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Linear Body Measurements as Predictor of Body Weight in Hararghe Highland Goats under Farmers Environment: Ethiopia

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Abstract: This study was conducted to investigate the relationship between body weight and morphological measurements and to estimate body weight from body measurements in Hararghe highland goat breed. A total of twelve variables which included body weight, heart girth, body length, body condition score, chest width, pelvic width, wither height, rump length, rump height, ear length, horn length and scrotal circumference was measured from 930 goats under farm situation to see their relationship with body weight. A correlation and regression analyses between body weight as a response variable and body measurements as predictor variable was conducted. The highest and significant ($p<0.01$) correlation was recorded between body weight and heart girth (0.96) for male and (0.93) for female goats. Heart girth alone has explained the variation in body weight with coefficient of determination of 0.82 and 0.73 for males and females, respectively. Body weight of goats can be predicted from heart girth, body condition, rump length, wither height and pelvic width with coefficient of 0.95 for male and 0.90 for female goat. It could be concluded that, body weight can be predicted with high accuracy from body measurements to support marketing, breeding, feeding and veterinary services in the rural settings.

Key words: Live Weight · Correlation · Goat And Regression

INTRODUCTION

Livestock is an asset and foundation for the livelihood for the majority of Ethiopians. It has a multiple role in economic, social and cultural development of the country. The livestock sector has low contribution potential in Ethiopia [1].Shortage of animal feeds, grazing land and livestock health problems, low genetic potential are the fore front challenge for livestock development [2, 3]. The levels of foreign exchange earnings from livestock and livestock products are also much lower than would be expected, given the size of the livestock population [4]. Goat plays a significant economic role for the farming communities living in lowland, midland as well as highland agro ecologic zones of Ethiopia. Goats being smaller sized animal and more prolific, have lower requirements in terms of capital and maintenance costs and are also kept with less risk in investment. They are also easier to sell when cash is needed for school fees or other purposes [5]. Goats have the ability to produce milk and meat under harsh environmental conditions that might limit productivity of sheep and cattle [6]. Ethiopia is home for 21,884,222 heads of goats [7] contributing to more than 12% of the annual meat production of the country [8].

Hararghe Highland goat breed is among the diverse indigenous goat genetic resource distributed in different agro ecologies western and eastern Hararghe of Ethiopia. There is a pressing to know the weight of animal to make decisions for breeding, feeding and veterinary service provision under farmers' settings. Body weight of animals varied as a function of breed, feed, health and general husbandry situation under which the animals kept [9]. Estimating the live weight using body measurements is

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practical, faster, easier and cheaper in the rural areas where the resources are insufficient for the breeder [10]. The best method of measuring weight of animals without scale is to regress body weight on certain linear measurements which can be easily measured, with higher associations and interpreted [11]. There is research evidence that, body measurements differ according to breed, gender, yield type and age [12]. There are charts that show the estimated weights according to the body measurements in the countries where animal industry is developed and live animal marketing is weight based. However, there is paucity of information to goats' weight for making decisions in the developing countries such as Ethiopia. Therefore, there is a need to estimate weight using simple methods where weighbridge is not readily available and its use is not practically feasible. Live body weight of goats increased with increasing rate until the eruption of the first pairs of incisors (1PPI) which is at the age of about 16 months and then gradually decrease at late maturity[13,14]. Literature stated that there is a cyclical change in does weight around the breeding cycle and the younger does are gaining faster than older one [15]. Therefore; it is important to model prediction linear equations for animals at different growth stage and sex group.

The current study is conducted to determine the association between body weight and linear measurements of indigenous Hararghe highland goat breed, as to determine the best regression model for live weight estimation to be used by farmers without the use of weighing scale.

MATERIALS AND METHODS

The Study Area: The study was conducted in Western Hararghe of eastern Ethiopia possessing different agro ecologies ranging from 1300-2450 masl. The area is characterized by mixed farming system and partly agro pastoral with erratic rainfall distribution averaged as 963mm per annum. There are two main seasons (dry season that covered from November to early April and wet season from mid April to October).The study area is predominantly known for cattle and goat fattening practices as income source and milk for infant diet.

Data Collection Procedures: Data was collected from small holder goat keepers by considering flock size and number in a participatory approach. Both men and women headed households were sources of data. A total of 930 indigenous Hararghe highland goat breed comprising 320 kids (156 male and 164 female) and 610 adult (175 male and 435 female) were randomly selected. The goats were stratified into male and female as well as into five age groups estimated based on dentition and age recall information from goat owners. The morphological parameters included were body weight (BWt in kg), heart girth (HG in cm), body length (BL in cm), wither height (WH in cm), pelvic width(PW in cm), scrotum circumference (SC in cm) for males, chest width (CW in cm), rump height(RH in cm), rump length (RL in cm), ear length (EL in cm), horn length(HL in cm) and body condition score (BCS) using the 5 point scale (1=very thin, 2=thin, 3= average, 4=fat and 5=very fat/obese) for both sexes [16].

Statistical Analysis: Correlations (Pearson's correlation coefficients) between body weight and different body measurements were computed within each sex and dentition categories. Stepwise REG procedures of SAS ver.9.2 was employed to predict live weight from body measurements [17]. The choice of the best fitted regression model was selected using coefficient of determination (R^2) and Mean standard error (MSE). The multiple regression models was followed to estimate body weight from body measurements for male and females in a separate analyses.

$$Yj = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + e_j \text{ for female,}$$

$$Y_j = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11} + e_j \text{ for males}$$

where,

Y_j = the dependent variable body weight; β0 = the intercept; X_1, X_2, X_3, X_4, X_5,X_6, X_7, X_8, X_9,X_{10} and X_{11} are the independent variables BL, HG,CW, WH, PW, RL, RH, EL, HL, BCS and SC (for male only), respectively and β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, β_{10} and β_{11} are the regression coefficient of these variable
ej = the residual error.

RESULTS AND DISCUSSION

Correlation Between Body Weight and Measurements: The correlation coefficient between live weight and other body measurements for males and females and for different age groups are presented in Table 1. Live weight was correlated significantly ($P < 0.001$) with most of the body measurements. Heart girth revealed the highest

Table 1: Coefficients of correlation between body weight and other body measurements for Hararghe Highland goat breed within age groups and sex

		Age Group											
		0PPI		IPPI		2PPI		3PPI		4PPI		0-4PPI	
Body measyrement		M	F	M	F	M	F	M	F	M	F	M	F
Body Condition	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.227**	0.443***	0.477***	0.489***	0.527***	0.324**	0.676***	0.469***	0.763***	0.378***	0.588***	0.188***
Body length	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.734***	0.693***	0.612***	0.533***	0.667***	0.721***	0.18^{NS}	0.558***	0.46**	0.481***	0.879***	0.843***
Heart Girth	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.903***	0.855***	0.903***	0.814***	0.892***	0.840***	0.855***	0.828***	0.878***	0.807***	0.965***	0.937***
Height at Wither	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.677***	0.745***	0.821***	0.331**	0.838***	0.528***	0.776***	0.695***	0.648***	0.40***	0.884***	0.785***
Chest width	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.334***	0.584***	0.455**	0.185^{NS}	0.433**	0.388***	0.181^{NS}	0.301**	0.385*	0.408***	0.602***	0.427***
Pelvic width	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.805***	0.149*	0.756***	0.547***	0.77***	0.606***	0.586***	0.383***	0.678***	0.615***	0.875***	0.364***
Rump height	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.834***	0.762***	0.876***	0.619***	0.829***	0.676***	0.63***	0.502***	0.463**	0.56***	0.926***	0.852***
Rump height	N	179	189	48	89	37	76	30	85	34	160	331	599
	r	0.68***	0.649***	0.56***	0.283**	0.776***	0.333**	0.235^{NS}	0.355***	0.613***	0.27***	0.853***	0.692***
Ear length	N	179	189	48	89	37	76	30	85	34	160	331	599**
	r	0.464***	0.269***	0.212^{NS}	0.128^{NS}	0.234^{NS}	0.145^{NS}	0.322^{NS}	0.065^{NS}	0.173^{NS}	0.259**	0.574***	0.444***
Horn length	N	114	100	21	52	21	43	17	56	15	111	188	362
	r	0.614***	0.661***	0.585**	0.376**	0.452*	0.294^{NS}	0.454^{NS}	0.487***	0.319^{NS}	0.25**	0.779***	0.768***
Scrotal circumference	N	173	NA	43	NA	23	NA	NA	NA	NA	NA	240	NA
	r	0.746***	NA	0.554***	NA	0.611**	NA	NA	NA	NA	NA	0.748***	NA

NS = non-significant; *P<0.05; ** P<0.01; 1PPI = 1 Pair of Permanent Incisors; 2 PPI = 2 Pair of Permanent Incisors; 3PPI = 3 Pair of Permanent Incisors; 4PPI = 4 Pair of Permanent Incisors; M = Male; F = Female, NA = Not -available; (-) = No value taken; N= number of observation; r=coefficient of correlation

correlation coefficient with body weight for both sexes and at all age groups, which depicts that, the increase in heart girth is accompanied by the increase in body weight. The present study is in agreement with a number of workers in small farmers setting [18, 19]. It was found that the correlation between body weights and body measurements in pooled data (0 to 4 dentition classes) were higher than those the rest of dentition/age groups/. The correlation between body weight and most of the body measurements tend to be higher at early ages of goats than at later stages. The result is in agreement with a number of workers [18, 19, 20]. The higher significant correlation coefficient between body weight and linear body measurements at all age groups suggests that a combination of body measurements and/or heart girth alone would provide a good predictor of live weight in goats in the fields with no access to weighing scales. This is in agreement with the findings of previous works [21, 22].

The higher correlation coefficients between body weight and measurements for males indicated the fact that, body weight could be predicted more accurately in males as compared to female goats [23]. There was also correlation between live weight and SC with correlation coefficient of 75%, 55% and 61% at age of 0PPI, 1PPI and 2PPI, respectively. This implies the fact that selection of male goats based on SC could be used to improve male animals. It was argued that, measurement of SC is thus essential to ensure evaluation of breeding males [24]. Thus selection could be based on testicular circumference [25, 26].

Prediction of Body Weight from Body Measurements: The prediction equations to estimate body weight from body measurements for different sexes and age groups are presented in Table 2 and 3. The variation in body weight was explained to a large extent by heart girth in this study, which concurs very well with a number of earlier workers [18, 20, 21, 23, 27, 28, 29]. The results of this study confirm that the body weight of Hararghe goats can be predicted with confidence from heart girth measurements. The value of R^2 increased as more independent variables were added to the regression equation so that estimating weight using a single body measurement is not the only suitable criterion for predicting body weight. However it is important to consider the economic feasibility, ease of application, time it consume to use and technical ability of the end users to use the model in adopting the multiple regression model developed. The higher R^2 value and smaller MSE obtained in this study using a single or multiple predictor variable indicated that all the linear body measurements used as independent variables were good estimators of body weight in goats (Table 2 and 3).

Table 2: Body weight prediction equations for female Hararghe Highland Goat Breed at different age groups

Age group	Equations	β0	β1	β2	β3	β4	β5	β6	R^2	R^2 Change	MSE
OPPI	HG	-22.8	0.67						0.73	0.000	2.15
	HG+BC	-24.48	0.62	1.65					0.78	0.003	1.95
	HG+BC+RHT	-27.42	0.49	1.55	0.19				0.80	0.003	1.87
	HG+BC+RHT+CW	-27.19	0.46	1.51	0.17	0.23			0.81	0.003	1.83
	HG+BC+RHT+CW+RL	-27.5	0.43	1.4	0.14	0.23	0.32		0.81	0.005	1.80
IPPI	HG	-38.0	0.93						0.66	0.000	2.50
	HG+BC	-36.30	0.84	1.36					0.69	0.007	2.39
	HG+BC+EL	-43.0	0.84	1.39	0.53				0.71	0.01	2.35
2PPI	HG	-31.7	0.83						0.71	0.000	2.74
	HG+RHT	-49.83	0.66	0.46					0.78	0.006	2.38
	HG+RHT+BL	-47.98	0.58	0.35	0.18				0.80	0.01	2.29
3PPI	HG	-29.89	0.80						0.69	0.000	2.57
	HG+HW	-39.83	0.61	0.37					0.76	0.006	2.24
	HG+HW+BC	-38.99	0.57	0.34	1.60				0.80	0.01	2.08
	HG+HW+BC+PW	-48.62	0.56	0.31	1.42	0.37			0.81	0.009	2.00
4PPI	HG	-29.8	0.82						0.65	0.000	2.70
	HG+PW	-31.87	0.68	0.85					0.70	0/004	2.51
	HG+PW+RHT	-42.9	0.61	0.73	0.26				0.73	0.005	2.41
	HG+PW+RHT+BL	-45.71	0.55	0.75	0.25	0.13			0.74	0.007	2.35
	HG+PW+RHT+BL+RL	-49.55	0.53	0.67	0.24	0.16	0.32		0.75	0.008	2.30
	HG+PW+RHT+BL+RL+BC	-48.58	0.50	0.63	0.24	0.16	0.28	0.64	0.76	0.009	2.29
0-4PPI	HG	-31.42	0.83						0.88	0.000	2.67
	HG+RHT	-36.26	0.69	0.22					0.89	0.003	2.58
	HG+RHT+BC	-38.63	0.68	0.22	1.08				0.89	0.001	2.50
	HG+RHT+BC+BL	-38.93	0.62	0.20	1.16	0.10			0.90	0.001	2.48
	HG+RHT+BC+BL+RL	-39.37	0.58	0.17	1.06	0.12	0.29		0.90	0.001	2.45
	HG+RHT+BC+BL+RL+HW	-39.66	0.58	0.13	1.07	0.11	0.28	0.06	0.90	0.001	2.44

BL= Body length; HG = Heart Girth; CW = Chest width HW = Height Wither; PW = Pelvic Width; RHT = Rump height;RL=Rump Length; EL=Ear length; BC= Body Condition; 0PPI = 0 Pair of Permanent Incisors, 1PPI =1 Pair of Permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 3PPI = 3 Pairs of Permanent Incisors; 4PPI = 4 Pairs of Permanent Incisor; 0-4PPI= all categories of goats from 0PPI to 4PPI.

Table 3: Body weight prediction equations for male Hararghe highland goat breed for different age groups

Age group	Equations	β0	β1	β2	β3	β4	β5	R^2	R^2 Change	MSE
0PP1	HG	-21.99	0.66					0.82	0.000	1.89
	HG+RL	-23.85	0.58	0.55				0.84	0.002	1.77
	HG+RL+RHT	-26.03	0.46	0.45	0.18			0.85	0.003	1.70
	HG+RL+RHT+BC	-27.14	0.45	0.41	0.18	0.66		0.86	0.003	1.66
	HG+RL+RHT+BC+EL	-29.04	0.45	0.36	0.16	0.72	0.31	0.87	0.004	1.63
1PPI	HG	-41.19	0.98					0.81	0.000	2.15
	HG+ RHT	-50.23	0.61	0.52				0.88	0.005	1.72
	HG+RHT+BC	-49.58	0.49	0.58	1.22			0.90	0.007	1.60
	HG+RHT+BC+PW	-47.0	0.42	0.54	1.04	0.41		0.91	0.008	1.54
2PPI	HG	-33.69	0.88					0.79	0.000	2.97
	HG+HW	-44.51	0.59	0.48				0.87	0.007	2.36
	HG+HW+PW	-40.25	0.51	0.37	0.66			0.91	0.009	2.07
3PPI	HG	-51.7	1.10					0.73	0.000	2.67
	HG+HW	-58.20	0.79	0.46				0.85	0.013	2.04
	HG+HW+BC	-52.79	0.73	0.35	2.26			0.88	0.014	1.88
4PPI	HG	-50/47	1.13					0.77	0.000	3.11
	HG+BC	-38.88	0.85	2.98				0.84	0.01	2.66
0-4PPI	HG	-36.21	0.92					0.93	0.000	2.77
	HG+BC	-37.82	0.86	1.91				0.94	0.0004	2.55
	HG+BC+RL	-38.31	0.77	1.62	0.52			0.95	0.0004	2.44
	HG+BC+RL+HW	-40.0	0.66	1.62	0.48	0.15		0.95	0.0006	2.35
	HG+BC+RL+HW+PW	-39.64	0.64	1.51	0.43	0.14	0.23	0.95	0.0007	2.34

BL= Body length; HG = Heart Girth; CW = Chest width HW = Height Wither; PW = Pelvic Width; RHT = Rump height;RL=Rump Length; EL=Ear length; BC= Body Condition; 0PPI = 0 Pair of Permanent Incisors, 1PPI =1 Pair of Permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 3PPI = 3 Pairs of Permanent Incisors; 4PPI = 4 Pairs of Permanent Incisor

Table 4: Live weight values corresponding to heart girth measures for Female Hararghe highland goats

Heart girth (cm)	Live weight (kg)	Heart Girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)
43	4.27	57	15.89	71	27.51	85	39.13
44	5.1	58	16.72	72	28.34	86	39.96
45	5.93	59	17.55	73	29.17	87	40.79
46	6.76	60	18.38	74	30.0	88	41.62
47	7.59	61	19.21	75	30.83	89	42.45
48	8.42	62	20.04	76	31.66	90	43.28
49	9.25	63	20.87	77	32.49	91	44.11
50	10.08	64	21.7	78	33.32	92	44.94
51	10.91	65	22.53	79	34.15	93	45.77
52	11.74	66	23.36	80	34.98	94	46.6
53	12.57	67	24.19	81	35.81	95	47.43
54	13.4	68	25.02	82	36.64	96	48.26
55	14.23	69	25.85	83	37.47		
56	15.06	70	26.68	84	38.3		

Table 5: Live weight values corresponding to heart girth measures for male Hararghe highland goats.

Heart girth (cm)	Live weight (kg)	Heart Girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)
45	5.19	58	17.15	71	29.11	84	41.07
46	6.11	59	18.07	72	30.03	85	41.99
47	7.03	60	18.99	73	30.95	86	42.91
48	7.95	61	19.91	74	31.87	87	43.83
49	8.87	62	20.83	75	32.79	88	44.75
50	9.79	63	21.73	76	33.71	89	45.67
51	10.71	64	22.67	77	34.63	90	46.59
52	11.63	65	23.59	78	35.55	91	47.51
53	12.55	66	24.51	79	36.47	92	48.43
54	13.47	67	25.43	80	37.39	93	49.35
55	14.39	68	26.35	81	38.31	94	50.27
56	15.31	69	27.27	82	39.23	95	51.19
57	16.23	70	28.19	83	40.15	96	52.11

Table 6: Comparison of measured and calculated live weight values for Female Hararghe highland goat

Measured live weights (kg)	Corresponding results based on regression equations for live weights (kg)					
	HG	HG+RHT	HG+RHT+BC	HG+RHT+BC+BL	HG+RHT+BC+BL+RL	HG+RHT+BC+BL+RL+HW
8	8.52	7.52	6.83	6.95	7.00	6.97
11	12.45	11.74	11.87	12.1	12.01	12.05
14	15.44	15.28	15.04	15.18	14.99	15.01
17	18.05	18.1	17.75	18.09	18.21	18.22
20	20.51	20.8	20.7	20.9	20.95	20.92
23	23.29	23.6	23.35	23.9	24.03	24.01
26	26.65	26.52	26.22	26.72	26.78	26.84
29	30.24	30.17	29.83	30.18	30.28	30.3
32	30.38	30.04	30.01	30.44	30.35	30.43
35	32.11	31.84	31.83	32.17	32.34	32.5
38	34.71	33.97	34.39	34.53	34.63	34.74
41	36.64	36.27	36.32	36.7	37.00	37.18

Table 7: Comparison of measured and calculated live weight values for Male hararghe highland goats

	Corresponding body weight based on regression equations for live weights (kg)				
Measured live weigths (kg)	HG	HG+BC	HG+BC+RL	HG+BC+RL+HW	HG+BC+RL+HW+PW
8	7.03	5.47	5.51	5.15	5.63
11	11.48	13.06	12.83	12.19	12.42
14	14.83	13.82	14.13	13.69	13.87
17	18.49	17.18	17.61	17.61	17.89
20	21.21	20.45	20.93	20.6	21.03
23	24.51	24.67	25.43	25.16	25.58
26	26.98	26.5	26.95	26.68	27.18
29	27.79	27.73	28.13	28.01	28.45
32	31.96	31.64	32.8	32.16	32.64
35	35.25	34.7	34.67	33.75	33.91
38	36.93	36.28	36.09	35.49	35.84
41	40.61	39.72	40.73	39.89	40.03
44	41.07	42.06	42.47	41.64	41.8
48	42.91	44.31	43.89	42.97	43.38
50	45.24	47.23	47.65	47.13	47.74

The correlation between body weight and measurement varies between breeds, age groups and sex which have led to run a regression analyses for sex and age category. The stepwise regression in females which included five variables showed significance ($P<0.05$) for 0PPI age group with R^2 and MSE values of 81% and 1.8, respectively. The inclusion of four parameters in the model was significant ($P<0.05$) for age group of 3PPI with R^2 and MSE values of 81% and 2.0, respectively. For age groups PPI and 2PPI, the inclusion of three variables in a step wise regression procedure were significant ($P<0.05$) with R^2 and MSE values of (71% and 2.35) and (80% and 2.29), respectively. There is a slight increase in R^2 and a decrease in MSE by including more body measurements in the model in both sex and age category. The regression analyses in males showed higher R^2 and lower MSE as compared to females, indicating that the weight of males could be measured with high accuracy as compared to females. The inclusion of six parameters in the model were found to have significant relation ($P<0.05$) for age group 4PPI and when the data were pooled (0-4PPI) for female goats with R^2 and MSE of (76% and 2.29) and (90% and 2.44), respectively. In the case of male pooled age groups data (0-4PPI) five regressors (HG, BC, RL, HW and PW) were found to be significantly associated ($P<0.05$) with body weight with R^2 and MSE values of 95% and 2.34). Similarly the regression verified different number of parameters for different age categories of male goats ranging from two to five variables having significant association ($P<0.05$) with body weight (Table 3). In this study, five of the examined body measurements were used while establishing the equations.

The body weight values corresponding to heart girth measures according to the output of this study for female and male goats are presented in Table 4 and 5. The comparison of the actual live body weight and predicted body weight from the linear regression equations are demonstrated in Table 6 and 7. The actual and computed body weight was more or less similar which confirms the fact that, body weight can be predicted from body measurements with accuracy. The present study is in agreement with a number of co-workers [18, 29]. Reports indicated that there was no significant difference between actual body weight (23.25 kg ± 2.73) and body weight predicted with the equation (23.25 kg ± 2.57) [18].

CONCLUSION

Body weight can be predicted from body measurements with high accuracy to support breed improvement and husbandry practices of Hararghe goats. Variation in body weight was explained to a large extent by heart girth. The inclusion of more body measurements on the top of heart girth improved the accuracy of the prediction model. In adopting the multiple regression model developed, it is important to consider the economic feasibility, ease of application, time it consume to use and technical ability of the end users. It is recommended to develop a simple chart that indicates heart girth and corresponding weights to be used by farmers and development agents to support genetic improvement, marketing, feeding and veterinary services.

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