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Simulation of the bovine production system in the Mexican tropics

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Key words: Potential yield, Agricultural regions, Animal load, Weight gain.

Abstract

The present research proposes to develop a simulation model to support the decision making of the bovine meat production system through grazing in the tropics. The simulation model was developed through the Stella v6.0.1 and R v3.4.2 software to calculate the potential yield of African star grass (*Cynodon plectostachyus*), German (*Echinochloa polystachya*) and Egypt (*Brachiaria mutica*) with their respective animal behavior (weight gain and animal load) for each agricultural region (Alluvial plains drained cañera-ganadera, Alluvial cacao-cattle plains, Palustre plains with hydrophytic vegetation and livestock and coastal plains cattle-coprera) and periods (dry, rain and northerly). The results of the model showed differences between the units of animal load per hectare for each type of grass and the daily weight gain between the agricultural regions, observing the highest yields in the dry season, in the region Palustre flat with hydrophytic vegetation and livestock, with the German and Egyptian pastures with an animal load of 5.7AU/ha and 4.8AU/ha, with weight gains of 0.439kg / day and 0.542kg/day respectively. The results of the simulation were validated by a scientific review of experimental data obtained in situ by the Colegio Superior de Agricultura Tropical (CSAT). It is concluded that the simulation model is able to make predictions results accessible and reliable, in such a way that the information is available as a tool for decision makers on the part of producers, investors and the government.

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Introduction

One of the main problems of cattle farming is the scarce development of accessible and reliable models that serve as support tools in decision making. Having information about natural resources in specific territories and times would help to observe differences in the productive variables between agroecological regions (Mochi, 2014). Geographical information systems (GIS) allow the generation of cartographies making it possible to group, represent and obtain georeferenced spatial information of any geographic coordinate (Niño and Danna, 2016). Simulation models are tools that currently stand out for their potential to evaluate production systems, relying on advances in computer science can be studied and predict with great precision the behavior of production systems, allowing to face changes in animal behavior due to management, climate, pasture phenology, among others (Villanueva-Castillo *et al.*, 2013). Through the development of simulation models, data and maps can be manipulated, which can be easily used to develop specific functions in a specific region of a production system, providing better results for decision making (Hernández *et al.*, 2011). The importance of the development and implementation of simulation models for any production system is that it allows the creation of tools (mobile applications) that are available online and serve as support for decision making (producers, investors, government) for a better management of resources and thus obtain an optimized, efficient and sustainable production (Candelaria *et al.*, 2011). Interoperability is achieved by combining temporal, spatial and systematic information (López-Caloca, 2017), within a methodology that develops a tool in the form of a simulation model that helps in decision-making in a bovine production system, such as that of the meat, to reduce the problems during the times of scarcity of fodder (Villanueva-Castillo *et al.*, 2013). Therefore, in the present investigation it is proposed to develop a simulation model to support the decision making of the bovine meat production system through grazing in the tropics.

Materials and methods

Study area

The research was conducted in the municipality of H. Cárdenas, Tabasco, Mexico, which is located in the humid tropics, between the geographic coordinates: 17°55'and 18°25' north latitude; and 93°16'and 94°08' west longitude; its altitude varies between 0 and 100 meters above sea level (msnm), in an area of 2049.24 km² (INEGI, 2012).

Classification of agricultural regions

The zoning of the agricultural regions was based on the work carried out (Osorio, 2008). This work takes into account the type factors of relief and association of dominant crops and grasses.

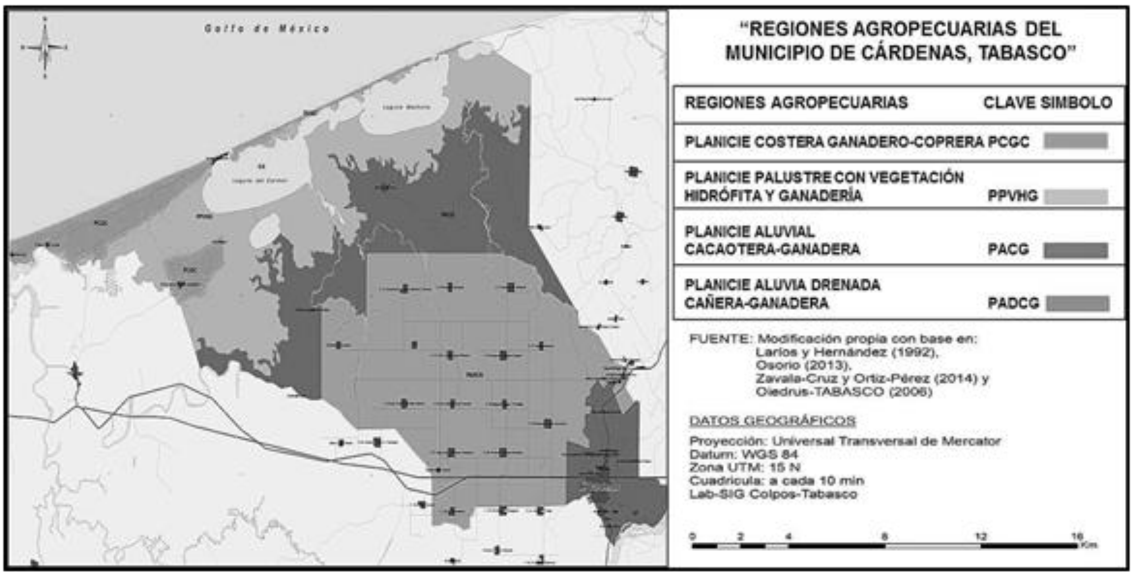

Fig. 1. Zoning of agricultural regions.

Agricultural regions

Four agricultural regions modified from previous works were differentiated: coastal plains cattle-coprera, marshy plain with hydrophytic vegetation and livestock, cacao-livestock alluvial plains, alluvial drainage cañe-ganadera. The four selected regions served as a basis to obtain the data of the factors and variables that intervened in the description of the bovine weight gain. Fig. 1 describes the four regions, the extension of the regions of the alluvial plain drained cane-livestock with 40% and the alluvial plain cacao-livestock with 29%. These four selected regions served as a basis for obtaining data on the factors and variables involved in the production of beef cattle (Osorio, 2008).

According, Niño and Danna (2016), since cartography allows the individual to locate, explore, delimit, manage, trade and support production activities. According, Domínguez-Domínguez *et al.* (2011) and Zavala *et al.* (2012), the soils that predominate in the agricultural regions studied are: Histosol, Solonchak, Gleysol, Arenosol, Fluvisol, Vertisol and Acrisol.

Delimitation and integration of agricultural regions

The integration of the agricultural regions (Osorio, 2008) was done by georeferencing the map with the QGIS version 2.6.1 program, where orthophotomaps were superimposed on the 1: 15000 scale regions of INEGI (2012).

Rectification of boundaries of agricultural regions

The boundaries of the agricultural regions were determined by retaking those established in several municipal studies (Table 1) and, when there were lags, they were improved by photointerpretation of the orthophotomaps taking into account the relief and land use factors, and tone, texture, shape and drainage, for each region. The final map was made at the level of recognition at 1: 250,000 scale.

Table 1. Cartography used to rectify the boundaries of the agricultural regions.

Agricultural Region Scale Source	Agricultural Region Scale Source	Agricultural Region Scale Source
Coastal plain Coprera	1:250000	Zavala y Ortiz (2015)
Palustre plain with hydrophytic vegetation and livestock	1:75000	Domínguez- Domínguez *et al.* (2011) Zavala y Ortiz (2015)
Alluvial drainage drained	1:250000	Domínguez- Domínguez *et al.* (2011)
Alluvial plain cacao-livestock	1:250000	Zavala y Ortiz (2015)

Factors and variables that intervene in the beef production of meat

In order to generate the simulation model, literature review was carried out, and thus, the factors and variables that determine the bovine production of meat were identified; for the animal factor the variable weight; for the prairie factor, the grass type variable according to Castellaro *et al.* (2007) and Vargas (2009); for the climate factor the variables radiation and temperature, according to Birrell and Thompson (2006), Hernández *et al.* (2011) and Graux *et al.* (2011) (Table 2).

Table 2. Factors and variables of the model for bovine meat production.

Factor Variables Units	Factor Variables Units	Factor Variables Units
	Global radiation	Calories / (Centimeters ^ 2-Days)
Weather	Maximum temperature	Degrees Celsius
	Minimum temperature	Degrees Celsius
Animal	Liveweight	Kilograms
Meadow	Type of grass	Kilograms / Hectares

The input parameters of the model are climate data based on average values of each agricultural region (Table 3).

Table 3. Values of the input variables of the agricultural regions.

Agricultural region	Season	Julian day	Maximum temperature	Minimum temperature	Global radiation
Alluvial plain drained cane-livestock	Dry	76	31.7	20.1	444.6
	Rains	212	33.4	22.4	419.6
	Nortes	350	28.3	19.0	211.8
Coastal plain livestock-coprera	Dry	76	31.0	20.8	436.3
	Rains	212	33.2	23.3	419.7
	Nortes	350	28.1	19.5	119.5
Palustre plain with hydrophytic vegetation and livestock	Dry	76	31.4	20.3	496.1
	Rains	212	33.1	22.6	462.9
	Nortes	350	28.5	19.6	294.3
Alluvial plain cacao-livestock	Dry	76	31.1	20.2	448.2
	Rains	212	33.1	19.2	427.5
	Nortes	350	28.1	19.2	317.2

For each agricultural region, two representative pastures with their respective characteristics were taken (Table 4).

Table 4. Values of pasture variables.

Agricultural region	Type of grass	Leaf area index	Daily weight gain	Dry material
Alluvial plain drained cane-livestock	Cynodon plectostachyus Echinochloa polystachya	1.9	0.383	22
		3.1	0.447	22
Coastal plain livestock-coprera	Echinochloa polystachya Cynodon plectostachyus	3.1	0.447	22
		1.9	0.383	22
Palustre plain with hydrophytic vegetation and livestock	Echinochloa polystachya Brachiaria mutica	3.1	0.447	22
		2.7	0.550	20
Alluvial plain cacao-livestock	Echinochloa polystachya Brachiaria mutica	3.1	0.447	22
		2.7	0.550	20

The sources used for the variables of the factors were the following: For the climate factor, the average of the annual databases of the climatological normals of the National Meteorological Service for the period 1981-2010 (maximum, minimum and global radiation) was calculated. For the prairie factor the index variable of leaf area (Guenni *et al.*, 2005), dry matter (Faría, 2006) and weight gain (Meléndez, 2012). We considered the types of pastures for each agricultural region (Ortiz y Zavala, 2012).

Development of the model

The model of the present work describes the potential production of weight gain (PPP) and the Animal Units (AU) per hectare of grazing cattle of the agricultural regions. The model consists of two submodels, potential biomass production (PPB) and potential production of weight gain. For the first sub-model, the methodology proposed by FAO was adopted, used by other researchers such as: Rivera-Hernández *et al.*, 2012, to calculate the potential yield of crops. The second sub-model describes the PPP and theAUs adding equations that calculate these variables from the PPB.

Evaluation of the results of the simulation model

For the evaluation of the results of the bovine meat production system, researches carried out by scientists of the Superior College of Tropical Agriculture (CSAT) in situ were used for the regions identified in this work, since it is the only institution of the State that has done studies complete about pasture production, related to the time, and meat production, which was required for the present work. The CSAT was closed by the government in 1985, due to the above, the data available to date does not cover the entire study area. The present study allows to identify the points of the municipality where it is necessary to focus the research in order to, in the future, offer the user of this type of services a broader description of the production of the entire region studied.

Results and discussion

The pastures chosen for this work are capable of developing in several regions and soils, and can also be used by the producer, due to the following characteristics: African star grass: can resist non-permanent flood soil; It develops satisfactorily in sandy soil and can develop in soils with salinity problems. German grass: it has an excellent growth in gleysoils (Gleysoles), is highly tolerant of poor drainage, can withstand certain salinity levels and grows better in saturated or seasonally flooded areas. Pasture Egypt: supports soil of high humidity and poorly drained soils where water is frequently waterlogged, adapts to soils from sandy to clay, tolerates moderate salinity (Meléndez, 2012).

Design of the simulation model

Fig. 2 shows the model that was designed to calculate the production of beef cattle in the four agricultural regions. The model developed in this paper is mechanistic and deterministic static based on the FAO zoning model, however, when interacting with a map, as well as parameters related to pastures, time of year, production of meat in production systems bovine, allows to improve the description of the system when adding the dimensions, temporal, spatial and systematic.

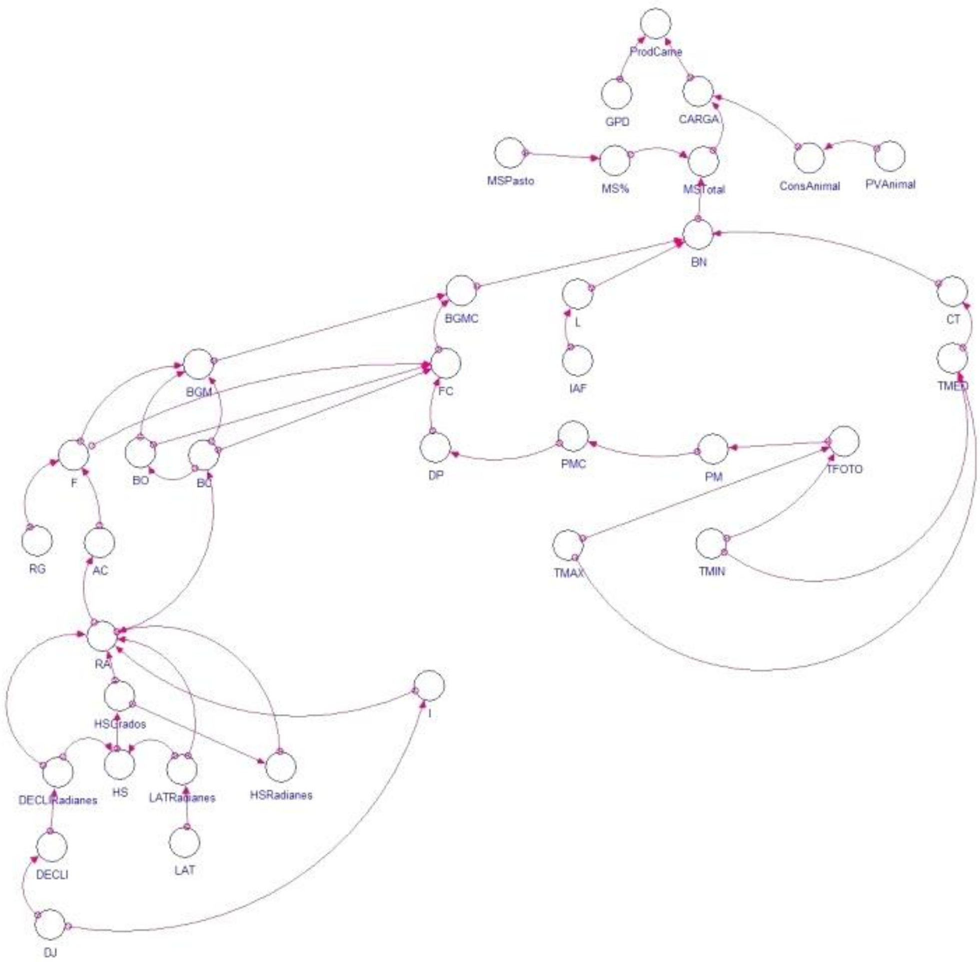

Fig. 2. Simulation model to calculate the beef production of meat.

Evaluation of the results of the simulation model for beef cattle production

The results showed differences of the productive variables between the agricultural regions, time of year and type of pasture (Table 7). To validate the data obtained by the model with the data generated in situ by the CSAT, similarity was observed in the values of the productive variables of animal load and weight gain. On the other hand, the developed model is feasible to be modified so that it better describes the beef production of meat in the municipality, however, currently, there is a need to carry out more research in the agricultural regions, since since it was closed In 1985, the CSAT ceased to generate on-site research on the production of pasture biomass and its relation to bovine production, which is essential for a better understanding of the bovine meat system.

Table 7. Potential bovine production by agricultural region and time of year for animals of 250kg live weight.

Agricultural region	Time of the year	Type of grass	UA	P. beef	BN	MS	GPD
Coastal plain livestock-coprera	Nortes	Cynodon plectostachyus	1.6	0.6	57.7	12.6	0.375
		Echinochloa polystachya	2.2	1.0	76.4	16.8	0.455
	Rains	Cynodon plectostachyus	3.8	1.4	131.5	28.9	0.368
		Echinochloa polystachya	5.1	2.2	174.1	38.3	0.431
	Dry	Cynodon plectostachyus	3.9	1.5	134.1	29.5	0.385
		Echinochloa polystachya	5.2	2.3	177.5	39.0	0.442
Palustre plain with hydrophytic vegetation and livestock	Nortes	Echinochloa polystachya	3.9	1.7	133.2	29.3	0.436
		Brachiaria mutica	3.3	1.8	124.0	24.8	0.545
	Rains	Echinochloa polystachya	5.4	2.4	186.2	40.9	0.444
		Brachiaria mutica	4.6	2.5	173.4	34.6	0.543
	Dry	Echinochloa polystachya	5.7	2.5	194.8	42.8	0.439
		Brachiaria mutica	4.8	2.6	181.4	36.2	0.542
Alluvial plain drained cane-livestock	Nortes	Cynodon plectostachyus	*2.3	0.9	80.3	17.6	*0.391
		Echinochloa polystachya	*3.1	1.3	106.4	23.4	*0.419
	Rains	Cynodon plectostachyus	*3.8	1.4	131.5	28.9	*0.368
		Echinochloa polystachya	*5.1	2.2	174.1	38.3	*0.431
	Dry	Cynodon plectostachyus	*3.9	1.5	135.9	29.9	*0.385
		Echinochloa polystachya	*5.2	2.3	179.9	39.5	*0.442
Alluvial plain cacao-livestock	Nortes	Echinochloa polystachya	4.1	1.8	140.7	30.9	0.439
		Brachiaria mutica	3.4	1.9	131.0	26.2	*0.559
	Rains	Echinochloa polystachya	5.1	2.3	176.3	38.7	0.451
		Brachiaria mutica	*4.3	2.4	164.1	32.8	*0.558
	Dry	Echinochloa polystachya	5.3	2.3	180.9	39.8	0.434
		Brachiaria mutica	*4.4	2.4	168.5	33.7	*0.545

* Values compared to literature

UA = Potential animal load per hectare

BN = Net biomass

MS= Dry material

GDP = Potential production of meat gain per animal per hectare per day

Región Planicie Aluvial drenada Canada-ganadera

The results of this investigation showed values of 3.9, 3.8 and 2.3AU/ha for the dry, rain and northern seasons, respectively. With respect, to the gain of weight for the dry season, rains and nortes an average of 0.385, 0.368 and 0.391kg/day was obtained, respectively. Similar results for this region were obtained by Castro *et al*. (1980), where the star grass of Africa (*Cynodon plestoctachyus*) has the highest production of forage during the dry season and therefore the highest values in UA of 3.7AU/ha and in the rainy season of 3.6AU/ha, with weight gains of 0.375 and 0.367kg/day, respectively. The lowest animal load was presented in the northern season with 2.2AU/ha and weight gains of 0.390kg/day, this may be due to the fact that the climatic conditions were inadequate for the development of the grass. The simulation model achieved an efficiency, when compared with Castro's results, a very small difference of less than 2%. Within the same agricultural region based on the German grass (Echinochloa polystachya), the results of the validation model for dry, rainy and northeastern times were 5.2, 5.1 and 3.1AU/ha with weight gains of 0.442, 0.431 and 0.419kg/day, respectively. These results when compared with those found by Moreno *et al*. (1977) had a maximum difference of 12%. ThisAUthor, obtained in the dry seasons 5AU/ha with gains of weight of 0.499kg/day and in rainy season 4AU/ha with gains of weight 0.494kg/day. While, during the northern season, the lowest yields were found with an animal load of 3.3AU/ha and a weight gain of 0.456kg/day. This could be because the low temperatures and short photoperiod affect the growth of the pastures.

Plain Alluvial region cacao-livestock

The results of the simulation, when the Egyptian grass (*Brachiaria mutica*) was used, were, for the dry season, 4.4AU/ha with weight gains of 0.545kg / day; rains of 4.3AU/ha with weight gains of 0.558kg/day; Y. for northers, 3.4AU/ha with weight gains of 0.559kg/day. This is probably due to the fact that minimum temperatures have a greater detrimental effect on forage production. Results similar to those of this investigation were found by Pérez *et al*. (1980), with the Egyptian grass (*Brachiaria mutica*), where the highest animal load in the production of meat, was in the dry seasons with parameters of 4.2AU/ha with gains of weight of 0.550kg/day and rainfall 4.0AU/ha with weight gains of 0.521kg/day. Having a difference to what is reported by the literature of approximately 6%.

Palustre plain with hydrophytic vegetation and livestock

The edaphic limitations that restrict the agricultural exploitation for this region is: flood, phreatic mantle and salinity, reason why in this region the pastures are cultivated in the meadows: German and Egypt that are highly tolerant to the bad drainage. In the simulation of the model the highest meat production parameters were found with 5.7AU/ha with a weight gain of 0.439kg/day, however, it is worth mentioning that this region presents flooding problems during most of the year (up to 10 months) for which its agricultural use is restricted. No information could be obtained from the literature on livestock production in this region.

Coastal plain livestock-coprera

The edaphic limitations that restrict the agricultural exploitation for this region are: fertility and texture. In this region pastures are cultivated: African and German Star that support salinity problems. In the simulation of the model, the lowest meat production parameters were found with 1.6AU/ha with a weight gain of 0.375kg/day. In addition, it is worth mentioning that this region presents problems to sustain high production parameters since the deficiency of nutrients and Water in the soil affects the growth of crops and livestock, thus limiting their agricultural use. Nor, in this region, was it possible to obtain information from the literature on livestock production. However, the results of the simulation can give us some information on the livestock production of the region that was previous to the results obtained in the present work.

Average productive values

Based on data from INEGI 2012, the average animal load was 1.8AU/ha/year; however, it can vary according to the live weight of the animal, type of grass and climate of each one of the agricultural regions. The simulation model used was based on the potential parameters, while the INEGI information is based on surveys to the producers of the number of animals they have on their land or ranches and in this way calculates the animal load. According to the validation of the simulation model, the highest yields were obtained in the dry and rainy seasons, presenting the lowest levels of meat production in the northern season, which is confirmed by previous studies. In this sense, otherAUthors such as Guenni *et al.*, 2005, mention that the factors that limit the growth of pastures are: fertilization to increase the coverage, the trampling, since it compacts the soil causing problems for growth, and the index of foliar area of the grasses that can vary according to the seasons, species and production system, and consider that a combination of several of these factors is the reason for the greater productions in dry and rainy seasons. In the dry season, the residual moisture left by the northern season allows for greater grass growth (Meléndez, 2012).

Examples of use of the simulation model as support in decision making

When the application is used by users (producer, government and investors), the objectives of each actor must be taken into account in order to make the most appropriate decision, for example: a) The producer can decide if, according to the time of year, maintain the same productive values of animal load throughout the year, and if not, at what time it would have to supplement. b) The investor who needs to build a refrigerated trail, can with this tool determine in which agricultural region could establish the building, in addition, know the production of meat and animal load. c) The government can use the results of the simulation to know the agricultural regions of greater production of meat, and make it known, through the federal or state government programs, to the producers or recommend to the investors the agricultural regions more productive to offer greater guarantees of profitability.

Conclusions

The simulation model, based on the zoning of agricultural regions, to estimate potential pasture performance, demonstrated its usefulness in the spatial and temporal description of the potential production of biomass that can later be used to describe cattle production. The developed model needs to be evaluated under different conditions, since factors such as soil type, residual moisture, flood, etc., can decrease the accuracy. The simulation models are able to achieve interoperability using data or cartographic information, through the adoption of data transfer protocols, and in this way make the results of the predictions accessible, with the aim of being used as a tool of decision making by the producer.

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