# The management of extensive livestock systems and its relationship with greenhouse gas emissions

## El manejo de sistemas ganaderos extensivos y su relación con los gases de efecto invernadero

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**Abstract**

During food fermentation, the digestive system of bovines generates methane gas as agricultural waste. Considering this, this study intended to evaluate different relationships between production type and management technologies, with enteric methane and nitrous oxide emissions, from beef cattle systems in the southern region of the San Luis province. To achieve this objective, 30 semi-structured surveys were conducted with regional producers. The producers were generally characterized, and the emissions were estimated through the application of the IPCC Level 2 protocols. Then, considering various techniques for technology management and adoption, these emissions were analyzed and compared. The production systems resulted to be heterogeneous in area, number of cattle, rodeo management, livestock unit, production, and other aspects. The estimated emission values were also variable depending on the form of expression, the management strategy adopted, and the production system applied. From a reductionist perspective of the aspects that characterize the extensive livestock systems evaluated, greenhouse gases emission values (GHG) are relative to the interaction of some predictive variables with the key factors of the production system and management techniques applied. Thus, when considering the emissions per kg sold, cow-calf+backgrounding or

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backgrounding systems, are environmentally more friendly than those of cow-calf, being the bull category the most sensitive to gas emissions. However, moderate or very good management in the cow-calf systems, tend to reduce them. Since the characteristics of the systems are so diverse, even for the same region, a broader and more integrated view is proposed for the expression of emissions, given by the set of variables that reflect the integral behavior of the system.

**Keywords**
methane • nitrous oxide • cow-calf system • backgrounding • semi-arid

## Resumen

Los bovinos, dado su sistema digestivo, generan gas metano como residuo durante la fermentación del alimento consumido. El objetivo de este estudio fue evaluar relaciones entre tipo de producción y tecnologías de manejo con las emisiones de metano entérico y óxido nitroso generado por el ganado bovino en sistemas extensivos del sur de San Luis. Para ello, se realizaron 30 encuestas semiestructuradas a productores de la región. Se realizó una caracterización general de los productores, se estimaron las emisiones mediante la aplicación de los protocolos del Nivel 2 del IPCC y se analizaron y relacionaron las emisiones teniendo en cuenta diversas técnicas de adopción y manejo de tecnologías. Se trata de sistemas productivos heterogéneos en sus distintas dimensiones (superficie, cantidad de ganado, manejo del rodeo, carga animal, producción etc.). Los valores de las emisiones estimadas también fueron variables dependiendo de la forma de expresión, el manejo adoptado y el sistema productivo aplicado. Desde una mirada reduccionista de los aspectos que caracterizan los sistemas ganaderos extensivos evaluados, los valores de emisiones de gases de efecto invernadero (GEI) son relativos a la interacción de algunas variables predictivas con los factores tipo de sistema de producción y técnicas de manejo aplicadas. Así, al considerar las emisiones por kg vendido, los sistemas cría+recría o recría resultan más amigables con el ambiente que los de cría, siendo la categoría toro la más sensible a las emisiones de gases. Sin embargo, un manejo moderado o muy buen manejo en los sistemas de cría conduce a reducirlas. Al ser tan diversas las características de los sistemas, aún para una misma región, se propone una visión más amplia e integrada para la expresión de las emisiones, dada por el conjunto de variables que reflejan el comportamiento integral del sistema.

**Palabras claves**
metano • óxido nitroso • cría bovina • recría bovina • semiárido

## Introduction

Methane ($CH_4$), nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$) emission resulting from many activities related to agriculture, energy production, transport, industry, and waste. Although these gases are released to the atmosphere, for livestock producers they entail energy loss. Among other reasons, this loss could be due to the lack of efficiency in the use of inputs and nutritional resources, since part of the energy ingested as food is lost in the form of $CH_4$ instead of being assimilated by the animal and used for production. These energy losses not only have implications for climate change (CC), but they are also negative to production (22, 23).

Livestock is a means of support for a wide sector of the population (18, 32) and its production, in large part, comes from extensive systems (27, 30, 36) in which the animal is gestated, raised, reared and finished with grass or forage. For some, these livestock systems are greenhouse gases (GHG) emitters (37), while for others, they play an important role in mitigating the CC (11, 18). The beef cattle systems of the San Luis province, Argentina, are very diverse, depending on the environmental and infrastructural conditions, and their structural, economic, and social resources (8, 14, 32). This diversity can also vary according to the type of production system, namely cow-calf system (9, 29, 39), backgrounding system, or finishing system. The incorporation of perennial grasses in degraded areas of the natural grassland constitutes an example of the improvement options for semi-arid livestock systems (29, 39). The type of production and management they apply (21, 26) will depend on the production strategy.

The intensity of GHG emissions (21) will depend on the characteristics and management of the beef cattle systems. The different interactions that occur between productive management and emissions, depend on the type of production system, its management, and the way of expressing emissions. For such reason, they must be particularly analyzed in order to develop appropriate management strategies for each situation. Research studies mention GHG emissions mainly referred to kg of animal produced (kg/animal) and area (ha) (4, 31). The objective of this study was to evaluate different relationships between production type and management technologies with the emissions of enteric methane and nitrous oxide generated by beef cattle systems in the southern region of the San Luis province.

## Materials and methods

Thirty surveys with farmers of agricultural establishments were conducted in the southern region of the Juan Martín de Pueyrredón Department in the San Luis province. The climate is semi-arid, with an average annual precipitation of 425 mm and an average annual temperature of 16°C. The soils have low water retention capacity and low to medium productivity (25), making them inadequate for crop implantation. Natural grassland constitutes the main food source for livestock, which is an important economic activity in the region (32). The native vegetation has low forest formations of carob trees (*Prosopis flexuosa*), jarilla shrubs (*Larrea divaricata*) and chañar (*Geoffroea decorticans*), sandy areas with grasslands (*Nassella tenuis, Piptochaetium napostaense, Poa ligularis*) and chañar islets (*Geoffroea decorticans*). In the region, extensive cow-calf systems prevail, based mainly on native grassland, and in a few cases, implanted pastures such as buffelgrass (*Cenchrus ciliaris*) and weeping love grass (*Eragrostis curvula*) (2). The survey collected detailed information on the size and structure of the systems, their production, livestock feeding, and technical management. With the collected information, a general descriptive analysis of cattle systems was carried out, mainly characterizing management.

The Level 2 protocols of the IPCC (15) were applied. $CH_4$ was estimated by means of enteric fermentation ($CH_4EF$) while $N_2O$ emissions from the managed soils ($N_2OMS$) were estimated considering the N of urine and manure spread in pastures by grazing animals. The emission results were expressed in kg $CO_2$ equivalent ($CO_2$ eq) ($CH_4$= 25 and $N_2O$= 298) (7). The emissions of the systems were expressed as animal emissions (Em/animal), calf emissions (Em/calf), area emissions (Em/ha), livestock unit emissions (Em/LU), animal live weight emissions (Em/LW), sold kg emissions (Em/kg sold).

The emission variables by animal category were analyzed using descriptive statistics and the ANOVA one-factor test was used for comparison. Tukey HSD test ($p<0.05$) was applied for variables in which the ANOVA was significant ($p<0.05$). To compare emissions in relation to production system type and management variables, another ANOVA was performed (Test Tukey). In addition, a Partial Least Squares (PLS) regression analysis (6) allowed observing the relationship between dependent variables (emissions), variables characterizing the system (predictors), and latent variables (factors) (table 1, page 180). The latent variables were unified and redefined according to their application levels, simplifying their manipulation (see coding in table 1, page 180). The analysis was performed using the InfoStat/P V2016 (5) software.

## Results and discussion

### General characteristics of extensive production systems

Table 2 (page 181), shows some general characteristics of the systems of the studied region. Producers are, on average, 56 years old, although 19% are younger than 45 (table 2, page 181). As for the use of the land, the average establishment size is highly variable (from 67 to 23400ha). All have cattle, mainly cow-calf systems with an average rodeo size of 466 heads, varying from 20 to 2141 heads. The average livestock unit is 0.13 LU/ha (0.05 to 0.46 LU/ha) or 8.12 ha/head. For cattle feeding, all establishments have nature pastures, some have also implanted perennial pastures (*Eragrostis curvula, Digitaria eriantha* and *Panicum coloratum*) and others, annual forage crops (if enough rains permit it). Additionally, some also need to purchase food at some point during the year (*Medicago sativa, Zea mayz*). As for the infrastructure, they have one or several paddocks, depending on the area or extention of their field. Regarding the availability of water for livestock, they have dams, perforations, and a network of aqueducts for the distribution of water, with tanks and drinkers.

Regarding livestock management, it is noted that a significant percentage of the establishments have technical assistance (veterinarian (43%), engineer (27%). The grazing system can be continuous or rotational. In relation to animal health control, a significant percentage practice bull review (41%) and rectal palpation (44%), provide reproductive vaccines (54%), parasites control (63%) and determine pregnancies.

As for the livestock reproductive system, 56% of the producers have a seasonal mating system and 44% have year-round mating systems. In addition to using a seasonal mating system, two producers apply artificial insemination.

The weaning rate has an average of 65%, although its minimum and maximum values are highly variable depending on the establishment (26-95%).

**Table 1.** Type of variables related to system characteristics and productive management.

**Tabla 1.** Tipo de variables relacionadas con las características del sistema y manejo productivo.

| Variables | Indicators | Description | Codification |
|---|---|---|---|
| **Predictors** | System characteristics | Implanted pastures (%) | % impl past |
| | | ha/paddocks | ha/paddock |
| | | Livestock unit/ha | LU/ha |
| | | kg sold/ha | kg sold/ha |
| **Factors (latents)** | Production system type | Cow-calf | C |
| | | Backgrounding | B |
| | | Cow-calf + Backgrounding | C+B |
| | Technical raising management | Grazing system: Continous, rotational | According to application[1]: none management (NM) moderate management (MM) appropriate management (AM) |
| | | Reproductive system: year-round mating, seasonal mating, artificial insemination | |
| | | Livestock controls: teeth examination, body condition, rectal palpation | |
| | Technical advice | Professional assistance: veterinarian, agronomist, accountant | According to: none technical advice (NA) moderate technical advice (MA) good technical advice (GA) |
| | Health in raising | Sanitary controls: reproductive vaccine, bull review, venereal control, parasites controls | According [2] to : no control (NC) 1 control (1C) 2 or more controls (2 o MC) |

[1]NA: continuous grazing, year-round mating, no livestock care control. MM: application of some management technique, some rotational grazing system, some controlled but irregular reproductive system, and some livestock care control. AM: rotational gazing system, seasonal mating system and/or artificial insemination, most or all livestock care control. [2]NC: no sanitary control applies. 1C: apply at least one sanitary control. 2 o MC: two or most sanitary controls apply.

[1]NA: pastoreo continuo, servicio reproductivo continuo, ningún control del ganado. MM: aplicación de alguna técnica de manejo, algún sistema de pastoreo rotativo y reproductivo controlado pero irregular, algún control del ganado. AM: sistema rotativo y estacionado y/o inseminación artificial, la mayoría o todos los controles del ganado. [2]NC: no aplica ningún control sanitario. 1C: aplican al menos un control sanitario. 2 o MC: aplican dos o la mayoría de los controles sanitarios.

In terms of production, they have an average of 18.3 and 138 kg sold/ha and LU, respectively, although their minimum and maximum values are also highly variable. When analyzing the system's output (sales), 45 % are weaned calves, 41% backgrounding animal (steer, heifer), and 14% are discarded animals (cow, bull) (table 2, page 181).

**Table 2.** Descriptive characteristics of the bovine systems in the study area (in percentage).

**Tabla 2.** Características descriptivas de los sistemas bovinos del área de estudio (en porcentaje).

| Variables | Description | Percentage (%) |
|---|---|---|
| **Producer's age (years)** | <45 | 19 |
| | 46-60 | 41 |
| | >61 | 41 |
| **Area (ha)** | <1000 | 33 |
| | 1001-3000 | 26 |
| | 3001-6000 | 31 |
| | >6000 | 10 |
| **Paddocks for grazing (number)** | A paddock | 20 |
| | 2-5 | 37 |
| | 6-10 | 27 |
| | >11 | 17 |
| **Cattle feed** | Native pastures | 100 |
| | Improved pastures | 23 |
| | Annual forage crops | 17 |
| | Purchased food | 50 |
| **Production system** | Cow-calf | 67 |
| | Backgrounding | 10 |
| | Cow-calf + Backgrounding | 23 |
| **Number of heads** | <100 | 37 |
| | 101-400 | 20 |
| | 401-700 | 30 |
| | >701 | 13 |
| **Technical assistance** | None technical advice (NA) | 53 |
| | Moderate technical advice (MA) | 30 |
| | Very good technical advice (GA) | 17 |
| **Grazing system** | Continuous | 23 |
| | Rotational | 77 |
| **Health control** | No control (NC) | 27 |
| | 1 control (1C) | 23 |
| | 2 or more controls (2 o MC) | 50 |
| **Raising management** | None management (NM) | 30 |
| | Moderate management (MM) | 40 |
| | Appropriate management (AM) | 30 |

**Management and emissions in extensive bovine systems**

After the protocol applications (Level 2) of the IPCC (15), the systems of the south of San Luis emitted a total of 22277872 kg $CO_2$ eq in a total area of 107954 ha and with a total number of 13288 animals, corresponding to 30 establishments. Such results emitted an average of 742596 kg $CO_2$ eq per establishment (from 24720 to 4255534 kg $CO_2$ eq). Table 3 (page 182) shows the emission values and their relationship with the type of production system and livestock management technique.

Depending on the way in which the general averages are analyzed, they can result varied and quite different at the same time, something interesting to analyze in order to have a broader vision and to obtain an approximate analysis of the production systems. Emissions results can be expressed in different ways (1): animal (20, 21), live weight (28) and area (4). From the total emissions, 84% corresponded to $CH_4$FE emissions. Similar results were found in other studies (20, 33, 34, 37).

A decrease in productive efficiency due to energy loss is mentioned (23), being, however, susceptible to improvement with the application of appropriate technologies that tend to mitigate gas emissions (10, 18, 21, 38).

The proportion of the categories in a system contributes to the characterization of the production type. Therefore, the variability of the emissions depends on the type of production system (19). In the systems here analyzed, the calf and bull categories significantly differed from all the other categories (P<0.05).

**Table 3.** Average values and standard deviation of emissions according to type of production system and management techniques (kg $CO_2$ eq).

**Tabla 3.** Valores promedios y desviación standard de emisiones de las explotaciones según tipo de sistema de producción y técnicas de manejo (kg $CO_2$ eq).

| Indicators | | Emissions kg $CO_2$ eq | | | | | |
|---|---|---|---|---|---|---|---|
| | | Em/calf | Em/ha | Em/LU | Em/LW | Em/kg sold | Em/animal |
| General Average | | 4864±1449 | 261±205 | 2052±372 | 6±1 | 20±9 | 1564±210 |
| Production system [1] | C | 4839±1240 | 243±225 | 1882[a]±333 | 5[a]±1 | 24[b]±7 | 1492±181 |
| | B | 3250±0 | 345±70 | 2194[ab]±171 | 7[b]±1 | 7[a]±6 | 1682±117 |
| | C + B | 5092±1854 | 269±200 | 2345[b]±298 | 6[a]±1 | 16[ab]±6 | 1668±242 |
| Raising management [2] | AM | 4829±1690 | 253±179 | 2189±358 | 6±1 | 18[a]±6 | 1678±199 |
| | MM | 4690±1014 | 225±136 | 1985±433 | 5±1 | 17[a]±5 | 1476±188 |
| | NM | 5287±1543 | 277±322 | 1877±338 | 5±1 | 29[b]±6 | 1452±195 |
| Animal health in raising [3] | 1 C | 4882±1822 | 250±76 | 1984±295 | 6±1 | 21±12 | 1587±162 |
| | 2 o MC | 4902±1544 | 248±177 | 2145±372 | 6±1 | 18±7 | 1611±212 |
| | NC | 4766±1051 | 295±324 | 1935±426 | 6±1 | 21±9 | 1457±229 |
| General technical assistance [4] | GA | 3970±1000 | 248±161 | 2090±465 | 6±1 | 20±6 | 1643±262 |
| | MA | 5414±1774 | 270±182 | 2146±185 | 6±1 | 13±7 | 1683±160 |
| | NA | 4903±1359 | 260±238 | 1987±425 | 6±1 | 23±8 | 1473±185 |

Different letters in the same column and by indicators indicate significant differences (p > 0.05) Test Tukey.

[1]C: cow-calf; B: backgrounding; C+B: cow-calf + backgrounding. [2]AM: appropriate management; MM: moderate management; NM: none management. [3]1 C: 1 control; 2 o MC: two or more controls; NC: no control. [4]GA: good technical advice; MA: moderate technical advice; NA: none technical advice.

Diferentes letras en la misma columna y por indicador indica diferencias significativas (p > 0,05) Test Tukey.

[1]C: cría; B: recría; C+B: cría+recría. [2]AM: muy buen manejo; MM: manejo moderado; NM: ningún manejo. [3]1 C: 1 control; 2 o MC: 2 o más controles; NC: ningún control. [4]GA: muy buena asistencia; MA: moderada asistencia; NA: sin asistencia.

The bull category emitted 35%; 35%; 65%; 30%; 39% more emissions than the cow, heifer, calf, young bull and steer categories, respectively. In cow-calf systems, as they include all animal categories (cow, replacement heifer, weaned calf, young bull, bull, cows raising their last calf) (12), intensities vary widely in their averages. The highest values were attributed to the heaviest category: bull. Therefore, to identify the categories present in the systems turn important, since emissions, according to various authors, can be very different among them (2, 3, 24, 34).

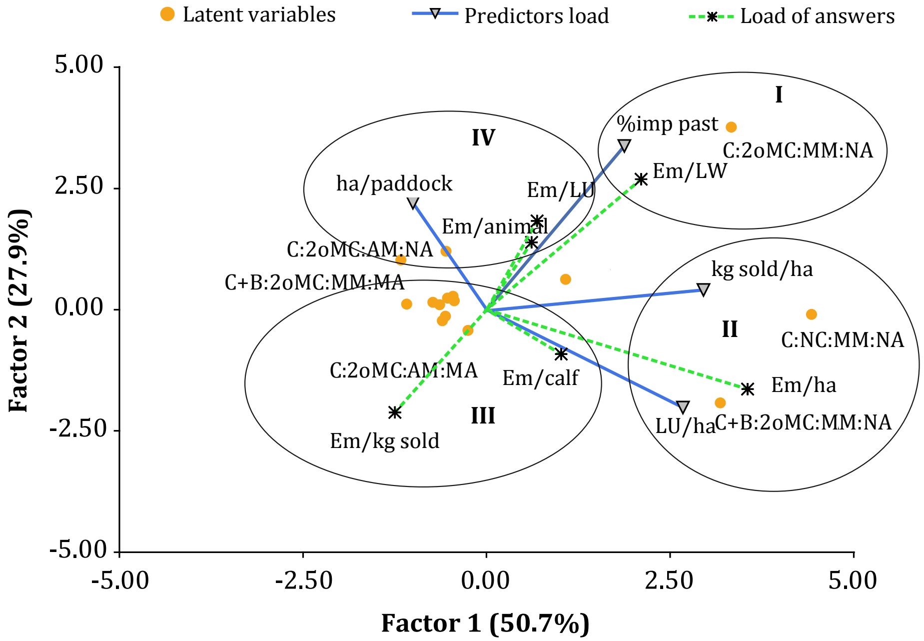
Depending on the type of system, the Em/animal, Em/calf and Em/ha showed no differences ($p>0.05$). On the other hand, when the emissions were considered from the point of view of Em/LU, Em/LW and Em/kg sold (table 3, page 182), significant contrasts were found ($p<0.05$). Regarding the emissions per Em/LW sold, the C systems emitted more gases than the B systems, similarly to the results found for grassland beef systems in Uruguay (4, 17, 28), in Argentina (20) and in Canada (1). The B systems emissions had similar values to those from Uruguay (17). When considering livestock unit load (LU/ha), C systems presented advantages in emissions with respect to those of B and C+B, since they constitute systems with low receptivity for their forage structure. In turn, C and C+B systems, emitted less Em/LW emissions, given the variability in categories and high weight of most of the animals in these systems.

Taking the different levels of raising management into account, significant differences were only found in Em/kg sold emissions, observing that those who apply moderate management or very good management, emitted fewer emissions than the ones which do not apply any raising management (table 3, page 182).

By relating certain characteristic aspects of these systems, their management and the emitted emissions, the first two main components of the PLS analysis explain 78.6% of the relationship found between emissions (response variables), with system management factors (latent variables) and system characteristics (predictors variables) (figure 1, page 184). The strongest predictors for emissions were kg sold/ha, % implanted grass and LU/ha. The % of implanted grass was related to Em/LW, while the LU/ha predictor was related to Em/ha and Em/calf emissions.

When analyzing the response, predictive and latent variables as a group, the following was observed: I) Em/LW emissions resulted to be highly related to the percentage of implanted pasture, C system, MM, 2 o MC and NA; II) Em/ha emissions were related to kg sold/ha, LU/ha and C, C +B, MM, NA and 2 o MC; III) Em/calf emissions and Em/kg sold emissions were related to C, 2 o MC, MA and AM; and IV) Em/animal and Em/LU emissions were associated with ha/ paddock, C, 2 o MC, AM and NA.

If the variables observed in figure 1 (page 184) are analyzed with the indicated values of the response variables and those related to management (table 3, page 182), the fact that the quadrant indicated as "I" refers to the systems that generate or emit greater emissions by Em/LW (C y NA >1400 $CO_2$eq; AM y 2 oMC >1500 CO2eq), can be detected. While quadrant "II" reflects intermediate to low emissions, "III" shows fewer emissions from Em/kg sold emissions but higher emissions from Em/calf emissions. The "IV" quadrant refers to lower emissions when expressed by Em/LU and Em/animal in the cow-calf system and without NA, but higher in AM and 2 o MC emissions.




Load of answers: Em/animal: animal emissions. Em/calf: calf emissions. Em/kg sold: kg sold emissions. Em/LU: livestock unit emissions. Em/LW: animal live weight emissions. Em/ha: hectare emissions. Latent variables: C: cow-calf. B: backgrounding. C+B: cow-calf + backgrounding. NM: None management. MM: moderate management. AM: Appropriate management. NA: No technical advice. MA: Moderate technical advice. GA: good technical advice. NC: no control. 1C: 1 control. 2 o MC: 2 or more controls. Predictors load: % impl past; ha/paddock; LU/ha; kg sold/ha.

Variables respuesta: Em/animal: emisiones por animal. Em/calf: Emisiones por ternero. Em/kg sold: Emisiones por kg vendido. Em/LU: emisiones por EV. Em/LW: emisiones por peso vivo animal. Em/ha: Emisiones por hectárea. Variables latentes: C: cría; B: recría; C+B: cría + recría; NM: ningún manejo; MM: manejo moderado; AM: muy buen manejo; NA: sin asistencia; MA: moderada asistencia; GA: muy buena asistencia; NC: ningún control; 1C: 1 control; 2 o MC: 2 o más controles. Variables predictoras: kg vend/ha; % pastura implantada; EV/ha; ha/potrero.

**Figure 1.** Triplot of the correlation between the interaction matrix of dependent variables (emissions), latent variables (system factors) and predictors (system characteristics).

**Figura 1.** Triplot de la correlación entre matriz de interacción entre variables respuestas (emisiones), latentes (factores del sistema) y predictores (características del sistema).

The analysis explains that the systems that apply or adopt any improvement techniques in the management of livestock production systems, emit fewer emissions. Different authors assert the importance and the need to have an adequate management in the farms in order to obtain fewer GHG emissions (4, 10, 35). Huerta *et al.* (2016) claim that the cow-calf system (C) is the main contributor of most of the environmental impacts analyzed, although they also assume that extensive systems have a better environmental performance than intensive systems in most of the categories studied. Becoña *et al.* (2014) demonstrate that, in a C system, moving on to an improved grazing (incorporating other pastures) and better livestock management, forage availability can be increased without increasing pasture area (increased receptivity), reducing a significant percentage of emissions. Dick *et al.* (2015) and Leguia *et al.* (2019), argue that, in order to reduce the environmental impacts of livestock productions, strategies should focus on productive improvement, for example by improving pasture management.

## Conclusions

Under a reductionist perspective of the aspects that characterize the extensive livestock systems evaluated, the GHG emission values are relative to the interaction of some variables related to the typical characteristics of the production systems and to some management techniques applied. In this sense, when considering the kg sold emissions, C+B or B systems turn to be environmentally friendlier than those of C, being the bull category the most sensitive to gas emissions. However, moderate management or very good management in C systems, reduces them. But, as the analysis of the emissions is relative to the predictor used, when the emissions are expressed in terms of LU emissions, C system is mostly favored. This feature reflects a limited receptivity of the forage structures of the semi-arid environment and, in counterpart, mitigation of emissions. Therefore, an exhaustive study in the choice of predictor variables and analysis factors, is suggested.

Since the characteristics of the systems are so diverse, even for the same region, an integrated vision for the expression of emissions is proposed, given the set of variables that reflect the integral behavior of the system (response, predictors and factors variables). From this perspective, the systems that apply or adopt one or several techniques for improving the management of livestock production systems, emit fewer emissions.

To continue deepening on the comparative studies between semi-arid production systems is proposed, evaluating emissions and considering other management variables such as socio-economic and environmental variables, not analysed in this opportunity.

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