Scientific Paper

Characterization of the pastureland and its management in a Voisin rational grazing system, in Panama

José Miguel Alejandro Domínguez-Escudero[1], Jesús Manuel Iglesias-Gómez[2] *https://orcid.org/0000-0002-9501-1938*, Yuseika Olivera-Castro[2] *https://orcid.org/0000-0002-5330-2390*, Milagros de la Caridad Milera-Rodríguez[2] *https://orcid.org/0000-0001-8531-3425*, Odalys Caridad Toral Pérez[2] *https://orcid.org/0000-0002-5917-3948* and Hilda Beatriz Wencomo-Cárdenas[2] *https://orcid.org/0000-0002-1450-5611*

[1]Productor investigador independiente, estudiante de la Maestría en Pastos y Forrajes, de la Estación Experimental de Pastos y Forrajes Indio Hatuey. [2]Estación Experimental de Pastos y Forrajes Indio Hatuey, Universidad de Matanzas, Cuba. E-mail: iglesias@ihatuey.cu, yuseika@ihatuey.cu, mmilera@ihatuey.cu, otoral@ihatuey.cu, wencomo@ihatuey.cu

Abstract

Objective: To characterize the pastureland and its management indicators in a Voisin rational grazing system, on undulating to cracked soils, in the humid tropic of Los Santos, Panama.

Materials and Methods: An intensive management system with Voisin rational grazing was evaluated, where the rotation of the animals was projected from the determination of its optimum resting point. Twenty four paddocks were used, with 1,9 days of average occupation. The effective stocking rate, grazing intensity, forage offer level and grazing pressure were the main management indicators.

Results: The effective stocking rate was high (3,63 LAU/ha as average) and showed significant differences ($p < 0,001$) in the first two-month period March-April, with regards to the others. The average grazing intensity was 148 LAU/ha/day. The forage offer level showed average availabilities of 27,8 kg DM/animal/day. The grass cover showed a slight trend to decrease, although substantial increase of the quantity of species was observed by the end of the evaluation. The average grazing pressure was high (5,56 kg DM/100 kg LW/day), just like the percentage of pastureland utilization (75,0 %). The average optimum resting time for all the species was 47 days.

Conclusions: The flexible management of Voisin rational grazing, with the determination of the optimum resting point, in cvs. Tanzania, Massai, Mulato II, Toledo and Llanero, produced changes in the management indicators, as well as in the stability of the plant species of the system.

Keywords: pastureland management, rotational grazing, humid tropics

Introduction

Cattle production is one of the main economic activities of the agricultural sector in Panama, where the surface that is used in animal husbandry (1 537 328 ha) is occupied in 15 % by natural pastures, in 46 % by the traditional ones and in 39 %, by cultivated pastures and protein banks (INEC, 2019). In these systems, pasture constitutes the main feed source, which is generally utilized under extensive grazing systems (Carbutt *et al*., 2017).

However, in such systems the management of cultivated species in rational and intensive way is hindered, and it is known that, when pastures are managed logically and efficiently, grasslands tend to regenerate naturally, the productive and reproductive indexes are improved and the animal husbandry system starts to generate ecosystemic services, especially carbon sequestration (Stanley *et al.,* 2018).

Intensive animal husbandry production systems, designed on agroecological bases, such as Voisin rational grazing systems, also constitute a strategic possibility to mitigate the anthropogenic emissions of greenhouse gases (Milera-Rodríguez *et al*., 2019). In these systems natural cycles are stimulated, agrotoxicals are not applied and the pasture utilization is done in the optimum resting time, when the plant has the required nutrients to feed cattle and, thus maximizes the harvest of organic matter per area unit and is managed with the carrying capacity in that space (Domínguez-Escudero, 2019). The use of silvopastoral systems and the selection of the adapted animal biotype are also included among these strategies (Marín-López *et al*., 2020).

Many factors act in an interrelated way and influence the productivity of grasslands (Pérez-Infante, 2013). They include the grazing intensity (stocking rate, grazing pressure, pasture availability and offer) and grazing frequency and time (age of pasture regrowth, season of the year). A management that does not take into consideration these aspects can cause considerable reductions in the yields and alter the botanical composition and

Received: October 28, 2021
Accepted: July 07, 2021

How to cite a paper: Domínguez-Escudero, José Miguel Alejandro; Iglesias-Gómez, Jesús Manuel; Olivera-Castro, Yuseika; Milera-Rodríguez, Milagros de la Caridad; Toral Pérez, Odalys Caridad & Wencomo-Cárdenas, Hilda Beatriz. Characterization of the pastureland and its management in a Voisin rational system, in Panama. *Pastos y Forrajes*. 44:eI19, 2021.

plant persistence, which affects, in turn, forage production and productivity of the exploitation.

There are results that combine stocking rate, grazing pressure and permanence time, with a technological approach in the rational management of different cultivated grasses and of their effect on the stability of floristic composition, dry matter availability, nutrient recycling, soil biota, underground phytomass, decrease of pests and diseases and animal production (Milera-Rodríguez *et al*., 2019).

From these antecedents, this research was conducted, in order to characterize the pastureland and management indicators under Voisin rational grazing, on undulating to cracked soils, in the humid tropic of Los Santos, Panama.

Materials and Methods

Location and duration of the essay. The research was conducted in the Ganadera Pajonales farm, which is located on km 4,5 of the Nuario village, Las Tablas district, Los Santos province, Panama Republic, at coordinates UTM N 575584, W 831759, at an altitude of 484 m.a.s.l., with undulated to uneven topography. The total area of the farm is 13,5 ha, 9,65 are dedicated to cattle grazing in a Voisin rational grazing system, divided into 40 paddocks with electrical fence. The essay was carried out between April, 2019, and February, 2020, in area of 8,40 ha, divided into 24 paddocks, of 0,35 ha as average.

Soil of the experimental area. The soils of the farm are yellowish brown in color, with loamy sandy texture (sand, 64 %; loam, 24 % and clay, 12 %). They show slightly acid pH (5,6), with organic matter contents of 3,78 %. The results of its chemical composition, obtained in the Soil Fertility Laboratory, of the Institute of Agricultural Research of Panama (Villarreal, 2020), are shown in table 1.

Climate of the experimental area. During the research period, rainfall was 1 491 mm (measured with a Hellman model pluviometer, installed in the farm), with the highest accumulated values in September and October. In the months that coincide with the dry season it did not practically rain (figure 1). The average temperature was 26 ºC, with minimum of 23 ºC and maximum of 30 ºC. The average relative humidity was 74 %, with minimum of 63 % and maximum of 86 %. These indicators were determined with a digital thermometer.

Pastureland characterization. The pastures that are reproduced by gamic seed were established through the no-tillage method, with a manual seed broadcaster, at a rate of 10-15 kg of seed/ha, after deep grazing by the animals, which took the basis pasture to a height of 8,0 cm from the soil, and the application of glyphosate herbicide 35,6 L at 1,5 %. For the stoloniferous grasses *Cynodon dactylon* L. Pers cv. Alicia and *Digitaria didactyla* Willd*,* planting was done directly in the field, with digging stick hoe, at 0,5 m between plants and rows. The legume *Arachis pintoi* Krapov & W. C. Greg was also established by stolons, in rows made with hoe, at 1,0 m of distance between them, and with continuous drilling.

At 120 days after being planted the establishment grazing was done, when most of the pastures were in phase of mature spike. The exploitation started when the pastures began to reach the optimum growth point, according to the species and the paddock. No fertilizer was applied during the establishment or in the exploitation period.

The pastures were managed under the laws and fundamentals of the Voisin rational grazing (Rúa-Franco, 2020). According to this method, the paddocks were not grazed chronologically, but the optimum resting time was determined, according to the recommendation made by Pinheiro-Machado (2016), through weekly tours in the grazing area. The occupation and resting days, as well as the grazing intensity and pressure, were managed according to the pasture availability and paddock size.

Animals. Fifty-three Zebu and F1 and F2 cross (Zebu x Holstein) steers were used, divided in two fattening groups. The first fattening period, with 27 animals, started in May, although the animals had been incorporating to the farm since March until April, and had an adaptation period of 15-30 days,

Table 1. Characteristics of the farm soil.

pH	P	K	Ca	Mg	Al	OM	Mn	Fe	Zn	Cu
	mg/L		Cmol/kg			%	mg/L			
5,6	Trace	139,9	3,7	3,2	0,2	3,78	104,6	29,6	3,1	5,2
Little acid	Low	High	Moderate	High	Low	Moderate	High	Moderate	Low	Moderate

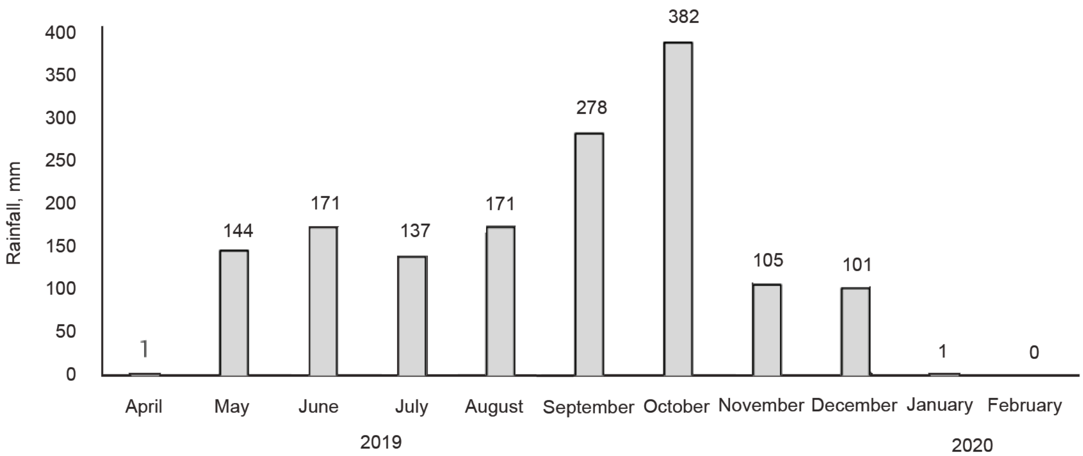

Figure 1. Dynamics of rainfall during the evaluation period.

according to the arrival of the different lots from the auction market. The second group (26 animals) started incorporation between October 15 and 20, with adaptation of 10-15 days. The fattening period started on November 1st. the initial weights were 369 and 401 kg for the first and second group, respectively (table 2).

Measurements and estimations. The indicators effective stocking rate, instantaneous stocking rate (LAU/ha), grazing intensity (LAU/ha/day), level of forage offer (kg DM/LAU/day), grazing pressure (kg DM/100 kg LW), number of rotations, occupation and resting time of the paddocks (days). The optimum resting time in days was also estimated. In the pastures height (cm) was measured upon the entrance to and the departure from the paddock, with graduated metric tape, at a rate of 30 observations per paddock. The availability (kg DM/ha/rotation) was estimated before the entrance of the animals to the paddocks, from the agile method proposed by Martínez *et al.* (1990), with cutting height of 20,0 and 10,0 cm in the erect and creeping ones, respectively. The frequency of present species, as well as their cover, was estimated at the beginning of the experiment and at the end of each season (three times). The first time the step method (EEPFIH, 1980) was followed, and the second, it was done according to the methodology of the Pastures and Forages Research Station Indio Hatuey, described by Machado *et al*. (1999).

Statistical analysis. The data were recorded in tables and introduced in Microsoft Excel for their analysis. They were grouped by two-month periods, for a better understanding of the management dynamics of pastures and animals in the farm. They were processed through a simple-classification variance analysis, after verifying whether they fulfilled the variance homogeneity assumptions by Levene’s test and error normality by Shapiro and Wilk test. In the cases in which significant differences were found among treatments, Duncan’s multiple comparison test was used, with 95 % confidence. For the floristic composition, frequency distribution analysis was performed. The statistical package IBM® SPSS® Statistics, version 22, was used.

Results and Discussion

Cover and dynamics of the species under management in Voisin rational grazing. Sixty-one families were identified, with 205 species (table 3). From them, the most important ones, because of their representation in the paddocks and their possible contribution to the animal diet, were Poaceae (32 species, with 43 varieties and cultivars), Fabaceae

Table 2. Quantity of animal groups evaluated in the fattening under grazing.

Group	Quantity of animals	Initial live weight	Duration of the period, days
1	27	369,0	150
2	26	401,0	79

Table 3. Number and cover of species present in the grazing area.

Groupings	Late dry season March-April	Early rainy season May-June	Early dry season November-December
Poaceae			
Number of varieties	29	36	43
Covered area, %	88	85	81
Fabaceae			
Number of species	9	23	25
Covered area, %	9	13	16
Weeds			
Number of species	13	62	71
Covered area, %	3	3	3

(26, which included 10 trees), Asteraceae (16) and Cyperaceae (9).

Among grasses, the most representative genera (%) were *Megathyrsus* (36,3), *Urochloa* (33,7), *Paspalum* (9,3), *Homolepis* (5,5) and *Digitaria* (3,9). Within legumes, *Arachis* (25,7), *Desmodium* (21,0), *Mimosa* (18,2), *Calopogonium* (8,2) and *Gliricidia* (4,7) were the most important ones.

Among grasses, the prevailing species in the system were *C. dactylon*, *D. didactyla* Willd cv. Swazi, *Urochloa arrecta* Morrone & Zuloaga cv. Tanner, *Megathyrsus maximus* (Jacq.) B. K. Simon & S. W. L. Jacobs x *Megathyrsus infestus* (Andersson) B.K. Simon & S.W.L. Jacobs cv. Massai, *M. maximus* cv. Tanzania, *Urochloa híbrido* (*Urochloa ruziziensis* (R. Germ. & C.M. Evrard) Crins *x Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster) cv. Mulato II, *U. brizantha* (Hochst. ex A. Rich.) R.D. Webster cv. Toledo and *Urochloa humidicola* (Rendle) Morrone & Zuloaga, cv. Llanero.

These data coincide with the report by Oliva *et al.* (2019) in natural pastures, where the dominant family was Poaceae, in monoculture as well as in silvopastoral systems. In turn, this coincides with the finding by Gandullo *et al*. (2013) in Argentina, and with the report by Ramírez-Tixe (2013) in Ecuador. Milera-Rodríguez and Machado-Castro (2016) in an intensive rational grazing system identified 75 species of several plant families, among them 32 grasses, 21 legumes and 22 weeds. Machado (2002), in a rational grazing system based on *A. gayanus* CIAT-621, with cover of 77,2 %, identified 53 species: 25 grasses, 16 legumes and 12 weeds. In studies conducted by Alonso-Amaro *et al.* (2019) in silvopastoral systems with four varieties of *Leucaena leucocephala*, in naturalized and cultivated pastures, 38 species were identified, belonging to 21 families, where *Megathyrsus*, *Cynodon*, and *Digitaria* were the most important grasses. Among the weeds *Mimosa pudica* L. and *Sida rhombifolia* L. stood out.

Villalba *et al.* (2014) indicate that one of the ecological benefits of the Voisin rational grazing is that diversity of plants of different biological forms (grasses, shrubs, climbing plants, lianas, trees) can be managed. This promotes biodiversity, improves the diet quality and livestock health, for which the temporary forage availability is widened.

Among the 76 tree and shrub species disseminated in the paddocks trumpet tree [*Tabebuia rosea* (Bertol.) DC., 103 individuals], turpentine tree [*Bursera simaruba* (L.) Sarg., 70], nance [*Byrsonima crassifolia* (L.) Kunth, 40] and West Indian elm [*Guazuma ulmifolia* Lam., 40] prevailed. The presence of browsing legume trees and shrubs was poor, which limits utilizing their advantages, which are related to nitrogen fixation and carbon sequestration (Sotelo-Cabrera *et al.,* 2017), to the improvement in the quality of animal diet (López-Vigoa *et al*., 2017) and, thus, to the reduction in the emission of greenhouse gases (Faurès *et al.,* 2013). Nevertheless, acceptable diversity of trees and shrubs (904 individuals; 107,6/ha) with different uses (fruits, timber, living posts, firewood, shade, etc.), was found, which allows to intensify the interactions and integration of the soil-tree-grass-animal complex, aimed at improving animal feeding and productivity, as well as the economic, social and environmental impact of the farm (Iglesias *et al*., 2017).

There was slight trend to decrease the grass cover (table 3), although substantial increase was observed of the quantity of species at the end of the evaluation (43 species), with the appearance of the genera *Andropogon, Axonopus, Cenchrus, Cynodon*, *Digitaria*, among others.

The decrease of cover occurred, mainly, in the natural pastures, which were progressively dominated by the legumes. They passed from 9,0 %

cover to 16,0 % with the highest percentages in the genera *Arachis*, *Desmodium* and *Gliricidia*.

The increase of weeds, of which 71 were recorded at the end of the evaluation, can be cataloged as relevant, although the cover percentages in grazing were low and stable (3,0 %).

In the herbaceous component, the presence of weeds (besides grasses and twining legumes, fundamentally) which interact with the tree component (forage, fruit, timber trees and shrubs, and others) and with the animals (Murgueitio *et al.*, 2016; Sisa-Benavides, 2017), plays a key role in the trophic network of complex agroecosystems, because they interact directly or indirectly with other components, and offer a broad spectrum of ecological and agronomic functions, among which are pollination and pest regulation, serving as refuge for natural and biological control agents. In the management of the Voisin rational grazing they are considered soil life indicators or evidence, or as consequence of inadequate pastureland management, when the animal does not consume or tramples them (Pinheiro-Machado, 2011).

From the 43 grasses identified at the end of the evaluation, 26 (60 %) corresponded to introduced pasture species. Among the creeping legumes, of 26 two (7,7 %) were recorded, which is equivalent to moderate to good quality pastures for cattle, and is an example of management efficacy through rational grazing, although the grazing intensities were not very high, and the animal as well as plant production could be optimized (Justo, 2015). Thus, cultivated grasses and legumes found favorable conditions for their growth, and expressed stability in time, which displaced the presence of natural grasses and contained the development of non-desired plants (Benvenutti and Cangiano, 2011; Cangiano and Brizuela, 2011). The possibility animals have to graze deeper in Voisin rational grazing, without selecting the best pastures (Rúa-Franco, 2020), originated that most of the species started their regrowth process at the same time, and that only those that had a more efficient photosynthetic process stood out, due to their adaptation to the edaphoclimatic conditions (Pinheiro-Machado, 2016).

Similar results were achieved by Ojeda-Falcón and Domínguez-Quintero (2020) in a Voisin rational grazing system with grasses of introduced *Urochloas* (Toledo and Ruziziensis), where the initial cover of grasses was 93,6 % and finalized with 91,6 %. The legumes started with cover of 2,3 % and ended with 5,6 %. In the case of weeds, they began with 4,2 % and concluded with 2,8 %.

Milera-Rodríguez and Machado-Castro (2016) in intensive rational grazing during three years found that, from a total of 32 identified grass species, 23 were counted at the beginning, and 25 at the end. Meanwhile, in legumes, of 21 identified species, 11 were present at the beginning and 14 at the end of the experimental period. In the classification of other families (weeds), from 22 existing ones, 15 were recorded at the beginning, and five at the end.

The data presented here are preliminary. They comprise only one year, for which final conclusions cannot be arrived at about the evolution and persistence of the pastureland, aspects that should be measured in the long term, because they depend on the factors management intensity, climate conditions, soil evolution, incidence of pests and diseases, among others (Villalobos-Villalobos and WingChing-Jones, 2019).

Muller-Stover *et al.* (2012) stated that the more lasting pasturelands are, the higher the environmental benefits they generate will be, such as the increase of soil organic matter and the reduction of greenhouse gas emissions. Economic benefits are also obtained, in the short and long term, because the costs related to replanting and rehabilitations are reduced.

Management indicators. Table 4 shows the effect of the management of Voisin rational grazing on the main studied species. The pasture utilization percentage was high (75,0 % as average), and did not show significant differences among the studied species, which was in agreement with the occupation time of the paddocks (between 1,7 and 2,3 days) and the deep grazing made by the animals (it was estimated that they grazed a horizon of a depth that varied between 41,0 and 67,0 cm). This indicates that the grazing intensity was quite accurate, and that the intake should have been high, although the residual material was high too, because the pasture height upon the departure of the animals from the paddocks varied between 19,0 and 37,0 cm, with differences among the different varieties ($p < 0,001$).

Carvalho *et al.* (2010) state that the grazing intensity has direct influence on the pastureland yield and height. It is described as the highest biotic factor that affects the quantity and quality of the available pasture in a pastoral environment and, consequently, influences intake per animal and per area. Pinheiro-Machado (2016) stated the law of fist, which refers that the pasture remnant after grazing

Table 4. Effect of the management of Voisin rotational management on the main studied species[¥].

Variable	Tanzania	Massai	Mulato	Toledo	Humidícola	SE ±
Utilization, %	72[ab]	75[ab]	69[b]	77[ab]	80[a]	1,261
Number of rotations	6,3[a]	5,7[ab]	5,0[ab]	4,4[b]	4,3[b]	0,224*
Days of occupation, days	1,7[a]	1,9[a]	2,3[a]	2,0[a]	1,8[a]	0,103
Optimum resting time, days	48[ab]	42[a]	51[b]	50[b]	51[b]	1,187*
Height entrance, cm	93[b]	81[bc]	71[c]	104[a]	70[c]	2,871***
Height departure, cm	33[bc]	27[b]	30[b]	37[c]	19[a]	1,413***

[¥]The studied species represented in the floristic composition: Massai (37,5 %), Toledo (21,0 %), Tanzania (12,5 %), Mulato II (12,5 %) and Humidícola (12,5 %).
a, b, c, d, e: Means with different superscripts in each column differ from $p < 0,05$ according to Duncan
$^{*}p < 0,05$; $^{**}p < 0,01$; $^{***}p < 0,001$

should be equal to a fist height (10 cm). Meanwhile, in rhizomatose and stoloniferous plants, grazing is always low. Other plants have their regrowth buds or meristems only in the aerial parts, situation in which the remnant should be sufficiently high to attend the specific morphology.

The number of rotations was high in the cvs. of the genus *Megathyrsus* (Tanzania and Massai), although they did not differ from the cv. Mulato II, but it did from Toledo and Llanero. These results are similar to the ones reported by Milera-Rodríguez and Martínez (2016) in *Megathyrsus* cv. Likoni, with 6,2 rotations per year.

Regarding the optimum resting time, there were significant differences among the species ($p < 0,05$). The cultivars of the genus *Megathyrsus* (Massai and Tanzania) showed a slightly higher recovery period, and cv. Massai differed from the cultivars of the genus *Urochloa* (Mulato, Toledo and Llanero). In a study conducted by Hernández *et al.* (2011), cv. Likoni (*Megathyrsus*) showed high proportion of fine roots or rootlets (< 0,2 mm of diameter), which confers it with higher capacity to extract water and nutrients from the lower layers.

The optimum resting time is the cornerstone of rational pasture management. It is a phenological stage, which varies between plant species, and shows differences according to the edaphoclimatic factors, topography, latitude, among others. Anyway, no general rules can be indicated (Pinheiro-Machado, 2016).

The results per two-month period of the main management indicators of the paddocks during the research period, which comprised two fattening cycles, are shown in table 5. Significant differences were observed among all the management indicators. In the LAUs there was difference ($p < 0,001$) with progressive increase, which is explained by the live weight increase of the animals through the two-month periods, with the exception of May-June, because the animals lost weight in April during the phase of adaptation to the system (approximately 11,0 kg) and, thus, the stocking rate decreased.

In the first two-month period (March-April), the effective stocking rate was higher than the rest ($p < 0,01$), because the grazing area was reduced to 3,4 ha, as strategy to increase forage intake and perform maintenance works in the fences. However, between the second (May-June) and the sixth one (January-February) there were no significant differences. In the second two-month period, the area increased to 5,02 ha, and since the third two-month period grazing was normalized in the 8,4 ha, with the 24 paddocks.

The grazing intensity averaged 148 LAU/ha/day, although in the dry periods (March-April, 2019, and January-February, 2020) the average was 178,5 LAU, because the occupation time given to the paddocks was higher (4,0 and 2,4 days).

These results are lower than those reported by Milera-Rodríguez *et al.* (2019) in dairy cows, where the grazing intensity was 212 LAU/ha/day, because the average size of the paddocks under exploitation was only 0,09 ha, with totally flat land topography.

The pasture offer and grazing pressure per two-month period were below the recommended ones for growing-fattening animals (Queirolo-Aguinaga *et al.,* 2015) in May-June and September-October. In the first case (19 kg DM/animal/day and 3,8 kg DM/100 kg LW), was related to the strategy of using follower animals (which increased the stocking rate in the system) to reduce the pasture height, highly lignified by the dry season, and increase its intake. The other aspect that had incidence was the almost null rainfall in the previous two-month period (March-April), which limited the growth of new pasture regrowths in this two-month period (Sánchez-Vélez, 2018).

Table 5. Performance of management indicators in the Voisin grazing system.

Indicator	Production two-month period						SE ±
	March-April, 2019	May-June	July-August	September-October	November-December	January-February, 2020	
LAU	20,5[c]	20,1[c]	22,0[bc]	31,0[a]	23,0[bc]	24,0[b]	0,934***
ESR, LAU/ha	6,0[a]	4,0[b]	2,6[b]	3,7[b]	2,7[b]	2,8[b]	0,341**
ISR, LAU/ha	48,7[c]	64,9[b]	62,9[b]	97,0[a]	65,7[b]	67,3[b]	3,577***
GI, LAU/ha/day	195[a]	117[e]	113[e]	175[b]	125[d]	162[c]	7,591***
FO, kg DM/animal/day	-	19[d]	31[b]	24[c]	34[a]	31[b]	2,804***
GP, kg DM/100 kg LW/day	-	3,8[b]	6,2[ab]	4,8[ab]	6,8[a]	6,2[ab]	0,631**
Rotations	1,0[d]	1,7[a]	1,1[cd]	1,5[ab]	1,3[bc]	1,2[cd]	0,066**
Occupation period, days	4,0[a]	1,8[b]	1,8[b]	1,8[b]	1,9[b]	2,4[ab]	0,265*
Resting periods, days	60[a]	20[b]	42[ab]	56[a]	60[a]	46[ab]	4,413*

ESR: effective stocking rate; ISR: instantaneous stocking rate, GI: grazing intensity, FO: forage offer, GP: grazing pressure
a, b, c, d, e: Values with non-common superscripts in the vertical differ at $p < 0,05$ according to Duncan
$^{*}p < 0,05$ $^{**}p < 0,01$ $^{***}p < 0,001$

In the second case (24 kg DM/animal/day and 4,8 kg DM/100 kg LW), the reason was also the introduction of extra animals to the system (follower lot + lot two, which was being incorporated for the next fattening cycle), with the subsequent increase of the effective and instantaneous stocking rate. The management of the leaders and followers is considered fundamental in Voisin rational grazing, which allows to reach high individual yields and fulfill the law of maximum yields (Pinheiro-Machado, 2016). However, these indicators were close to the limits stated by Cedeño-Vera and Loor-Loor (2017), who consider a high grazing pressure when the DM availability/100 kg LW/day is 3,0 kg or less. They also approach those reported by Senra *et al.* (2005), who refer that grazing pressure is favorable with higher values than 5,0 kg DM/100 kg LW, and consider it limit for the pastureland systems.

In the other analyzed two-month periods, forage availability and grazing pressure were over 30 kg DM/animal/day and 6,0 kg DM/100 kg LW respectively, which is related to the yield increase of pastures and stability in stocking rate. Marín *et al.* (2017) determined that the moment of rotation start is given by height, and that rotational grazing is characterized by managing high grazing pressure, when high availabilities are reached.

Conclusions

The flexible management of Voisin rational management with the determination of the optimum resting time in cvs. Tanzania, Massai, Mulato II, Toledo and Llanero modified the management indicators, as well as the stability of plant species of the system.

Acknowledgements

The authors thank the personnel of the Soil and Bromatology Laboratory of the University of Panama, campus Los Santos, Dr. Jorge Alejandro Troetsch and B.Sc. Silvia Guerra, of the Laboratory Dr. Maximiliano de Puy, of the S/M Cooperative of Milk Farmers of Panama, R.L. (Cooleche) from Chiriquí, and Dr. José Villarreal, of the Institute of Agricultural Research of Panama (IDIAP). In addition, gratitude is expressed to the farmers and specialists who participated in the three field days during the research in the Ganadera Pajonales farm, and contributed their knowledge and suggestions. Likewise, the participation of M.Sc. Milagros de la Caridad Milera Rodríguez is acknowledged, due to her contributions and knowledge about rational grazing.

Conflict of interests

The authors declare that there is no conflict of interests among them.

Authors' contribution

- José Miguel Alejandro Domínguez-Escudero. Executed the experiments, with the corresponding measurements, participated in the data processing and statistical analysis, searched for bibliographic information and participated in the paper writing.
- Jesús Manuel Iglesias-Gómez. Supervised the execution of the experiments, participated in the

data processing and satistical analysis, searched for bibliographic information and participated in the paper writing.

- Yuseika Olivera-Castro. Supervised the execution of the experiments, participated in the data processing and satistical analysis and revised the paper.
- Milagros de la Caridad Milera-Rodríguez. Contributed, with her kowledge on the topic, to the analysis of the experimental data and to writing the results.
- Odalys Caridad Toral-Pérez. Supervised the execution of the experiments, participated in the data processing and statistical analysis and revised the manuscript.
- Hilda Beatriz Wencomo-Cárdenas. Participated in the data processing and statistical analysis, supervised the experimental methodology.

Bibliographic references

Alonso-Amaro, O.; Lezcano-Fleires, J. C. & Suris-Campos, Moraima. Relación ecológica plantas arvenses-entomofauna beneficiosa en sistemas silvopastoriles del occidente de Cuba. *Pastos y Forrajes*. 42 (1):48-56. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942019000100048&lng=es&tlng=es, 2019.

Benvenutti, M. A. & Cangiano C. A. Características de las pasturas y su relación con el comportamiento ingestivo y consumo en pastoreo. En: C. A. Cangiano y M. Brizuela, eds. *Producción animal en pastoreo*. Balcarce, Argentina: Ediciones INTA. p. 259-290, 2011.

Cangiano C. A. & Brizuela, M. Efecto del animal sobre la pastura. En: C. A. Cangiano y M. Brizuela, eds. *Producción animal en pastoreo*. Balcarce, Argentina: Ediciones INTA. p. 291-314, 2011.

Carbutt, C.; Henwood, W. D. & Gilfedder, Louise A. Global plight of native temperate grasslands: going, going, gone? *Biodivers. Conserv*. 26:2911-2932. https://doi.org/10.1007/s10531-017-1398, 2017.

Carvalho, P. C. de F.; Anghinoni, I.; Moraes, A. de; Souza, E. D.; Sulc, M. R.; Lang, C. R. *et al.* Managing grazing animals to achieve nutrient cycling and soil improvement in no-till integrated systems. *Nutr. Cycl. Agroecosyst*. 88 (2):259-273, 2010. DOI: https://doi.org/10.1007/s10705-010-9360-x.

Cedeño-Vera, Mayra L. & Loor-Loor, A. A. *Influencia de la carga instantánea en los indicadores de producción de leche (UDIV) del hato bovino pasto y forraje ESPAM, UDFL*. Tesis previa a la obtención del título de Médico Veterinario. Manabí, Ecuador: Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López, 2017.

Domínguez-Escudero, J. M. A. Producción de carne mediante el pastoreo racional y el PRV, su implementación en las tierras altas de Los Santos, Panamá. Anais do III Encontro Pan-American sobre Manejo Agroecológico de Pastagens: PRV nas Américas. *Cadernos de Agroecología*. 14 (2):1-3. https://cadernos.aba-agroecologia.org.br/index.php/cadernos/article/view/2515/2273, 2019.

EEPFIH. Muestreo de pastos. *IV Seminario Científico-Técnico de Pastos y Forrajes*. Matanzas, Cuba: EEPF Indio Hatuey. https://biblioteca.ihatuey.cu/link/proyecto/seminarios/ivseminariocient.pdf, 1980.

Faurès, J. M.; Bartley, D.; Bazza, M.; Burke, J.; Hoogeveen, J.; Soto, Doris. *et al*. Module 3: Water management. In: Lucia Palombi and R. Sessa, coords. *Climate smart agriculture sourcebook*. Rome: FAO. p. 81-97, 2013.

Gandullo, R.; Fernández, Cristina; Schmid, P. & Giménez, G. Efecto de la variación ambiental en la flora, vegetación y productividad de los humedales "Mallines" de la provincia de Neuquén. Argentina. SEMIARIDA *Revista de la Facultad de Agronomía UNLPam*. 22 (Serie supl. 2 Congreso de Pastizales):75-83. http://rdi.uncoma.edu.ar/bitstream/handle/123456789/15515, 2013.

Hernández, L.; Milera, Milagros de la C. & Blanco, F. Influencia del sistema de explotación y la especie sobre los componentes de la fitomasa subterránea. En: Milagros de la C. Milera, ed. André Voisin: Experiencia y aplicación de su obra en Cuba. Matanzas, Cuba: EEPF Indio Hatuey. p. 426-442, 2011.

Iglesias, J. M.; Simón, L.† & Martín, G. J. Sistemas silvopastoriles en el contexto cubano. *Agroecología*. 12 (1):75-82. https://revistas.um.es/agroecologia/article/view/330371, 2017.

INEC. *Existencia de ganado vacuno, porcinos y gallinas en la República, según provincia y comarca indígena: años 2014-18*. Panamá: Instituto Nacional de Estadística y Censo. https://www.contraloria.gob.pa, 2019.

Justo, C. *Composición florística y especies indicadoras de la familia Asteraceae en la región de los campos del noreste de Uruguay y sur de Brasil*. Tesis de licenciatura. Montevideo: Universidad de la República, 2015.

López-Vigoa, O.; Sánchez-Santana, Tania; Iglesias-Gómez, J. M.; Lamela-López, L.; Soca-Pérez, Mildrey; Arece-García, J. *et al.* Los sistemas silvopastoriles como alternativa para la producción animal sostenible en el contexto actual de la ganadería tropical. *Pastos y Forrajes*. 40 (2):83-95. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942017000200001, 2017.

Machado, R. *Variaciones morfoestructurales y poblacionales de* Andropon gayanus *y su relación con la vegetación adventicia bajo pastoreo intensivo*. Tesis en opción al título de Doctor en Ciencias Agrícolas: EEPF Indio Hatuey, Universidad de Matanzas, 2002.

Machado, R.; Roche, R.; Toral, Odalys & González, E. Metodología para la colecta, conservación y caracterización de especies herbáceas, arbóreas y arbustivas útiles para la ganadería. *Pastos y Forrajes*. 22 (3):181-204. https://payfo.ihatuey.cu/index.php?-

journal=pasto&page=article&op=view&path%5B%5D=972, 1999.

Marín, Alejandra; Baldissera, T.; Pinto, C.; Garagorry, F.; Zubieta, A.; Giraldo, L. A. *et al. Una innovación en el manejo del pastoreo como estrategia para mejorar la producción animal y reducir las emisiones de GEI*. Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security, 2017.

Marín-López, D.; Matamoros, I. & Ramírez-Restrepo, C. A. *Estimación preliminar productiva y modelada de las emisiones y mitigación de gases de efecto invernadero en sistemas de producción de leche de Honduras*. Tesis de maestría en Ciencias en Agricultura Tropical Sostenible. Zamorano, Honduras: Escuela Agrícola Panamericana, 2020.

Martínez, J.; Milera, Milagros; Remy, V. A.; Yepes, I. & Hernández, J. Un método ágil para estimar la disponibilidad de pasto en una vaquería comercial. *Pastos y Forrajes*. 13 (1):101-110. https://payfo.ihatuey.cu/index.php?journal=pasto&page=article&op=view&path%5B%5D=1296, 1990.

Milera-Rodríguez, Milagros de la C. & Machado-Castro, R. Efecto del manejo intensivo racional sobre el comportamiento de gramíneas tropicales sin la aplicación de riego ni agroquímicos. 3. Evolución de las especies. En: Milagros de la C. Milera-Rodríguez, ed. *Manejo de vacas lecheras en pastoreo. Del monocultivo a la biodiversidad de especies*. Matanzas, Cuba: EEPF Indio Hatuey. p. 135-163, 2016.

Milera-Rodríguez, Milagros de la C. & Martínez, J. Efecto del manejo intensivo racional sobre el comportamiento de gramíneas tropicales sin la aplicación de riego ni agroquímicos. 1. Disponibilidad de materia seca. En: Milagros de la C. Milera-Rodríguez, ed. *Manejo de vacas lecheras en pastoreo. Del monocultivo a la biodiversidad de especies*. Matanzas, Cuba: EEPF Indio Hatuey, p. 116-126, 2016.

Milera-Rodríguez, Milagros de la C.; Machado-Castro, R.; Alonso-Amaro, O.; Hernández-Chavez, Marta & Sánchez-Cárdenas, Saray. Pastoreo racional intensivo como alternativa para una ganadería baja en emisiones. *Pastos y Forrajes*. 42 (1):3-12. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942019000100003, 2019.

Muller-Stöver, D.; Hauggaard-Nielsen, H.; Eriksen, J.; Ambus, P. & Johansen, A. Microbial biomass, microbial diversity, soil carbon storage, and stability after incubation of soil from grass-clover pastures of different age. *Biol. Fertil. Soils*. 48 (4):371-383, 2012. DOI: https://doi.org/10.1007/s00374-011-0633-6.

Murgueitio, E.; Uribe, F.; Molina, C.; Molina, E.; Galindo, W. F.; Chará, J. *et al. Establecimiento y manejo de sistemas silvopastoriles intensivos con Leucaena*. E. Murgueitio, W. F. Galindo, J. D. Chará y F. Uribe, eds. Cali, Colombia: CIPAV, 2016.

Ojeda-Falcón, A. D. & Domínguez-Quintero, O. Pastoreo Racional Voisin, ruta agroecológica sustentable en suelos ácidos-arenosos de baja fertilidad natural. *Ctro. Agr*. 47 (2):41-53. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0253-57852020000200041, 2020.

Oliva, M.; Collazos, R.; Vásquez, H.; Rubio, Karol & Maicelo, J. L. Composición florística de especies herbáceas forrajeras en praderas naturales de las principales microcuencas ganaderas de la región. *Sci. Agropecu*. 10 (1):109-117, 2019. DOI: https://dx.doi.org/10.17268/sci.agropecu.2019.01.12.

Pérez-Infante, F. *Ganadería eficiente. Bases fundamentales*. La Habana: Asociación Cubana de Producción Animal, 2013.

Pinheiro-Machado, L. C. Las bases científicas del Pastoreo Racional Voisin. 1er Encuentro Panamericano sobre Manejo Agroecológico de Pastizales. *Cadernos de Agroecología*. 6 (1):1-15. https://silo.tips/download/memorias-del-1er-encuentro-pan-americano-sobre-manejo-agroecologico-de-pastizale, 2011.

Pinheiro-Machado, L. C. *La dialéctica de la agroecología. Contribución para un mundo con alimentos "sin venenos"*. Buenos Aires: Hemisferio Sur, 2016.

Queirolo-Aguinaga, A. A.; Nabinger, C., Carvalho, P. C. de F. & Muliterno Thurow, Juliana. Manipulação estacional da oferta de forragem para otimizar a produtividade da pastagem natural. *Memorias del Congreso de Producción Animal ALPA 2015*. Puerto Varas, Chile: ALPA. p. 369, 2015.

Ramírez-Tixe, María G. *Diversidad florística a diferente altitud en el ecosistema páramo en siete comunidades de la OSG UNOCANT*. Tesis presentada como requisito parcial para obtener el título de Ingeniero Forestal. Riobamba, Ecuador: Facultad de Recursos Naturales, Ecuela de Ingeniería Foretal, Escuela Superior Politécnica de Chimborazo. http://dspace.espoch.edu.ec/bitstream/123456789/2790/1/33T0112%20.pdf, 2013.

Rúa-Franco, M. *Manual práctico del Pastoreo Racional Voisin*. Colombia: CEG Internacional, 2020.

Sánchez-Vélez, E. V. Determinación de la época de corte del pasto Toledo (*Brachiaria brizantha*) mediante la cuantificación de proteínas en la hoja. Trabajo de titulación como requisito previo a la obtención del título de Ingeniero Agropecuario. Los Ríos, Ecuador: Facultad de Ciencias Agropecuarias, Universidad Técnica de Babahoyo, 2018.

Senra, A.; Martínez, R. O.; Jordán, H.; Ruiz, T.; Reyes, J. J.; Guevara, R. V. *et al*. Principios básicos del pastoreo rotacional eficiente y sostenible para el subtrópico americano. *Rev. cubana Cienc. agríc.* 39 (1):23-30. https://redalyc.org/articulo.oa?id=193017852003, 2005.

Sisa-Benavides, Ligia A. *Implementación del sistema silvopastoril (SSP) modelo cercas vivas y barreras rompevientos en las veredas Páramo y Tobal del municipio de Tutazá Boyacá*. Trabajo aplicado para optar por el título de Zootecnista: Escuela de Ciencias Agrícolas, Pecuarias y del Medio Ambiente CEAD-DUITAMA, Universidad Nacional Abierta y a Distancia, 2017.

Sotelo-Cabrera, M. E.; Suárez-Salazar, J. C.; Álvarez-Carrillo, F.; Castro-Núñez, A.; Calderón-Soto, V. H. & Arango, J. *Sistemas sostenibles de producción ganadera en el contexto amazónico. Sistemas silvopastoriles: ¿una opción viable?* Publicación CIAT No. 448. Cali, Colombia: CIAT, 2017.

Stanley, Paige L.; Rowntree, J. E.; Beede, D. K.; DeLonge, Marcia S. & Hamm, M. W. Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems. *Agr. Syst*. 162:249-258, 2018. DOI: https://doi.org/10.1016/j.agsy.2018.02.003.

Villalba, J. J.; Provenza, F. D.; Gibson, Natalie & López-Ortíz, Silvia. Veterinary medicine: the value of plant secondary compounds and diversity in balancing consumers and ecological health. In: B. C. William and S. López-Ortiz, eds. *Issues in agroecology: present status and future prospectus 3. Sustainable food production includes human and environmental health*. Berlín: Springer. p. 165-190, 2014.

Villalobos-Villalobos, L. A. & WingChing-Jones, R. Mechanical removal of senescent material for pasture recovery. *Agron. Mesoam*. 30 (3):821-840, 2019. DOI: https://doi.org/10.15517/am.v30i3.36625.

Villareal, J. E. Resultados de investigación del programa de suelos del IDIAP. Panamá: Instituto de Investigaciones Agropecuarias de Panamá, 2020.