Research Article

Body Shape and Size Differences in Tropical Hair Sheep from the Ecuadorian Amazon

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Abstract | Morphometric studies in animals of zootechnical interest under tropical conditions allow for the identification of functional patterns to be considered when implementing crossbreeding programs. To this end, a study was conducted to characterize the morphometric variability and functional morphostructural typology of sheep in the province of Orellana, Ecuador. Using probabilistic sampling from an estimated population of 3,015, measurements were taken from 385 multiparous female sheep belonging to four genetic groups (Black Belly, Pelibuey, Santa Inés, and a Black Belly × Katahdin cross). Twenty linear body measurements were recorded, and seven zoometric indices were calculated. According to descriptive statistics, the coefficients of variation ranged from 5% to 20%, revealing low variability for some traits and moderate variation for others within the population. Although statistically significant differences in live weight were observed among genetic groups (P =0.02), body condition score did not vary (P =0.50). Furthermore, all zoometric indices showed no significant differences between breeds: body mass index (85.6 ± 6; P =0.3), cephalic index (65 ± 6; P =0.2), thoracic index (97 ± 6; P= 0.6), pelvic index (95 ± 8; P = 0.3), and relative thoracic depth index (113 ± 3; P =0.8), indicating proportional stability for body structure. On the other hand, according to principal component analysis, the first three (PC1, PC2, and PC3) explained 77.23% of the total variability, with body size being the main discriminating factor. Consequently, sheep in the northern Ecuadorian Amazon share similar body proportions across breeds, with no significant differences in zoometric indices. However, principal component and cluster analyses reveal clear divergence in overall body size, from larger Santa Ines to more compact Black Belly and Pelibuey animals. These patterns define a single meat-type tropical biotype in which structural size, rather than body shape, is the main axis of variation.

Keywords: Northern amazon, Biotype, Tropical livestock, Functional morphology, Sustainability, Small livestock

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INTRODUCTION

Sheep (*Ovis aries*) are one of the most widespread domesticated species worldwide, notable for their importance in meat and wool production (Dairy Sheep Association America, 2015; Pulina and Bencini, 2004). Estimates suggest that the production of sheep meat amounts to approximately 14.5 million tons (FAO, 2018). Asia and Africa account for more than 70% of the global sheep population, followed by Europe with 10.7%, Oceania with 8.4%, and the Americas with 7.2% (Rosegrant *et al.*, 2009).

In Ecuador, the Amazon region has shown some variation in its agricultural production systems. In fact, a study by Peralta *et al.* (2024), shows that 92% of a total of 5,963 agricultural production units operate on a subsistence basis. According to The Ecuadorian National Institute of Statistics and Censuses (INEC, 2022), in Ecuador there are a total of 551,960 sheep, of which 517,346 are located in the Sierra region, 33,500 on the coast, and 1,114 in the Amazon region, where according to Agrocalidad (2022), there is a sheep population of 876 animals in the province of Orellana. The same source also indicates that the continuous agricultural area and production survey (INEC-ESPAC, 2025), shows a production of 497,000 metric tons of sheep meat. INEC (2022) reports a national per capita consumption of 9.90 kg/person/year. In the Ecuadorian Amazon, hair sheep farming began in the 1990s, with the Black Belly and Pelibuey breeds being the most prominent (Magap, 2022). These breeds, known for their hardiness and adaptability to tropical climates, gradually spread throughout the various provinces of the Amazon region. Currently, sheep farming plays an important role in meat production in the region, providing income for local families (Moyano *et al.*, 2020). Therefore, sheep production in Ecuador is significant because it is profitable and generates income for rural producers, with all family members participating due to the animals' manageable size and docility (INEC-ESPAC, 2025). Furthermore, it is worth highlighting that this livestock activity offers a variety of products including meat, milk, wool, hides, tallow, and manure (Chagas *et al.*, 2022). Sheep production has increased in the Ecuadorian Amazon due to the demand for essential products, with meat representing a viable food alternative for the population. Tropical breeds such as Black Belly, Pelibuey, Katahdin, and Santa Inés are particularly relevant in the area. However, it is important to consider that the aforementioned breeds exhibit genetic variation developed over the years, which could be linked to their adaptability to the environment, reproductive and productive management, and feeding practices. This genetic variability is a necessary factor to consider in the development of selection programs and sustainable management of sheep production in the Amazon region (Moyano *et al.*, 2020).

Valuing the genetic diversity of sheep in the province of Orellana is essential because it enables production systems to adapt to potential environmental and economic changes, such as climate variability and market fluctuations. In this context, Feliciano (2016). Emphasizes that identifying animals based on specific characteristics is vital for achieving a proper ethological or racial classification. Zoometry, which involves a series of measurements and zoometric indices, serves as a technique for classifying animals within a specific biotype (Hernández *et al.*, 2016; Temoche *et al.*, 2024). Consequently, it is important to incorporate morphometric measurements, indices, and performance characteristics into breeding programs to establish the relationship between conformation and the animal's zootechnical function (Estrada *et al.*, 2025; Granero and Anaya, 2023). Therefore, morphological traits, mainly body size, shape, and proportions, are practical, low-cost indicators that reflect the combined effects of genotype and environmental adaptation (FAO, 2012). Besides this, these characteristics enable researchers to classify animal populations into distinct groups based on measurable phenotypic attributes, helping to distinguish breeds and ecotypes (Fernández *et al.*, 2008). For this reason, the correlation among certain morphometric measurements facilitates the calculation of indices known as zoometric indices, which are valuable for assessing the development and aptitude of animals (Rainier *et al.*, 2021).

These measurements also allow for the identification of morphometric characteristics that can be improved, selecting individuals with superior genetics (Granero and Anaya, 2023). Morphometrics deals with the study of measurements of different body regions suitable for recording (Estrada *et al.*, 2025; Temoche *et al.*, 2024). Various instruments are used to perform these measurements, such as measuring tapes, sticks, scales, digital calipers for small measurements, and graduated scales, especially for animals that are more difficult to handle (Santa-ramírez *et al.*, 2020). Based on the above, this research characterized the zoometric measurements of tropical sheep in the province of Orellana to understand morphostructure as an indicator of tropical resilience for decision-making regarding production implications.

MATERIAL AND METHODS

Study area

The province of Orellana is located in the northern region of the Ecuadorian Amazon. According to the GADPO (2015), the province has an area of 21,730 km², representing 45.47% of the total area within the Amazon region. The region's climate is characterized by tropical rainforest (INAMHI, 2021). The average annual temperature is 29.7°C, and rainfall reaches 2,942 mm. INEC (2021). estimates that the population in 2018 was 157,520. Indigenous peoples (Kichwa, Shuar, and Waodani) constitute 31% of the ethnic group; mestizos, or people of mixed Spanish and Indigenous ancestry, make up 57.5%. The small Afro-Ecuadorian minority (4.9%) makes up the remaining ethnic groups (González-Andrade *et al.*, 2009). There are differences between the practices of the settlers and those of the indigenous people. The former are primarily focused on small-scale, intensive agricultural systems, while the latter are more varied and include subsistence farming (Kovacic and Viteri, 2020; Torres *et al*., 2018).

Sampling procedure

For this study, given that the province of Orellana is territorially divided into four cantons (GADPO, 2015), a proportionally allocated stratified probabilistic sampling approach was applied (Cheung, 2023), where the sample was distributed according to the relative size of each canton, as shown in Table 1.

Table 1: Distribution of the number of sheep according to the cantons in the province of orellana.

Canton	Animal population	Percentage	Sample size
Joya de los Sachas	2200	60	140
Francisco de Orellana	1000	27	130
Loreto	500	13	115
Aguarico	15	0	0
Total	3.715	100	385

After obtained the data according to the canton, a formula for finite population samples was used (DeMatteis and Kalton, 2025: Equation 1).

$$n = \frac{N * Z\alpha 2 * p * q}{e2 * (N - 1) + Z\alpha 2 * p * q}$$

Where: N = population size; Z = Z-table value for a 95% confidence limit (1.96); P = probability of success (0.5); Q = probability of failure (0.5); e = permissible error (0.4).

Consequently, in each canton, a total of 385 animals were randomly measured, with the criterion that they be at least two years old and multiparous to be described and phenotypically characterized, according to the methodology outlined by Rainier *et al*. (2021).

Morphometric evaluation and zoometric indices

To standardize data collection and minimize measurement errors, these measurements were taken by the same person and their research assistant at 7:00 a.m., before the animals were taken out to pasture, thereby avoiding biases caused by food intake. A total of 18 linear body measurements were taken (Table 2; Figure 1), and seven zoometric indices were calculated to infer body conformation, productive fitness, and the degree of morphofunctional harmony (Estrada *et al*., 2025). Zootechnical indices were estimated based on previous studies conducted with small ruminants, which have proven to be extremely useful in predicting body functionality, productive capacity, and adaptation to grazing conditions.

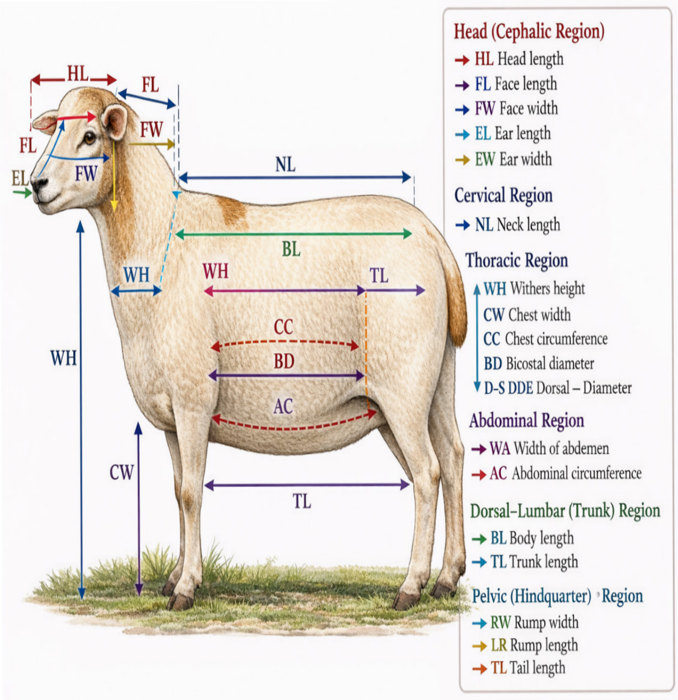

Figure 1: Linear body measurements taken on each sampled sheep.

Statistical analysis

All variables were subjected to normality analysis using SAS statistical software version 9.1.3 (SAS Institute Inc., Cary, NC) and the Kolmogorov-Smirnov test (P = 0.22 to 0.36). Homogeneity of variances was assessed using Levene's test (F = 0.98, df_1 = 3, df_2 = 381, P = 0.401). Subsequently, a one-way analysis of variance (ANOVA) (breed effect) was performed using the PROC GLM procedure, and means were compared using Tukey's test. Additionally, a principal component analysis (PCA) was conducted to determine clustering patterns based on similarities among individuals, followed by ascending hierarchical cluster analysis. Prior to performing the principal component analysis (PCA), multicollinearity among variables was assessed. Variance Inflation Factors (VIF) were calculated, and all values were below the commonly accepted threshold (VIF < 5), indicating no severe multicollinearity issues among the variables. To improve interpretability, components were rotated using the Varimax method. The first principal component (PC1) explained 51% of the total variance and was associated with overall body size, as indicated by high loadings of morphometric variables. The hierarchical cluster analysis was performed using Ward's method with Euclidean distance. This method was selected because it minimizes the total within-cluster variance, leading to the formation of compact and homogeneous groups. that the variables analyzed are continuous morphometric measurements, Ward's method is particularly appropriate, as it tends to produce clusters with low internal variability and clear separation among groups.

Links Researchers

Table 2: Description of linear body measurements (in centimeters, cm) taken from 385 adult sheep in orellana province.

Quantitative linear body measurements	Description
Head length (HL)	From the initial occipital part or region of the forehead to the upper lip
Face length (FL)	From the middle of the occipital bone to the nostrils
Face width (FW)	Distance between the angles of the face below the eyes
Ear length (EL)	From the base of the cartilage to the tip of the ear.
Ear width (EW)	Widest part of the ear at the middle
Neck lengt (NE)	Distance from the withers to the poll
Withers height (WH)	Distance from the ground to the highest point of the internal tuberosities of the ileum
Chest width (CW)	taken from the arch of the 5th rib
Chest circumference (CC)	The highest region of the withers and sternum behind the elbow line
Bicostal diameter (BD)	From the limits of the coastal region in relation to the articulation of the elbow
Dorsal-sternal diameter (D-E-D)	From the shoulder blade to the breastbone
Width of the abdomen (WA)	Height of the 8th rib
Abdominal circumference (AC)	Part of the back and the eighth rib
Trunk length (TL)	From the shoulder blade to ischial tuberosity
Body length (BL)	From the scapula to the ischial tuberosity.
Height at the withers (HW)	From the animal's hooves to the highest point of the rump
Rump width (RW)	The distance between both iliac crests was measured
Length of the rump (LR)	Length from the external iliac crest to the most caudal region of the buttock
Cane perimeter (CP)	The measurement was taken at the middle of the shaft

Table 3: Morphological indices calculated from quantitative linear body measurements taken on 385 adult sheep in orellana, province.

Index	Formulas	References
Body mass index (BMI)	BL/CC*100	(Arvandi and Nugiartiningsih, 2024)
Cephalic index (CI)	FW/FL*100	(Mekonnen *et al.*, 2025)
Thoracic index (TI)	BD/D-E-D*100	(Estrada *et al.*, 2025)
Pelvic index (PI)	RW/LR*100	(Granero & Anaya, 2023)
Proportionality index (PI)	WH/BL*100	(Mekonnen *et al.*, 2025)
Metacarpal index (MI)	CP/CC*100	(Estrada *et al.*, 2025)
Relative chest depth index (RCDI)	D-E-D/WH*100	(Bravo, 2010)

RESULTS

Descriptive statistics and variability

The descriptive statistics of the determined morphometric variables are shown in Table 4. This initial study highlights broad linear and circumferential variations, indicating potential functional morphological aspects. Despite this, according to the coefficient of variation (CV), the values were below 30%, suggesting homogeneous individuals or variables, live weight varied between breeds (P = 0.02). We observed that the Santa Inés breed had a live weight 0.2; P = 0.5; Table 5). In the cephalic region, the head circumference (HC) showed a marked difference (P < Santa Inés breeds stood out 28.68 ± 1.64 cm on average 0.038). In this respect, the Black Belly, Pelibuey, and that was approximately 28% lower than that of the other breeds (34 ± 6 kg vs. 47 kg). However, no variation was observed in body condition score between breeds (2.6 ± low communality (CV, 5–16). However, it is worth noting that, although the measurements were taken before the animals were moved to the paddocks (i.e., 7:00 a.m.), a CV of 20/100 was observed for WA. These results are consistent with the strong correlations identified (r =0.53 to 0.81; P =0.02 to 0.001), indicating consistent patterns of growth and physical development such as reported. (Hernández *et al.*,2016; CV, < 8%).

Breed differences in linear body measurements

The least squares adjusted means of the main zoometric vs. 26.2 ± 1.64 cm for the Black Belly × Katahdin cross. Regarding FW, a statistical trend was observed (P < 0.06; measurements according to breed and anatomical region are shown in Table 5. Starting with the productive Black Belly × Katahdin, 12.8 ± 1.18 cm). Similar results were reported for the measurement of NE (cervical region) when comparing breeds (P = 0.06; Table 5). However, in this case, Santa Inés animals showed a larger measurement compared to the others (29.5 vs. 23.3 ± 3.7 cm). With respect to thoracic capacity, which is key for greater oxygenation and, consequently, better productive capacity, larger measurements of WH, BD, and D-E-D were evident in the Santa Inés breed (P = 0.03 to 0.01). For this reason, WA, AC, and BL values were higher for this breed (P = 0.6 to 0.005; Table 5). Similarly, in the pelvic region, this study reports higher values of HW (74.5 ± 3.3 cm), RH (21.5 ± 1.7 cm), and TL (38 ± 4.1 cm) for Santa Inés breed animals.

Table 5 (HL), Head length; (FL), Face length; (FW), Face width; (EL), Ear length; (EW), Ear width; (NE), Neck length; (WH), Withers height; **(CW)**, Chest widt; (CC), Chest circumference; (BD), Bicostal diameter; **(D–E–D)**, Dorsal–sternal diameter; (WA), Width of the abdomen; (AC), Abdominal circumference; (BL), Body length; (TL), Trunk length; (HW), Height at the withers ; (RW), Rump width; (LR), Length of the rump; (TL), Tail length; (CP), Cane perimeter. SEM, estándar error of the mean; [a-c] Means with different letter in the same row differ at P < 0.05; [x-z] Means with different letter in the same row differ at P < 0.10

Zoometric indices and proportional stability

Table 6 shows the morphometric indices obtained according to the formulas described above (Table 3). In this case, no statistically significant differences were observed for any of the indices determined in sheep from the province of Orellana (P = 0.08 to 0.2). Therefore, the reported means are 85 ± 6 (BI), 65 ± 6 (CI), 97 ± 6 (TI), 95 ± 6 (pelvic index), 94 ± 6 (PI), 9 ± 1 (MI), and 113 ± 3 (RCD). As correlation analyses have shown that BI was moderately associated with body measurements of the head and thorax (r = −0.54 to 0.53; P = 0.02), TI with most of the thoracic measurements (r = −0.59 to 0.52; P =0.02 to 0.001), and CI showed association with face width and abdomen variables (r = 0.50 to 0.70; P < 0.001).

Principal component analysis (PCA)

Table 7 shows the principal component matrix with explained variance, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and the communality of the zoometric indices. According to the analyses, PC1 explains 51% (overall body size), PC2 14.71% (cranial and neck proportions), and PC3 11.14% (thoracic conformation and robustness), resulting in a cumulative value of 77.23%. In this regard, it was observed that PC1 describes an axis of overall body size, integrating variables associated with structural growth and morphometric development.

Table 4: Summary of the stepwise selection of quantitative traits obtained from the stepwise discriminant analysis performed on 39 morphometric variables.

N°	Item	Mean	Max	Min	SD¹	VC²
1	Head length (HL)	28	31	23	1.9	7
2	Face length (FL)	20	24	18	1.4	6
3	Face width (FW)	13	16	11	1.3	10
4	Ear length (EL)	10	14	9	1.27	11
5	Ear width (EW)	7	8	6	0.65	9
6	Neck lengt (NE)	24	31	19	4.28	17
7	Withers height (WH)	70	78	62	3.8	5
8	Chest width (CW)	26	34	16	3.6	14
9	Chest circumference (CC)	89	98	78	5.3	5
10	Bicostal diameter (BD)	78	89	70	4.8	6
11	Dorsal-sternal diameter (D-E-D)	80	88	74	4.3	5
12	Width of the abdomen (WA)	39	54	26	8.1	20
13	Abdominal circumference (AC)	94	113	54	13.5	14
14	Trunk length (TL)	38	54	30	6.2	16
15	Body length (BL)	74	85	67	4.7	6
16	Height at the withers (HW)	70	78	62	3.8	5
17	Rump width (RW)	19	23	13	2.1	11
18	Length of the rump (LR)	20	25	18	1.6	8
19	Cane perimeter (CP)	7	9	7	0.74	9

SD¹, standard deviation; VC², variation coefficient.

Table 5: Least square means of body measurement (cm) of sheep population.

Breed				**Productive**		
	Body weight			**Body condition score**		
Black Belly	35.8			2.6		
BB × Kathadin	34.6			2.6		
Pelibuey	33.5			2.7		
Santa Ines	47.5			2.7		
SEM	6.3			0.2		
P = value	0.02			0.5		
Morphometric Traits	Cephalic Region					
	Thoracic					
	(HL)	(FL)		(FW)	(EL)	(EW)
Black Belly	28.14^{a}	20.8		13.1^{y}	10.7	6.4
BB × Kathadin	26.2^{b}	19.8		12.8^{z}	10.8	6.6
Pelibuey	28.2^{a}	20.5		13.2^{y}	10.2	7.0
Santa Ines	29.7^{a}	21.0		15.0^{x}	12.2	7.0
SEM	1.64	1.47		1.18	1.16	0.65
P = value	0.038	0.58		0.06	0.12	0.42
	Cervical					
	(NE)					
Black Belly	23.7^{y}					
BB × Kathadin	23.0^{y}					
Pelibuey	23.0^{y}					
Santa Ines	29.5^{x}					
SEM	3.7					
	Thoracic					
	(WH)	(CW)	**(CC)**		(BD)	(D-E-D)
Black Belly	68.6^{b}	26.0	89.2		79.7^{b}	79.7^{b}
BB × Kathadin	69.8^{b}	24.6	89.0		75.4^{b}	78.6^{b}
Pelibuey	69.2^{b}	25.5	86.7		74.7^{b}	76.5^{bc}
Santa Ines	75.0^{a}	26.2	91.0		82.2^{a}	85.2^{a}
SEM	3.1	3.9	5.5		4.1	3.5
P = value	0.03	0.9	0.7		0.04	0.01
	Abdominal					
	(WA)			(AC)		
Black Belly	40.0^{bc}			88.7^{bc}		
BB × Kathadin	35.8^{c}			90.2^{b}		
Pelibuey	40.5^{bc}			93.5^{b}		
Santa Ines	42.7^{a}			106.5^{a}		
SEM	3.3			5.0		
P = value	0.6			0.1		
	Dorsal–Lumbar					
	(BL)				Truck length (TL) tronco	
Black Belly	73.1^{b}				38.2	
BB × Kathadin	75.0^{b}				35.2	
Pelibuey	71.7^{c}				40.5	
Santa Ines	81.2^{a}				40.2	
SEM	3.5				6.4	

Table continues on next page...........

Breed	Productive		
	Body weight	Body condition score	
P = value	0.005	0.5	
	Pelvic		
	(RW)	(LR)	(TL)
Black Belly	18.5[b]	9.4	34.4[a]
BB × Kathadin	18.0[b]	19.4	28.6[b]
Pelibuey	17.7[bc]	19.7	33.2[a]
Santa Ines	21.5[a]	21.5	38.0[a]
SEM	1.7	1.5	4.1
P = value	0.02	0.2	0.02
	Appendicular region		
	Cane perimeter		
Black Belly	7.4		
BB × Kathadin	7.4		
Pelibuey	7.5		
Santa Ines	8.5		
SEM	0.65		
P = value	0.07		

Table 6: Analysis of morphometric indices in sheep of orellana province.

Indexes	Breed				SEM	P value
	Black Belly	BB × Kathadin	Pelibuey	Santa Ines		
Body mass index (BI)	82	84	83	89	6	0.3
Cephalic index (CI)	63	64	64	71	6	0.2
Thoracic index (TI)	100	95	97	96	6	0.6
Pelvic index (PI)	96	92	90	100	8	0.3
Proportionality index (PI)	93	93	96	92	5	0.6
Metacarpal index (MI)	8	8	9	9	1	0.3
Relative chest depth index (RCDI)	116	112	110	113	3	0.08

SEM; standard error of the mean.

Table 7: Principal component matrix with explained variance, Kaiser-Meyer-Olkin measure (KMO) of sampling adequacy, and communalities of zoometric indices.

Metric	PC1	PC2	PC3
Eigenvalue	6.680	1.912	1.448
Variance percent (%)	51.38	14.71	11.14
Accumulated variance (%)	51.38	66.09	77.23
Test	**Value**		
Kaiser-Meyer-Olkin (KMO)	0.786		
Bartlett Chi-square	180.687		
g.l.	78		
Sig.	0.001		

Cluster analysis

Figure 2 shows the cluster analysis. Based on the proportions, clear morphological differences between breeds can be observed. In this regard, Santa Inés animals clustered around positive proportions of proportion 1, influenced by their greater live weight and structural development. Blackbelly, on the other hand, showed greater internal dispersion, indicating marked phenotypic variability within the breed. In contrast, the Black Belly × Katahdin cross tended to show a more compact build, suggesting morpho-productive homogeneity. Finally, the Pelibuey breed had a more vertical distribution of body proportions rather than absolute size. Consequently, based on these findings, it could be said that structural size is the main discriminating factor between breeds.

DISCUSSION

The unique biological and ecological characteristics that distinguish tropical sheep from other breeds are studied based on functional morphostructural divergence as well as classification (Liang et al., 2025). Our work indicated a cephalic variation (CV) of less than 30% in all zootechnical measurements, thus indicating a relatively homogeneous population. This can be compared with

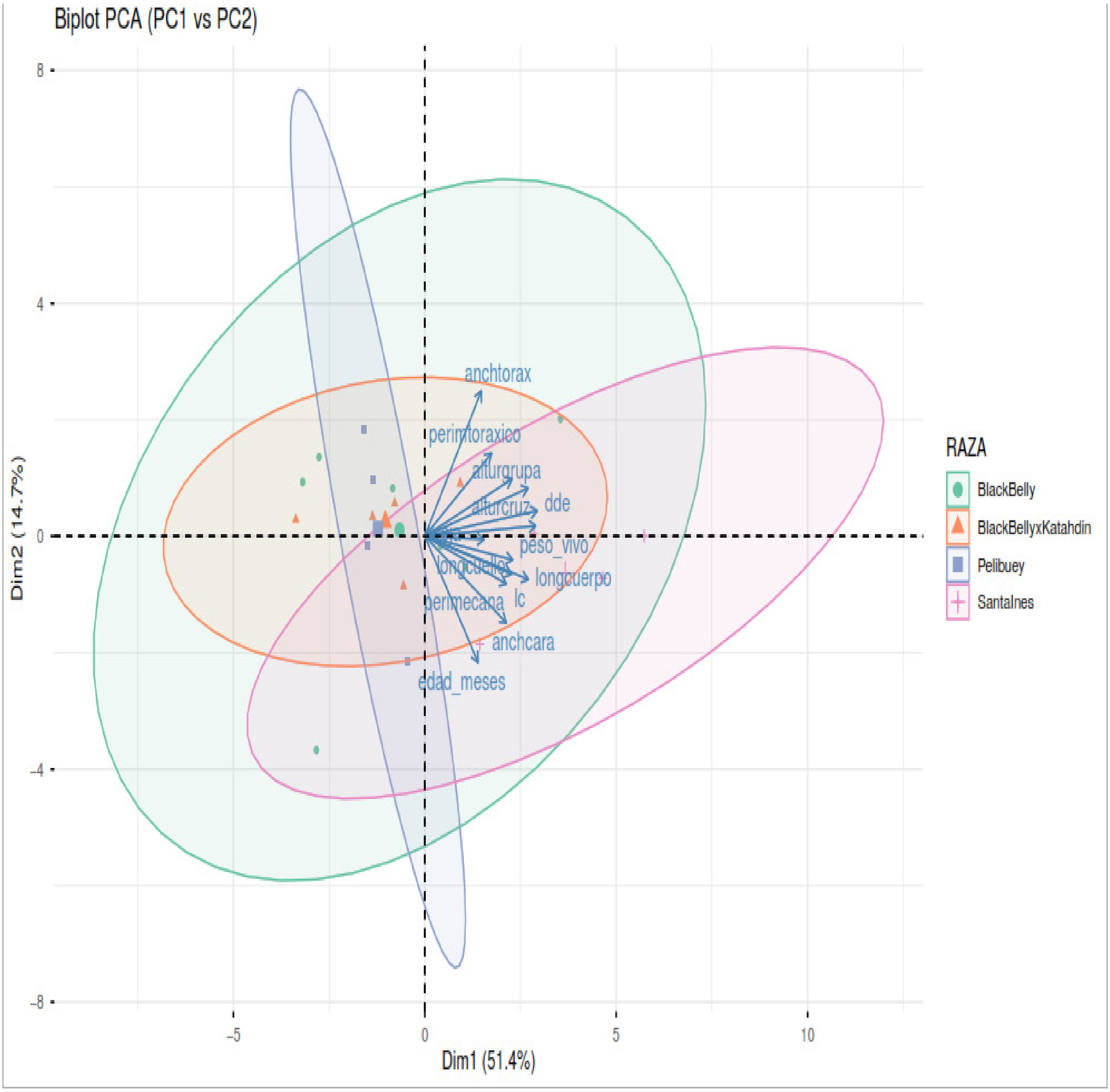

Figure 2: Principal component analysis (pca) of morphometric in sheep.

other studies in which the population has been under comparable environmental pressure and production management systems (Hernández et al., 2016; VC, < 8%). In fact, previous studies have shown that sheep from temperate climates, subjected to high temperatures and limited resources, develop distinctive morphological and genetic traits and are able to survive in harsh conditions (Berihulay *et al*., 2019; Nel *et al*., 2023). Shiguano-Andy. (2023) reported different data for the cephalic region in Black Belly and Pelibuey sheep than ours. While we agree that age is a key factor to consider due to the peak of development, as well as genetics, it is important to highlight that animals with African genetics have demonstrated remarkable adaptations, making them an essential reservoir of adaptive fitness traits (Silveira *et al*., 2024). Consequently, most genetic studies today have focused on understanding these genomic adaptations so that animals can thrive in adverse conditions (Yang *et al*., 2016; Zhu *et al*., 2025). In this regard, Berihulay *et al*. (2019) state that body size and shape are among the most dominant morphological characteristics influenced by thermoregulatory mechanisms in warm and/or tropical environments. In a more local context, specifically in the province of Orellana, body morphology could be strongly influenced by thermoregulatory mechanisms (in response to high temperature and relative humidity) or by metabolic efficiency. Therefore, despite the clear differences observed between breeds, live weight could be directly affected by factors such as the animals' physiological or nutritional statuses (Temoche *et al*., 2024). Furthermore, body condition score is another important indicator of productive status; in fact, it provides an indication of fat and muscle coverage over key skeletal areas (Gerhart *et al*., 1996). Ideally, animals should have a score between 2.5 and 3.5. On the other hand, our research group reported that pastures, being conditioned by low soil quality, result in lower nutritional quality, which is also a point to consider (Guamán-Rivera *et al*., 2026; Guamán-Rivera, Sánchez-quispe, *et al*., 2024; Guamán Rivera *et al*., 2023). However, the 28% difference in live weight observed for the Santa Inés breed could be interpreted as a greater structural result, but the absence of differences in body condition score would indicate that the energy status between breeds was comparable. Although the measurements were taken under fasting conditions, the variability observed in the abdominal WA measurements would be interpreted as fluctuations in rumen filling rather than structural differences, as noted by Céspedes-Calderón. (2025). Furthermore, greater development in thoracic variables would indicate greater cardiorespiratory capacity, a trait associated with productive performance under extensive systems in the tropics. Therefore, these findings would (Fonseca *et al*., 2024; Yang *et al*., 2024).

On the other hand, an important indicator of this work is the proportional stability of the zoometric indices despite size differences. These predictions are based on the differences in absolute size between breeds, so, zoometric indices show that body proportions follow a relatively constant line. In this case, a marked morphofunctional balance is observed, determined by respiratory capacity and locomotor conformation. Granero and Anaya (2023) stated that, from an adaptation standpoint, absolute size is less important than body proportionality. With this argument, this first study under tropical conditions in Ecuador reaffirms that the evaluated breeds fit within a functional tropical biotype and are therefore differentiated by their growth rather than their body structure. Thus, the breeds analyzed in the study in Orellana exhibit a distinctly mesocephalic, robust, and meat-producing biotype (Salako, 2006). For this reason, this proportional stability, despite differences in absolute size, may have important functional implications for animals raised under humid tropical conditions. In such environments, maintaining consistent body proportions could contribute to efficient thermoregulation, locomotor balance under extensive grazing, and metabolic economy, all of which are critical for resilience under heat stress and fluctuating nutritional availability (Guamán-Rivera *et al*., 2024). From a functional standpoint, proportional harmony may be more relevant than absolute size, as it reflects the integration of anatomical regions that support physiological efficiency. However, this apparent uniformity should be interpreted with caution. The absence of significant differences in zoometric indices may not necessarily indicate true biological equivalence among breeds. It could also be influenced by factors such as limited statistical power to detect subtle differences, the relatively narrow range of genetic groups evaluated, or the homogenizing effect of shared environmental and management conditions. In particular, animals raised under similar feeding regimes, climatic stressors, and production systems may converge phenotypically, masking underlying genetic or functional divergence. Therefore, the observed proportional stability may reflect both adaptive convergence and methodological constraints inherent to zoometric indices.

Within the context of achieving resilient production systems aligned with the conditions and livestock farming practices of the northern Ecuadorian Amazon, these types of studies allow for the identification of crossbreeding programs. Santa Ines exhibited greater structural development, while Black Belly and Pelibuey displayed compact morphologies patterns consistent with tropical biotypes adapted to humid Amazonian conditions (Rainier *et al*., 2021). The proportional stability of zoometric indices ($P = 0.08$) indicates morphofunctional balance, which is key to efficiency in extensive systems. These findings support genetic improvement programs aimed at enhancing functional morphological adaptations in the Amazonian context. In this context, it is important to recognize that zoometric indices, while useful for describing general morphostructural patterns, may have limited sensitivity to detect fine-scale biological differences under conditions of high environmental uniformity. Therefore, the lack of differentiation in proportional indices should be complemented with functional, productive, and possibly genomic indicators to better understand the adaptive significance of these populations in tropical systems.

CONCLUSION

The absence of significant differences in zoometric indices among breeds ($P = 0.08–0.8$) suggests a relative conservation of body proportions across the evaluated sheep populations rather than definitive evidence of a single shared morphostructural pattern. This proportional stability, despite clear differences in live weight and overall body size, indicates that morphometric variation in these tropical systems is primarily expressed through scale (size) rather than shape. Although this study did not directly measure survival, reproduction, health, or productivity, the combination of homogeneous body proportions, live weight differences, and stable body condition suggests a shared functional conformation that can serve as a baseline for future research integrating performance and environmental data.

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NOVELTY STATEMENT

This study provides the first local morphometric characterization of tropical hair sheep raised in the Ecuadorian Amazon, showing that the evaluated breeds share a common proportional body pattern despite clear differences in overall body size. It also adds new evidence that body size, rather than body shape, is the main axis of variation under humid tropical conditions, offering a functional baseline for future breeding and adaptation programs in Orellana.

AUTHOR'S CONTRIBUTION

Conceptualization, Michael Cesar Hidalgo Lopez, Santiago Guamán Rivera, Edgar Gualberto Salazar Álvarez, Dalton Euclides Sarango Guamán and Victor del Coral. Data collection, Michael Cesar Hidalgo Lopez, Santiago Guamán Rivera, Edgar Gualberto Salazar Álvarez, Dalton Euclides Sarango Guamán and Victor del Coral. Statistical analysis, Santiago Guamán Rivera, Michael Cesar Hidalgo Lopez, Diego Fernando Maldonado Arias, Edgar Gualberto Salazar Álvarez, Dalton Euclides Sarango Guamán and Victor del Coral prepared the manuscript for publication

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest

REFERENCES

AGROCALIDAD (2022). Agencia de regulación y control fito y zoosanitario.www.agrocalidad.gob.ec. Last accesed on 12 September 2022.

Berihulay H, Abied A, He X, Jiang L, Ma Y (2019). Adaptation mechanisms of small ruminants to environmental heat stress. Anim., 9, 75. https://doi.org/10.3390/ani9030075

Céspedes-Calderón M (2025). Caracterización del sistema de crianza caprina (Capra hircus) en tres caseríos del distrito san juan de la Virgen – Tumbes, Tesis de grado. Univ. Nac. de tumbes.

Chagas AC, de S, Tupy O, Dos-Santos IB, Esteves SN (2022). Economic impact of gastrointestinal nematodes in morada nova sheep in Brazil. Rev. Bras. de Parasitol. Vet., 31(3), 1–10. https://doi.org/10.1590/s1984-29612022044

Cheung AKL (2023). Probability proportional sampling. In F. maggino (Ed.), encyclopedia of quality of life and well-being research. Springer Int. Publishing (pp. 5472–5474). https://doi.org/10.1007/978-3-031-17299-1_2269

Dairy Sheep Association America. Proceedings of the 21st Annual. Madison, Wisconsin, USA (2015). November 5 – 7

DeMatteis J, Kalton G (2025). Sampling from finite populations. in m. lovric (Ed.), international encyclopedia of statistical science. Springer Berlin Heidelberg (pp. 2247–2253). https://doi.org/10.1007/978-3-662-69359-9_546

Estrada R, Guelac-mori E, Pedemonte-Cruz C, Chiqui-Condori KM, Pacherres KM, Cerdan-Ramos D, Zúñiga-Aranibar DM (2025). Morphometric variation and production constraints of criollo sheep in the high andes of southern peru. Agric., 1–16. https://doi.org/10.3390/agriculture15171860

FAO (2012). Phenotypic characterization of animal genetic resources (Issue 11). Commission on genetic resources for food and agriculture. https://www.fao.org/home/es. Last accessed on 16 December

FAO (2018). World livestock: transforming the livestock sector through the sustainable development goals.

Feliciano C (2016). Shades of race: how phenotype and observer characteristics shape racial classification. Am. Behav. Sci., 60(4),390–419.https://doi.org/10.1177/0002764215613401

Fernández I, Álvarez I, Sangare M, Bouchel D (2008). Multivariate analyses on morphological traits of goats in burkina faso abstract zusammenfassung introduction the burkina faso goat population is formed by a total of 10 , 035 , 687 heads . This livestock represent the 69 . 5 % of the domestic ruminants ex. Arch. Tierz., Dummerstorf, 51, 588–600. https://doi.org/10.5194/aab-51-588-2008

Fonseca PAS, Vega AS, Arranz JJ, Gil BG (2024). Integration of selective sweeps across the sheep genome : understanding the relationship between production and adaptation traits. Genet. Sel. Evol. https://doi.org/10.1186/s12711-024-00910-w

GADPO (2015). Development and land management plan of the province of orellana.

Gerhart KL, White RG, Cameron RD, Russell DE (1996). Estimating fat content of caribou from body condition scores. The J. Wildl. Manag., 60:713-718. https://doi.org/10.2307/3802369

González-Andrade F, Roewer L, Willuweit S, Sánchez D, Martínez-Jarreta B (2009). Y-STR variation among ethnic groups from ecuador: mestizos, kichwas, afro-ecuadorians and waoranis. forensic science international: Genet., 3:e83-e91. https://doi.org/10.1016/j.fsigen.2008.08.003

Granero A, Anaya G (2023). Morphostructural differences between the historical genetic lines of the spanish merino sheep. Anim., 13, 313. https://doi.org/10.3390/ani13020313

Guamán Rivera SA, Guerrero-Pincay AE, Ortiz-Naveda NR, González-Marcillo RL (2023). Prediction of the nutritional values by INRA (2018) feed evaluation system of Megathyrsus maximus subjected to different grazing strategies. J. Agric. Environ. Int. Dev. (JAEID), 117:117-140. https://doi.org/10.36253/jaeid-14203

Guamán-Rivera S, Sánchez-quispe H, Pomavilla-Guaminga S, Toalombo-Vargas P, Oswaldo C, Flores-Guerra C, Guacapiña-Viteri A, David C, Carrillo-Guilcapi C, Salgado-Ruiz V (2024). Evaluation of brachiaria decumbens production by humus plus mycograss biofertilisers effect. SDGsRev., 4, 1–17. https://doi.org/10.47172/2965-730X.SDGsReview.v4.n03.pe02023

Guamán-Rivera SA, Briones-García J, Arias-Aleman L, Casierra-Cardenas A, Salazar-Saltos A, Sánchez- Quispe H, Ruiz-Salgado M, Baquero-Tapia M (2026). Effect of acetylsalicylic acid to mitigate biotic stress of grass (Panicum maximum). J. Global Innov. Agric. Sci., 14(1). https://doi.org/10.22194/JGIAS/26.1788

Guamán-Rivera SA, Herrera-Feijoo R, Velepucha-Caiminagua HJ, Avalos-Peñafiel V, Aguilar-Miranda G, Melendres-Medina E, Baquero-Tapia M, Cajamarca-Carrazco D, Fernández-Vinueza D, Montero-Arteaga A, Zambrano-Cedeño J (2024). Silvopastoral systems as a tool for recovering degraded pastures and improving animal thermal comfort indexes in Northern Ecuador. Braz. J. Biol., 84:e286137. https://doi.org/10.1590/1519-6984.286137

Hernández JA, Lepe M, Macedo R, Arredondo V, Cortez CE, García LJ, Prado O (2016). Morphological study of socorro island merino sheep and its crosses with hair breeds. Trop. Anim. Health Prod. https://doi.org/10.1007/s11250-016-1177-4

INAMHI (2021). Direccion gestion meteorologica estudios e investigaciones meteorologicas, ecuador. Last accesed on 18th January 2023 www.serviciometerologico.gob.ec. 1–12.

INEC (2021). Encuesta de superficie y producción agropecuaria continua 2020 contenido. INEC. Buenas Cifras Mejores Vidas, 1–49. https://www.ecuadorencifras.gob.ec/estadisticas-agropecuarias-2/. Last accessed on 12 December

INEC (2022). Proyecciones poblacionales.https://www.ecuadorencifras.gob.ec/proyecciones-poblacionales/. Last access May 1st, 2022. https://www.ecuadorencifras.gob.ec/proyecciones-poblacionales/. Last access December 15, 2019

INEC- ESPAC (2025). Encuesta de superficie y producción agropecuaria continua (ESPAC) 2019. Quito, Ecuador. https://www.ecuadorencifras.gob.ec/estadisticas-agropecuarias-2/. Last accessed on 12 December

INEC-ESPAC (2025). Encuesta de superficie y producción agropecuaria. usos del suelo. https://www.ecuadorencifras.gob.ec/estadisticas-agropecuarias-2/. Last accessed on 12 December

Kovacic Z, Viteri O (2020). The lose - lose predicament of deforestation through subsistence farming : Unpacking agricultural expansion in the Ecuadorian Amazon. J. Rural Stud., 51:105-114. https://doi.org/10.1016/j.jrurstud.2017.02.002

Liang Q, Ji D, Wang X, Peng X, Zhang J, Ge C, Zheng Y, Gao T (2025). Comparative histomorphometric and transcriptomic analysis reveals potential genetic determinants of pelage variation between hairy and coarse-woolly sheep. BMC Genomics, 26:1104. https://doi.org/10.1186/s12864-025-12260-y

MAGAP (2022). Agricultural stadistic. Accessed on 14 January 2022. www-magap.gob.ec.

Moyano J, Leib SA, Marini PR, Fischman ML (2020). Effect of mineral supplementation on the macromineral concentration in blood in pre- and postpartum blackbelly sheep. Anim., 10,1206. https://doi.org/10.3390/ani10071206

Nel C, Werf JHJV, Rauw W, Schalk W (2023). Challenges and strategies for genetic selection of sheep better adapted to harsh environments. Anim. Front., 13:43-52. https://doi.org/10.1093/af/vfad055

Peralta AVP, Guamán-Rivera SA, Tobar-Ruiz MG, Sánchez-Salazar ME, Oscullo PDC, Ñuste LFM (2024). Typology and characterization of the agricultural productive units in the NE Amazonian region of Ecuador. J. Adv. Vet. Anim. Res., 11(1), 171–180. https://doi.org/10.5455/javar.2024.k762

Pulina G, Bencini R (2004). Dairy sheep nutrition. cabi publishing is a division of cab international CABI, USA. https://doi.org/10.1079/9780851996813.0000

Rainier H, Whannou V, Afatondji CU, Ahozonlin MC, Id MS, Lanterbecq D, Demblon D, Romuald M, Houinato B, Hippolyte L, Id D (2021). Morphological variability within the indigenous sheep population of Benin. PLoS ONE, 10:e0258761. https://doi.org/10.1371/journal.pone.0258761

Rosegrant MW, Fernandez M, Sinha A, Alder J, Ahammad H, de Fraiture C, Eickhour B, Fonseca J, Huang J, Koyama O, Omezzine AM, Pingali P, Ramirez R, Ringler C, Robinson S, Thornton P, Van-Vuuren D, Yana-Shapiro H (2009). International assessment of agricultural knowledge, science and technology for development (IAASTD): Agriculture at a Crossroads, global report. Washington, DC, USA: Island Press. pp.307-376.

Salako A (2006). Application of morphological indices in the assessment of type and function in sheep. Int. J. Morphol., 24:13-18. https://doi.org/10.4067/S0717-95022006000100003\

Santa-ramírez G, Cuevas-gonzález J, Leal-villamíl J, Muñoz-ramos J (2020). Correlación de variables morfométricas para deslizamientos en la cuenca del río. Ingeniería y Cienc., 16: 145-168. https://doi.org/10.17230/ingciencia.16.31.7

Shiguano-Andy D (2023). Caracterización morfológica de los ovinos mestizos en la estación experimental pastaza. Tesis de grado. Escuela Superior Politécnica de Chimborazo, Ecuador

Silveira RMF, McManus CM, Carrara ER, De Vecchi LB, de Sousa Carvalho JR, Costa HHA, Pilonetto F, Fávero LPL, Landim AV (2024). Adaptive, morphometric and productive responses of brazilian hair lambs: Crossing between indigenous breeds - A machine learning approach. Small Ruminant Res., 232, 107208. https://doi.org/10.1016/j.smallrumres.2024.107208

Temoche V, Godoy D, Trillo F, Ortiz N, Cruz J (2024). Morphological and phaneroptic traits of creole goats reared in an extensive system in the dry forest of tumbes , Peru. Biodiversitas, 25: 4148-4161. https://doi.org/10.13057/biodiv/d251114

Torres B, Günter S, Acevedo-Cabra R, Knoke T (2018). Livelihood strategies, ethnicity and rural income: The case of migrant settlers and indigenous populations in the Ecuadorian Amazon. For. Policy Econ., 86:22-34. https://doi.org/10.1016/j.forpol.2017.10.011

Yang J, Li W, Lv F, He S, Tian S, Peng W, Sun Y, Zhao Y, Tu X, Zhang M, Xie X, Wang Y, Li J, Liu Y, Shen Z, Wang F, Liu G, Lu H (2016). Whole-genome sequencing of native sheep provides insights into rapid adaptations to extreme environments. 33:2576-2592. https://doi.org/10.1093/molbev/msw129

Yang J, Wang DF, Huang JH, Zhu QH, Luo LY, Lu R (2024). Structural variant landscapes reveal convergent signatures of evolution in sheep and goats. Genome Biol., 25:148. https://doi.org/10.1186/s13059-024-03288-6

Zhu L, Tang L, Zhang K, Nie H, Gou X, Kong X (2025). genetic and epigenetic adaptation mechanisms of sheep under multi-environmental stress environment. Mol. Sci., 26,3261. https://doi.org/10.3390/ijms26073261