Cow-calf operation management clusters, Argentina[1]

Vanesa A Vistarop *, Alejandro J Larriestra †, Claudina Vissio †, Federico Demateis Llera §, Graciela N Yaful *, Carlos J Blanco #, Julián A Bartolomé ||.

*Carrera de Medicina Veterinaria-UNRN, Choele Choel, Rio Negro, Argentina, 8360; CIT Río Negro-CONICET, Rio Negro, Argentina, 8336. †Facultad de Ciencias Veterinarias UNRC, Rio Cuarto, Córdoba, Argentina, 5800. § Estación Experimental Agropecuaria General Villegas, Instituto Nacional de Tecnologia Agropecuaria (INTA), General Villegas, Buenos Aires, Argentina, 6230. # Facultad de Ciencias Veterinarias UBA, Ciudad Autónoma de Buenos Aires, Buenos Aires, Argentina, B1001. || Facultad de Ciencias Veterinarias UNLPam, General Pico, La Pampa, Argentina, 6360.

* Corresponding author: vavistarop@unrn.edu.ar

LAY SUMMARY

This research aimed to understand productivity and good management practice (GMP) adoption among cow-calf operations in Río Negro Province, Argentina. A survey of 142 of 1,229 operations in Avellaneda and Pichi Mahuida counties provided data on productivity measures, herd structure variables, and GMP adoption. Productivity was measured as the number of calves per 100 cows and the number of calves per 100 hectares. Cow-calf operations were then analyzed based on the county of origin and adoption of the breeding season. Operations were then grouped according to the main GMPs adopted, and the productivity was calculated to assess the performance of each group. The analysis revealed that operations with a three-month breeding season exhibited better productivity metrics than those with year-round breeding. Additionally, three distinct farm types of cow-calf operations were identified, each with different profiles based on GMP adoption. The high GMP adoption cluster showed significantly higher productivity (85 calves/100 cows) than the other clusters did. These findings help to understand the cow-calf operation segment and could guide targeted interventions to improve productivity in Rio Negro's cow-calf operations by promoting the adoption of GMPs.

TEASER TEXT

The cow-calf operations management clusters enhanced our understanding of the beef cattle sector in Río Negro province, Argentina. Three different clusters were identified according to GMP adoption combined with productivity measures, representing a fundamental insight to design extension programs to promote and encourage GMP adoption, thus improving herd productivity

ABSTRACT

This research was conducted to gain more insight into the productivity and good management practice (GMP) adoption of cow-calf operations in Río Negro Province, Argentina. The objectives were to characterize productivity and management profiles according to GMP adoption, identify herd clusters, and describe the performance and productivity within each specific cluster. A survey sample of 142 out of 1,229 cow-calf and cow-calf to-finish operations from Avellaneda and Pichi Mahuida counties provided data on productivity, herd structure, and GMP adoption. The productivity variables, calves per 100 cows (C/100 c) and calves per 100 ha (C/100 ha), were described statistically using quartiles, and differences by county according to the three-month breeding season adoption were explored. Moreover, herd structure and GMP-related variables were subjected to multiple correspondence analysis (MCA) with complete-link hierarchical cluster analysis to typify the operations. A total of 127 out of 142 farmers provided productivity data, showing median values of 79.00 C/100 c (Q1= 67.00; Q3= 85.00) and 4.58 C/100 ha (Q1= 2.78; Q3= 8.00). A Significant difference was found between three-month and year-round breeding operations for both variables (82.00 C/100 c vs 75.50 C/100 c; P=0.0006 and 5.60 C/100 ha vs 3.97 C/100 ha; P=0.0072). Three farm clusters (Cl) were identified: Cl 1 (low adoption), Cl 2 (moderate transition), and Cl 3 (GMP-oriented). Cl 3 showed the highest GMP adoption level, and a significant difference was found in the C/100 c variable (85.00 C/100 c vs. 76.00 and 80.00 for Cl 1 and 2, respectively; P=0.0233). Cluster profiling enhances our understanding of the cow-calf operation segment and highlights the importance of GMP adoption for improving productivity in cow-calf operations. The results should be interpreted with caution due to the limitations of a cross-sectional study showing correlational associations. Nevertheless, it provides insights for designing science-based and targeted interventions to improve the

performance of the beef cattle industry in Río Negro, Argentina, and may be the basis for prospective or interventions studies in the future.

Keywords: clusters, cow-calf operation, beef cattle, good management practices, survey, typification.

List of abbreviations:

AU, Animal Unit

DM, dry matter

GMP, Good Management Practices

Cl, cluster

z, confidence interval

a, amplitude

C, calves weaned in 2020

c, total number of cows during 2019

ha, hectares

Q2, second quartile

IQ range, interquartile range

Q1, first quartile

Q3, third quartile

RF, relative frequencies

MCA, multiple correspondence analysis

PCA, principal component analysis

BS, breeding season

HW, hired workers

PD, pregnancy diagnosis

BSE, heifer breeding soundness evaluation

PC, principal components

US, United States

BQA, Beef Quality Assurance

LW, live weight

INTRODUCTION

The Rio Negro province belongs to the "eastern monte of northern Patagonian" ecoregion in Argentina [Ministerio de Agricultura, Ganadería y Pesca (MAGYP), 2021], and is limited by sanitary barriers, considered as a foot-and-mouth disease-free region without vaccination [Programa de Servicios Agrícolas Provinciales (PROSAP), 2015]. The province is mainly fruit producing, but the 1,1% participation in the bovine national stock [Ministerio de Hacienda (MH), 2017] makes beef cattle production relevant, since it is impossible to import meat or purebred animals from the north of the barrier. Valley and plateau plains are the regions described with a high percentage of native plant species (Peralta and Klich, 2021; Bertani, n.d). The climate is cold and dry, and the rainfall is 277 mm for Choele Choel city from Avellaneda County (Bertani, n.d.). Native vegetation in plateau plains (Bertani, n.d.) produces 221-383 kg dry matter (DM)/ha (PROSAP, 2015) in extensive cattle-raising areas (Bertani, n.d.) with stocking rates varying from 7.4 to 13.2 animal units per hectare (AU/ha, PROSAP, 2015). Implanted species such as corn, oats, and barley, as well as annual and perennial legumes and grasses, are distributed along the valley plain under irrigated conditions, producing 7-9 tn DM/ha; 7-8 tn DM/ha, and 6 tn DM/ha, respectively (PROSAP, 2022) in an intensive agricultural area (Bertani, n.d.) with stocking rates of 5.8 AU/ha (PROSAP, 2015).

Given these geographical and climatic conditions, the beef cattle population in Río Negro province was approximately 695,179, mainly located in the east, especially in Avellaneda (27.0%), Pichi Mahuida (21.1%), Adolfo Alsina (16.6%), and General Conesa (14.8%) counties (SENASA, 2023) with Aberdeen Angus and Hereford as the predominant breeds (PROSAP, 2015). Production is extensive, and according to the steer-to-cow ratio of 0,07 (27,960/360,286) [Servicio Nacional de Calidad Agroalimentaria (SENASA), 2020], it is non-corporate cow-calf production in marginal regions where calf retention is not economically viable (Rosemberg, 1986). The ratio between calves weaned (C) and the total number of mated cows (c) expressed as C/100 c, a non-precise indicator of weaning rate, is in the range of 53–60%, with a calf harvest of 0.04 calves/ha/year and a herd efficiency in the range of 13–27%, indicating the number of calves weaned based on the total number of cows in the inventory (PROSAP, 2015). Weaning is performed at 6 months (MAGyP, 2021) with 150 kg at no specific moment of the year due to the high percentage of year-round breeding herds (PROSAP, 2015). This practice could be adopted because cattle breeding generates the possibility of obtaining additional income due to cattle ownership, and it is supported by the stability of productive indicators during the last 50 years. Consequently, being a cattle owner tends to compensate the productive inefficiency measured as weaning or calving rate (Ponssa et al., 2019)

Economical aspects contrast with cattle breeding efficiency, since it takes place in extensive grazing systems, as occurs in Rio Negro province, demanding seasonal management with the adoption of a three-month breeding season to get a 12-month calving interval (Marx, 2008), being the goal of the cow-calf operation system. Consequently, overall productivity is evaluated through calf production at weaning, reinforcing reproductive performance of cows (Marx, 2008; Herring, 2014). In contrast, reports concerning reproductive failures, year-round breeding, poor nutrition, absence of health programs, and deficient feeding management have been described among Río Negro cow-calf operations (PROSAP, 2015). Despite this, there is no systematic description of beef cattle herds in Rio Negro, using a probabilistic sampling design depicting farm typology according to Good Management Practices (GMP) and productivity. Conversely, typologies have been used in dairy production systems to describe health standards for mastitis status (Visio et al., 2013), and replacement heifer management (Demateis Llera, 2021). Identifying farm clusters may help understand the heterogeneity of the beef cattle management segment and properly design policy interventions by targeting similar groups (Alemu et al., 2016).

Based on a previous and regional study in Argentina characterizing beef cattle by identifying technologies to improve productivity (Gregoretti et al., 2024), the hypothesis of this study is that there are significant differences in productivity (C/100c and C/100 ha) in cow-calf and cow-calf to-finish operations in Rio Negro Province, Argentina, characterized by different levels of GMP adoption; farms with higher GMP adoption have better productivity measures. The objectives of this study were to 1) characterize productivity and management profiles according to GMP adoption and, 2) identify herd clusters (Cl) and describe the performance and productivity within each specific cluster among Rio Negro cow-calf and cow-calf to-finish operations.

MATERIALS AND METHODS

STUDY POPULATION

The research target population was 3,129 operations from the Río Negro province, with a herd size of ≤ 250 cows for 85% of them. The sampling frame was restricted to Avellaneda and Pichi Mahuida counties, where 48,1% of the cows were located (SENASA, 2020), and distributed among 1,229 cow-calf and cow-calf-to-finish operations. The experimental units were operations with cows, involving cow-calf and including cow-calf-to-finish as a technological improvement of cow-calf operations by calf retention decision (Rosemberg, 1986). The sample size was calculated using the equation $n = \left(\frac{2Z_{1-\alpha/2}}{a}\right)^2 * 0.25$ (Infostat, 2011) to estimate a proportion of 50% or less, with a 95% confidence interval (z) and amplitude (a) smaller than 0.6. Subsequently, 145 cow-calf operations were selected through stratified random sampling according to herd size distribution. The strata were conformed considering 250 cows, and depended on the 33rd percentile, with the following strata distribution for Avellaneda County: 1 (10–20 cows), 2 (21–70 cows), and 3 (71–250 cows); and Pichi Mahuida County: 1 (10–60 cows), 2 (61–130 cows), and 3 (131–250 cows). The final sample consisted of 142 cow-calf operations, because three refused to participate, resulting in 71 farmers from each county.

DESIGN AND DATA COLLECTION

This study involved a cross-sectional survey tailored based on published data and local veterinarians´ opinions (Young et al., 2012) to gather information on productivity, herd structure, and GMP adoption. The survey included 76 questions divided into six main topics: 1) breeding herd structure and facilities; 2) enterprise characteristics (family labor, hired workers, and advisers); 3) cows, bulls, and heifers' reproductive and nutritional management; 4) cows, bulls, and heifers' health management; 5) calf management; and 6) productivity measures. The questions were asked considering current practices, except for courses taken, accounting for a respondent's lifetime as a period. The calf/cow ratio was used to evaluate productivity as a proxy variable for weaning rate (PROSAP, 2015; Olmo et al., 2016). This was calculated using the calves weaned in 2020 (C) divided by the total number of mated cows (c) during the previous year and expressed by 100 cows as follows: C/100 c. In addition, a secondary ratio was calculated using the calf harvest during 2020 divided by an area of 100 ha and expressed as follows: C/100 ha. Finally, a defined breeding season was established for no longer than 3 months [U. S. Department of Agriculture, Animal, and Plant Health Inspection Service, Animal Health NAHMS (USDA), 2009; Herring, 2014].

The survey was phone-delivered and conducted between May and November 2020 and no ethical oversight or institutional approval was required. The potential participants were contacted through a farmers' organization named Sociedad Rural Argentina, and a letter describing the study objectives and scope was sent to them following Vissio et al. (2013). Then, participants were included in the study upon their consent. The survey was pre-tested by inviting 13 farmers to participate, following Demateis Llera et al. (2010) and Sheppard et al. (2015) guidelines. Ultimately, 129 farmers were surveyed to complete the final sample of 142 herds (13 pre-tested and 129 post-tested).

DATA ANALYSIS

The quantitative variables C/100 c and C/100 ha were described using the second quartile (Q2) and the interquartile range (IQ range), calculated using the first (Q1) and third quartile (Q3) as $Q1 - Q3$. Subsequently, the Wilcoxon signed-rank test was used to evaluate differences between county and breeding season herd adoption using a threshold of significance of $P < 0.05$. Categorical, herd structure, and GMP-related variables were used to describe the management profile by employing absolute and relative frequencies (RF, Infostat, 2011).

The herd structure and GMP-related variables with an RF smaller than 0.85 were subjected to Multiple Correspondence Analysis (MCA) within each topic to reduce collinearity. Variables with greater RF were not included in the MCA due to a lack of variability (Gaspar et al., 2008). High relative weight variables considering ax 1 were selected to typify operations and submitted to complete-link hierarchical cluster analysis using Gower as the measure of distance (Vissio et al., 2013; Dematteis Llera, 2010). The Kruskal-Wallis test was used to evaluate the differences in productivity between Cl with a threshold of significance of $P < 0.05$, and principal component analysis (PCA) was performed to depict a graphical cluster distribution. The optimal number of clusters was determined by examining the dendrogram and identifying the level at which the largest increase in linkage distance occurred, indicating natural group separation. Additionally, the variance explained by two principal components (PC) showed how the reduced-dimensional representation captured the underlined structure of the original data, and the cophenetic correlation coefficient assessed the dendrogram`s fidelity to the original dissimilarities. Subsequently, optimal clustering was retained only if it could be interpreted (Infostat, 2011).

RESULTS

PRODUCTIVITY CHARACTERIZATION OF THE POPULATION UNDER STUDY

Three out of 145 farmers refused to participate, resulting in a 98% response rate. This sample represented nearly 11.5% of the farmer population in both counties. Among them, 127 (89%) provided data to calculate productivity. The medians for the entire sample were 79.00 (Q1= 67.00; Q3= 85.00) and 4.58 (Q1= 2.78; Q3= 8.00) for C/100c and C/100 ha, respectively. A significant difference was found for C/100 ha between counties (3.29 vs 5.21; P=0.0488), and C/100c and C/100 ha ratios were higher for herds adopting a three-month in contrast to year-round breeding season (BS; 82.00 vs. 75.50, P=0.0006 and 5.60 vs 3.97, P=0.0072; Table 1)

MANAGEMENT PROFILE ACCORDING TO GMP ADOPTION

The studied farms were located mainly in the plateau plain region (81%), with an even distribution of cow-calf (49%) and cow-calf-to-finish operations (51%, Table 2). These farms had an area and herd size of up to 2,500 ha (59%) and 200 cows (74%), respectively (Table 2). The median values for area and herd size were 2,500 ha (Q1= 1,100; Q3= 5,000) and 123 cows (Q1= 58; Q3= 210), respectively. Aberdeen Angus and Hereford were the predominant breeds in these herds, and most farms had adequate facilities (93%, Table 2).

Almost all of the studied operations were family farms, with at least one family member involved, and 58% did not hire workers. Most farmers had completed elementary school, one-third high school, and one-third university studies, and were aged 41–60 years. Elementary school education was predominant among hired workers (HW), and the age range was the same as that of the farmers. Veterinarians technically advised most farmers (74%) on specific demands (57%) and only 37% farmers discussed GMP adoption with their advisers. A total of 18% of the farmers were able to provide information about pregnancy and weaning rates (Table 3).

Regarding breeding management, most performed natural services with pure-breed bulls, and had a year-round breeding system. Moreover, pregnancy diagnosis (PD) and calving monitoring were not commonly adopted (Table 4), and most of the reproductive animal categories were fed native vegetation (94%) without measuring corporal conditions (74%, Table 5). The most reported health practices were vaccination against brucellosis (96%), deworming (73%), and mineral vitamin supplementation (64%, Table 6). In addition, the calves were weaned between 3 and 6 months (68%), nurtured, and fed native vegetation (63%) using a complete vaccination protocol (84%, Table 7).

CLUSTERS DESCRIPTION FOR GMP ADOPTION AND PRODUCTIVITY

Cluster (Cl) analysis of operations yielded the most significant results for a three-cluster solution considering the following herd structure and GMP adoption variables: production area, combined operations in different production areas, beef cattle production system, family labor supply, external labor supply, HW educational level, technical adviser, type of technical assistance, BS, bull origin, heifer breeding soundness evaluation (BSE), PD and methods, date of PD, bull test for venereal diseases, brucellosis heifer test, dog deworming, calf age at weaning, and calves` vaccination protocol. Consequently, each of the three Cl had a unique profile, and the characteristics of each Cl are described in Table 8.

Cluster 1 included 41 farms mostly specializing in cow-calf to-finish operations, mainly located in the plateau plain region combined with operations in the valley plain near the Negro River. The labor supply was external, and most had only completed their elementary education. In this Cl, most farms had year-round breeding herds. Related to other practices, PD and bull tests for venereal diseases were not performed, and health management of the weaned calves was deficient. Most farmers performed the brucellosis heifer test and had the highest number of non-dewormed dogs. Regarding technical assistance, this Cl profile presented low-frequency herd professional advice.

Cluster 2 included 82 farms specializing in cow-calf operations, mainly located in the plateau plain region. They usually did not hire workers, and family labor prevailed. This Cl showed a high percentage of year-round breeding herds, but a moderate percentage of the farmers had a BS lasting from four to six months during the year. Moreover, the majority of calves were weaned, but showing poor health management. Like Cl 1, farmers did not perform PD and tests for venereal diseases, but they practiced the brucellosis heifer test. Unlike Cl 1, it had more regular technical assistance.

Finally, Cl 3 included 19 farms specializing in cow-calf to-finish operations, sharing the same spatial distribution as Cl 1. The labor supply was predominantly external with no formal education. Farmers in this cluster adopted a defined BS and performed PD by using transrectal palpation and ultrasonography of the uterus. In addition, bull tests for venereal diseases, brucellosis heifer tests, and calves' vaccination protocols during weaning had been widely adopted by farmers. Moreover, they showed the highest percentage of farms without dogs, and those with dogs had them dewormed. All the farms received regular technical assistance from veterinarians and agronomists.

Regarding the ratios used to describe the performance of the operations, herds belonging to Cl 3 showed higher median values for the C/100 c variable than those included in Cl 1 and Cl 2 (85 C/100c for Cl 3 vs 76 C/100c and 80 C/100c for Cl 1 and 2, respectively; P= 0.0233; Table 9). According to the PCA, the dimensionality was reduced for a clearer visualization of the multivariate information as a pattern of differences among clusters into two axes of PC (Fig. 1). These PC explained 29% of the total variability in the dataset, and the contributions of the variables to each PC (PC loadings) and the variance of the data set explained by each PC (eigenvalues) are listed in Table 10. Finally, the cophenetic correlation coefficient was 0.65.

DISCUSSION

The findings revealed significant differences in productivity among the profiles of operations in Rio Negro Province, Argentina; characterized by different levels of GMP adoption. In this sense, operations from Cl 3 with higher GMP adoption presented better productivity. The biplot was useful to detect patterns, attempting to verify rather than identify that a given cluster dissection looks reasonable (Jolliffe, 2002). Cluster 3 (green-colored) showed a distinct spatial separation, suggesting a unique profile, in contrast to Cl 1 (red) and 2 (yellow) that overlapped partially (Fig. 1). These patterns were confirmed by describing similarities in GMP among Cl. The cophenetic correlation indicates a moderate relation between distances in the reduced and original space, if a value of 0.81 is consider as a high relation (Vissio et al., 2013). This suggests that the PCA-based clustering provides a reasonable, though not perfect, summary of the data structure (Sokal and Rohlf, 1962).

The GMP involved in this research matches the main challenges in cow-calf operations, as Martin et al. (2018) identified in the US. Although the C/100 ha values did not differ from the Argentinian average (PROSAP, 2015), the C/100 c values were higher than the 59.7% Argentinian average (SENASA, 2023), 75% Australian average (Burns et al., 2010), and between 75% and 93% reported for the US (Short, 2001). While this value was around the recommended weaning rate benchmark of 85% (Marx, 2008) for the whole dataset, it could be overestimated, especially among year-round breeding herds. Previous studies have explored the correlation between calves born and weaned, being moderate to high positive (Martinez et al., 2004). This supports the use of calves born as a proxy for the weaning rate by Olmo et al. (2016) as a reproductive outcome due to the absence of abortion rate and calving intervals data. The calving interval may not be a precise indicator, especially in year-round breeding herds, as observed in this study and reported by Kugler et al. (2008) for the region. Despite its imprecision, C/100 c has been used in previous reports in Rio Negro province establishing useful values for comparison, such as 60% (Kugler et al., 2008) and 35-65% (PROSAP, 2015). Moreover, Kugler et al. (2008) proposed early weaning in year-round breeding herds to reduce the calving interval, helping to establish a breeding season. Nevertheless, more efforts should be made to promote a three-month BS adoption, emphasizing tradition as the most important factor to determine calving season (USDA NAHMS, 2009) and considering that increased age of farmers reduces the likelihood of adoption, related to the labor requirements for handling animals with the potential risk of injuries, suggesting that if older farmers do not adopt this practice at an earlier age, they are unwilling to change as they age (Ward et al., 2008).

The cluster analysis revealed different profiles on a defined BS, as the main GMP. This is the most impactful management tool because it is deeply involved in improving profitability (Benner et al., 2018), as was observed in this study, for C/100c and C/100 ha variables, showing significant differences for herds adopting it. It is due to the adjustment between herd nutritional requirements and environmental supplies (Fontes et al., 2020) for seasonal management. Only Cl 3 adopted this practice, but for Cl 1 and Cl 2, this was not the rule. Consequently, it is reasonable to name Cl 3 as GMP-oriented, because it allows other practices to be consolidated (Fontes et al., 2020).

Establishing a three-month BS consistent with 86.7 days (USDA NAHMS, 2017a) and 2.2–3.5 months (Sheppard et al., 2015) is an improvement opportunity for farmers in Cl 1 and 2, through reproductive efficiency (White, 2014) by culling all non-lactating cows (Burns et al., 2010). Despite showing a high percentage of year-round breeding season herds for Cl 2, consistent with the 54.5% reported by USDA NAHMS (2009), it is possible to name this Cl as "moderate transition", due to BS length from four to six months (Benner et al., 2018), though a longer breeding period allows a cow to be rebred after early embryonic death or abortion, it also leads to late calving (White, 2014). Finally, Cl 1 was named as "low adoption", having the highest percentage of year-round breeding season herds. In this cluster is difficult to establish a front-end loaded pattern (Fontes et al., 2020), with 65% of cows breeding a 21-day cycle (White, 2014), managing the herd as a homogeneous group (Herring, 2014) and consequently, a three-month BS allowing testing for venereal diseases, attending calves at delivery, and performing PD (USDA NAHMS, 2009; Jelinsky et al., 2015).

The PD practice provides information regarding the success of the BS (White, 2014). This practice was common for Cl 3, with similar values of 48.9% (Jelinsky et al., 2015) and 50% (Waldner et al., 2013) for Canadian beef cattle. However, Cl 1 showed a low adoption level, similar to 19.3% (USDA NAHMS, 2017a). Regarding the methods displayed, transrectal palpation predominated, and ultrasonography was only remarkable in Cl 3, analogous to 8.8% (USDA NAHMS, 2017a). This method makes it possible to detect an embryo between 26 and 33 days with 97.7% sensitivity (Pieterse et al., 1990), depicting a reproductive profile using gestational age data (White, 2014; Larson et al., 2016;). Finally, Cl 3 not only showed that PD can be enhanced through ultrasonography but also highlighted its adoption at weaning to segregate all non-lactating cows (Burns et al., 2010).

Transrectal palpation and ultrasonography are also useful for BSE in females. It is a practice performed before the onset of the BS, involving body weight monitoring, reproductive tract scoring, and pelvic area measurement (Larson et al., 2016). For heifers, BSE is critical for calving at 2 years, weaning 138 kg more than calves born from 3-year-old heifers (Nuñez Dominguez et al., 1991). According to this, only Cl 3 had the highest percentage of farmers combining some of the techniques mentioned above, even though in all clusters, an external observation was mostly performed. Moreover, BSE was practiced in bulls, involving tests for venereal diseases, semen analyses, and scrotal circumference measurement (USDA NAHMS, 2017a). Specifically, bull tests for venereal diseases were not performed before the beginning of the BS by a high percentage of farmers in Cl 1 and Cl 2, similar to 21.3% reported in Saskatchewan (Jelinski et al., 2015). Unlike Cl 3, values were similar to 53.6% (USDA NAHMS, 2017a) and 60.3 % (Waldner et al., 2013), showing higher levels of adoption. Although BSE includes more than just this test, its adoption enables the detection of sub-fertility bulls with potentially devastating effects (Diskin and Kenny, 2016).

According to a survey conducted in the United States (US) and Canada, weaning calves to induce estrus is highly recommended by 100% of veterinarians (Fike et al., 2017). In this regard, almost all Cl 3 and a smaller number of Cl 2 farmers had adopted it, which is in contrast with Cl 1. Moreover, not only weaning adoption but also age and methods need to be considered. Regarding age, 64% of veterinarians recommended weaning between three and six months (Fike et al., 2017), comparable to this study, with the highest percentage of farmers weaning calves at six months belonging to Cl 3. This value is close enough to the five months reported by Story et al. (2000), with the benefits of improving body condition scores in cows. Finally, regarding methods, all farmers performed weaning immediately before selling, which is a less recommended practice (Fike et al., 2017). In contrast, other studies have suggested weaning with complete or minimal separation and the use of anti-suckling devices (Fike et al., 2017; Wilson et al., 2017) to reduce stress within a preconditioning program (Wilson et al., 2017).

A preconditioning program includes a calf vaccination protocol before weaning, which was adopted by 74.5% of respondents regarding cow-calf practices in the US (Martin et al., 2018). The present study showed higher values for Cl 3, similar to 85.3% (Waldner et al., 2013), and 90% (Fike et al., 2017) reported among Canadian and US beef herds, respectively. In the US, the most common vaccinations for calves were infectious bovine rhinotracheitis (IBR, 51.8%), parainfluenza 3 virus (PI 3, 45.9%), bovine respiratory syncytial virus (BRSV, 47.8%), *Clostridium chauvoei* and/or *Clostridium septicum* and/or *Clostridium novyi* and/or *Clostridium sordellii* (47.4%) and *Clostridium perfringens* (34.4%, USDA NAHMS, 2017b). In Argentina, the same vaccines are used, except for the inclusion of anthrax, responsible for two outbreaks in 2018 in the province of study (SENASA, 2019a), even though it is not a mandatory practice. Foot-and-mouth disease and brucellosis are mandatory vaccinations in Argentina. Brucella abortus strain 19 is applied to female calves from 3 to 8 months in all the provinces except in Tierra del Fuego (SENASA, 2019b) and foot-and-mouth disease is applied to every category in all the provinces except the Patagonian region (SENASA, 2010). Except for brucellosis, nearly 100% of farmers in Cl 1 and Cl 2 did not adopt a calf vaccination protocol. This is similar to other categories with reports promoting vaccination protocol adoption in heifers and cows to prevent reproductive diseases (PROSAP, 2015). Ideally, to improve immune functions, calves should be preconditioned by weaning 45 days before sale, performing two series of clostridial and viral vaccinations, castration, dehorning, and feed bunk adaptation (Wilson et al., 2017).

The most common advisers in operations that promote GMP adoption are veterinarians (Ward et al., 2008; Griffin, 2009; Jelinsky et al., 2015). In this study, regardless of the cluster, veterinarians were the most common advisers, with an even higher percentage than the 50.8% reported by the USDA NAHMS (2009) and nearly 62.7% reported by Waldner et al. (2013). This contrasts with Cl 3, having both veterinarians and agronomists. Nevertheless, the farmers' technical assistance across any cluster mostly relied on disease-related demands, such as diagnosis, treatment, or prevention, as reported by the USDA NAHMS (2009) and Gonzalez Padilla et al. (2019). Professional assistance should encourage farmers to focus on practices to reduce labor by using computerized records (Ward et al., 2008) for financial decisions (USDA NAHMS, 2009) for at least three years (Griffin, 2009), which was uncommon in this research, regardless of the cluster.

Good Management Practice's adoption depends on the availability of adequate facilities and human capital. In this study, facilities did not represent a restriction, unlike a study carried out in Mexico, and probably related to low GMP adoption levels (Gonzalez Padilla et al., 2019). Regarding human capital, more advanced age and lower education level reduce the likelihood of adopting a defined BS and PD (Ward et al., 2008). According to this, the farmers' average age in this study, regardless cluster, was within 40 to 60 years, as reported by Jelinsky et al. (2019), and 53 to 65 years reported by Alemu et al. (2016), both for Canadian beef cattle. Regarding educational level, the highest percentage of HW had elementary school, as Vissio et al. (2013) reported on dairy farms in Cordoba, Argentina (60.8%). Unlike in the US, the HW highest percentage had a high school degree or lower, within the range of 42–79% (Short, 2001). Focusing on education or training can be an opportunity for farmers in Cl 1 and 2 to adopt reproductive management practices (Ward et al., 2008). This is supported by a study where producers with a college degree are more likely to adopt technology, management practices, and production systems by enhancing the ability to process information (Pruitt et al., 2012). This is remarkable because Beef Quality Assurance (BQA) certification increases as age decreases (Martin et al., 2018), and it is limited by educational level (Griffin, 2009). As a summary, cow-calf farmers are lower adopters of management practices than dairy and hog producers (Pruitt et al. 2012) and the percentage of income dependence of beef cattle is an indicator of adoption (Ward et al., 2008).

The sampling fraction was close to 14.2% (Jelinski et al., 2015) and 12.3% (Fike et al., 2017) for beef cattle, with a response rate exceeding 85%, which is deemed adequate (Singleton and Straits, 2010) and supports reliable estimates from the study (Groves, 2006). A phone-delivered survey (Alemu et al., 2016; Sheppard et al., 2015) presents advantages and disadvantages (Gubrium et al., 2012). Nonetheless, the assistance from farmers' organizations may have contributed to achieving a high level of participation, as noted by Vissio et al. (2013).

Finally, through the Cl description, three different profiles of GMP adoption were identified and associated with productivity as found by Gregoretti (2024) for Santa Fe Province, Argentina. An improvement of 70 and 96% was determined for kg live weight/ha/year (LW/ha/year) and gross margin US dollars/ha (U$S/ha), respectively. This was due to technological adoption such as increasing forage supply and improving herd management techniques (Gregoretti et al., 2024). In this study, results should be interpreted with caution, since they represent associations and not causation due to the limitations of the cross-sectional study design, with all the variables collected at the same time. Nevertheless, to the best of our knowledge, this is the first time that considering typologies by grouping operations was used as a strategy (Ventura et al., 2016) according to GMP and productivity to gain an in-depth understanding of Río Negro beef cattle, even though the amount of the variability explained by two PC is low. Consequently, using these results as an exploratory research could guide a longitudinal study to improve knowledge to better account for productivity (White, 2014; Diskin and Kenny, 2016).

CONCLUSIONS

Cluster profiling based on good management practices adoption enhanced our insight into the Río Negro cow-calf operation segment. The Cluster analysis yielded the most significant results for a three-Cluster solution, each exhibiting a distinct profile of good management practices adoption and productivity levels. Consequently, following the variables, Cluster 3 named as "GMP-oriented" showed the highest good management practices standards and best productive outcomes. Even though these results should be interpreted with caution due to a cross-sectional study, these findings may inform longitudinal data collection or interventions through pilot studies in the future. Finally, this was an approach which relied on statistical characterization and has the potential to guide the design of evidence-based communication programs with specific and targeted interventions for certain groups sharing similar characteristics, thereby improving cow-calf operation productivity in Río Negro, Argentina.

Disclosures

The authors declare no conflicts of interest.

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LITERATURE CITED

Alemu, A.W., Amiro, B.D., Bittman, S., McDobald, D. and Ominski, K.H. 2016. A typological characterization of Canadian beef cattle farms on a producer survey. Can. J. Anim. Sci. 96: 187-202. https://doi.org/10.1139/cjas-2015-0060

Benner, J.W., Grosse, R., Ligon, J.S., and Siegle, L. 2018. Transitioning Beef Cattle to a Defined Breeding and Calving Season. Virginia Cooperative Extension. https://vtechworks.lib.vt.edu/items/021df90d-71ca-4fb1-aecc-b02412c3e9e4/full

Bertani, L.A., Ferrari, L.E. (n.d.). Atlas del Valle Medio: mapa geomorfológico y de calidad de las tierras. http://observatoriogeograficoamericalatina.org.mx/egal5/Nuevastecnologias/Sig/06.pdf (Accessed 14 jun 2025)

Burns, B. M., Fordyce, G., and Holroyd, R. G. 2010. A review of factors that impact on the capacity of beef cattle females to conceive, maintain a pregnancy and wean a calf—Implications for reproductive efficiency in northern Australia. Anim. Reprod. Sci. 122: 1-22. https://doi.org/10.1016/j.anireprosci.2010.04.010

Demateis Llera, F., Vissio, C., Turiello, M.P., Herrero, M.A. and Larriestra, A.J. 2021. Heifer management characterization in dairy herds from the wets of Buenos Aires, Argentina. Braz.

J. Vet. Res. Anim. Sci. 58, e178793. https://doi.org/10.11606/issn.1678-4456.bjvras.2021.178793

Diskin, M., and Kenny, D. 2016. Managing the reproductive performance of beef cows. Theriogenology. 86: 379–387. https://doi.org/10.1016/j.theriogenology.2016.04.052

Fike, G., Simroth, J., Thomson, D., Schwandt, E., Spare, R., and Tarpoff, A. 2017. A survey of recommended practices made by veterinary practitioners to cow-calf operations in the United States and Canada. Prof. Anim. Sci. 33: 716–728. https://doi.org/10.15232/pas.2017-01642

Fontes, P. L., Oosthuizen, N., and Lamb, G. C. 2020. Reproductive management of beef cattle. In Elsevier eBooks (pp. 57–73). https://doi.org/10.1016/b978-0-12-817052-6.00004-5

Gaspar, P., Escribano, M., Mesías, F., De Ledesma, A. R., and Pulido, F. 2007. Sheep farms in the Spanish rangelands (dehesas): Typologies according to livestock management and economic indicators. Small. Rumin. Res. 74: 52–63. https://doi.org/10.1016/j.smallrumres.2007.03

González-Padilla, E., Lassala, A., Pedernera, M., and Gutierrez, C. G. 2019. Cow-calf management practices in Mexico: Farm organization and infrastructure. Vet. Méx. OA. 6(3). https://doi.org/10.22201/fmvz.24486760e.2019.3.677

Gregoretti, G., Baudracco, J., Dimundo, C., Lazzarini, B., Scarel, J., Alesso, A., & Machado, C. 2024. Traditional cow-calf systems of the northern region of Santa Fe, Argentina: current situation and improvement opportunities. *Revista De La Facultad De Ciencias Agrarias UNCuyo*, *56*(1), 106–116. https://doi.org/10.48162/rev.39.127

Griffin, D. 2009. Cow-Calf Operation Beef Quality Assurance. In Elsevier eBooks (pp. 587–594). https://doi.org/10.1016/b978-141603591-6.10112-5

Groves, R. M. 2006. Nonresponse rates and nonresponse bias in household surveys. Public Opinion Quarterly. 70: 646–675. https://doi.org/10.1093/poq/nfl033

Gubrium, J., Holstein, J., Marvasti, A., and McKinney, K. 2012. The SAGE Handbook of Interview Research: The Complexity of the Craft. In SAGE Publications. Inc. eBooks. https://doi.org/10.4135/9781452218403

Herring, A. D. 2014. Beef cattle production systems. In CABI eBooks. https://doi.org/10.1079/9781780645070.0000

Infostat - Statistical software. (n.d.). http://www.infostat.com.ar/

Jelinski, M., Campbell, J., Hendrick, S., and Waldner, C. 2015. Survey of Saskatchewan beef cattle producers regarding management practices and veterinary service usage. PubMed. 56: 66–72. https://pubmed.ncbi.nlm.nih.gov/25565718

Jelinski, M., Bergen, R., Grant, B., and Waldner, C. 2019. Adoption of technology and management practices by Canadian cow-calf producers. PubMed. 60: 287–293. https://pubmed.ncbi.nlm.nih.gov/30872852

Jolliffe, I. T. 2002. Principal component analysis (2nd ed.). Springer (pp 78-80, 215) https://doi.org/10.1007/b98835

Kugler, N., Giorgetti, H. D., Rodríguez, G. D., Cecchi, G., Montenegro, O. A., & Busso, C. A. 2008. Cow performance in conventional versus early weaning herds in North Patagonia, Argentina. *Rangelands*, *30*(1), 12–16. https://doi.org/10.2111/1551-501X(2008)30[12:CPICVE]2.0.CO;2

Larson, R. L., White, B. J., and Laflin, S. 2016. Beef Heifer Development. Vet. Clin. North Am. Food Anim. Prac. 32: 285–302. https://doi.org/10.1016/j.cvfa.2016.01.003

Ministerio de Agricultura, Ganadería y Pesca. (2021). Resultados Económicos Ganaderos. Argentina. https://drive.google.com/file/d/1Zs31qYhZ1PxeTjZsd4vBjH9JVeIWq8Ck/view

Ministerio de Hacienda Provincia de Rio Negro (MAGYP). (2017). Informes Productivos Provinciales, Argentina. https://es.scribd.com/document/652219709/informe-productivo-rionegro

Martin, M. S., Grau, S. A., Rutherford, B. W., Grandin, T., and Edwards-Callaway, L. N. 2018. Survey of cow-calf producer perspectives on management strategies and industry challenges. Part 1: handling practices, and health and industry challenges. Transl. Anim. Sci. 3: 195–203. https://doi.org/10.1093/tas/txy138

Martinez, G. E., Koch, R. M., Cundiff, L. V., Gregory, K. E., & Van Vleck, L. D. 2004. Number of calves born, number of calves weaned, and cumulative weaning weight as measures of lifetime production for Hereford cows1. *Journal of Animal Science*, *82*(7), 1903–1911. https://doi.org/10.2527/2004.8271903x

Marx, T. 2008. The beef cow-calf manual. https://doi.org/10.5962/bhl.title.115623

Núñez-Dominguez, R., Cundiff, L. V., Dickerson, G. E., Gregory, K. E., and Koch, R. M. 1991. Lifetime production of beef heifers calving first at two vs three years of age1. J. Anim. Sci. 69: 3467–3479. https://doi.org/10.2527/1991.6993467x

Olmo, L., Ashley, K., Young, J. R., Suon, S., Thomson, P. C., Windsor, P. A., and Bush, R. D. 2016. Improving smallholder cattle reproductive efficiency in Cambodia to address expanding regional beef demand. Trop. Anim. Health Prod. 49: 163–172. https://doi.org/10.1007/s11250-016-1175-6

Peralta, P. F., & Klich, M. G. (2021). Analysis of spontaneous vegetation in semi-arid cattle fields of the middle valley of Río Negro. Rodriguésia, 72. https://doi.org/10.1590/2175-7860202172122

Pieterse, M., Szenci, O., Willemse, A., Bajcsy, C., Dieleman, S., and Taverne, M. 1990. Early pregnancy diagnosis in cattle by means of linear-array real-time ultrasound scanning of the uterus and a qualitative and quantitative milk progesterone test. Theriogenology. 33: 697–707. https://doi.org/10.1016/0093-691x(90)90547-7

Ponssa, E. E., Rodríguez, G. A., Castelletti, A. J., & Machado, C. F. 2019. Resultado por Tenencia en Cría Bovina: ¿Un Arma de Doble Filo? Revista Argentina de Economía Agraria, 20(1), 9-30. Recuperado a partir de https://raea.org.ar/revistaaaea_arg/article/view/28

Programa de Servicios Agrícolas Provinciales (PROSAP). 2022. Estrategia provincial para el sector agroalimentario (EPSA). Gobierno de la provincia de Rio Negro, Ministerio de la producción y Agroindustria.

https://www.argentina.gob.ar/economia/planificacion-del-desarrollo-y-la-competitividad-federal/prosap/estrategias-provinciales

(Accessed 5 jun 2025)

Programa de Servicios Agrícolas Provinciales (PROSAP) and Ministerio de Agricultura, Ganadería y Pesca de la Provincia de Río Negro (MAGyP). 2015. Desarrollo institucional para la inversión, proyecto FAO UTF ARG 017, provincia de Río Negro, Argentina. https://studylib.es/doc/4825175/actividad-pecuaria-en-la-provincia-de-r%C3%ADo-negro

(Accessed 11 march 2025)

Pruitt, J., Gillespie J., Nehring, R. and Qushim, B.2012. Adoption of Technology, Management Practices, and Production Systems by U.S. Beef Cow-Calf Producers. J. Agric. Appl. Econ. 44: 203-222.

https://doi.org/10.1017/S1074070800000274

Rosenberg, F. J. 1986. Boletín del centro Panamericano de Fiebre Aftosa, (52).

https://iris.paho.org/handle/10665.2/50255

Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA). 2010. Modificación de la estrategia de vacunación en relación con la erradicación de la fiebre aftosa (Resolución 181/2010).

(Accessed 9 jun 2025)

Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA). 2019a. 2do informe de notificaciones de enfermedades denunciables – carbunclo bacteridiano. https://www.argentina.gob.ar/sites/default/files/informe_carbunclo_2010-2019_1.pdf (Accessed 11 march 2025.)

Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA). 2019b. Plan nacional de control y erradicación de brucelosis bovina en la República Argentina (Resolución 67/2019). https://www.argentina.gob.ar/normativa/nacional/319485/actualizacion (Accessed 9 jun 2025)

Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA). 2020. Anuario estadístico 2020, Centro Regional Patagonia Norte. https://www.argentina.gob.ar/sites/default/files/anuario_estadistico_senasa_crpn_2020.pdf (Accessed 29 may, 2025).

Sheppard, S. C., Bittman, S., Donohoe, G., Flaten, D., Wittenberg, K. M., Small, J. A., Berthiaume, R., McAllister, T. A., Beauchemin, K. A., McKinnon, J., Amiro, B. D., MacDonald, D., Mattos, F., and Ominski, K. H. 2015. Beef cattle husbandry practices across Ecoregions of Canada in 2011. Can. J. Anim. Sci. 95: 305–321. https://doi.org/10.4141/cjas-2014-158

Short, S. D. 2001. Characteristics and production costs of U.S. Cow-Calf operations. AgEcon Search. https://doi.org/10.22004/ag.econ.262282

Singleton, R. and Straits, B. C. 2010. Approaches to social research. Oxford University Press. https://books.google.com.ar/books?id=o5yePwAACAAJ

Sokal, R. R., & Rohlf, F. J. 1962. The comparison of dendrograms by objective methods. Taxon, 11(2), 33–40. https://doi.org/10.2307/1217208

Story, C. E., Rasby, R. J., Clark, R. T., and Milton, C. T. 2000. Age of calf at weaning of spring-calving beef cows and the effect on cow and calf performance and production economics. J. Anim. Sci. 78: 1403. https://doi.org/10.2527/2000.7861403x

U. S. Department of Agriculture, Animal, and Plant Health Inspection Agency, Animal Health NAHMS. 2009. Part II: Reference of Beef Cow-calf Management Practices in the United States, 2007-08 U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale Park, MD. p 49. http://www.aphis.usda.gov/animal_health/nahms/index.shtml

U. S. Department of Agriculture, Animal, and Plant Health Inspection Service, Animal Health (USDA NAHMS). 2017a. Beef 2017 Report 1: Beef Cow-calf Management Practices in the United States. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale Park, MD. pp 71, 45 y 79. http://www.aphis.usda.gov/animal_health/nahms/index.shtml

U. S. Department of Agriculture, Animal, and Plant Health Inspection Service, Animal Health (USDA NAHMS). 2017b. Beef 2017 Report 2: Beef Cow-calf Health and Management Practices in the United States. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale Park, MD. pp 43. https://www.aphis.usda.gov/sites/default/files/beef-2017-part2.pdf

Ventura, R., Larmer, S., Schenkel, F. S., Miller, S. P., and Sullivan, P. 2016. Genomic clustering helps to improve prediction in a multibreed population1. J. Anim. Sci. 94: 1844–1856. https://doi.org/10.2527/jas.2016-0322

Vissio, C., Dieser, S.A., Raspanti, C.G., Giraudo, J.A., Bogni, C.I., Odierno, L.M. and Larriestra, A.J. 2013. Dairy herd mastitis program in Argentina: Farm clusters and effects on bulk milk somatic cell counts. Pak. Vet. J. 33: 80-84.

Waldner, C., Jelinsky, M.D., and McIntyre-Zimmer, K. 2013. Survey of Western Canadian beef producers regarding calf-hood diseases, management practices, and veterinary service usage. Can. Vet. J. 54: 559-564. PMID: 24155446; PMCID: PMC3659451.

Ward, C. E., Vestal, M. K., Doye, D. G., and Lalman, D. L. 2008. Factors affecting adoption of Cow-Calf production practices in Oklahoma. J. Agric. Appl. Econ. 40: 851–863. https://doi.org/10.1017/s1074070800002376

White, B.J. 2014. Beef Herd Record Analysis. In Bovine Reproduction, R.M. Hopper (Ed.). https://doi.org/10.1002/9781118833971.ch40

Wilson, B. K., Richards, C. J., Step, D. L., and Krehbiel, C. R. 2017. BEEF SPECIES SYMPOSIUM: Best management practices for newly weaned calves for improved health and well-being1. J. Anim. Sci. 95: 2170–2182. https://doi.org/10.2527/jas.2016.1006

Young, I., Rajic, A., Perez, E., Sanchez, J., Larriestra, A., Perez, L. A., and McEwen, S. A. 2012. Knowledge and attitudes towards food safety and reported use of good production practices among a sample of cattle producers in Santa Fe, Argentina. Arch. Med. Vet. 44: 225-235

Author Contributions

We declare that all authors are in agreement with the content of the manuscript and have made substantial contributions as follows: Vistarop, Larriestra, Bartolome, Blanco and Yaful contributed to the conception and design of the experiments; Vistarop performed the survey; Vistarop, Vissio, Dematteis and Blanco contributed to statistical analysis; Blanco, Bartolome and Larriestra validated it; Vistarop and Larriestra wrote the first draft of the manuscript and Bartolome and Blanco contributed to the final revision.

Figure 1. Distribution of 142 operations according to the first two principal components (PC1 and PC2), summarizing the variability and obtained through Principal Component Analysis (PCA).

Each point represents a farm, colored by cluster group based on herd structure and Good Management Practices (GMP) adoption. Cluster 3 (green) shows a distinct spatial separation, positioning in the upper right graph region, suggesting not only a unique profile but also a strong link with the variables represented by PC1 and PC2. On the other side, Clusters 1 (red) and 2 (yellow) overlap partially, indicating the existence of similarities between them, separating from Cl 3.

PCA, Principal Component Analysis.

PC, Principal Component.

Cl, Cluster.

Table 1. Productivity of the population under study, according to the whole dataset, county of origin, and a three-month breeding season adoption

Variable	Categories (n)	C/100 c [1] Median and IQ Range (Q1-Q3)	P-values	C/100 ha [2] Median and IQ Range (Q1-Q3)	P-values
Overall	127	79.00 (67.00-85.00)		4.58 (2.78-8.00)	
County	Avellaneda (62)	77.00 [a] (65.00-85.00)	0,1371	3.29 [b] (1.68-16.44)	0.0488
	Pichi Mahuida (65)	80.00 [a] (73.00-86.00)		5.21 [b] (3.92-7.52)	
Three-month breeding season adoption	Yes (51)	82.00 [b] (76.00-87.00)	0.0006	5.60 [b] (3.91-9.08)	0.0072
	No (76)	75.50 [b] (61.00-83.00)		3.97 [b] (1.75-6.91)	

[1] Calves weaned in 2020 (C) divided by the total number of cows mated (c), expressed by 100 cows
[2] Calves weaned in 2020 (C) divided by area (ha), expressed by 100 ha
[a, b] letters within a column for each category with different superscripts differ (P< 0,05), as analyzed by the Wilcoxon Signed Rank test

Table 2. Characterization according to breeding herd structure and facilities among 142 cow-calf operations surveyed (number and percentage)

Variable	Categories	Operations (number, and %)
Production area	Valley plain	22 (15%)
	Plateau plain	115 (81%)
	Combination	5 (4%)
Combine operations in different production areas	Yes	57 (40%)
	No	85 (60%)
Beef cattle production system	Cow-calf	70 (49%)
	Cow-calf to finish	72 (51%)
Predominant breed	Aberdeen Angus	62 (44%)
	Hereford	69 (49%)
	Combinations	11 (8%)
Herd size (ha [1])	Up to 1000 ha	35 (25%)
	From 1001 to 2500 ha	48 (34%)
	From 2501 to 5000 ha	33 (23%)
	More than 5000 ha	26 (18%)
Herd size (number of females)	Up to 50 cows	33 (23%)
	From 51 to 100 cows	24 (17%)
	From 101 to 200 cows	48 (34%)
	More than 201 cows	37 (26%)
Presence of perimeter fence	Yes	141 (99%)
	No	1 (1%)
Presence of divisions	Yes	128 (90%)
	No	14 (10%)
Electrical fence usage	Yes	101 (71%)
	No	41 (29%)
Presence of working chute	Yes	139 (98%)
	No	3 (2%)
Presence of squeeze chute	Yes	131 (92%)
	No	11 (8%)
Presence of veterinarian gate	Yes	111 (78%)
	No	31 (22%)
Presence of holding pens	Yes	139 (98%)
	No	3 (2%)
Presence of scale	Yes	61 (43%)
	No	81 (57%)
Presence of loading chute	Yes	134 (94%)
	No	8 (6%)
Facilities status	Without facilities	3 (2%)
	Deficient facilities	7 (5%)
	Good facilities	132 (93%)

[1] Ha, hectares

Table 3. Characterization according to family labor, hired workers, and advisers among 142 cow-calf operations surveyed (number and percentage)

Variable	Categories	Operations (number, and %)
Family labor supply (no. family members)	1	68 (48%)
	2	50 (35%)
	More than 2	24 (17%)
Farmer age (years old)	Up to 40	34 (24%)
	From 41 to 60	73 (51%)
	More than 61	35 (24%)
Farmer educational level	Without	6 (4%)
	Primary	45 (32%)
	Highschool	47 (33%)
	Tertiary/University	44 (31%)
Took courses related to animal production	Yes	63 (44%)
	No	79 (55%)
External labor supply (no. HW [1])	Without HW	82 (58%)
	1 HW	35 (25%)
	More than 1 HW	25 (18%)
HW age	Without HW	82 (58%)
	Up to 40	19 (13%)
	From 41 to 60	32 (23%)
	More than 61	9 (6%)
HW educational level	Without HW	82 (58%)
	HW without education	7 (5%)
	HW primary level	29 (20%)
	HW high school level	10 (7%)
	HW tertiary/university level	3 (2%)
	Does not know	11 (8%)
Technical adviser	Without	8 (6%)
	Veterinary	105 (74%)
	Veterinary and agronomist	29 (20%)
Type of technical assistance	Without adviser	8 (6%)
	Demands to plan (nutrition, practices, or financial analysis)	53 (37%)
	Demands for disease attention (prevention, treatment or diagnosis)	81 (57%)
Discussion about GMP [2] with the adviser	No adviser	8 (6%)
	Yes	53 (37%)
	No	81 (57%)
Keep records about productivity outcomes	Yes	25 (18%)
	No	117 (82%)

[1] HW, hired workers
[2] GMP, good management practices

Table 4. Characterization according to cows, bulls, and heifers' reproductive management among 142 cow-calf operations surveyed (number and percentage)

Variable	Categories	Operations (number, and %)
Tagged animals	Yes	138 (97%)
	No	4 (3%)
BS [1]	Year-round BS	89 (63%)
	3 months BS	20 (14%)
	From 4 to 6 months BS	33 (23%)
Breeding system	Natural	125 (87%)
	Artificial insemination	3 (2%)
	Combination	14 (10%)
Bull origin	Own, from seedstock	70 (49%)
	Own, others non-seedstock	31 (22%)
	Own, raised in the operation	27 (19%)
	Combine sources	12 (8%)
	Borrowed	2 (1%)
Bulls' selection	Yes	87 (61%)
	No	55 (39%)
Replacement heifer origin [2]	Seedstock	1 (1%)
	Others, non-seedstock	12 (8%)
	Cow-calf operation raised	123 (87%)
	Combine sources	5 (3%)
	Do not replace	1 (1%)
Heifer age at first BS	From 15 to 18 months	78 (55%)
	24 months, variable, and without a criterion	65 (45%)
Heifer BSE [3]	External observation	58 (41%)
	Body weight	17 (12%)
	Reproductive tract score	2 (1%)
	Combine	11 (8%)
	None	54 (38%)
PD [4] and methods	No PD	94 (66%)
	Yes, transrectal palpation	44 (31%)
	Yes, ultrasonography	4 (3%)
Date of PD	PD at no specific moments	124 (80%)
	At weaning time	28 (20%)
Previous abortion identification	Yes	49 (35%)
	No	80 (56%)
	Do not know	13 (9%)
Abortion diagnosis	Yes	14 (10%)
	No	128 (90%)
Calving monitoring	Yes	57 (40%)
	No	85 (60%)

[1] BS, breeding season

[2] Replacement heifer origin. The seedstock was the operation where the breeders are, considered the genetic suppliers. Others, non-seedstock were operations without documented pedigrees, as informal suppliers of genetic. Cow-calf operation raised is a calf raised in the operation to be a cow through farmers' phenotypic selection

[3] BSE, breeding soundness evaluation. It is a set of practices performed before the onset of the BS for reproductive categories. Involves body weight monitoring, reproductive tract scoring, and pelvic area measurement in heifers; and tests for venereal diseases, semen analyses, and scrotal circumference measurement in bulls

[4] PD, pregnancy diagnosis

Table 5. Characterization according to cows, bulls, and heifers' nutritional management among 142 cow-calf operations surveyed (number and percentage)

Variable	Categories	Operations (number, and %)
Alfalfa hay	Yes	38 (27%)
	No	104 (73%)
Native vegetation	Yes	133 (94%)
	No	9 (6%)
Implanted species: pastures	Yes	17 (12%)
	No	125 (88%)
Grain concentrate	Yes	11 (8%)
	No	131 (92%)
Corn sillage	Yes	3 (2%)
	No	139 (98%)
Corporal condition measurement	Yes	37 (26%)
	No	105 (74%)

Table 6. Characterization according to cows, bulls, and heifers' health management among 142 cow-calf operations surveyed (number and percentage)

Variable	Categories	Operations (number, and %)
Brucellosis diagnosis	Yes	49 (35%)
	No	93 (65%)
Brucellosis-free herd	Yes	30 (21%)
	No	112 (79%)
Vaccination against reproductive diseases (IBR[1]-DVB[2], leptospirosis, campylobacteriosis	Yes	19 (13%)
	No	123 (87%)
Vaccination against brucellosis	Yes	136 (96%)
	No	6 (4%)
Tuberculosis diagnosis	Yes	16 (11%)
	No	126 (89%)
Deworming	Yes	103 (73%)
	No	39 (27%)
Mineral and vitamin supplementation	Yes	91 (64%)
	No	51 (36%)
Annually bulls test for venereal diseases	Yes	67 (47%)
	No	75 (53%)
Bull test for venereal diseases before the beginning of the BS [3]	Yes	40 (28%)
	No	102 (72%)
Brucellosis heifer test at the entrance of the operation after purchased	Yes	21 (15%)
	No	121 (85%)
	No entrance	99 (69%)
Dog deworming	Without dogs	34 (24%)
	Dogs dewormed	98 (69%)
	Dogs without deworming	10 (7%)

[1] IBR, Infectious Bovine Rhinotracheitis
[2] BVD, Bovine Viral Diarrhea
[3] BS, Breeding Season

Table 7. Characterization according to calf management among 142 cow-calf operations surveyed (number and percentage)

Variable	Categories	Operations (number, and %)
Weaning date	No weaning	46 (32%)
	Between 3 and 6 months	96 (68%)
Castration	Yes	81 (57%)
	No	59 (42%)
	Variable	2 (1%)
Nutritional supplementation at weaning	Yes	82 (58%)
	No	60 (42%)
Food offered around the weaning	Native vegetation	89 (63%)
	Implanted pastures	28 (20%)
	Others (including supplementation with concentrates)	25 (18%)
Calves' vaccination protocol	Yes	119 (84%)
	No	23 (16%)
Treatment and/or cull out sick calves	Yes, cull out	21 (15%)
	Yes, treatment	38 (27%)
	Yes, both	56 (39%)
	No	27 (19%)

Table 8. Cluster profiling regarding breeding herd structure; enterprise characteristics (family labor, hired workers, and adviser); cows, bulls, and heifers' reproductive and nutritional management; cows, bulls, and heifers' health management, and calves' management, among 142 cow-calf operations surveyed

Variable	Categories	Operations (number)		
		Cl 1 n= 41	Cl 2 n= 82	Cl 3 n=19
		Operations (%)		
Production area	Valley plain	17	12	26
	Plateau plain	76	85	74
	Combination	7	2	0
Combine operations in different production areas	No	41	73	42
	Yes	59	27	58
Beef cattle production system	Cow-calf operation	37	66	5
	Cow-calf to-finish operations	63	34	95
Family labor supply (no. family members)	1	61	39	58
	2	29	43	16
	More than 2	10	18	26
External labor supply (no. HW) [1]	Without HW	29	84	5
	1 HW	29	12	68
	More than 1 HW	41	4	26
HW educational level	Without HW	29	84	5
	HW without education	7	1	16
	HW primary level	37	9	37
	HW high school level	7	2	26
	HW tertiary/university level	7	0	0
	Does not know	12	4	16
Technical adviser	Without	10	5	0
	Veterinary	76	77	58
	Veterinary and agronomist	15	18	42
Type of technical assistance	Without adviser	10	5	0
	Demands to plan (nutrition, practices, or financial analysis)	41	34	42
	Demands for disease attention (prevention, treatment, or diagnosis)	49	61	58
BS [2]	Year-round BS	76	59	53
	Three-months BS	10	10	42
	From 4 to 6 months BS	15	32	5
Bull origin	Own, from seedstock	54	45	58
	Own, others non seedstock	12	29	11
	Own, raised in the operation	24	16	21
	Combine sources	10	9	5
	Borrowed	0	1	5
Heifer BSE [3]	External observation	51	33	53
	Body weight	12	10	21
	Reproductive tract score	0	2	0

	Combine	2	9	16
	None	34	46	11
PD [4] and methods	No PD	80	67	32
	Yes, transrectal palpation	20	30	58
	Yes, ultrasonography	0	2	11
Date of PD	PD at no specific moments	88	85	42
	At weaning time	12	15	58
Bull test for venereal diseases at the beginning of the BS	No	71	73	42
	Yes	29	27	58
Brucellosis heifer test at the entrance to the operation after purchased	No	29	11	5
	Yes/no entrance	71	89	95
Dog deworming	Without dogs	12	33	11
	Dogs dewormed	71	65	84
	Dogs without deworming	17	2	5
Weaning date	No weaning	59	24	11
	Between 3 and 6 months	41	76	89
Calves' vaccination protocol	No	88	95	26
	Yes	12	5	74

[1] HW, Hired Workers
[2] BS, Breeding Season
[3] BSE, Breeding Soundness Evaluation
[4] PD, Pregnancy Diagnosis

Table 9. Cluster profiling regarding productivity measures of 142 cow-calf operations surveyed

Variable	Categories	Cluster [1] (number)			P-values
		Cl 1 (35)	Cl 2 (78)	Cl 3 (14)	
		Q2 and range IQ (Q1-Q3)			
Productivity measures	C/100c [2]	76.00 ^{a} (67.00-85.00)	80.00 ^{a} (70.00-85.00)	85.00 ^{b} (82.00-90.00)	0.0233
	C/100ha [3]	4.78 ^{a} (2.27-9.20)	4.61^{a} (2.80-7.72)	4.54 ^{a} (3.00-6.47)	0.9667

Note: the summatory of operations of the three clusters is 127 operations, the number of producers providing data to calculate productivity (15 were not able to provide data).

$^{a, b}$ letters within a row for each productivity measure with different superscripts differ (P< 0,05), as analyzed by the Wilcoxon Signed Rank test

[1] Cl, cluster

[3] Calves weaned in 2020 (C) divided by the total number of cows mated (c), expressed by 100 cows

[4] Calves weaned in 2020 (C) divided by area (ha), expressed by 100 ha

Table 10. Contributions of each variable to PC1 and PC2 (PC loadings) and variance explained by each PC (eigen vectors) from 142 cow-calf operations surveyed

Variables	PC [1] 1	PC 2	e [2] 1	e 2
Production area	0.02	0.3	0.01	0.20
Combine operations in Different production areas	0.44	-0.34	0.26	-0.22
Beef cattle production system	0.59	-0.06	0.35	-0.04
Family labor supply	-0.32	0.05	-0.19	0.03
External labor supply	0.81	-0,3	0.48	-0.20
HW [3] educational level	0.74	-0.28	0.44	-0.19
Adviser	0.25	0.33	0.15	0.22
Type of technical assistance	-0.11	-0.04	-0.07	-0.03
BS [4]	0.11	0.71	0.06	0.47
Bull origin	-0.15	-0.08	-0.09	-0.06
Heifer BSE [5]	-0.26	-0.15	-0.15	-0.10
PD [6] and methods	0.37	0.71	0.22	0.47
Date of PD	0.44	0.74	0.26	0.49
Bull test for venereal disease at the entrance to the operation	0.26	-0.16	0.16	-0.11
Brucellosis heifer test at the entrance to the operation	-0.09	0.02	-0.05	0.01
Dog deworming	0.33	-0.39	0.19	-0.26
Weaning date	0.37	0.16	0.22	0.11
Calves` vaccination protocol	0.42	-0.1	0.25	-0.07

Note: the PC loadings are correlation coefficient between the original variable and each PC, indicating the variable's contributions. Even though is not a rule, values higher than 0.5, such as beef cattle production system, external labor supply and HW educational level are higher contributors to PC 1 and BS, date of PD, PD and methods are higher contributors to PC 2. Negative values indicate the directions of the correlation. The eigen values are the measure of variance of the data set being explained by each PC.

[1] PC, Principal Components

[2] e, eigen values

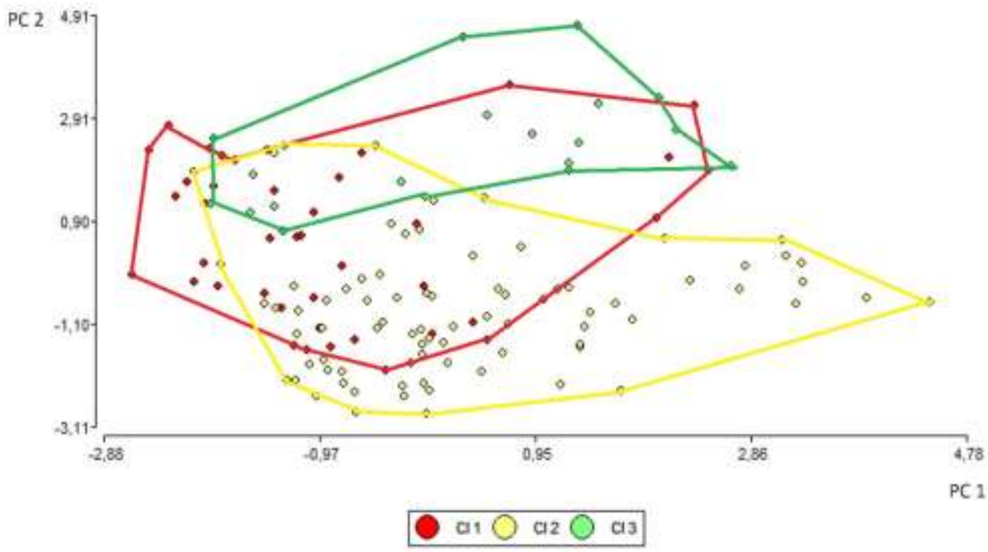
[3] HW, Hired Workers

[4] BS, Breeding Season

[5] BSE, Breeding Soundness Evaluation

[6] PD, Pregnancy Diagnosis

Figure 1



Graphical Abstract