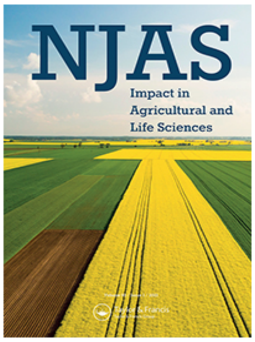

Taylor & Francis
Taylor & Francis Group

NJAS: Impact in Agricultural and Life Sciences

ISSN: 2768-5241 (Online) Journal homepage: www.tandfonline.com/journals/tjls21

Typification, characterization, and differentiation of sheep production systems in the Brazilian semiarid region

Robson Mateus Freitas Silveira, Angela Maria de Vasconcelos, Valdson José da Silva, Wilder Hernando Ortiz Vega, Paula Toro-Mujica & Josiel Ferreira

To cite this article: Robson Mateus Freitas Silveira, Angela Maria de Vasconcelos, Valdson José da Silva, Wilder Hernando Ortiz Vega, Paula Toro-Mujica & Josiel Ferreira (2021) Typification, characterization, and differentiation of sheep production systems in the Brazilian semiarid region, NJAS: Impact in Agricultural and Life Sciences, 93:1, 48-73, DOI: 10.1080/27685241.2021.1956220

To link to this article: https://doi.org/10.1080/27685241.2021.1956220

NJAS: IMPACT IN AGRICULTURAL AND LIFE SCIENCES
2021, VOL. 93, NO. 1, 48–73
https://doi.org/10.1080/27685241.2021.1956220

Taylor & Francis
Taylor & Francis Group

OPEN ACCESS Check for updates

Typification, characterization, and differentiation of sheep production systems in the Brazilian semiarid region

Robson Mateus Freitas Silveira [a], Angela Maria de Vasconcelos [a], Valdson José da Silva [b], Wilder Hernando Ortiz Vega [a], Paula Toro-Mujica [c] and Josiel Ferreira [d]

[a]Department of Animal Science, State University of Acaraú Valley (UVA), Sobral, Brazil; [b]Department of Animal Science, Federal Rural University of Pernambuco (UFRPE), Recife, Brazil; [c]Institute of Agrifood, Animal and Environmental Sciences, O'Higgins University, San Fernando, Chile; [d]Department of Animal Science, Federal Rural University of the Semiarid Region (UFERSA), Mossoró, Brazil

ABSTRACT

The complexity of livestock production systems implies the interrelation of physical, technical, social, environmental, and animal factors. This study aimed (*i*) to classify and characterize farms in representative typologies and (*ii*) to point out the main factors responsible for the differences between the sheep farm typologies in Brazilian semiarid region. A structured questionnaire with 29 variables related to social, physical, livestock, technological, herd management, and productive indicators was applied to 65 sheep farmers. The farms typology was classified, characterized, and differentiated using several techniques of multivariate analysis. Three sheep production systems were identified: Emerging (16 farms): young adults farmers, medium farms and herds, intensive management, intermediate technological level, and high meat production; Conventional (40 farms): adult farmers, smallholder farms, small herds, low technological level, and low meat production; and traditional (09 farms): mature farmers, large farms and herds, extensive management, low technological level, and high meat production. Social, physical, livestock, herd management, technological, and productive factors showed discriminatory power ($P < 0.05$) to differentiate typologies. The family-based productive system still represents the primary sheep production system. Sheep farming in the Brazilian semiarid region is characterized as extensive, heavily dependent on natural resources, and susceptible to seasonal variations. Some common characteristics among the farms studied were the use of family labour and the predominance of extensive breeding with low stocking density. The emerging system is expanding and may represent the future of sheep farms. It is believed that the traditional system can intensify its management and migrate to the emerging system in the future. It is recommended to direct public policies that encourage the efficient succession of workers in sheep farming, adoption of technologies,

CONTACT Robson Mateus Freitas Silveira robsonmateus1994@hotmail.com
Supplemental data for this article can be accessed here.

and training of know-how professionals. The insertion of young farmers was considered a determining factor in the future of the sheep production system in the Brazilian semiarid region.

KEYWORD Farming system; multivariate analysis; rural livelihood; small ruminants

1. Introduction

Worldwide, sheep farming in semiarid regions is typically located in marginal areas, where other animal species with greater profitability, such as beef or dairy cattle, are not adapted to use the available pastoral resources (Toro-Mujica et al. 2019). Brazil has approximately 18.41 million sheep, of which 65.6% is in the Northeast, followed by the South (24.99%), Midwest (4.33%), Southeast (3.12%), and North (2.95%) [IBGE | Censo Agro 2017| Home 2017]. The Brazilian Northeast has an area of 1.542.000 km^2, about 18.26% of the area of the country, and is considered the most densely populated semiarid region globally (Marengo, Torres, Alves 2017).

Sheep production in drylands presents social, cultural, environmental, and economic importance, and is one of the primary sources of food security and income for families. The sheep production systems are generally characterized as extensive in several regions of the world, as in northeastern Brazil (Costa, Almeida, Pimenta Filho, Holanda, Santos 2008; Teixeira et al. 2015; Arandas et al. 2020), Chile (Toro-Mujica, Aguilar, Vera, Rivas, García 2015, Toro-Mujica et al. 2019), Lebanon (Chedid, Tourrand, Jaber, Hamadeh 2018), and India (Naqvi, De, Gowane 2013), in which animals graze on natural pastures and native vegetation throughout the year. The systems usually present the predominance of mix and locally adapted breeds, low stocking rates, family labour with low levels of education of the farmers, and the scarce prospect of continuity of their descendants in productive activity. The main products obtained from the system are meat and leather.

Animal production systems are complex and interlinked by biological, social, cultural, climatic, economic, and technological indicators. According to Köbrich et al. (2003), the conceptualization is usually based on herd size, grazing schemes, and production, but it does not include all aspects of the system. The production system can be closely associated with the relation between the feed condition of animals and the phases of production; moreover, the relationship rearing system and the technology used in the production. With this, it is possible to define general differences between systems. However, it is unlikely that the level of technology of the system would allow a broader understanding of the production systems.

Studies indicate that sheep farming in the Brazilian semiarid region is a subsistence activity, extensive, dependent on natural pastures in the *Caatinga* biome, to produce mainly meat (Silva et al. 2011; De F. Guilherme et al. 2017). However, the general approach of descriptive methods generally used may extrapolate the results, which reduce the reliability and relevance of these studies. The farm typologies may help comprehend the complexity of farming systems by providing a simplified representation of the diversity within the farming system, organizing farms into relatively homogenous groups, i.e. farm types (Toro-Mujica et al. 2012, 2019; Castro et al., 2021). The typologies and characterization of the livestock systems have been carried out in many studies through different methodologies and statistical techniques. For example, Toro-Mujica et al. (2019) described, through the combination of multivariate statistical methods, three types of sheep farms in Chilean semiarid region and proposed recommendations for the farm development, with an emphasis on the perspective and continuity of sheep farmers in livestock activity.

It was hypothesized that in the Brazilian semiarid (*i*) there is more than one sheep production system and that (*ii*) they are dynamic, mainly in the physical, livestock, and production factors. Thus, the objectives of this study were (*i*) to classify and characterize farms in representative typologies and (*ii*) to point out the main indicators responsible for the differences between the typologies of sheep production systems in the Brazilian semiarid region.

2. Materials and methods

2.1. Area of the study

A random sampling of 65 sheep farms (sheep number = 6,184), situated in seven cities in *Ceará* state, northeast region, Brazil, was used for the typology analysis. The climate of the region is Bsh (B – Dry, s-semiarid, h-low latitude and altitude) according to the Köppen Climatic Classification (Alvares, Stape, Sentelhas, De Moraes Gonçalves, Sparovek 2013). The predominant relief of the region is composed of plains with generally shallow and rocky soils, characterized by low levels of organic matter and fertility (Silveira et al. 2018). The predominant natural vegetation is represented per *Caatinga* biome, rich in forage species in its three strata: herbaceous, shrub, and arboreal.

2.2. Data collection and processing

The variables selected for the questionnaires were defined by extension technicians, sheep farmers, and specialized in sheep production systems. For example, variables related to reproductive biotechnics, silage use, and milk production were not included because it is not common in sheep production systems in the Brazilian semiarid region. The information about the sheep production system and farmers were collected using a structured questionnaire with categorical and continuous variables was applied *in loco*. First, the study project was presented to the farmers, including the objectives and goals to be achieved. Posteriorly, we asked if he was interested in collaborating by participating in the study. If so, the questionnaire was applied. As a selection criterion, the interviews were conducted only on the farm itself with the farmers or technicians responsible for managing the herd. The interview was made through formal conversation and divided into six blocks of indicators: (*i*) social, (*ii*) physical, (*iii*) livestock, (*iv)* herd management, (*v*) technological, and (*vi*) productive. After completing the questionnaire, a technical visit to the farm was conducted for the reliability of the information collected. The interview time was between 1 and 3 hours for each farmer. All interviews were conducted by a technical/professional from July 2017 to September 2018. The answers were registered on forms and transferred to a Microsoft Excel® spreadsheet. The original variables initially used for the statistical analysis are shown in Table 1.

The stocking rate (sheep ha^{-1}) was obtained by dividing the number of animals on the farm by the area used sheep farming. The variables of the programs, facilities and equipments, and preventive health were defined using a score scale ranging from 0 to 8. The following facilities and equipments program were considered: main facilities, shed for feeding, isolation facilities for sick animals, and feedlot facilities; and equipment such as balance, forage engine, hydraulic pump, and tractor. For control of preventive health program: vaccination program against diseases such as gastrointestinal endoparasites, ectoparasites, mastitis, caseous lymphadenitis, ecthyma, rage, pneumonia, and clostridiosis.

2.3. Statistical analyses

Multivariate analysis techniques were used in the development, differentiation, and validation of farm typologies. All analyses were performed in the IBM SPSS Statistics for Windows, version 20 (IBM Corp., Armonk, N.Y., USA, 2010). Data analysis was carried out in five successive steps:

Step 1st. [*Choice of variables*] Definition of the correlation matrix of the factorial analysis. From these correlations, only one variable of each pair of variables with high partial correlation was kept. At least one variable for each factor was selected to build the typology. The performance of this procedure was essential to meet the presuppositions of multicollinearity. The inclusion of at least one variable of each indicator in the typological analysis was also considered.

Step 2nd. [*Variables reduction*] From 29 variables, only 13 were selected using factor analysis (Table 1). The statistic of Kaiser-Meyer-Olkin (KMO = 0.790) and the sphericity Bartlett test (Chi-square: 466.22, $P < 0.001$) shown the adequacy of the model in this study. Factors with eigenvalues greater than 1 (Kaiser's rule; Kaiser 1960) were used in the hierarchical cluster analysis (H_{CA}). The rotated component

Table 1. Physical, social, livestock, herd management, technological, and productive indicators of the farms under study (n = 65 farms).

Indicators	Continuous variables	Descriptive statistics			
		Minimum	Median	Maximum	Interquartile range
Social	Farmer's age (years)[€]	18.00	47.00	76.00	27.00
	Farmer's experience (years)	7.00	30.00	60.00	28.50
Physical	Farm area (ha)	10.00	85.0	450.00	200.0
	Area of the farm for sheep farming (ha) [€]	8.00	76.00	420.00	131.00
	Facilities areas (m^2)	30.00	205.00	520.00	210.50
	Facilities and equipment score (0 – 8) [€; 1]	1.00	4.00	8.00	1.50
Livestock	Sheep (n) [€]	30.00	90.00	320.00	70.50
	Ewes (n)	10.00	45.00	200.00	68.00
	Lactating ewes (n)	7.00	25.00	120.00	53.00
Herd management	Stocking density (sheep ha^{-1})	0.33	1.33	7.22	2.29
	Supply of commercial concentrate (months) [€]	1.12	5.00	12.00	4.00
	Dry period grazing (hours) [€; 2]	7.00	14.00	24.00	6.00
	Rainy period grazing (hours)[3]	11.00	16.00	24.00	7.00
	Sexual precocity (months) [€]	6.00	9.00	12.00	3.00
	Age at first lambing (months)	10.50	14.00	18.00	4.00
	Ram: ewe ratio	26.00	50.00	90.00	17.50
	Preventive health program score (0 – 8) [€; 4]	1.00	4.00	8.00	2.00
	Age at slaughter (months) [€]	6.00	11.00	18.00	3.00
Production	Live weight production (kg sheep sale $farm^{-1}$ $year^{-1}$) [€; 5]	110.00	473.0	2460.00	1232.50
	Carcass weight (kg) [€]	8.14	11.58	16.00	2.18
	Categorical variables	Descriptive statistics			
			N		Frequency
Social	Level of schooling (%)[€]	Illiterate	18		27.70
		Literate	21		32.30
		Higher School	14		21.50
		High School	12		18.50
	Family workforce (%)		44		67.70

(*Continued*)

Table 1. (Continued).

Indicators	Continuous variables	Descriptive statistics			
		Minimum	Median	Maximum	Interquartile range
Livestock	Ram breed (%)	Local adapted[6]	29		44.60
		Dorper	16		30.80
		Mix[7]	20		24.60
	Ewes breed (%)	Local adapted	26		40.00
		Dorper	5		7.70
		Mix	34		52.30
Herd management	Mineral supplementation (%)		36		55.38
	Herd replacement (%)		22		33.84
	Castration (%)		29		44.61
Technological	Technical assistance (%)		22		33.84
	Zootechnical bookkeeping (%)[€]		18		27.69

[€]Variables used for the factor analysis (F_A) and canonical discriminant analysis (C_{DA}).
[1]A score ranging from 1 to 8 was assigned according to the available:
(i) Facilities (principal corrals; shed of feeding; isolation facilities for sick animals; and feedlot facilities).
(i) *E*quipments (balance, forage engine, hydraulic pump, and tractor).
[2]January 1st to July 31th.
[3]August 1st to December 31th.
[4]A score ranging from 1 to 8 was assigned according to the available e herd preventive health program (a program of vaccination against diseases caused by vaccination program against diseases such as gastrointestinal endoparasites, ectoparasites, mastitis, caseous lymphadenitis, ecthyma, rage, pneumonia, and clostridiosis).
[5]Production in live weight of animals for slaughter.
[6]Breed from a species occurring *in situ* or maintained in *ex situ* condition, represented by a group of animals with genetic diversity developed or adapted to a particular ecological niche and formed from natural selection.
[7]Sheep descended from multiple breeds of the same species, often breeding without any human intervention, recordkeeping, or selective breeding.

matrix was developed using orthogonal rotation, varimax method, with Kaiser's normalization method to describe the factor analysis according to their relationship with the original variables. The communalities of the variables used in the factor analysis varied from $0.55 \leq X \geq 0.91$.

Step 3rd. [*Number of typologies*] The optimal number of clusters was identified using the H_{CA}. In particular, the elbow rule based on Ward method (Ward 1963) was used in order to decide the most appropriate number of clusters. For defining the ideal number of clusters, it was necessary to plot the number of clusters against the change of the fusion coefficient for each stage (each stage reflects a combination between two clusters) and find the two stages with the highest jump in the difference between their distance coefficients (Gelasakis, Valergakis, Arsenos, Banos 2012). This was obvious for stages 62 and 63 (Table 1 – Supplementary material). Afterwards, the number of stages (n = 62) was subtracted from the number of observations (n = 65); the result indicated the ideal number of clusters (n = 3). For validating the H_{CA}, a two-step cluster was performed. Euclidean distance measurement was selected and 3 clusters of the elbow rule were fixed.

Step 4th. [*Comparisons between clusters*] First, it is tested the assumptions of homogeneity of variances using Levene's test, the normality of the errors using the Shapiro-Wilk's test, and the presence of outliers using the box-plot graph. Most of the quantitative variables did not present residues with a normal distribution (75% of the variables) and normality test (50% of the variables) (Table 2 – Supplementary Material). For this reason, non-parametric Kruskal-Wallis test was chosen using the median as a measure of central tendency. For categorical variables, the differences between groups were estimated using the χ^2 test with Bonferroni correction. Significance was accepted if $P < 0.05$.

Step 5th. [*Differentiation of the typologies*] The canonical discriminant analysis (C_{DA}) was used for two purposes: (*i*) to define which indicators individually have discriminatory power to differentiate the three typologies in order to verify Hypothesis 2, and (*ii*) to evaluate the classification dynamics of the farms in their group of origin by biplot the first two canonical discriminating functions using the same variables selected for factorial analysis. Both C_{DA} was performed by the stepwise method. Finally, the discriminant power of the indicators/variables was evaluated by eigenvalue, Wilks' Lambda statistic, standardized coefficients, and classification of farms in their group of origin.

3. Results

3.1. General characteristics of the surveyed farms

Social, physical, livestock, herd management, technological, and productive indicators are presented in Table 1. The farmers were on median 47 years old, with 30 years of experience in sheep farming with generally low-level

Table 2. Initial eigenvalues, sums of rotation of the square loads[1], and the percentage of variance explained and the factorial loads of the three first factors for the studied sheep farms in Brazilian semiarid region.

- Total variance explained

Factors	Initial eigenvalues			Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.82	37.04	37.04	3.36	25.86	25.86
2	2.80	21.55	58.59	3.15	24.22	50.08
3	1.36	10.46	69.05	2.47	18.97	69.05

- Rotated component matrix

Variables	Factors			Communalities
	1	2	3	
Live weight production (kg sheep sale farm^{-1} year^{-1})[2]	0.95	−0.10	0.00	0.91
Area of the farm for sheep farming (ha)	0.84	0.01	−0.04	0.70
Sheep (n)	0.91	0.02	0.02	0.82
Facilities and equipment score (0 – 8)[3]	0.50	−0.40	0.37	0.55
Carcass weight (kg)	0.69	−0.37	0.09	0.67
Sexual precocity (months)	−0.05	0.69	−0.28	0.55
Level of schooling	0.15	−0.80	0.06	0.67
Farmer's age (years)	0.05	0.82	−0.10	0.68
Zootechnical bookkeeping	−0.23	0.76	−0.19	0.66
Dry period grazing (hours)[4]	−0.08	0.51	−0.64	0.67
Preventive health program score (0 – 8)[5]	0.29	0.01	0.81	0.74
Age at slaughter (months)	0.21	0.11	−0.73	0.59
Supply of commercial concentrate (months)	0.01	−0.46	0.77	0.81

[1]Eigenvectors weights ≥ 0.50 and ≤-0.50 have been typed bold.
[2]Production in live weight of animals for slaughter.
[3]A score ranging from 1 to 8 was assigned according to the available:
(i) Facilities (principal corrals, shed of feeding, isolation facilities for sick animals, and feedlot facilities).
(i) Equipments (balance, forage engine, hydraulic pump, and tractor)
[4]August 1st to December 31th.
[5]A score ranging from 1 to 8 was assigned according to the available e herd preventive health program (a program of vaccination against diseases caused by vaccination program against diseases such as gastrointestinal endoparasites, ectoparasites, mastitis, caseous lymphadenitis, ecthyma, rage, pneumonia, and clostridiosis).

education (27.7% – Illiterate and 32.3% – Literate). The farms were run mainly by family members (67.7%). The farms showed a median of 85.0 ha, with 89.4% used for sheep production and 1.33 animals per ha, approximately. The median herd was composed of 90 sheep, where 45 are ewes and 55.5% in lactation. The predominant breed of ewes was Mix (52.3%) (mix from multiple breeds of the same species, often breeding without any human intervention, recordkeeping, or selective breeding), while the ram was local adapted (44.6%), especially *Santa Inês* breed. The animals spent most of the time grazing on a natural pasture (*Caatinga* biome), and received commercial concentrate for 5 months, mainly from August to December each year, and 55.4% of the farms offered mineral supplementation. All matings were natural with a mean 1 ram: 50 ewes' ratio, and obtaining at 9 months to sexual maturity and first lambing at 14 months, approximately. Only 33.8% of the farmers have specialized technical assistance and adopt zootechnical bookkeeping. The farms send the animals to the slaughter at 11 months of age, with a carcass weight of 11.58 kg. The median live weight production was 473.0 kg farm^{-1} year^{-1}.

3.2. Typology and characterization

Initial eigenvalues, sums of rotation of the square loads, the percentage of variance explained, and the factorial loads of the three first factors are shown in Table 2. The first factor explained 25.9% of the total variation, and the three factors explained 69.0% of the variance. The major eigenvector weights in three factors were: (*1*) production in live weight, number of sheep, area of the farm for sheep farming, carcass weight, and facilities and equipment score; (*2*) farmers age and schooling level, animal sexual precocity, zootechnical bookkeeping, and dry period grazing; and (*3*) preventive health program, commercial concentrate supplementation, dry period grazing, and age at slaughter.

Three sheep production systems were obtained: emergent, conventional, and traditional systems (Figure 1(A)). These three systems represented 16 (24.6%), 40 (61.5%), and 9 (13.8%) farms of the total sample, respectively. The model's goodness-of-fit measure was 0.50, revealing good cluster quality (Figure 1(B)).

Table 3 indicates the median and interquartile range (IQR) for the continuous variables, while Table 4 indicates the frequencies (%) for the categorical variables, as well as the statistical differences among the systems. The three systems shared some common characteristics, e.g. family workforce ($P = 0.051$), animal castration ($P = 0.056$), mineral supplementation ($P = 0.073$), and breed of ram ($P = 0.337$) and ewes ($P = 0.792$).

According to the differences and similarities found between the typologies obtained (Tables 3 and 4), it is possible to describe as follows:

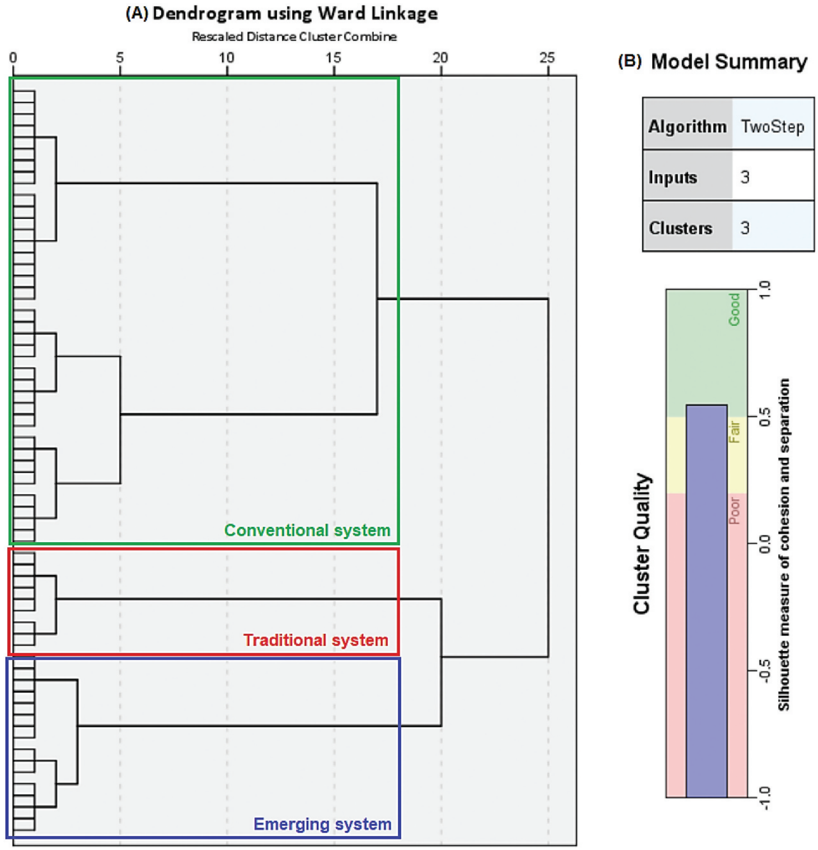

Figure 1. Dendrogram of the H_{CA} (A) and goodness-of-fit measure of the number of clusters through two-step cluster (B) for the three production systems formed by sheep in the Brazilian semiarid region. Model summary*Inputs*: 3 are number of factors (Table 2).*Clusters*: 3 was determined by Ward method, elbow rule (Ward 1963) (Table 1 – Supplementary material)

- *Emerging system: Young adult farmers, medium farms and herds, intensive management, intermediate technological level, and high meat production (16 farms; 24.6%)*

The young farmers in these production systems showed a high schooling level ($P < 0.05$) associated with experience in sheep farming. Datasets of the sheep, where 162.50 ha are used for sheep production. The median herd was composed of 128 animals, where 65 were lactating ewes. The animals remained a short time ($P < 0.01$) in grazing during periods of years; however, a more considerable period receiving supplementation ($P < 0.01$). Ewes showed sexual precocity ($P = 0.01$), and the systems contain a high preventive

Table 3. Comparison of medians by the Kruskal-Wallis test for sheep production systems according to the indicators under study (Results are medians and interquartile range; n = 65 farms).

		Sheep production systems						*P* value
		Emerging		Conventional		Traditional		
Indicators	Variables	(n = 16 farms)		(n = 40 farms)		(n = 09 farms)		
Social	Farmer's age (years)	39.00^b	11.75	53.00^a	26.75	65.00^a	10.00	= 0.001
	Farmer experience (years)	25.00^b	10.50	28.00^b	30.00	45.00^a	11.00	< 0.001
Physical	Farm area (ha)	220.00^a	96.25	30.0^b	240.00	300.00^a	215.00	< 0.001
	Area of the farm for sheep farming (ha)	162.50^a	95.00	27.50^b	57.25	230.00^a	280.00	< 0.001
	Facilities areas (m^2)	310.50^a	122.50	105.50^b	150.00	400.0^a	232.50	< 0.001
	Facilities and equipment score (0 – 8) [1]	6.50^a	1.75	4.00^b	1.00	5.00^a	2.00	< 0.001
Livestock	Sheep (n)	128.00^a	44.25	55.00^b	45.00	198.00^a	65.00	< 0.001
	Ewes (n)	92.00^a	22.25	29.50^b	28.00	112.00^a	31.50	< 0.001
	Lactating ewes (n)	65.00^b	15.25	14.50^c	17.00	83.00^a	17.50	< 0.001
Herd management	Stocking rate (sheep/ha) [2]	0.76^b	0.61	2.01^a	2.57	0.80^b	1.21	= 0.001
	Age at slaughter (months)[€]	8.00^c	2.50	11.50^b	2.75	15.00^a	4.50	< 0.001
	Supply of commercial concentrate (months)[¥]	8.00^a	4.80	5.00^b	3.00	3.00 c	1.00	< 0.001
	Ram: ewe ratio	45.00^b	11.75	40.00^b	18.75	55.00^a	20.00	< 0.001
	Dry period grazing time (hours) [3]	11.00^b	4.75	15.00^a	5.00	19.00^a	7.50	= 0.001
	Rainy season grazing time (hours) [4]	14.00^b	3.75	16.50^a	6.75	18.00^a	6.50	= 0.006
	Sexual precocity (months)	7.00^b	2.75	9.00^a	3.00	10.00^a	3.50	= 0.001
	Preventive health program score (0 – 8) [5]	6.00^a	2.00	4.00^b	2.00	4.00^b	1.00	< 0.001
	Age at first lambing (months)	12.25^b	1.75	14.50^a	3.00	15.00^a	3.25	< 0.001
Production	Live weight production (kg sheep sale $farm^{-1}$ $year^{-1}$)[6]	1420.00^b	319.00	232.50^c	240.00	2037.50^a	327.50	< 0.001
	Carcass weight (kg)	13.40^a	1.42	10.86^b	1.17	13.19^a	1.48	< 0.001

[a-c]Different letters on the same line indicate significant difference by the Kruskal Wallis test with 5%.

[1]A score ranging from 1 to 8 was assigned according to the available:

(i) Facilities (principal corrals, shed of feeding, isolation facilities for sick animals, and feedlot facilities);

(i) Equipments (balance, forage engine, hydraulic pump, and tractor).

[2]Stocking density = number of sheep/ Area of the farm for sheep farming.

[3]January 1st to July 31th.

[4]August 1st to December 31th.

[5]A score ranging from 1 to 8 was assigned according to the available e herd preventive health program (a program of vaccination against diseases caused by vaccination program against diseases such as gastrointestinal endoparasites, ectoparasites, mastitis, caseous lymphadenitis, ecthyma, rage, pneumonia, and clostridiosis).

[6]Production in live weight of animals for slaughter.

Table 4. Frequencies (%) and comparisons between the three production systems for categorical variables using Pearson Chi-square analysis.

		Sheep production systems			
		Emerging	Conventional	Traditional	
Indicators	Variables	(n = 16 farms)	(n = 40 famrs)	(n = 09 farms)	*P* value
Social	Level of schooling				
	Illiterate	6.20[b]	35.00[a]	33.30[a]	= 0.013
	Literate	12.50[b]	37.50[a]	44.40[a]	
	High School	50.00[a]	12.50[b]	11.10[b]	
	Higher School	31.20[a]	15.00[a]	11.10[a]	
	Family workforce	50.0[a]	77.50[a]	66.70[a]	= 0.051
Livestock	Ram breed				
	Locally adapted [1]	43.80[a]	40.00[a]	66.70[a]	= 0.337
	Mix[2]	18.80[a]	37.50[a]	22.20[a]	
	Dorper	37.50[a]	22.50[a]	11.10[a]	
	Ewes breed				
	Locally adapted	43.80[a]	37.50[a]	44.40[a]	= 0.792
	Mix	43.80[a]	57.50[a]	44.40[a]	
	Dorper	12.50[a]	5.00a	11.1[a]	
Technological	Zootechnical bookkeeping	81.20[a]	20.00[b]	11.10[b]	< 0.001
	Technical assistance	81.20[a]	20.00[b]	11.10[b]	< 0.001
Herd management	Herd replacement	87.50[a]	32.50[b]	22.20[b]	< 0.001
	Mineral supplementation	68.80[a]	57.50[a]	22.20[a]	= 0.073
	Castration	62.50[a]	22.50[a]	11.50[a]	= 0.056

[ab]Frequencies within a row different superscript differ ($P < 0.05$).

[1]Breed from a species occurring *in situ* or maintained in *ex situ* condition, represented by a group of animals with genetic diversity developed or adapted to a particular ecological niche and formed from natural selection.

[2]Sheep descended from multiple breeds of the same species, often breeding without any human intervention, recordkeeping or selective breeding.

health programme score ($P < 0.001$) with a low age at slaughter ($P < 0.001$). This system presented higher percentages of farms that carried out herd replacement ($P < 0.001$), age at first lambing ($P < 0.001$), and received specialized technical assistance ($P < 0.001$).

- *Conventional system: Older farmers, smallholder farm, small herds, less intensive management, low technological level, and low meat production (40 farms; 61.5%)*

Older farmers with low schooling level ($P < 0.05$) and smaller farm and facilities areas ($P < 0.001$). This system showed the highest ($P < 0.01$) stocking density, with the least herd ($P < 0.001$) and the number of animals of 55 sheep, ≅ 29 ewes, and ≅14 lactating ewes. Comparing with the emerging system, in the present system, the animals remained longer grazing during two periods of years ($P < 0.01$). The percentage of farms that use herd replacement was the same ($P > 0.05$) in the traditional system. The systems presented slaughter of 11 months with the lesser carcass weight and live weight production by year ($P < 0.001$).

- *Traditional system: Older farmers, large farms and herds, extensive management, low technological level, and high meat production (09 farms; 13.8%)*

Farmers in this system presented large areas with 300 ha, where 76.70% used for sheep production. Farm and facilities areas were larger ($P < 0.01$) than the conventional system, but similar to emerging. The number of sheep and ewes were similar ($P > 0.05$) to the emerging system; however, the farmers showed a greater grazing management time ($P < 0.01$). The technological indicator variables, preventive health program score, and sheep sexual precocity were similar ($P > 0.05$) to the conventional system. Sheep production (kg sheep sale farm^{-1} year^{-1}), on the other hand, was greater compared to the conventional system ($P < 0.01$), with a median age of 15 months. The carcase weight, however, was similar ($P > 0.05$) to the emerging system.

3.3. Differences and similarities among sheep production systems

The summary of the C_{DA}, the classification of the farms in their group of origin, and the main discriminatory variables according to the indicators are shown in Table 5. All the indicators under study individually presented discriminatory power ($P < 0.05$). The productive indicator had the highest percentage of classification of farms (95.2%) in their group of origin, while the social indicator, the lowest percentage (66.2%).

The classifying dynamics of the three typologies in their group of origin are shown in Figure 2. It was observed, through the centroids, which the emerging system is between the conventional and the traditional. It was also

Table 5. Summary, farm classification, and standardized coefficients of the first two canonical discriminant functions.

Indicators	C_{CC} (%)[1]	Classification (%) by sheep production systems (n) [2]			Variance explained (%)		Lambda of Wilks[3] (*P* value)		Main variables[4]
		Emerging (n = 17 farms)	Conventional (n = 40 farms)	Traditional (n = 9 farms)	F_1	F_2	F_1	F_2	
Social	66.2	50.0 (8)	80.0 (32)	33.3 (3)	59.0	41.0	< 0.0001	< 0.0001	Farmer's age and farmer's experience
Physical	87.7	87.5 (14)	95.00 (38)	55.6 (5)	94.5	5.50	< 0.0001	< 0.0001	Facilities and equipment score, farm area, and facility areas
Livestock	92.3	93.8 (15)	95.0 (38)	77.8 (7)	100.0	-	< 0.0001	-	Ewes in lactation
Herd management	87.7	75.0 (12)	95.0 (38)	77.8 (7)	78.7	21.3	< 0.0001	< 0.0001	Age at slaughter, preventive health program score, dry period grazing time, and stocking density
Technological	69.2	81.3 (13)	80.0 (32)	0.0 (0)	100.0	-	< 0.0001		Zootechnical bookkeeping
Production	95.2	93.8 (15)	95.0 (38)	100.0 (9)	99.0	1.0	< 0.0001	= 0.020	Live weight production and weight carcass

[1]Total percentage of cases correctly classified: C_{CC} = cases correctly classified.
[2]Percentage of cases correctly classified by dairy systems production:
[3]Statistic test: discriminat canonical functions (F_1 and F_2) with $P < 0.05$ of Lambda of Wilks were considered significant.
[4]Indicators:
Social (farmer's age, years; farm's experience, years; level of schooling, %; family workforce, %); ***Physical*** (farm area, ha; area of the farm for sheep farming, ha; facilities areas, m^2; facilities and equipment score, 0–8); ***Livestock*** (sheep, n; ewes, n; lactating ewes, n; ram breed, %; ewes breed, %); ***Herd management*** (stocking density, sheep ha^{-1}, supply of commercial concentrate, months; dry period grazing, hours; rainy period grazing, hours; sexual precocity, months; age at first lambing, months; ram: ewe ratio, n; preventive health program score, 0–8; age at slaughter, months; mineral supplementation, %, herd replacement, %, castration, %); ***Technological*** (technical assistance, %; zootechnical bookkeeping, %); and ***Production*** (live weight production, kg sheep sale $farm^{-1}$ $year^{-1}$; carcass weight, kg.

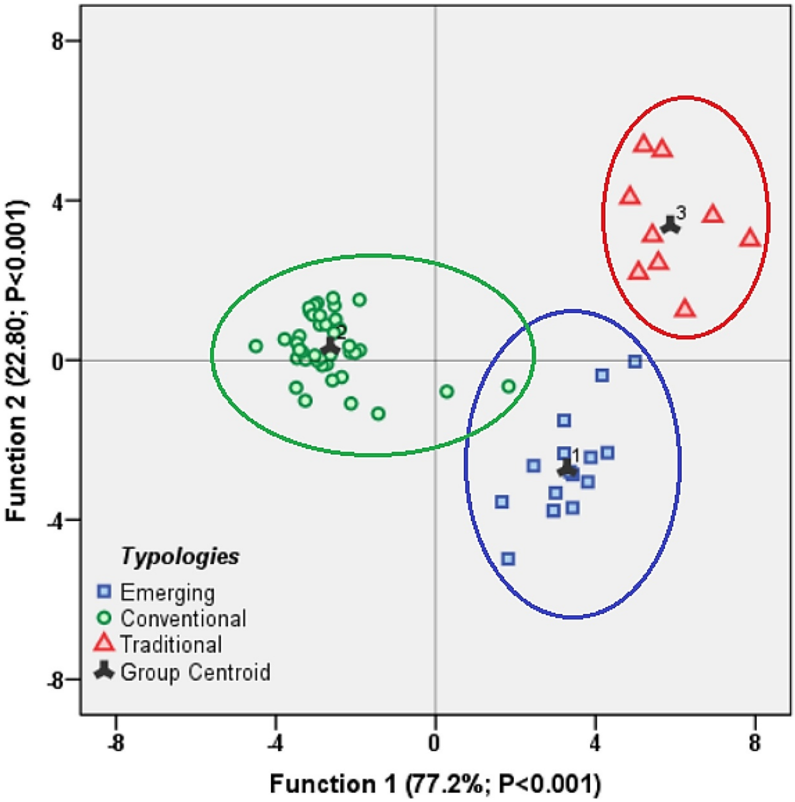

Figure 2. Two-dimensional plot of the canonical discriminant analysis showing the dynamics of physical, livestock, social, herd management, technological, and productive indicators according to the three typologies of sheep farms in the Brazilian semiarid region. Indicators:***Social*** (farmer's age, years; level of schooling, %); ***Physical*** (area of the farm for sheep farming, ha; facilities and equipment score, 0 – 8); ***Livestock*** (sheep, n); ***Herd management*** (supply of commercial concentrate, months; dry period grazing, hours; sexual precocity, months; preventive health programme score, 0 – 8; age at slaughter, months); ***Technological (***zootechnical bookkeeping, %); and ***Production*** (live weight production, kg sheep sale farm^{-1} year^{-1}; carcass weight, kg)

found that one farm in the conventional system was classified as emerging, which resulted in a general classification rate of 98.5% of the farms correctly classified in their group of origin. Of the 13 variables used in the C_{DA}, only preventive health programme, sheep production, age at slaughter, area of the farm for sheep farming, facilities and equipment programme, farmer's age, and zootechnical bookkeeping showed discriminatory power ($P < 0.001$), with emphasis on physical and productive indicators (77.2%) (Table S_3 – Supplementary Material). It is also interesting to note that when all variables were evaluated together, at least one variable from each indicator was important to discriminate groups, except for the livestock indicator.

4. Discussion

4.1. Typological development, differentiation, and validation

The characterization of animal production systems is complex because of the large number of variables necessary for classification (Riveiro, Mantecón, Álvarez, Lavín 2013), requiring a systemic approach to understand their globality and dynamics (Campos 2003). It is possible to reduce complexity by forming groups of farms with common characteristics, based on the search for the largest difference between the groups and the smallest within them. This is the first study carried out on sheep farms in the Brazilian semiarid region using procedures that combine analytical and specialized methods to construct farm typologies.

The multivariate approach allowed detecting large differences between the sheep production systems, helping to visualize different groups. It was possible to identify three sheep production systems, from farms with large areas and high meat production to smaller farms and low production, confirming Hypothesis 1. This classification is based on an analysis that used specialized methods in the development of typologies, and we included social, physical, livestock, herd management, technological, and productive indicators to develop these three types of farms, unlike other investigations that use descriptive methods (De S. Farias et al. 2014; Alves et al. 2017; Kato, Belchior, De Sousa, De Morais 2019), which can extrapolate the results, reducing their relevance and credibility.

Besides the C_{DA} showed that all indicators under study individually have discriminatory power to differentiate the three typologies, which partially rejects Hypothesis 2, i.e. the sheep production systems in the Brazilian semiarid are different in social, dimensional, technological, livestock, management, and productive aspects. The validation of the typology was confirmed when 98.5% of the farms were classified in their original group when all the studied variables were used. Results similar to the present study was reported in the Chilean semiarid region by Toro-Mujica et al. (2019), who defined three sheep farm typologies: (*i)* middle-aged farmers, high educational level, farms and herd large; (*ii)* elderly and experienced farmers, traditional in sheep farming, low level of education and large farms and herd, and (*iii)* elderly farmers, with small farms and herd. These similarities between systems indicate that our findings and recommendations may be useful for developing sheep farming in other drylands of the world.

4.2. Characterization of the three sheep production systems

4.2.1. Social indicator

The age and experience of the sheep farmers were important in the classification of farms. When considering the age of the farmers and the experience in the activity, it was observed that all the farmers are experienced in the rearing of sheep. The social indicators were fundamental to differentiate the farmers, mainly those of the emerging system, composed of the new ones compared to the other systems. It can be assumed that these young farmers are heirs of the farmers of the traditional system, which explains the experience in the activity by family succession. The breeding of sheep in the Brazilian semiarid region is characterized as traditionally familiar farming (Kato, Belchior, De Sousa, De Morais 2019; Arandas et al. 2020). It was also observed an increase in the farmers schooling level, although studies show that sheep production in the Brazilian semiarid region is managed by farmers with low educational levels (De S. Farias et al. 2014). This scenario may be changing since De F. Guilherme et al. (2017) report an increase in sheep farmers' educational level, possibly the farmers of the emerging system. We can suppose that this increase is the result of the adoption of public policies to retain young people in the countryside through vocational courses in the area of agriculture and technological capabilities aimed at animal production in the semiarid. It is important to consider that the rural exodus in Brazil occurs mainly in the semiarid region since in this area resides about half of the Brazilian rural population, due to the low agricultural production and means of subsistence (Alves, Da Silva E Souza, Marra 2011).

Given the advanced age of farmers in the conventional and traditional systems (> 52 years), we suggest that policymakers adopt measures to support the sheep meat production and marketing. For example, the inclusion of sheep meat in school meals through the direct purchase of the government from the farmer by the Food Purchase Program of the Brazilian federal government would stimulate the production of sheep meat, increasing the demand for meat of sheep in the market, contributing to the socio-economic sustainability. In the semiarid region of Chile, Toro-Mujica et al. (2019) report that the advanced age of farmers will lead to continuous reductions in sheep farms by at least 44.0% in the next generation unless steps are taken to encourage generations to stay younger. The authors also indicated that the effect of offspring on the permanence of farms is another factor to consider since, at the national level, the size of the family tends to decrease.

4.2.2. Physical indicator

The total area and the area used for sheep farming were also adequate variables to differentiate the systems since they allowed the classification of the typologies, mainly between the traditional and conventional systems, because the productive system adopted in these farms is extensive and the management practices were similar (Tables 3 and 4). Toro-Mujica et al. (2012) indicated that farms' physical characteristics are fundamental for the classification and characterization of sheep production systems in southern Spain. The conventional system farms, the largest production system, had a median area of less than 30 ha, in agreement with studies by Costa et al. (2008) and

De S. Farias et al. (2014), which show that more than half of the sheep herd in the Brazilian semiarid region are distributed on small farms. Facilities and equipment score was another important variable of the physical indicator for classifying farms, as it provides an indication of investment in infrastructure and the level of mechanization of production systems (Gelasakis et al. 2017). However, caution is needed in interpreting the highest scores of traditional and emerging systems, as both systems had similar facilities areas due to the greater number of sheep in this system (Table 3), but not necessarily facilities with the same sheep production function.

4.2.3. Livestock indicator

The number of animals was also another important classification variable in the characterization of the typologies. In the farms evaluated in this study, this affects important management decisions, such as stocking density and seasonal use of pastures. These decisions play a fundamental role in feed management in extensive systems that cannot be improved only through infrastructure modernization. In general, this hypothesis is confirmed by the low stocking rate used by the farmers in response to the low forage production of native pasture, mainly in the dry period. The increase in the availability and nutritional value of the *Caatinga* pasture would be possible through practices such as replenishment of soil nutrients (Costa, Almeida, Pimenta Filho, Holanda, Santos 2008), manipulation of woody vegetation, rearing and thinning of trees and shrubs, and enrichment of the herbaceous stratum (Batista and de Souza, 2015; Araújo et al. 2019).

The breed was not an important variable to classify the farms. Purebred or crossbred sheep do not affect management decisions. The farmers opt for specific breeds to improve productive potential but do not change management practices. For example, it is very common to use the *Santa Inês* breed to increase the meat and milk production of the locally adapted breeds. However, the farmers do not take into account the greater nutritional requirement of this breed compared locally adapted animals. Therefore, much of the productive capacity of some breeds is wasted, with production being limited by available resources. We suggest that farmers could improve production by combining management with the genetic potential of their animals. In this study, all three production systems adopted some genetic improvement strategy, but the emerging system farms presented greater zootechnical control and herd replacement.

4.2.4. Herd management indicator

Supplementation with commercial concentrated, together with grazing time, was important for identifying the degree of intensification of nutritional management. The animals in the emerging system showed less grazing time, both in the rainy and in the dry period, and the farmers supplemented the animals with concentrated feed for a longer period than the other production systems. Farmers of the conventional and traditional system, on the other hand, used concentrated supplementation as a dry period management tool (from August to December). Generally, supplementation is provided at the end of the day without considering the nutritional requirements by animal category (maintenance, lactation, pregnancy, and weight gain). Additionally, the choice of ingredients by sheep farmers depends on the price of concentrated feeds in the market (Rogério et al. 2016).

The reproductive management was evaluated considering the ram: ewes' ratio, sexual precocity, and age at first lambing. The adoption of reproductive biotechnologies such as artificial insemination is not common in farms in the region under study (De F. Guilherme et al. 2017). The older age at first calving of ewes in traditional and conventional systems is explained by the sexual precocity of these animals; on the other hand, ewes in the emerging system are usually younger at first calving. The high ram: ewes ratio in the traditional system can be explained by the more extensive management observed in these farms (Simplício and Santos, 2005). In general, it is recommended to adopt the breeding season on the farms aiming a greater reproductive control and increasing the reproductive and productive efficiency of the farms. It may also favour the standardization of lambs in terms of age and weight, allowing the marketing of more uniform animals. The low reproductive efficiency of extensive sheep systems in drylands is due to climatic conditions and feed shortages (De, Kumar, Balaganur, Naqvi 2020).

The preventive health score has already been used by Gelasakis et al. (2012) on sheep farms. In this study, emerging system farmers adopted a more efficient health programme, probably due to the more intensive management and specialized technical assistance. The conventional and traditional systems had similar health programmes and were more susceptible to losses, mainly caused by verminous. (Silva et al. 2011) reports that verminous, caseous lymphadenitis, rabies, clostridiosis, mamitis, ectoparasites, pneumonia, and contagious ecthyma were the main diseases observed in sheep and goat herds in the Brazilian semiarid, which agrees with the diseases used to create the score of preventive health programme used in the present study.

4.2.5. Technological indicator

Sheep farms in semiarid regions are commonly characterized by low technological levels and lack of technical assistance (Silva et al. 2011; Ibidhi, Frija, Jaouad, Ben Salem 2018; Arandas et al. 2020), which is in line with our findings. In general, the low technological level results from low investment in sheep livestock in the family farming (greater production system). However, our study shows that this scenario may be changing considering that young farmers with a higher education level in the emerging system use zootechnical bookkeeping and receive technical assistance (Table 4).

According to De Oliveira et al. (2013), young farmers are more likely to accept new technologies and adopt new management practices to increase production.

The main problems faced by sheep farming in the semiarid regions were related to the lack of technology adoption, which compromises the sustainability of sheep farming. According to Campos (2003), technology makes a difference when adopted in the production system. There is a minimum of techniques to be programmed, without which raising small ruminants does not offer economic viability. This set ranges from procedures, methods, experiences, know-how to mechanisms and management tools (Campos 2003; Lucena et al. 2018).

4.2.6. Productive indicator

The classification of farms into typologies allowed a clear distinction between them in productive efficiency. The farms with more intensive management slaughtered the animals in a shorter time, approximately at the age of 8 months, with carcass weight equal to farms that slaughtered at 15 months. We encourage studies of economic analysis in these production systems to clarify whether this productive efficiency is feasible to the farmer because of the revenues and costs. According to Gelasakis et al. (2017), more intensive farms exhibit a high profit-variation and higher production cost than extensive farms since they tend to be more vulnerable to the increases in feed costs or seasonal variations. Thus, intensification is rewarded through increased revenue and increases the level of uncertainty to the farmers.

Live weight production is commonly used to classify sheep farms (De F. Guilherme et al. 2017), which justifies the high weight in the PC_1 eigenvector (Table 2) and the differences between production systems. Productivity is driven by management, the purpose of raising sheep and production conditions. However, high productivity is the result of successful management and not a classification criterion. Productivity relies on proper management, which is the general objective of farmers. For example, the higher production of body weight and the shorter period of slaughter observed on farms in the emerging systems can be associated with feeding practices and intensive management. Moreover, the high production of this system is justified by the early weaning of the lambs and due to more efficient handling practices. Although production variables can be used to classify the farms, it is not possible to know if management and production are independent (Gelasakis et al. 2017).

4.3. Differences and similarities between sheep production systems

Although the livestock indicator presented discriminatory power (Table 5), when we analysed the variables used in the construction of the typology simultaneously in C_{DA}, it was observed that the number of sheep did not show any power of differentiation between the production systems. Thus, the largest herd size did not necessarily mean large production of live weight, mainly in extensive sheep systems in semiarid regions, in which the mortality rate is high (Alencar et al. 2010). The animals gain weight through compensatory weight gain in the rainy season. This hypothesis was confirmed when only the number of lactating ewes (a variable that reflects the number of lambs) showed discriminatory power in the livestock indicator. It was observed that the numbers of sheep and ewes were equal (Table 3), but the number of lactating ewes was higher in the traditional and lower in the emerging sheep production system. This indicates that the emerging system farmers managed the farms more intensively and with greater efficiency in managing the farm. The highest percentages of farms in the emerging system that adopted the herd bookkeeping and replacement of females from the herd (Table 4) helped farmers make general management decisions for these farms. Indicators such as kg of lamb weaned per ewes per year were indicated to assess the productive efficiency of the ewes as a criterion for disposal.

The second discriminant function, although with a lower percentage of discrimination, but no less important, demonstrated that the variables that represent social, herd management, and technological indicators were essential to differentiate the production systems, especially the emerging from the traditional and conventional. This result showed that, although sheep farming in semiarid regions is extensive, we cannot develop a typology of farms using only dimensional and productive aspects, which is in line with our concept of the production system. The inclusion of variables from the different production system indicators in the factor analysis justifies the high percentage of farms correctly classified in their group of origin, which validates the typology developed (Figure 2).

Although there were differences among sheep production systems, it was observed farms studied shared some characteristics: *i*) sheep breeding is still a family activity, and *ii*) the predominant production system is extensive farming, agreeing with other studies that characterized sheep production systems in drylands regions worldwide (Iñiguez 2011; Chedid, Tourrand, Jaber, Hamadeh 2018).

Finally, the emerging system was an important discovery of this study. It is formed by a group of young farmers that stood out in the intensification of the management, production, facilities, and equipment. This system may expand and represent the future of sheep farms in the Brazilian semiarid region. The migration from the traditional to the emerging system would happen in the coming generations. On the other hand, the conventional system stood out only in the social aspects and older animals being slaughtered, which can represent food security for families, since this system was classified as subsistence-based on family production. This system is characterized by small farms (61.5% of the farms) and still being the main sheep production system, which is in line with several studies on the characterization of sheep production systems in semiarid regions of the world (Naqvi, De, Gowane 2013; Toro-Mujica, Aguilar, Vera, Rivas, García 2015, Toro-Mujica et al. 2019).

5. Final remarks and future research

Sheep farming has social, cultural, and economic importance in the Brazilian semiarid region. This study was carried out to understand the heterogeneity of sheep production systems, creating the basis for defining public policies for the sustainable development of sheep production systems in the Brazilian semiarid. The study was based on the premise that sheep production systems in semiarid zones are distinct, mainly in physical, livestock, and productive factors.

A systematic approach combining three multivariate techniques with different objectives to group and discriminate the diversity of sheep production systems in a representative farm typology using social, physical, livestock, technological, productive factors, and management practices. The approach allowed the identification and validation of three different typologies as emerging, traditional, conventional sheep production systems. The emerging system is managed by schooled young, farms with a higher technological level and efficient in meat production; the traditional system has the largest grazing areas and the number of lactating ewes, but with low productivity; and the conventional, the largest productive system, is characterized by smallholder farms with production destined to the subsistence of families. Despite the peculiarities, all systems are based on family labour, and strongly dependent on natural resources.

The development of typology using the approach used in this study may help to define targeted-oriented public policies and increase sheep production efficiency, This study highlighted the need of improving the management and adoption of technologies, but it need to consider particularities of each group of producers. The future of sheep farming in the Brazilian semiarid region depends on the creation of socioeconomic projects to fix young famers in the sheep farming activity and rural extension programmes with training of know-how professionals. Future larger-scale research should be carried out using this systematic approach with all indicators of the production system, including economic feasibility, to define and evaluate the economic sustainability of these production systems.

Highlights

- Three sheep production systems were revealed through techniques of multivariate analysis: emergent, conventional, and traditional
- Social, physical, livestock, herd management, technological and productive indicators show discriminatory power between the three sheep production systems

- The participation of young producers was considered a key factor in the future of the sheep production system in the Brazilian semiarid
- The breeding of sheep in the Brazilian semiarid region is characterized as traditionally familiar farming

Acknowledgements

The Agribusiness Secretariat of the Municipality of *Bela Cruz*, especially Mr Carlos César de Carvalho for his support, all sheep farmers interviewed, and technicians from the Technical Assistance and Rural Extension Company of *Ceará* state (*EMATERCE*).

Authorship contribution statement

R. M. F. Silveira – Conceptualization, Data collect, Data curation, Data analysis, Methodology, Writing - original draft, Funding acquisition.

A. M de Vasconcelos **–** Supervision, Project administration, Validation, and Final review

V. J. da Silva – Conceptualization, Supervision, Validation, Writing and editing and Final review

W. H. O. Vega - Conceptualization, Validation, Final review.

P. Toro-Mujica – Conceptualization, Validation and Final review

J. Ferreira - Conceptualization, Validation and final review

Disclosure statement

No potential conflict of interest was reported by the authors.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent to publish

The authors state that all human participants in the research provided consent for the publication of the data.

Data availability

Data will be made available on request.

ORCID

Robson Mateus Freitas Silveira http://orcid.org/0000-0003-2285-9695
Angela Maria de Vasconcelos http://orcid.org/0000-0002-9690-974X
Valdson José da Silva http://orcid.org/0000-0001-5650-9648
Wilder Hernando Ortiz Vega http://orcid.org/0000-0001-9742-4501

Paula Toro-Mujica http://orcid.org/0000-0002-6452-3113
Josiel Ferreira http://orcid.org/0000-0002-5927-0545

References

Alencar, S. P., Mota, R. A., Coelho, M. C. O. C., Nascimento, S. A., de O.Abreu, S. R., & Castro, R. S. (2010). Perfil sanitário dos rebanhos caprinos e ovinos no sertão de Pernambuco. *Ciência Animal Brasileira*, *11*(1), 131–140. doi: 10.5216/cab.v11i1.4051.

Alvares, C. A., Stape, J. L., Sentelhas, P. C., De Moraes Gonçalves, J. L., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(6), 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Alves, A. R., Da Silva Vilela, M., Meira de Andrade, M. V., Da Silva Pinto, L., Brito de Lima, D., & Lopes Lima, L. L. (2017). Caracterização do sistema de produção caprino e ovino na região sul do estado do Maranhão, Brasil. *Veterinária E Zootecnia*, *24*(3), 515–524. https://doi.org/10.35172/rvz.2017.v24.287

Alves, E., Da Silva E Souza, G., & Marra, R. (2011). Êxodo e sua contribuição à urbanização de 1950 a 2010 1,2. *Revista de Política Agrícola*, *2*, 80–88. https://seer.sede.embrapa.br/index.php/RPA/article/view/61

Arandas, J. K. G., Alves, Â. G. C., Facó, O., Belchior, E. B., Shiotsuki, L., & Ribeiro, M. N. (2020). Characterization of the sheep farming system in the Brazilian semiarid from the multivariate perspective. *American Journal of Animal and Veterinary Sciences*, *15*(3), 185–197. https://doi.org/10.3844/ajavsp.2020.185.197

Araújo, A. R., Rodriguez, N. M., Rogério, M. C. P., Borges, I., Saliba, E. O. S., Santos, S. A., Pompeu, R. C. F. F., Fernandes, F. E. P., Monteiro, J. P., & Muir, J. P. (2019). Nutritional evaluation and productivity of supplemented sheep grazing in semiarid rangeland of northeastern Brazil. *Tropical Animal Health and Production*, *51*(4), 957–966.

Batista, N. L., & De Souza, B. B. (2015). Caprinovinocultura no semiárido brasileiro - fatores limitantes e ações de mitigação. *Agropecuária Científica No Semiárido*, *11*(1), 01–09. http://www.cstr.ufcg.edu.br/acsa/RevistaACSA-OJS:http://150.165.111.246/ojs-patos/index.php/ACSA

Campos, R. T. (2003). Tipologia dos produtores de ovinos e caprinos no estado do Ceará. *Revista Econômica do Nordeste*, *34*, 85–112. http://www.repositorio.ufc.br/handle/riufc/1161

Castro, M.S.M., de Sousa Oliveira, D., dos Santos Fontenelle, R.O. et al. (2021). Understanding the dairy production systems in rural settlements in the Brazilian semi-arid region: characterization, typology, and holistic perception. *Trop Anim Health Prod 53*, 417. https://doi.org/10.1007/s11250-021-02840-x

Chedid, M., Tourrand, J. F., Jaber, L. S., & Hamadeh, S. K. (2018). Farmers' perception to change and adaptation strategies of small ruminant systems in the West Bekaa of Lebanon. *Small Ruminant Research*, *167*, 16–21. https://doi.org/10.1016/j.smallrumres.2018.07.025

Costa, R. G., Almeida, C. C., Pimenta Filho, E. C., Holanda, E. V., & Santos, N. M. (2008). Caracterização do sistema de produção caprino e ovino na região semi-árida do estado da Paraíba. Brasil. *Archivos de Zootecnia*, *57*(218), 195–205.

de A. Kato, H. C., Belchior, E. B., De Sousa, D. N., & De Morais, O. R. (2019). Diagnóstico Tecnológico De Produção Da Caprinovinocultura No Município De Tauá – Ce. *DESAFIOS - Revista Interdisciplinar Da Universidade Federal Do Tocantins*, *6*(2), 10–17. https://doi.org/10.20873/uft.23593652201962p10 de F. Guilherme, R., De Farias, D. A., Alves, J. R. A., Da Costa, D. F., Pinheiro, R. R., Alves, F. S. F., De Azevedo, S. S., & Alves, C. J. (2017). Characterization and typology of sheep and goat production systems in the State of Paraíba, a semi-arid region of north-eastern Brazil. *Semina: CienciasAgrarias*, *38*(4), 2163–2178. https://doi.org/10.5433/1679-0359.2017v38n4p2163

De, K., Kumar, D., Balaganur, K., & Naqvi, S. M. K. (2020). Effect of environmental factors on estrus synchronization and artificial insemination success in farmers flock in sheep under semi-arid tropical region. *Reproduction in Domestic Animals*, *55*(7), 777–784. https://doi.org/10.1111/rda.13683

de Lucena, C. C., de Guimarães, V. P., Martins, E. C., Cisne Júnior, J. V., de Oliveira, D. S., & da S Barreto, L. L. (2018). Diagnóstico da caprinocultura e ovinocultura do município de Sobral – CE. *Documentos/Embrapa Caprinos E Ovinos, Documento 127*, 1–38.

De Oliveira, A. G., De Oliveira, V. S., De Arruda Santos, G. R., Dias Ferreira, A. C., Santos, G. S., De Lima, E. P. T., Dos Santos Sobrinho, D. C., & Carvalho, C. T. G. (2013). Diagnóstico socioeconômico da produção leiteira em três assentamentos de reforma agrária no semiárido do Estado de Sergipe. *Semina:Ciencias Agrarias*, *34*(4), 1869–1878. https://doi.org/10.5433/1679-0359.2013v34n4p1869

de S. Farias, J. L., Araújo, M. R. A., De, Lima, A. R., Alves, F. S. F., Oliveira, L. S., & de Souza, H. A. (2014). Análise socioeconômica de produtores familiares de caprinos e ovinos no semiárido cearense, Brasil. *Archivos de Zootecnia*, *63*(241), 13–24. https://dx.doi.org/10.4321/S0004-05922014000100002

Gelasakis, A. I., Rose, G., Giannakou, R., Valergakis, G. E., Theodoridis, A., Fortomaris, P., & Arsenos, G. (2017). Typology and characteristics of dairy goat production systems in Greece. *Livestock Science*, *197*(December2016), 22–29. doi: 10.1016/j.livsci.2017.01.003.

Gelasakis, A. I., Valergakis, G. E., Arsenos, G., & Banos, G. (2012). Description and typology of intensive Chios dairy sheep farms in Greece. *Journal of Dairy Science*, *95*(6), 3070–3079. doi: 10.3168/jds.2011-4975.

IBGE | Censo Agro 2017 | Home. (2017). *Censo Agropecuário 2017*. https://censos.ibge.gov.br/agro/2017/

Ibidhi, R., Frija, A., Jaouad, M., & Ben Salem, H. (2018). Typology analysis of sheep production, feeding systems and farmers strategies for livestock watering in Tunisia. *Small Ruminant Research*, *160*, 44–53. doi: 10.1016/j.smallrumres.2018.01.010.

Iñiguez, L. (2011). The challenges of research and development of small ruminant production in dry areas. *Small Ruminant Research*, *98*(1–3), 12–20. doi: 10.1016/j.smallrumres.2011.03.010.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *20*(1), 141–151. doi: 10.1177/001316446002000116.

Köbrich, C., Rehman, T., & Khan, M. (2003). Typification of farming systems for constructing representative farm models: Two illustrations of the application of multivariate analyses in Chile and Pakistan. *Agricultural Systems*, *76*(1), 141–157. doi: 10.1016/S0308-521X(02)00013-6.

Marengo, J. A., Torres, R. R., & Alves, L. M. (2017). Drought in Northeast Brazil—past, present, and future. *Theoretical and Applied Climatology*, *129*(3–4), 1189–1200. doi: 10.1007/s00704-016-1840-8.

Naqvi, S. M. K., De, K., & Gowane, G. R. (2013). Sheep production system in arid and semi-arid Regions of India. *Annals of Arid Zone*, *52*, 1–9. http://epubs.icar.org.in/ejournal/index.php/AAZ/article/view/63347/0

Riveiro, J. A., Mantecón, A. R., Álvarez, C. J., & Lavín, P. (2013). A typological characterization of dairy Assaf breed sheep farms at NW of Spain based on structural factor. *Agricultural Systems*, *120*, 27–37. doi: 10.1016/j.agsy.2013.05.004.

Rogério, M. C. P., Araújo, A. R., Pompeu, R. C. F. F., Silva, A. G. M. E., de Morais, E., de Q Memória, H., & de S Oliveira, D. (2016). Manejo alimentar de caprinos e ovinos nos trópicos. *Veterinária E Zootecnia*, *23*(3), 326–346.

Silva, R. A. B., Batista, M. C. S., Nascimento, C. B., Alves, R. P. A., Alves, F. S. F., Pinheiro, R. R., Sousa, M. S., Diniz, B. L. M., Cardoso, J. F. S., & Paula, N. R. O. (2011). Caracterização zoosanitária da ovinocultura e da caprinocultura na microrregião homogênea de Teresina, Piauí, Brasil. *Arquivos Do Instituto Biológico*, *78*(4), 593–598. doi: 10.1590/1808-1657v78p5932011.

Silveira, R. M. F., Roberto Sá, J., Maria de Vasconcelos, A., Cristina de Souza Ribeiro, M., Freitas Viera, E., Alves Gonçalves, M., & Borges Ferreira, J. (2018). Atributos químicos de um Neossolo Flúvico cultivado com capim elefante (Pennisetum purpureum Schum) no município de Bela Cruz. *Agropecuária Científica No Semiárido*, *14*(4), 325–330. https://doi.org/10.30969/acsa.v14i4.1049

Simplicio, A. A., & Santos, D. O. (2005). Estação de monta x mercado de cordeiro e leite. *I Simpósio De Caprinos e Ovinos Da Escola de Veterinária Da UFMG*, *84*, 1–17. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/36612/1/AAC-Estacao-de-monta.pdf

SPPS. (2010). *Statistical package for the social, 20*.

Teixeira, W. C., Santos, H. P., Silva, J. C. R., Rizzo, H., Marvulo, M. F. V., & De Castro, R. S. (2015). Perfil zoosanitário dos rebanhos caprinos e ovinos em três mesorregiões do estado do maranhão, brasil. *Acta Veterinaria Brasilica*, *9*(1), 34–42. https://doi.org/10.21708/avb.2015.9.1.4438

Toro-Mujica, P., Aguilar, C., Vera, R., Rivas, J., & García, A. (2015). Sheep production systems in the semi-arid zone: Changes and simulated bio-economic performances in a case study in Central Chile. *Livestock Science*, *180*, 209–219. doi: 10.1016/j.livsci.2015.07.001.

Toro-Mujica, P., Arraño, C., Vera, R., Robles, L., del Río, C., Corvalán, E., & Riveros F., J. L. (2019). Perspectives of abandonment/continuity of typological groups of sheep farms in the semi-arid region of Central Chile. *Economia Agraria y Recursos Naturales*, *19*(2), 113–132. https://doi.org/10.7201/earn.2019.02.06

Toro-Mujica, P., García, A., Gómez-Castro, A., Perea, J., Rodríguez-Estévez, V., Angón, E., & Barba, C. (2012). Organic dairy sheep farms in south-central Spain: Typologies according to livestock management and economic variables. *Small Ruminant Research*, *104*(1–3), 28–36. doi: 10.1016/j.smallrumres.2011.11.005.

Ward, J. H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, *58*(301), 236–244. doi: 10.1080/01621459.1963.10500845.