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Original

Spatial characterization of the bovine livestock in the Colombian Orinoquia

Raúl Molina-Benavides[1*] D.Sc; Clarita Bustamante Z[2] M.Sc; Adriana Martínez A[1] M.Sc; José Uribe C[1] M.Sc; Johan Redondo O[2] Ph.D.

[1]Universidad Nacional de Colombia sede Palmira. Carrera 32 # 12-00, Palmira-Colombia.
[2]Instituto de investigación de recursos biológicos Alexander von Humboldt. Calle 28A # 15-09, Bogotá D.C - Colombia.
*Correspondence: ramolinab@unal.edu.co

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ABSTRACT

Objective. Use Geographic Information Systems (GIS) as a complementary tool to characterize cattle farming in the Orinoquia region. **Materials and methods**. Through the use of space technologys, information concerning the livestock orientation, physiography, vegetation cover and land registry of the study zone was collected for further analysis over Microsoft ACCESS software. **Results**. In a high percentage of the cattle ranches located in the four departments (Casanare: 72.7%, Meta: 49.5%, Arauca: 42% and Vichada: 32%) the cover of pastures, grasslands and secondary vegetation predominates, confirming the expansion in the agricultural border that has had the cattle activity in the country. **Conclusions**. The use of complementary tools such as GIS allows for better planning and efficient distribution of resources to improve the functioning of production systems, for example, in zones where the predominant coverage matrix is grasslands, strategies in pro of sustainability can focus on the implementation of silvopastoral systems, contrary to what would happen in areas where the matrix has a high percentage of natural forests.

Keywords: Geographic information systems; land cover; polygons; spatial data analysis (*Source: CAB*)

RESUMEN

Objetivo. Utilizar los sistemas de información geográfica (SIG) como herramienta complementaria para caracterizar la ganadería bovina realizada en la región de la Orinoquia. **Materiales y métodos**. A través del uso de tecnologías espaciales se recopiló la información concerniente a la orientación ganadera, fisiografía, cobertura vegetal y catastro de la zona de estudio para su posterior análisis a través del software ACCESS de Microsoft. **Resultados.** En un alto porcentaje de los predios ganaderos ubicados en los cuatro departamentos de la Orinoquía (Casanare:72.7%, Meta:49.5%, Arauca:42% y Vichada:32%) predominan las coberturas de pastos, herbazales y vegetación secundaria, confirmando la expansión en la frontera agropecuaria que es promovida por la actividad ganadera en el país.

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Conclusiones. El uso de los SIG, permite realizar una mejor planificación y distribución eficiente de los recursos destinados a mejorar el funcionamiento de los sistemas de producción. Por ejemplo, en zonas donde la matriz de coberturas predominante son los pastizales y herbazales, las estrategias en pro de la sostenibilidad pueden enfocarse en la implementación de sistemas silvopastoriles, contrario a lo que pasaría en zonas donde la matriz de coberturas tenga un alto porcentaje de bosques naturales.

Palabras clave: Análisis de datos espaciales; coberturas de la tierra; sistemas de información geográfica; polígonos (*Fuente: CAB*).

INTRODUCTION

Approximately 40% of global arable land is dedicated to livestock production, which materializes in large tracts of land occupied by pastures and crops to feed these animals (1,2,3). Colombia has not been the exception in terms of the use of its continental area, livestock is using 85% more land without vocation for this activity, bringing with it problems of conservation and inadequate management of the environment (4,5,6).

In Colombia, more than 95% of production systems are based on grazing (7), that is, animals and their environment are directly exposed to the weather, often generating negative feedback effects that result in the degradation of production systems and the natural resources that support them (7,8).

Colombia has a bovine inventory close to 23 million animals, which are located on 39 million of hectares, classifying the country's livestock activity as extensive. This stocking rate of 0.6 animals/ha has not changed significantly in the last twenty years, revealing the low technological transformation of the livestock sector (8,9).

Of the total inventory, 56% are female, 26% are male and the remaining are animals younger than one year; This activity is carried out on 500,000 farms. The Colombian livestock activity has three orientations: i) meat production, ii) milk production and iii) dual purpose. Only 5% of the national inventory is classified as specialized dairy, while 35% is dedicated to dual purposes and the remaining 60% is engaged in extensive fattening and breeding activities. (8,9,10).

Of the 23 million head of cattle present in Colombia for the year 2015, 21.52% were in the Orinoquia region (according to the livestock inventory reported by the ICA). Traditionally, this region has been characterized by extensive livestock farming dedicated to meat production, exhibiting an orientation of 50% for meat, 40% dual purpose and 10% dairy (11,12). Historically, the departments of Casanare and Meta have contributed the largest number of animals to the inventory of the region, followed by the departments of Arauca and Vichada (Figure 1).

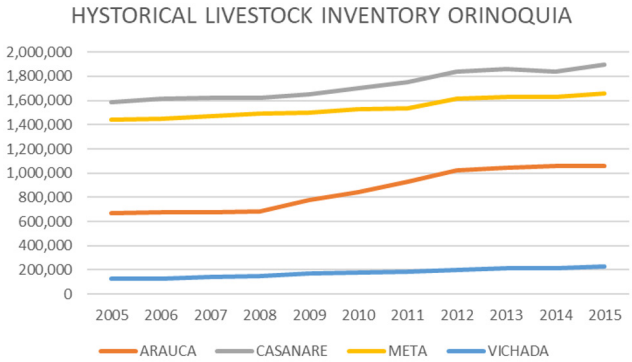

Figure 1. Historical livestock inventory 2005-2015 of the Orinoquia region. Source: ICA.

Given the complexity of livestock agroecosystems due to its multiple components (soil, vegetation coverage, relief, water, among others) (4), it is necessary to appeal to methodologies that allow knowing and understanding the dynamics of production systems (4,8,13).

Then biophysical characterization appears as a valid tool when it comes to knowing how livestock systems are shaped; What are its biotic components, limitations and potentials compared to other systems (14), seeking to generate policies that promote the sustainability of these agroecosystems (4,8,15).

This characterization can be addressed through novel technologies such as geographic information systems (GIS), which allow studying and analyzing agroecosystems at different spatial scales to generate more accurate information on their use and management (16).

Due to the aforementioned and changing the paradigm that livestock in Colombia can be classified only by its orientation, the number of heads per area, the use of inputs and the introduction of technology, ignoring the various combinations of the aforementioned factors and the different vegetation covers and reliefs typical of the Colombian territory, which may affect the dynamics of livestock activity, the objective of this document is to characterize bovine farming carried out in the Colombian Orinoquia region according to the number of farms found under the different livestock orientations, physiography and vegetation coverage, through GIS as a complementary characterization tool.

MATERIALS AND METHODS

Location. The livestock characterization was carried out in the Orinoquia region (Figure 2), following the steps proposed by Bermúdez et al., 2017 y Ochoa & Valerazo, 2014 (6,17). Through GIS, base cartography was compiled on geographic parameters such as: livestock orientation, physiography, vegetation coverage and cadastre of the study area.

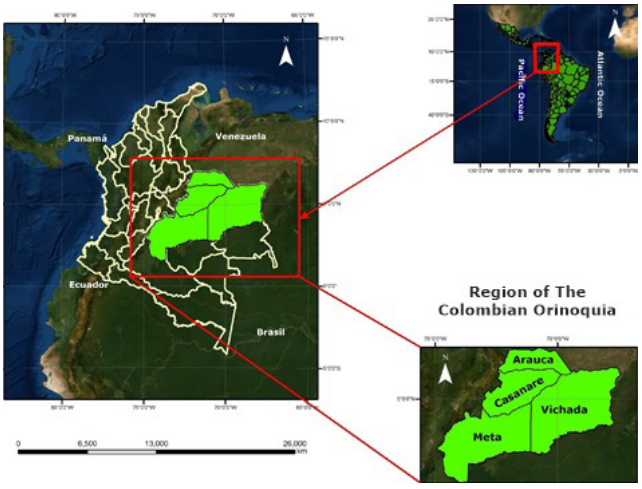

Figure 2. Study area corresponding to the region of the Colombian Orinoquia. Source: own elaboration.

Physiography of Orinoquia region. The shape of reliefs identified and defined from the comprehensive analysis of topographic, geological, hydrological and soil information, allow relatively homogeneous units to be formed for their analysis (18).

Eight homogeneous land surfaces were found for the Orinoquia region (Figure 3), which are named below:

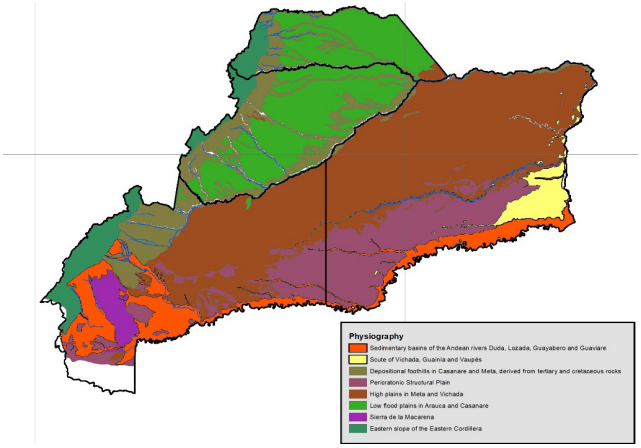

Figure 3. Reliefs found in the Colombian Orinoquia. Source: Institute for Biological Research Alexander von Humboldt.

Sedimentary basins of the Andean rivers Duda, Lozada, Guayabero and Guaviare (SBARDLGG).

Scute of Vichada, Guainía and Vaupés (SVGV).
Depositional foothills in Casanare and Meta, derived from tertiary and cretaceous rocks (DFCM).
Pericratonic Structural Plain (PSP).
High plains in Meta and Vichada (HPMV).
Low flood plains in Arauca and Casanare (LFPAC).
Sierra of the Macarena (SM).
Eastern slope of the Eastern Cordillera (ESEC).

In Figure 3, the physiographic distribution of the Orinoquia region can be seen. This map was used to analyze the intersection between the livestock orientation and its location within the relief of the study area.

Vegetation coverage of the Orinoquia region. The spatio-temporal association of characteristic plant elements, which make up structural and functional units, define the vegetation coverage of a place (19). Eight vegetation coverage were found for the Orinoquia region (Figure 4). These are listed and described below, following the definitions proposed by the Alexander von Humboldt Institute for Biological Research:

Natural forests (NF): In this category are dense, fragmented, gallery or riparian forests, and mangroves. This cover is characterized by trees with a height greater than 5 m and a canopy density greater than 70%.

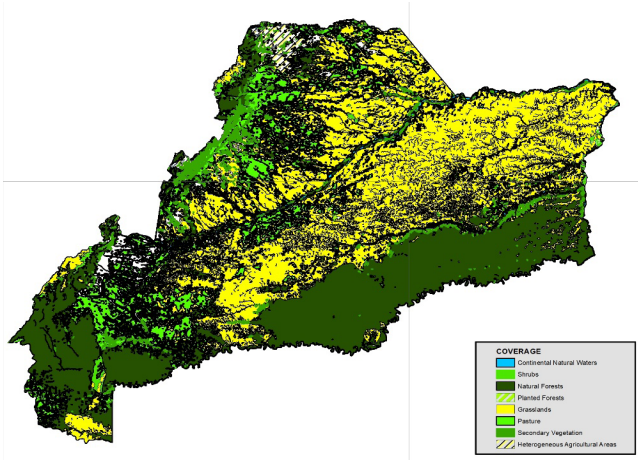

Figure 4. Vegetation coverage found in the Colombian Orinoquia. Source: Institute for Biological Research Alexander von Humboldt.

Secondary Vegetation (SV): In this category are stubble and vegetation coverage in a state of early succession. This vegetation is characterized by being of low height, which is generally the product of the succession process of pastures or crops, towards tree cover.

Continental natural waters (CNW): Are the rivers, lagoons, lakes or flooded areas present in the analyzed area.

Pasture (PT): In this category are clean, wooded, weedy or stubbled pastures. This cover includes herbaceous species that have been planted, generally used for livestock activities.

Grasslands (GL): In this category are paramo, savanna and xerophytic grasslands, which are characterized by the dominance of herbs and grasses. Additionally, these grasslands can present trees and shrubs.

Heterogeneous agricultural areas (HAA): Coverage characterized by the combination of different types of crops, annual and permanent; pastures and crops; crops, pastures and natural spaces.

Planted forests (PF): Coverage where predominate broadleaf and coniferous planted forests.

Shrubs (SH): Cover in which woody vegetation corresponding to bushes predominates. This category includes paramo, savanna or xerophytic shrubs.

Annual or transitory crops (ATC): Vegetable coverage made up of crops with a vegetative cycle lasting one year or less. Generally, after harvest, it is necessary to re-sow or plant to continue producing.

In Figure 4, you can see the distribution of vegetation coverage in the Orinoquia region. This map was used for the analysis of the intersection between livestock orientation and its association with the vegetation coverage of the study area.

Livestock orientation for the Orinoquia region. According to the purpose of the livestock producer, the livestock orientation can be broadly classified into specialized animals for milk production, animals dedicated to meat production and dual-purpose animals. Within the group dedicated to meat production, it is subdivided into breeding, raising and fattening (9). For the Orinoquia region, 6 orientations were found, which can be seen in Figure 5. This map was used to analyze the intersection between the livestock orientation and its association with the vegetation coverage, the physiography and the cadastre of the study area.

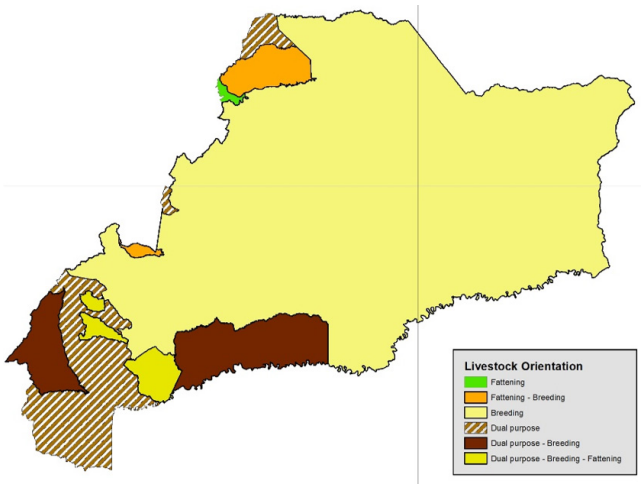

Figure 5. Livestock orientation in the Colombian Orinoquia. Source: Fedegan.

Cadastre for the Orinoquia region. Cadastral maps are a series of polygons that delimit the area of a property, whether private, common or state. For this study, it corresponds to the areas located in the rural area of the region (Figure 6). However, for the Vichada department, the cadastre was found only for a third of its territory.

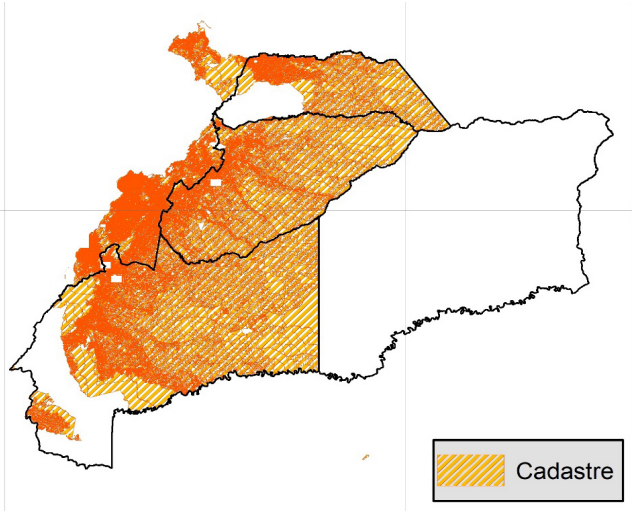

Figure 6. Cadastral map of the Colombian Orinoquia. Source: IGAC

The layer that represented the political division of the Orinoquia region, was used to delimit the study area, using the clip geoprocessing tool, from the specialized GIS software, ArcGIS version 10.6. Once the spatial information was delimited according to the areas of the region, a series of intersections (Intersect) were performed, which is a superposition geoprocessing technique between two layers; the first is the input layer and the other is considered to be an overlay, both geometries must be of the polygon type and as a result a new layer is obtained which will retain information from both (20), generating spatial and tabular information, which shows the combination of the parameters taken into account.

Data analysis. For the analysis of the information, the data obtained in ArcGIS was migrated to a specially designed interface in Microsoft Access, which has a query generation tool that allows organizing and debugging the information by applying different filters according to the desired criteria.

Forms were created that allowed the creation of different types of tables with information on the type of existing coverage, its proportions, and properties that meet different criteria in terms of physiography, coverage and livestock orientation. The main condition for the inclusion of farms as ranchers, having as a premise that more than 95% of the country's livestock systems are under grazing (7), was to have at least vegetation coverage of pastures, or pastures and different combinations with other coverage.

The used programming algorithms were elaborated by means of SQL instructions, such as DELETE, INSERT INTO, UPDATE, combining with grouping levels through GROUP BY, combined with SUM, and when required, creating orderings, through ORDER BY options.

The results obtained, from the interaction between SIG and ACCESS, were presented descriptively.

RESULTS

The results of the intersection between livestock orientation, vegetation coverage, physiography and cadastre, gave the following information that is presented for each of the departments:

Arauca. For the department of Arauca there were 2576 farms destined for bovine livestock, of which 98.25% is oriented to breeding and 1.74% to dual purpose. The 2531 farms dedicated to breeding represent 1094202 ha; the 45 properties dedicated to the dual purpose are equivalent to 2071 ha.

531 farms, equivalent to 13100 ha, are found only with pasture coverage; 263 farms, equivalent to 18479 ha, are covered with pastures and natural forests; 571 farms, equivalent to 178516 ha, are covered with pastures and grasslands; 406 farms, equivalent to 280 415 ha, are covered with pastures, grasslands and natural forests.

Table 1 shows the most recurrent coverage and physiography combinations for each of the livestock orientations in the department.

Table 1. Most representative livestock combinations for the department of Arauca.

Orientation	Coverage	Physiography	Farms	Area (ha)
Breeding	PT, GL	LFPAC	506	152188.16
Breeding	PT, GL, NF	LFPAC	283	177026.67
Breeding	PT	LFPAC	272	8348.47
Breeding	PT	DFCM	180	2080.06
Breeding	PT, NF	LFPAC	125	7982.40
Breeding	PT, NF	DFCM	103	4060.02
Breeding	PT, GL, NF	DFCM, LFPAC	97	79693.55
Dual purpose	PT, AAH	LFPAC	19	1054.31
Dual purpose	PT, HAA	DFCM, LFPAC	12	605.16
Dual purpose	PT, HAA	DFCM	12	410.31

Casanare. For the department of Casanare, 23848 cattle farms were found, of which 98.74% are oriented to breeding; 1.24% for dual purpose and 0.0083% for fattening. The 23549 farms dedicated to breeding represent 3009937 ha; the 297 farms dedicated to the dual purpose are equivalent to 27221 ha and, the 2 farms destined for fattening correspond to 2555 ha.

13354 farms, equivalent to 122768 ha are found only with pasture coverage; 2265 farms, equivalent to 97256 ha, are covered with pastures and secondary vegetation; 1722 farms, equivalent to 399100 ha, are covered with pastures and grassland; 1482 farms, equivalent to 115161 ha, are covered with pastures and natural forests; 312 farms, equivalent to 42409 ha, are covered with pastures, secondary vegetation and natural forests.

Table 2 shows the most recurrent coverage and physiography combinations for each of the livestock orientations in the department.

Table 2. Most representative livestock combinations for the department of Casanare.

Orientation	Coverage	Physiography	Farms	Area(ha)
Breeding	PT	DFCM	11645	74656
Breeding	PT, SV	DFCM	1781	81778
Breeding	PT, GL	LFPAC	1173	329833
Breeding	PT, GL, NF	LFPAC	1029	527064
Breeding	PT	LFPAC	902	33411
Breeding	PT, NF	DFCM	714	38684
Dual purpose	PT	DFCM	68	1722
Dual purpose	PT, NF	DFCM	60	5291
Dual purpose	PT, ATC	DFCM	56	1408
Dual purpose	PT, NF, ATC	DFCM	44	3961
Dual purpose	PT, NF, GL	DFCM	13	2431
Fattening	PT, GL, SH, NF, HAA, ATC	ESEC	1	2364
Fattening	PT, CNW, SV, NF	ESEC	1	191.55

Meta. For the department of Meta, 31416 farms for bovine livestock were found, of which 44.16% is oriented to breeding; 31.10% for dual purposes; 18.22% is oriented to the dual purpose-breeding-fattening; 3.6% for fattening-breeding and 2.9% for dual-purpose breeding. The 13874 farms dedicated to breeding represent 373866 ha; the 9759 farms dedicated to the dual purpose are equivalent to 27221 ha; the 5724 farms destined for dual purpose-breeding-fattening correspond to 853302 ha; 1136 farms dedicated to fattening are equivalent to 44152 ha and, 923 farms destined to dual purpose-breeding are equivalent to 762011 ha.

With coverage of only pastures are the following farms: 6885 farms oriented to breeding, represent 62494 ha; 5745 dual purpose farms, equivalent to 82726 ha; 2929 farms oriented to the double purpose-breeding-fattening, equivalent to 64314 ha. With pastures coverage plus natural forests are the following farms: 2458 farms oriented to breeding, equivalent to 324042 ha; 1613 farms oriented to the dual purpose-breeding-fattening, equivalent to 163330 ha and, 1459 farms oriented to the dual purpose that represent 128572 ha. With pastures coverage plus grasslands and natural forests, 1043 farms oriented to breeding were found, totaling 1059286 ha.

Table 3 shows the most recurrent coverage and physiography combinations for each of the livestock orientations in the department.

Table 3. Most representative livestock combinations for the department of Meta.

Orientation	Coverage	Physiography	Farms	Area(ha)
Breeding	PT	ESEC	5549	30133
Breeding	PT, ATC	ESEC	1395	64654
Breeding	PT, NF	ESEC	937	77693
Breeding	PT, GL, NF	HPMV	923	956853
Breeding	PT	HPMV	856	14539
Dual purpose	PT	DFCM	2326	31218
Dual purpose	PT	ESEC	2272	22787
Dual purpose	PT	SM	738	10785
Dual purpose -breeding-fattening	PT	ESEC	1133	35489
Dual purpose -breeding-fattening	PT, NF	DFCM	1002	66253
Dual purpose -breeding-fattening	PT	DFCM	764	14425
Dual purpose -breeding-fattening	PT	HPMV	764	4842
Fattening-breeding	PT	ESEC	519	4805
Fattening-breeding	PT, NF	ESEC	224	13491
Dual purpose -breeding	PT, NF	DFCM	144	11955
Dual purpose -breeding	PT, NF	HPMV	115	28767
Dual purpose -breeding	PT, NF	ESEC	105	14747

Vichada. For the Vichada department, according to its cadastral map (shp.), 145 farms destined for bovine livestock were found, of which 100% are oriented to breeding. These properties represent 3122525 ha.

73 properties, equivalent to 1091913 ha, are covered with pastures, grasslands and natural forests; 46 properties, equivalent to 289389 ha, are covered with pastures and grasslands.

Table 4 shows the most recurrent coverage and physiography combinations for each of the livestock orientations in the department.

Table 4. Most representative livestock combinations for the department of Vichada.

Orientation	Coverage	Physiography	Farms	Area(ha)
Breeding	PT, NF, GL	LFPAC, SM	43	649573
Breeding	PT, GL	ESEC, LFPAC	23	102824
Breeding	PT, NF, GL	ESEC, LFPAC	19	148140
Breeding	PT, GL	LFPAC, SM	18	136730

DISCUSSION

Many times, to understand the problems of an activity in a certain territory, it is necessary to study them systemically, articulating the interrelationships of the components. It is here that the characterization carried out in this study, using geographic information systems, becomes relevant. Generally, characterizations of livestock systems are carried out using instruments such as surveys, where productive, reproductive, technological, and socioeconomic information on the activity is collected in very specific areas, given the cost of collecting the information. (6,14,17,21). By using GIS, as a complementary tool for the collection of information, it is possible to study livestock activity at larger spatial scales, allowing a broader view of the use and management of natural resources at the basin, region or department level, using existing information. Additionally, it allows to include and analyze the different elements that make up these agroecosystems, their interactions and their relationship with anthropic intervention, that is, not only is the activity characterized by the breed of animals, livestock inventory, orientation (milk, meat and double purpose), zootechnical parameters and size of the area, if not allowing a spatial analysis to be carried out including determining factors when making decisions such as vegetation coverage, relief, soil, among others.

The number of livestock farms found in this work, according to the polygons provided by the cadastral Shapefiles and the condition imposed for their inclusion in the work, identified a number of farms for each department that differs with values presented by the Colombian Federation of Cattlemen «Fedegan» and the Colombian Agricultural Institute «ICA» through the aphtose fever vaccination cycles for 2015. For example, for the department of Arauca, this work defined 2576 farms as ranchers; "Fedegan" and "ICA" found more than 9000. For the department of Casanare, this work defined 23848 farms as ranchers, "Fedegan" and "ICA" found between 13 and 14 thousand. For the Meta department, this work defined 31416 farms as ranchers, «Fedegan» and «ICA» found between 13 and 14 thousand. For the Vichada department, given the little cadastral information of the shp. With which we worked, the number of properties found in this work (145), is much lower than the 1400 properties presented by «Fedegan» and «ICA». The differences found between this study and the data from other entities could be attributed to the fact that the information on the vaccination cycles is subject to the number of users who vaccinate, assuming that 100% of the cattle ranchers in the country, or region in this case, do. Additionally, many of the country's livestock production systems are made up of several farms (polygons), with their own cadastral registry, but given their spatial continuity they are managed as if they were a single farm; before the entities in charge of vaccination they have only registered one property.

In a high percentage of the cattle ranches located in the four departments (Casanare: 72.7%, Meta: 49.5%, Arauca: 42% and Vichada: 32%) the coverage of pastures, grasslands and secondary vegetation predominate, that is, it confirms the expansion in the agricultural frontier that livestock activity has had in the country, making extensive use of the land (6,16).

Regarding the predominant livestock orientation in the Orinoquía, 69% of the farms defined as cattle farmers in this work were oriented to breeding, 17% to dual purpose and, the remaining 14% was distributed in the other orientations (fattening , fattening-breeding, dual-purpose breeding, dual-purpose-breeding-

fattening). These results agree with those presented by (4,11,12), who state that the characteristics of the region allow the livestock orientation to lean towards meat production (breeding, fattening, dual purpose) and not to the dairy due to the lack of technification in pastures and infrastructure.

In conclusion, the characterization studies through GIS allow to improve the planning and efficient distribution of the resources destined to the operation of the different productive systems, for example, in areas where the predominant coverage matrix is pastures and grasslands, strategies in pro sustainability can focus on the implementation of silvopastoral systems, contrary to what would happen in areas where the matrix has a high percentage of natural forests.

Conflicts of interest

The authors declare no conflict of interest.

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