fruit	3			Forests
Totolquelite	*Melanthera nivea*	Weed	Leaf	2			Scrubland
Uña de gato	*Sphinga platyloba*	Liana	Leaf		1		Pastures
Viborana	*Asclepia curassavica*	Weed	Leaf			1	Pastures
Zarza	*Mimosa pigra*	Weed	Leaf	1	1		Forests
Zorrillo	*Petiveria alliacea*	Shrub	Leaf	3	1	3	Pastures and forest gaps