The Journal of Animal & Plant Sciences, 27(1): 2017, Page: 40-47
ISSN: 1018-7081

CHAID AND LOGISTIC REGRESSION APPROACHES FOR ASSESSING THE EFFECTS OF NON-GENETIC FACTORS ON LAMB MORTALITY

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ABSTRACT

Lamb output from the ewe flock is a key determinant of the profitability of sheep farming. Here, we assessed the association between various factors (ewe breed, month of birth, year of birth, birth type, lamb sex and lamb birth weight) on lamb mortality (within the first 60 days of life) using data collected in northern Turkey between 2006 and 2014. The study included a total of 1958 lambs, including the Romanov (R), Awassi (I), Kivircik (K), Tuj (T), Anarom (AN), R×I (Romanov×Awassi), R×K (Romanov×Kivircik), R×A (Romanov×Akkaraman), R×M (Romanov×Morkaraman) and F1 Romanov (Romanov× Turkish native) breeds. CHAID (Chi-Square Automatic Interaction Detector) analysis correctly classified 99.2% of surviving lambs and 12.4% of dying lambs, while 100% of surviving lambs and no dying lambs were correctly classified by logistic regression analysis. CHAID and logistic regression analyses correctly determined 91.5% and 91.1% of lamb mortality, respectively. The most important variables for the estimation of lamb mortality in the CHAID and logistic regression models were month of birth and lamb breed. Based on our findings, we propose that the CHAID algorithm (AUC of 0.843) is better to classify lamb mortality than a logistic regression analysis approach (AUC of 0.613).

Key words: Lamb mortality, Ewe breed, CHAID, logistic regression**.**

INTRODUCTION

Lamb mortality is a major cause of lower productivity in sheep. Studies have indicated that non-genetic factors are largely expected to contribute to lamb mortality (Vostry and Milerski, 2013) and affect production potential (Gbangboche *et al*., 2006). Various researchers have reported how non-genetic factors (e.g., low birth weight, breed, age of dam, parity, sex of lamb, injury, poisoning, type of birth, season, month of birth, year of birth and mothering ability) affected lamb survival (Susic *et al*., 2005; Khan *et al*., 2006; Morris *et al*., 2000; Mandal *et al*., 2007; Sawalha *et al*., 2007; Vatankhah and Talebi, 2009).

Classification tree and logistic resgresion can be applied to determine the effects of non-genetic variables on lamb mortality. Eyduran *et al*. (2008) used regression tree modelling to study the effects of dam age, genotype, sex, birth type and year of birth on Noduz and Karakas lamb birth weight. Khan *et al*. (2014) and Mohammad *et al*. (2012) used regression tree modelling to estimate the live weights of lambs from body measurements. Piwczyński (2009) established the factors responsible for the number of lambs reared from a fertilized mother using a classification tree approach. Classification trees and logistic regression analysis were used to predict the mortality of Polish Merino lambs between birth and weaning (Piwczyński *et al*., 2012). These statistical methods have also been used to investigate the relationship between PrP genotypes and litter size in Polish Merino, Black-headed, Ile de France and Berrichon du Cher breeds (Grochowska *et al*., 2014). A regression tree was also used to detect the relationship between body weight and morphometric traits of Uda sheep (Yakubu, 2012). Paim *et al*. (2013) used logistic regression to analyze the sheep mortality rate from birth to slaughter.

CHAID (Chi-Square Automatic Interaction Dedector) are classified under data mining. These methods define the relationship between a dependent variable and independent variables. CHAID analysis has some advantages over other approaches (Topal *et al*., 2010a; Topal *et al*. 2010b; Koyuncugil and Ozgulbas, 2010; Bayram *et al*., 2015) including; "(1) being a multivariate analysis technique that identifies the size and rank of statistically significant differences; (2) being a nonparametric method that is not required to satisfy assumptions; (3) presents multiway splits instead of binary splits of the predictor variables; (4) applicable to all types of dependent and independent variables (continuous, nominal and ordinal); (5) is unchanging under transformations of independent variables; (6) includes the most important variables explaining the dependent variable and eliminates insignificant variables; (7) provides a graphical representation of the data and interactions within the data set can be determined and the graphical interpretation of complex results containing the interactions; (8) the model has the capability of overcoming missing values in the dependent and independent variables; and (9) the output is highly visual and easy to interpret".

Here we aimed to evaluate, by logistic regression and CHAID (Chi-Square Automatic Interaction Detector) analyses, the extent of breed and heterosis effects on the causes of preweaning mortality of lambs, including the effects of year of birth, month of birth, ewe breed, birth type, lamb sex and birth weight.

MATERIALS AND METHODS

Descriptions of the study area: Erzurum is a city in northern Turkey located at 39.91 latitude and 41.28 longitude and at an elevation of 1,914 m above sea level. Erzurum has a humid continental climate with severe winters, no dry season, warm summers and strong seasonality. According to the Holdridge life zones system of bioclimatic classification, Erzurum is situated in or near the cool temperate steppe biome. The mean total annual precipitation at Erzurum is 414.1 mm (414.1 Litre/m²). Winter daytime temperatures average -2.1°C, falling to -10°C overnight. In spring, temperatures are typically ~10°C during the afternoon with overnight lows of 0°C. During summer, the mean temperature peak is 24.7°C and the mean lowest temperature is 10.3°C. During autumn, mean temperatures decrease to highs of 14.4°C and lows of 2.3°C (generally shortly after sunrise).

Breed descriptions and flock management: Within this study, a total of 1,958 lambs of various breeds were born between 2006 and 2014. The lamb genotypes included are: Romanov (R), Awassi (I), Kivircik (K), Tuj (T), Anarom (AN), R×I (Romanov×Awassi), R×K (Romanov×Kivircik), R×A (Romanov×Akkaraman), R×M (Romanov×Morkaraman) and F1 Romanov (Romanov×native Turkish). The Romanov breed was established by embryo transfer and maintained as purebred. The Awassi, Morkaraman, Akkaraman and Tuj breeds are fat tailed breeds with low prolificacy and are recognized as native breeds in Turkey. Kivircik is a meat and milk type thin tailed breed that is mostly raised in northwest Turkey. The R×I, R×K, R×A and R×M breeds were obtained by crossbreeding Awassi, Kivircik, Akkaramn and Morkaraman ewes with Romanov rams via laparoscopic insemination. F1 Romanov is the first cross of eight native lamb breeds (Chios, Kivircik, Kangal Daglic, Morkarman, Akkaraman, Kivircik, Awassi) from seven agricultural regions of Turkey. Anarom (50% Romanov and 50% Turkish native breeds [TNB]) is a synthetic breed of sheep that was developed by crossbreeding parental Romanov and eight maternal TNBs. The native breeds were involved in an annual program to produce Romanov × TNB F1 animals. The males and females of each subsequent generation (F1, F2 and F3) were then inter se mated. Animals produced after the 3rd generation were considered a new breed.

Lambs survival was measured from the start of lambing to weaning, which occurred at 8 weeks of age. Lamb breed, month of birth, year of birth, birth weight of lambs, litter size at birth and lamb gender were recorded. All lambs were offered a complete creep diet (2.50 Mcal of ME kg^{-1} DM with 16% CP) by approximately 14 days of age. The average amount of creep feed consumed by the lambs was estimated at 100 g/h/day. After 14 days of age, lambs were offered an ad libitum concentrate (2.75 Mcal of ME kg^{-1} DM with 12% CP) diet and 500 g dry grass hay/head/day.

Statistical analysis: Logistic regression and CHAID analyses were used to investigate lamb mortality. F tests, the Chi-square and likelihood ratio are used to specify the best next split at each step when the dependent variable is continuous, nominal and ordinal respectively.

Our CHAID model was designed so that values belonging to at least 40 individuals in the parent node and 20 individuals in the child nodes be situated for detect the random effects of ewe breeds, year of birth, month of birth, birth type, lamb sex and lamb birth weight on lamb mortality. In the CHAID model, the significant difference is calculated by the *p*-value gained from a Pearson Chi-square test. The α_{merge} and α_{split} values given at 5% level.

Logistic regression can be used to detect the functional model between the categorical dependent variable and categorical or continuous independent variables.

The logistic regression function is defined as follows;

$$P(Y=1)=\frac{1}{1+e^{-(\beta_0+\beta_1 X_{1+\cdots+}\beta_n X_n)}}$$

where P(Y=1) is the probability of stillbirth, β_0 is the constant of the equation and $\beta_{1,\dots,}\ \beta_n$ are the coefficients of the individual risk factors.

The area under the ROC curve (AUC), which shows the percentage of correct classifications, is used to compare the CHAID and logistic regression models (Bayram *et al*., 2015). The AUC value changes between 0.0 and 1.0, with values of 1.0, 0.0 and 0.5 indicating an ideal positive estimate, ideal negative estimate and poor estimate respectively (Bayram *et al*., 2015). The statistical analysis was made using the SPSS software package (SPSS, 2004).

RESULTS AND DISCUSSION

Crosstab table (survival and death numbers and percentages) and Pearson Chi-square values for birth type, sex of lamb, month of birth, year of lambing and lamb mortality are given in Table 1.

Table 1. Lamb mortality across the investigated factors, N (%).

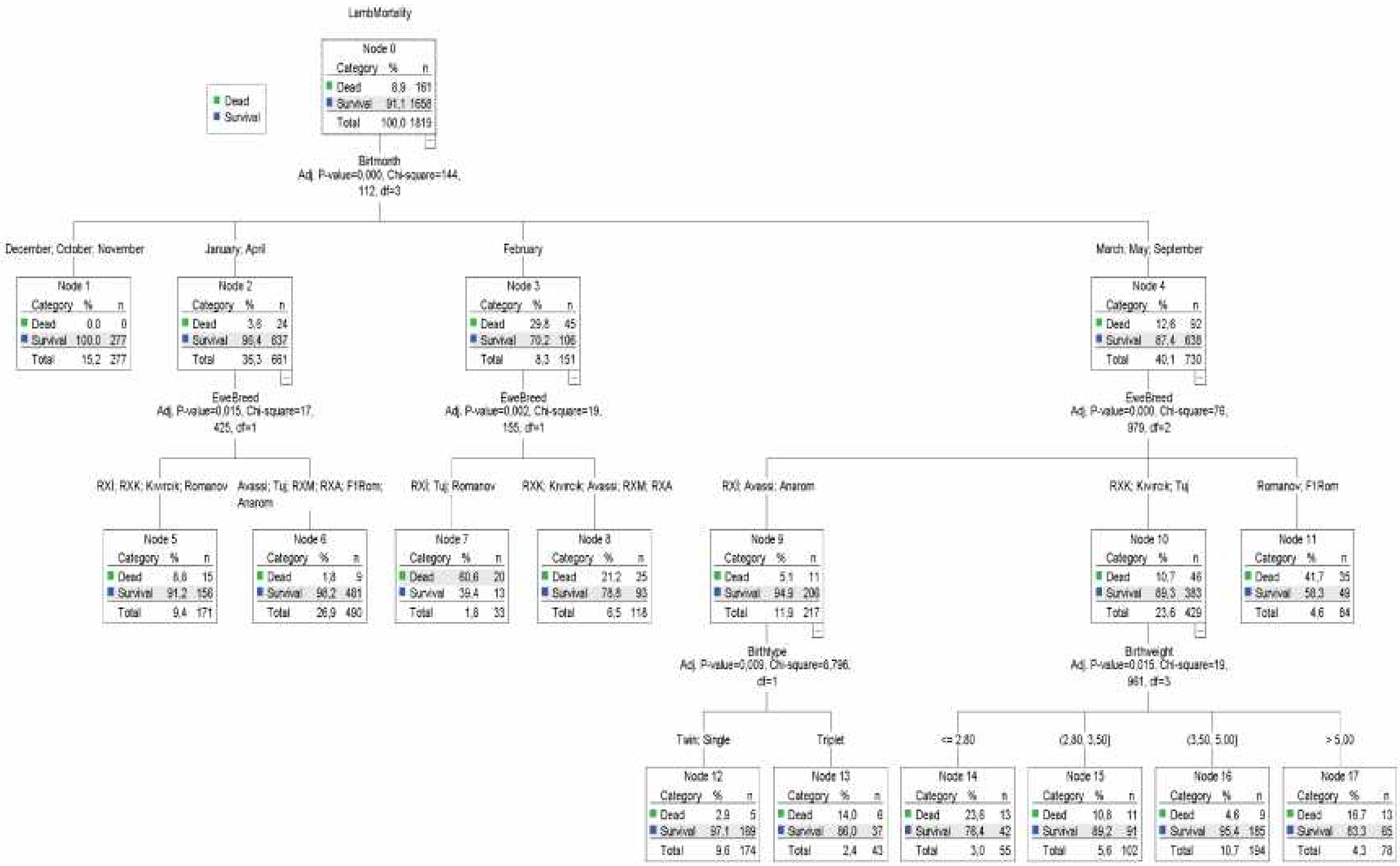
Factor		Lamb mortality			P
		Total	Survival	Dead	
Birth Type	Singleton	699	655 (93.7)	44 (6.3)	0.009
	Twin	839	753 (89.7)	86 (10.3)	
	Triplet	281	250 (89.0)	31 (11.0)	
Sex	Female	908	831 (91.5)	77 (8.5)	0.489
	Male	911	827 (90.8)	84 (9.2)	
Ewe Breed	Romanov	75	51 (68.0)	24 (32.0)	0.001
	Awassi	352	340 (96.6)	12 (3.4)	
	Kıvırcık	347	308 (88.8)	39 (11.2)	
	Tuj	227	208 (91.6)	19 (8.4)	
	Anarom	146	140 (95.9)	6 (4.1)	
	Romanov X Awassi	70	65 (92.9)	5 (7.1)	
	Romanov X Kıvırcık	154	144 (93.5)	10 (6.5)	
	Romanov X Akkaraman	147	137 (93.2)	10 (6.8)	
	Romanov X Morkaraman	134	127 (94.8)	7 (5.2)	
	F1-Rom	167	138 (82.6)	29 (17.4)	
Month of birth	January	376	360 (95.7)	16 (4.3)	0.001
	February	151	106 (70.2)	45 (29.8)	
	March	260	228 (87.7)	32 (12.3)	
	April	285	277 (97.2)	8 (2.8)	
	May	341	295 (86.5)	46 (13.5)	
	September	129	115 (89.1)	14 (10.9)	
	October	74	74 (100)	0 (0)	
	November	72	72 (100)	0 (0)	
	December	131	131 (100)	0 (0)	
Year of birth	2006	519	477 (91.9)	42 (8.1)	0.001
	2007	168	168 (100.0)	0 (0.0)	
	2008	99	88 (88.9)	11 (11.1)	
	2009	43	38 (88.4)	5 (11.6)	
	2010	265	209 (78.9)	56 (21.1)	
	2011	450	414 (92.0)	36 (8.0)	
	2012	119	115 (96.6)	4 (3.4)	
	2014	156	149(95.5)	7 (4.5)	

The figures in parenthesis indicate the percentage

There was a significant relationship between lamb mortality and ewe genotype, lambing season and year of lambing, whereas progeny gender was not significantly related to lamb survival (P>0.05) (Table 1). Increased litter size (twins and triplets) at birth lead to increased lamb mortality and more twin and triplet born lambs died than single-born lambs (P≤0.001). Lamb mortality was higher for Romanov (32.0%) than for F1 Romanov lambs (17.4%). Kivircik lambs (11.2%) had the highest lamb mortality among the native breeds, with the Tuj and Awassi breeds having mortalities of 8.4% and 3.4%, respectively. The survivability of the F1 Romanov lambs was improved in the F3 generation, in which the Anarom synthetic breed had been developed by strict selection on mothering ability and lamb survival. In addition, Romanov crossbreeding with the four main maternal breeds (Awassi, Akkaraman, Kivircik and Morkaraman) resulted in similar and acceptable lamb mortality rates. Thus, Romanov can be recommended for use in crossbreeding programs with native breeds to improve reproductive performance without adverse effect on survivability of lambs.

There was a significant (P≤0.001) relationship between month of birth and mortality of lamb, with the highest mortality observed in February (29.8%), May (13.5%) and March (12.3%), while lambs born in October (0.0%), November (0.0%), December (0.0%), April (2.8%) and January (4.3%) had the lowest mortality rates.

CHAID diagram of birth type, sex, ewe breed, month of birth, year of birth and lamb birth weight on lamb mortality is given in Figure 1. Here, the number and percentage of lamb mortality were presented as the parent node (Node 0). Among the lamb population, the rates of surviving and dying lambs were 91.1% and 8.9%, respectively.



R×İ: Romanov/Awassi; R×K:Romanov/Kıvırcık; R×A: Romanov/Akkaraman; R×M: Romanov/Morkaraman

Figure 1. Tree diagram of combined categories and subsets obtained from CHAID analysis.

This node was split into four child nodes (Node 1, Node 2, Node 3 and Node 4) according to month of birth. In the CHAID model, birth month was the most important predictor variable determining lamb mortality. A total of 277 lambs were in Node 1, 661 in Node 2, 151 in Node 3 and 730 in Node 4. The survivability of lambs born in December, October and November was 100% in Node 1. In Node 2, the survivability of January and April born lambs was 96.4%, which dropped to 70.2% in Node 3 (February born lambs). The March, May and September born lambs (Node 4; n=730) had a mortality rate of 12.6%. Month of birth was identified as an important factor for lamb survivability, with December, October, November, January and April being the best months for lambing. This is in line with the findings of Mustafa *et al*. (2014), who found that lambing season has an important effect on lamb mortality rates and that autumn was optimal. Susic *et al*. (2005) reported that lambs born in winter (December–February) had higher mortality rates than those born in Spring (March–May) and autumn (September–November), respectively. Vatankhah and Talebi (2009) reported that month of birth had a significant effect on lamb mortality in Lori-Bakhtiari Lambs while Sawalha *et al*. (2007) also found a significant effect for month of birth in Scottish Blackface sheep.

Node 2 was split into two child nodes (Node 5 and Node 6) according to ewe breed**,** which was the second most important variable affecting lamb mortality (Fig. 1). In the CHAID diagram, the Node 5 (January and April) group (born from R×İ, R×K, Kivircik and Romanov breeds) had 91.2% (156/171) survivability, while Node 6 (January and April, born from Awassi, Tuj, R×M, R×A, F1 Romanov and Anarom breeds) had 98.2% (481/490) survivability.

Node 3, which represents the month of February, had the highest lamb mortality rates and was further divided into Nodes 7 and 8 according to lamb breed. The mortality rates of the lambs increased to 60.6% for the R×İ, Tuj and Romanov breeds and 22.1% for the R×K, Kivircik, Awassi, R×M and R×A (Node 8). Based on Node 7 and 8, to decrease the lamb mortality rate, we propose that mating should be scheduled in such a way that lambing does not occur in February. Based on our findings, we recommend April, October, November, and December as the optimum breeding period for the region and breeds addressed here. Almost all the breeds tested were influenced by the season of lambing for survivability (Nodes 5–8).

Node 4 was split into three child nodes (Nodes 9–11) according to ewe breed (Fig. 1). As can be seen in CHAID diagram, Node 9 (R×İ, Awassi, and Anarom) lambs born in March, May and September had the highest survivability rate (94.9%, 206/217). Lambs in Node 10 (R×K, Kivircik, and Tuj; March, May and September) and 11 (Romanov and F1 Romanov; March, May and September) had 89.3% and 58.3% survivability respectively. The child nodes of Node 4 show that seven lamb breeds had the highest survival rates in the months March, May and September. Regardless of lamb breed, month of birth was most favorable in March (within the winter season), May (within the spring season) and September (within the autumn season).

Node 9, which corresponds to the ewe breeds R×İ, Avassi and Anarom, was further broken down according to the birth type, either singleton and twin lambs (Node 12) or triplet lambs (Node 13). The birth type was the third most important variable affecting lamb mortality rate (Fig. 1). Nodes 12 and 13 showed that lamb mortality is significantly higher for lambs born as triplets (14.0%) than as twins (2.9%). This is similar to the findings of Vostry and Milerski (2013), who found that survival decreases with increasing numbers of lambs per litter. Vatankhah and Talebi (2009) reported that type of birth had a significant effect on lamb mortality in Scottish Blackface sheep.

Node 10 was split into four child nodes (Node 14–17) according to lambing birth weight, which was the fourth most important predictor variable for lamb mortality in the CHAID model. Lambs born from R×K, Kivircik and Tuj in the months of March, May and September and that were ≤2.80 kg at birth (Node 14) had a 76.4% survivability rate. Node 14 lambs with birth weights of >2.80 to ≤3.50 kg had a survival rate of 89.2%, Node 15 (birth weights of >3.50 to ≤5.00 kg) had a survival rate of 95.4% and Node 16 (birth weight >5 kg) had a survival rate of 83.3%. Lamb birth weight had a significant effect on survival rates, with between 3.00 and 5.00 kg being the optimum range for survival. This is in line with the findings of Mustafa *et al*. (2014) who reported that lamb birth weight significantly affected mortality. Morel *et al*. (2008) indicated that mortality rate was higher in lambs with lower birth weights than in those with higher birth weights. Novak and Poindron (2006) reported an optimum birth weight of between 3.0 and 5.5 kg, while Deribe *et al*. (2014) reported that the birth weight of the kids had no effect on lamb mortality rate.

According to our CHAID analysis, month of birth, lamb breed, litter size and birth weight are the most important variables for determining lamb mortality. Sex and year of birth were ineffective at determining lamb mortality and are not shown in the tree diagram. These findings are consistent with the literature. Mustafa *et al*. (2014) found that lambing season had a significant effect on the mortality and gender of newborns, whereas litter size had no effect. In Sahelian sheep, Turkson and Sualisu (2005) concluded that the most significant risk factors for lamb mortality are sex, season and birth weight. Similarly, Vatankhah and Talebi (2009) reported that the year of birth, month of birth, sex and lamb birth weight had significant effects on lamb mortality.

The percentage of correct classification, risks, standard error of risk, AUC, standard error of AUC and predicted values obtained by fitting the CHAID model to predict lamb mortality are indicated in Table 2.

Table 2. Classification results of CHAID analysis regarding lamb mortality.

Lamb mortality		**Predicted**		
		Survival	**Death**	**Total**
Observed	Survival	1645 (99.2%)	13 (0.8%)	1658
	Death	141 (87.6%)	20 (12.4%)	161
	Total	1786 (98.2%)	33 (1.8%)	1819
	Percent Correct: 91.5%	Risk:0.085	Standard Error of Risk: 0.007	
	AUC=0.843***	Standard Error of AUC=0.015		

In the CHAID model, 99.2% of lamb survival and 12.4% of lamb deaths were correctly classified, while 0.8% of lamb survival and 87.6% of lamb deaths were wrongly assigned when using month of birth, ewe breed, birth type and lamb birth weight. Thus, CHAID analysis correctly determined 91.5% of lamb mortality (Table 2). The compatibility of the model could be said to be favorable because the CHAID analysis had a fairly high efficiency (91.5%) and a low risk value (8.50%). Moreover, the AUC value (0.843) was significantly different from 0.5 (P≤0.001) in the estimated model; thus the CHAID algorithm classifies the group significantly better than by chance. The AUC value was close to 1.0, indicating ideal positive estimate.

Logistic regression analyses for determining dependent (mortality rates) and independent variables such as ewe breeds, year of birth, month of birth, birth type, lamb sex and lamb birth weight and their results are shown in Tables 3 and 4.

The logistic regression model including ewe breeds, year of birth, month of birth, birth type, lamb sex and lamb birth weight estimated the lamb mortality variable with 91.1% accuracy (Table 3), with an AUC value of 0.613 (P≤0.01). The obtained AUC values indicate correct classification of the rates of lamb survival and mortality by the models. AUC values close to 1 indicate that the compatibility of the model is good, whereas values close to 0.5 suggest that the model is not compatible. The AUC value obtained in this study was close to 0.5, indicating poor model compatibility.

Table 3. Classification results of logistic regression analysis regarding lamb mortality.

Lamb mortality		**Predicted**		
		Survival	**Death**	**Total**
Observed	Survival	1658 (100.0%)	0 (0.0%)	1658
	Death	161 (100.0%)	0 (0.0%)	161
	Total	1819	0	1819
	Percent Correct: 91.1%	AUC=0.613***	Standard Error of AUC=0.022	

The cut value is 0.500

Table 4. The coefficients and significance of independent variables in the logistic regression model regarding lamb mortality

Variables in the model	**β**	**S.E**	**Wald X^2**	**df**	**P**	**Exp(β)**
Ewe Breed	0.074	0.027	7.270	1	0.007	1.076
Year of birth	0.001	0.000	4.249	1	0.039	1.001
Month of birth	0.126	0.031	16.674	1	0.001	1.134
Sex	0.073	0.168	0.187	1	0.665	1.075
Birth Weight	0.107	0.100	1.142	1	0.285	1.113
Birth Type	-0.268	0.145	3.427	1	0.064	0.765
Model X^2 = 1464.768				6	0.001	
Hosmer and Lemeshow X^2 = 14.208				8	0.077	

X^2: Chi- Square; β: Regression coefficients; S.E.: Standard error of the coefficient
df: Degree of freedom; p: significance; Exp(β): Exponentiated logistic coefficients.

The Chi-square value was computed as 1464.77 with logistic regression (p≤0.001). This indicates that there is a meaningful relationship between lamb mortality rate and the independent variables. The Hosmer and Lemeshow X^2 value was calculated as 14.21 but was not statistically significantly (P>0.05). This result means that the model developed are compatible with the data set which indicates observed values and estimated values by the model are not different. Birth type had a negative effect on mortality rate, whereas ewe breed, year of birth, month of birth, lamb sex and lamb birth weight have positive effects on mortality rate (Table 4). When litter size was increased from single to triplets, survival rates significantly decreased. Female lambs had higher survival rates than males. Birth weight had a positive correlation with survival rates. The mortality rate was lower in winter than in other seasons and survival rates increased in subsequent years with better management and adaptation of new breeds throughout the years.

Conclusion: According to CHAID analysis, 99.2% of lamb survival and 12.4% of lamb mortality were correctly classified, while 0.8% of lamb survival and 87.6% of lamb mortality were wrongly assigned using month of birth, ewe breed, year of birth and lamb birth weight. CHAID analysis correctly determined 91.5% of lamb mortality. According to logistic regression analysis, 100.0% of lamb survival but no lamb mortalities were correctly classified using ewe breeds, year of birth, month of birth, birth type, lamb sex and lamb birth weight. Logistic regression analysis correctly determined 91.1% of lamb mortality. The estimation of the lamb mortality variable by these two statistical approaches were equally accurate. The most important variables for the estimation of lamb mortality in the CHAID and logistic regression models were month of birth and ewe breed. The higher AUC value (0.843) computed for the CHAID algorithm suggests that the CHAID model outperforms logistic regression analysis (AUC of 0.613) for the estimation of lamb mortality.

Conflıct of Interest: We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript. Mehmet TOPAL declares that he has no conflict of interest. Ebru EMSEN declares that she has no conflict of interest. Aycan Mutlu YAĞANOĞLU declares that he has no conflict of interest.

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