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Article

Characterization of the seasonal forage balance in 17 municipalities in the tropical zone of central Veracruz, Mexico

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Abstract:

The objective was to characterize the forage balance during the dry and rainy seasons in 17 municipalities in the tropical zone of central Veracruz, Mexico, in order to typify and identify recommendation domains. For this purpose, the 2019 national livestock register data were used through the Individual Livestock Identification System (SINIIGA in Spanish), which records each production unit (PU). The seasonal forage balance was calculated for each LPU to estimate the dry matter (DM) requirements per animal unit; having thus determined the average DM deficit, it was grouped into the 17 municipalities. General linear models and descriptive values were used for a total number of 17,892 PU. These production units had an average area of 19.40 ha, 23.67 animal units (AU) per herd, and a stocking rate of 1.22 AU ha^{-1}. This rate was considered high for the technological conditions of the area, where the forage balance is usually negative in the dry season. The authors concluded that the forage balance in the rainy season is positive and, therefore, recommend considering the use of technologies for forage conservation during the dry season. Furthermore, there is a need to typify the different conditions of the PU more precisely in order to provide more site-specific recommendations.

Keywords: Animal unit, Livestock production unit, Stocking rate, Forage balance, Dry matter.

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Introduction

Latin America and the Caribbean are at the forefront of the global fight against hunger, with livestock as one of the main drivers of sustainable production[1,2]. In Mexico, livestock production is based on the grazing of native forages and some introduced forages[3]. The characterization of a region provides a comprehensive understanding of its natural, physical, economic, socio-cultural, and environmental circumstances. This knowledge allows diversifying and adopting technologies by identifying the so-called recommendation domains[4]. In the Mexican tropics, 80 % of the dual-purpose system (DPS) is concentrated in the states of Veracruz, San Luis Potosí, Tamaulipas, Chiapas, and Tabasco[5]. The most important factor limiting production in the tropics is the low availability and quality of forage, coupled with drought, heat waves, and poor soil fertility[6]. As in other tropical regions, central Veracruz faces a dry matter (DM) deficit during the dry season[7]. Estimating the animal carrying capacity is essential to achieving sustainable livestock production. This requires the development of innovative theoretical and experimental work to perform this task in an operational, low-cost manner[8]. Most livestock production units (PU) of the cattle ranchers in central Veracruz do not estimate the animal carrying capacity of their paddocks and do not have enough feed to face the dry season. Therefore, the ecosystems deteriorate and the amount of biomass in the dry season decreases year after year[9]. The purpose of this study was to characterize the seasonal forage balance in 17 municipalities in the tropical area of central Veracruz.

Material and methods

Study population

The research was carried out in the central region of the state of Veracruz de Ignacio de la Llave, Mexico, located between latitudes 17°03´18´´ and 22° 27´18´´, and longitudes 93°36´13´´ and 98°36´00´´. With a surface area of 72,417 km^2, the state is located in the east of the Mexican Republic. In terms of territorial extension, it ranks tenth at the national level and represents 3.7 % of the national territory[10]. The study area is located at an altitude of up to 67 m asl. According to the Köppen-Geiger classification, the climate is tropical AW, with an average annual temperature of 25.9 °C and an average annual rainfall of 1,393.3 mm[11,12].

Sample selection

Basic information from the January to December 2019 period, captured in the inventory system of the National Livestock Register[13] through the National System of Individual Livestock Identification (SINIIGA in Spanish) of the regional window of the central zone of Veracruz, was used to characterize the forage balance through some production functions. The research was carried out based on information from 17,749 dual-purpose grazing PU distributed among 17 municipalities (Actopan, Alvarado, Ángel R. Cabada, Camarón de Tejeda, Cotaxtla, Ignacio de la Llave, Jamapa, La Antigua, Lerdo de Tejada, Manlio Fabio Altamirano, Medellín, Paso de Ovejas, Paso del Macho, Soledad de Doblado, Tierra Blanca, Tlalixcoyan, and Veracruz) in the tropical area of central Veracruz. These data were previously analyzed and filtered, separating those PU that offered very atypical or confusing information.

Database variables

The following PU variables municipality, location, and total surface area (ha)were drawn from the SINIIGA database and broken down into areas (ha) with irrigation, summer mountain pastures (native grasses), irrigated pastures, rainfed pastures, introduced rainfed pastures, introduced irrigated pastures, irrigated forage and rainfed forage; the livestock inventory was broken down into cows, sires, suckling calves, calves (number of females and males), heifers, steers, horses, and sheep. The livestock inventory was expressed in total Animal Units (AU), and the stocking rate, in AU ha^{-1}[14].

The following equivalences were used to express the livestock inventory in AU: cows*1; sires*1.25; heifers*0.75; steers*0.7 female or male calves*0.4; suckling calves*0.25; horses*1.2; and, sheep*0.1. The stocking rate for each PU was calculated as Livestock inventory in AU/total area.

Pasture and forage production (tDM ha^{-1} year^{-1})

Pasture and forage yields were estimated for the categories collected in the database, and annual dry matter (DM) yield indicators were applied for the dry and rainy seasons, with and without irrigation, in Mexico[6,15]. To estimate the yields in tons of dry matter per hectare (t DM ha^{-1}) for the dry and rainy seasons, it was assumed indices of 1 and 3 for summer mountain pastures, 2.4 and 5.6 for irrigated grassland, 1.5 and 3.5 for rainfed grassland, 4.8

and 7.2 for irrigated introduced grassland, 2.4 and 5.6 for rainfed introduced grassland, 9 and 11 for irrigated forage, and 3.6 and 8.4 for rainfed forage, respectively.

Pasture and forage requirements (tDM ha^{-1} $year^{-1}$)

A feed intake capacity of 2.5 % of the daily DM $days^{-1}$[16] was considered. The annual requirement for an AU was formulated in terms of tDM ha^{-1}. For the area in which the municipalities under study are located, a dry season of 7 mo (213 d) and a rainy season of five months (152 d) were considered. Dry matter requirements in the dry season (RDMDS) were calculated with the formula:

RDMDS = Total AUs*450*2.5%*213,

and the requirements of dry matter in the rainy season (RDMRS), with the equation:

rainfed forage RDMRS= Total AUs*450*2.5%*152.

For both periods, the DM requirements were expressed in tons of dry matter (tDM).

Dry matter yields in dry and rainy seasons

These yields were obtained depending on the use of the area according to SINIIGA. The use of the area refers to the utilization of the land as summer mountain pasture, irrigated or rainfed meadows, etc. Thus, the dry matter yields in the dry season (DMYDS) were calculated with the following formula:

DMYDS= (summer mountain pasture*1) + (irrigated grassland*2.4) + (rainfed grassland*1.5) + (introduced grassland with irrigation*4.8) + (introduced rainfed grassland*2.4) + (forage with irrigation*9) + (rainfed forage*3.6),

and the dry matter yields in the rainy season (DMYRS), with the equation:

DMYRS= (summer mountain pasture *3) + (irrigated grassland*5.6) + (rainfed grassland*3.5) + (introduced grassland with irrigation*7.2) + (introduced rainfed grassland*5.6) + (forage with irrigation*11) + (rainfed forage*8.4)[6,16].

Balance in the dry and rainy seasons

The balance in the dry season (BDS) was calculated with the formula:

BDS = dry matter yield in the dry season – dry matter requirements in the dry season,

and the balance for the rainy season (BRS), with the formula:

BRS= dry matter yield in rainy season – dry matter requirements in the rainy season.

Overall load

It was obtained by dividing the AU calculated by the area registered for each production unit and was expressed as AU ha^{-1}.

Statistical analysis

The information was analyzed using general linear models and descriptive values for the production units in the area.

The AU, AU/ha, d, BDS, and BRS were analyzed using general linear models including the effect of municipalities as a fixed effect. The equation of the model used in each case was:

$$y = X\beta + e$$

Where:

y = the response variable (AU, AU/ha RDMRS, RDMRS, DMYDS, DMYRS, BDS, and BRS);
β = the vector of solutions to the fixed effects included in the model (municipality or AU);
X = the incidence matrix relating the observations (response variable) to the explanatory variables (municipality for the analysis of variance);
e = the vector of random residual effects.

Comparisons between means were performed using Fisher's protected multiple t test, with the PDIFF option of PROC GLM[(17)].

Results

Table 1 shows the number of observations and descriptive statistics. Altogether, 17,892 PU were analyzed in the 17 municipalities studied. The difference between the RDMRS and the RDMDS is 28.56 % of the tDM^{-1}. On the other hand, the difference between the DMYRS and the DMYDS is 56.13 % of the tDM^{-1}, with a difference between the BRS and the BDS of 126.71 % of the tDM^{-1}

Table 1: Descriptive statistics of the seasonal forage balance in 17 municipalities of central Veracruz, Mexico

Variable	Mean	SD	Minimum	Maximum
Surface area of the PU, ha	19.40	20.06	5.00	149.55
AU	23.67	26.73	0.25	577.60
AU ha^{-1}	1.41	0.88	0.01	5.00
RDMDS, tDM^{-1}	56.67	64.00	0.60	1382.77
RDMRS, tDM^{-1}	40.48	45.71	0.43	987.70
DMYDS, tDM^{-1}	41.94	48.51	-244.80	735.00
DMYRS, tDM^{-1}	95.61	105.82	-571.20	982.73
BDS, tDM^{-1}	-14.73	46.03	-1163.77	539.05
BRS, tDM^{-1}	55.13	80.37	-581.03	779.21

SD= standard deviation; mean= average of the 17 municipalities under study; PU= production units; AU= animal units, RDMDS= requirements of dry matter in the dry season; tDM= tons of dry matter; RDMRS= requirements of dry matter in the rainy season; DMYDS= dry matter yield in the dry season; DMYRS= dry matter yield in the rainy season; BPS= balance in the dry season; BRS= balance in the rainy season.

Regarding the significance levels of the effects considered in the models for the different production functions (AU, AU/ha, RDMDS, RDMRS, DMYDS, DMYRS, BPS, and BPL), the effect of the variable municipality was found to be significant for all the variables analyzed (P<0.01). Table 2 shows the least squares means and standard errors for the studied variables. The municipalities with the highest number of AU per PU on average were La Antigua (33.55 ± 2.86), Veracruz (30.39 ± 1.73), and Cotaxtla (29.75 ± 0.82) (P<0.05), while the municipalities with the lowest number of AU per PU were Jamapa (19.76 ± 1.31), Paso de Ovejas (19.08 ± 0.91), and Paso del Macho (15.87 ± 1.21). As for AU ha^{-1}, the municipalities of La Antigua (1.69 ± 0.09), Lerdo de Tejada (1.68 ± 0.08), and Veracruz (1.62 ± 0.06) had the highest number of AU/ha (P<0.05), while Actopan (1.14 ± 0.02), Camarón de Tejeda (1.12 ± 0.05), and Paso del Macho (0.84 ± 0.04) had the lowest (P<0.05).

Table 2: Least squares means and standard errors of the seasonal forage balance in 17 municipalities of central Veracruz, Mexico

Municipality	AU per PU	AU ha^{-1} per PU	RDMDS (tDM)	RDMRS (tDM)	DMYDS (tDM)	DMYRS (tDM)	BDS (tDM)	BRS (tDM)
Actopan	21.91± 0.72^{ce}	1.14± 0.02^{g}	52.46± 1.72 ^{ce}	37.47± 1.23^{cfj}	44.31± 1.30^{cde}	102.54± 2.84^{c}	-8.15± 1.24^{cde}	65.07± 2.15^{c}
Alvarado	25.36± 0.72^{c}	1.42± 0.02^{de}	56.41± 1.73 ^{e}	40.29± 1.23^{cfg}	40.32± 1.31^{cef}	93.79± 2.85^{ce}	-16.09± 1.24^{h}	53.50± 2.15^{de}
Ángel R. Cabada	21.51± 0.72^{deg}	1.57± 0.02^{ab}	51.48± 1.72 ^{eg}	36.77± 1.23^{hij}	31.26± 1.30^{hij}	72.79± 2.84^{de}	-20.23± 1.23^{i}	36.02± 2.15^{g}
Camarón de Tejeda	20.39± 1.45^{deg}	1.12± 0.05^{fg}	48.81± 3.47 ^{eg}	34.86± 2.48^{hijk}	43.59± 2.62^{bcf}	100.42± 5.71^{bc}	-5.22± 2.48^{bd}	65.56± 4.32^{c}
Cotaxtla	29.75± 0.82^{a}	1.24± 0.03^{f}	71.21± 1.95 ^{a}	50.87± 1.39^{ae}	60.43± 1.48^{a}	139.32± 3.22^{bc}	-10.78± 1.40^{eg}	88.45± 2.43^{a}
Ignacio de la Llave	19.77± 0.78^{dg}	1.61± 0.03^{a}	47.34± 1.87 ^{dg}	33.81± 1.33^{hijk}	30.02± 1.41^{j}	69.93± 3.08^{ce}	-17.31± 1.34^{hi}	36.12± 2.33^{g}
Jamapa	19.76± 1.31^{deg}	1.47± 0.04^{ce}	47.30± 3.14 ^{dg}	33.79± 2.24^{hijk}	34.04± 2.37^{gij}	79.32± 5.17^{deg}	-13.26± 2.25^{fgh}	45.54± 3.91^{ef}
La Antigua	33.55± 2.86^{a}	1.69± 0.09^{ab}	80.31± 6.85 ^{a}	57.36± 4.89^{a}	52.96± 5.18^{ab}	118.40 11.30^{f}	±-27.35± 4.91^{j}	61.03± 8.55^{bce}
Lerdo de Tejada	23.26± 2.52^{bcd}	1.68± 0.08^{ab}	55.68± 6.03 ^{bced}	39.77± 4.31^{cdefi}	37.68± 4.56^{fi}	87.91± 9.94^{cef}	-18.01± 4.32^{ghi}	48.14± 7.52^{efg}
Manlio Fabio Altamirano	20.04± 1.04^{deg}	1.48 0.03^{ce}	47.96± 2.49 ^{dfg}	34.26± 1.78^{hijk}	34.75 1.88^{gi}	±78.91± 4.10^{ab}	-13.22± 1.78^{fgh}	44.65± 3.11^{ef}
Medellín	23.68± 0.84^{c}	1.52± 0.03^{bc}	56.69± 2.02 ^{ce}	40.50± 1.44^{f}	39.16± 1.53^{fg}	88.55± 3.33^{fg}	-17.54 1.45^{hi}	49.05± 2.52^{ef}
Paso de Ovejas	19.08 0.91^{df}	±1.16± 0.03^{fg}	45.68± 2.18 ^{dh}	32.63± 1.55^{k}	43.78± 1.65^{c}	99.21± 3.59^{f}	-1.90± 1.56^{b}	66.58± 2.72^{c}
Paso del Macho	15.87 ± 1.21^{f}	0.84± 0.04^{h}	38.00± 2.89 ^{i}	27.14± 2.07^{l}	44.90± 2.19^{be}	104.71± 4.77^{a}	6.89± 2.07^{a}	77.57± 3.61^{b}
Soledad de Doblado	20.82 ± 0.8^{cg}	1.22± 0.03^{f}	52.24± 1.91 ^{egh}	37.32± 1.37^{hij}	47.38± 1.45^{bd}	110.01± 3.15^{bcd}	-4.86± 1.37^{bd}	72.69± 2.39^{dc}
Tierra Blanca	25.69 ± 0.42^{b}	1.47± 0.01^{ce}	61.50± 1.04 ^{b}	43.93± 0.74^{c}	42.16± 0.79^{ce}	93.93± 1.71^{f}	-19.33± 0.74^{i}	50.00± 1.30^{ef}
Tlalixcoyan	26.89 ± 0.52^{b}	1.57± 0.01^{ac}	64.37± 1.24 ^{b}	45.98± 0.89^{bd}	44.00± 0.94^{ce}	98.18± 2.05^{de}	-20.37± 0.89^{i}	52.2± 1.55^{ef}
Veracruz	30.39 ± 1.73^{a}	1.62± 0.06^{a}	72.75± 4.14 ^{a}	51.96± 2.96^{ab}	51.14± 3.13^{b}	115.44± 6.83^{bc}	-21.6± 2.97^{i}	63.47± 5.17^{ce}

AU= animal units per PU; PU= production units; UA/ha= animal units per hectare per PU; tDM= tons of dry matter; RDMDS= requirements of dry matter in dry season; RDMRS= requirements of dry matter in the rainy season; DMYDS= dry matter yield in the dry season; DMYRS= dry matter yield in the rainy season; BDS= balance in the dry season; BRS= balance in the rainy season.

$^{a-k}$ Values with different letters within columns are significantly different (P<0.05).

Based on the results obtained, the municipalities with higher dry matter requirement in the dry season due to higher AU were La Antigua (80.31 ± 6.85), Veracruz (72.75 ± 4.14), and Cotaxtla (71.21 ± 1.95) (P<0.05). In the rainy season, La Antigua (57.36 ± 4.89), Veracruz (51.96 ± 2.96), and Cotaxtla (50.87 ± 1.39) exhibited the highest dry matter requirements (P<0.05). The highest dry matter yield in the dry season (DMYDS, tDM^{-1}) was found in the municipalities of Cotaxtla (60.43 ± 1.48), La Antigua (52.96 ± 5.18), and Veracruz (51.14 ± 3.13) (P<0.05). The lowest productions were recorded in the municipalities of Jamapa (34.04 ± 2.37), Ángel R. Cabada (31.26 ± 1.30), and Ignacio de la Llave (30.02 ± 1.41). The dry matter yield in the rainy season amounted to 30.36 % of the total dry matter yield in the year. The average dry matter yield in the rainy season (DMYRS tDM^{-1}) across the municipalities was 97.32 ± 3.08. The municipalities with the highest dry matter production in the rainy season were Cotaxtla (139.32 ± 3.22), La Antigua (118.40 ± 11.29), and Veracruz (115.44 ± 6.83) (P<0.05), while the municipalities with the lowest production were Manlio Fabio Altamirano (78.91 ± 4.10), Ángel R. Cabada (72.79 ± 2.84), and Ignacio de la Llave (69.93 ± 3.08).

The balance in the dry season (BDS t/DM^{-1}) was negative in most of the municipalities. The least affected municipality was Paso del Macho, with only 15.87 ± 1.21 AU, exhibiting a dry matter balance of 6.89 ± 2.07. The other municipalities showed a negative balance, ranging between -1.90 ± 1.56 (Paso de Ovejas) and -27.65 ± 4.91 (La Antigua). The higher negative balance in La Antigua is due to the fact that it is the municipality with the largest number of animal units (33.55 ± 2.86 AU).

The dry matter balance during the rainy season (BRS tDM^{-1}) averaged 57.39 ± 3.41 in all the municipalities. In all cases, the balance was positive, ranging between 36.02 (Angel R. Cabada) and 88.45 (Cotaxtla). The municipalities with the highest dry matter balance in the rainy season (P<0.05) were Cotaxtla (88.45 ± 2.43), Paso del Macho (77.57 ± 3.61), and Soledad de Doblado (72.69 ± 2.39). The municipalities with the lowest dry matter balance in this season were Manlio Fabio Altamirano (44.65 ± 3.11), Ignacio de la Llave (36.12 ± 2.33), and Ángel R. Cabada (36.02 ± 2.23).

Discussion

The tropics are characterized by a very changeable climatic diversity supported by soils with heterogeneous fertility indices and lacking fundamental nutrients for the production of nutritional quality fodder. Fodder resources must occupy a strategic place in order to achieve efficient livestock production, ensuring the basic nutritional elements for the cattle herd[18]. The stocking rate estimated in this research agrees with a study carried out in Las Choapas, Veracruz, where 1.3 AU/ha have been reported[19], and with Rangel *et al*[20], who report 1.2 AU/ha. In this study, the balance of pasture production against average needs was found to be negative in the dry season, similar to what has been reported in other studies[21]. On the other hand, this study showed a positive balance of pasture production in the 17 municipalities during the rainy season.

In the rainy season there is a positive balance of pasture unlike in the dry season, when the balance is negative, causing a deficit that could only be covered by applying technologies that profit from the forage surpluses of the rainy season[22]. This DM deficit influences the overall load, levels of yield, and growth rates. In the dry season, the dry matter yield and stocking rates can be increased by using hay[23]. Another way to improve the forage capacity of the PU is with such technology as silage, which is little used in the central zone of the state of Veracruz. In those cases when it is utilized, corn, sorghum, or varieties of corn, sorghum, or *Cenchrus purpureus* are employed[24]. A study on the inclusion of corn silage in dual-purpose production systems in southern Quintana Roo during the dry season showed a positive response in terms of forage yield and reduced costs of milk production[25]. Haymaking is another technology adopted in the tropics of Veracruz that profits from surplus forage during the rainy season[26]. Notably, in that study, the municipalities with the greatest dry matter deficit in the dry season were those with the highest stocking rates. As the stocking rate increases, the negative balance in the dry season also increases, evidencing incorrect pasture management[27]. Producing sufficient pasture and forage within the PU is the most feasible, profitable, and sustainable way to solve the food deficit in this area. It is highly possible to improve the forage capacity of Mexico's tropics. The first task is to establish good pasture management, introducing grass species with a higher yield capacity[28]. The inclusion of biomass banking technology with Cuba CT-115 grass in a dairy in the tropical zone of central Veracruz produced a higher forage yield, allowing an increase in the stocking rate, milk production, total number of cows in the herd, and weaned live weight and a reduction in supplementation[29]. Other technologies such as silvopastoral management[30] and the use of regenerative livestock farming are important to reduce the effects of forage shortage in the dry season without damaging the environment. The study showed the characterization of the forage balance in the tropics of central Veracruz, allowing, with the information thereby generated and the previously existing information, to launch other studies to increase productivity and profitability in the herds and reduce the effects of climate change on livestock in a sustainable way.

Conclusions and implications

The forage balance in the dry season is negative in all the municipalities except Paso del Macho, which has the lowest stocking rate. During the rainy season, all the municipalities in the study show a positive balance. This corroborates the need to include low-cost technologies for pasture management as well as to profit from the forage resources in the rainy season by conserving forage. These measures would help reduce the dry season pasture deficit and increase the productivity of livestock enterprises. There is a need to group the different PU more precisely in order to obtain more accurate information and thus achieve more homogeneous PU. Also, this would allow to formulate more precise technological recommendations for each specific area or LPU in a sustainable way. Good DM management and production are necessary to increase the stocking rate in the LPU of the municipalities under study.

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