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Utility of MARS Algorithm for Describing Non-Genetic Factors Affecting Pasture Revenue of Morkaraman Breed and Romanov × Morkaraman F1 Crossbred Sheep under Semi Intensive Conditions

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Authors' Contribution
AA conceived and designed the study and collected the data. EE analysed the data statistically. YEE and MMT interpreted the data and wrote the article.

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Pasture revenue, Morkaraman, Romanov × Morkaraman F1 crossbred, MARS, Data mining.

ABSTRACT

This study was conducted on indigenous Morkaraman breed and Romanov × Morkaraman F1 Crossbreed sheep reared under semi-intensive conditions in order to determine the influence of dam age, genotype, birth weight, year, sex and birth type at lambing, weaning weight, weaning age, grazing period and weight at the end of the grazing period on pasture revenue, which is defined as the obtained revenue per lamb from weaning period to the end of the grazing period. Multivariate adaptive regression splines (MARS) data mining algorithms in addition to least squares method were scrutinized comparatively in the prediction of weight at the end of grazing period. The best statistical approach was selected based on goodness of fit criteria *viz.* determination coefficient (R^2), adjusted coefficient of determination (R^2_{ADJ}), and Pearson correlation coefficient between the actual and the predicted values in the response trait handled. The greatest importance order was obtained for age at the end of grazing period (100%), followed by weight at the end of grazing period, weaning age, birth weight and grazing period. To obtain the pasture revenue, weight at the end of grazing period was required to be heavier than 26.2 kg, and age at the end of the grazing period was needed to be longer than 173 days. Average weaning weight of the lambs (15.7 kg) contributed the pasture revenue of 106.08 TL. When the weaning weights increased from 17.0 to 21.5 kg, the pasture revenue reduced from 79.56 to 7.34 TL. As a result, MARS algorithm may be a good approach to predict pasture revenue and to capture ideal cut-off values of significant factors affecting the revenue for increasing profitability of lamb meat production in the sheep.

INTRODUCTION

The presence and quality of the existing pasture land are important for cheaper and qualified small ruminant production. Provincial meadows and pastures in terms of current assets are of primary importance for eastern part of Turkey (Aksoy and Yavuz, 2012). The ovine sector in the region is mainly composed of low-yielding domestic races, largely based on land-based feeding conditions and a structure using limited inputs (Ertuğrul *et al*., 2010). With the increasing demand for sheep meat in Turkey, there was a need to study various aspects of the production chain, including costs and revenues of the system. Although there are numerous studies on the economic values for sheep meat in the world, it has not been studied enough in Turkey. Lôbo *et al*. (2011) estimated economic value for a sheep raised in pasture-based production system in semi-arid Brazil using data on the Morada Nova hair sheep breed. Bytyqi *et al*. (2015) studied economic values for production traits for different sheep breeds.

It is considered that the preference of the extensive lamb fattening system by lamb fattening enterprises can only be possible with the higher kilogram price of the obtained carcass. In the free market economy, selling of the carcass obtained as a result of extensive lamb fattening at a higher price due to aroma, rate of fat, appearance and similar factors can only occur with the establishment of the quality-price relation (Aydın *et al*., 2017).

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One of the most effective ways for covering the demand of the meat is lamb production. The ability of lamb to produce red meat is defined as live body weight and live weight gain and live body weight of lambs is noticeable in increasing profitability (Esenbuga and Dayioglu, 2002). In sheep production, growth-related quantitative traits i.e. weights at various periods (birth weight, weaning weight, weight at 6 months, yearling weight and weight at the end of the grazing period) are limited by genetic and non-genetic factors. However, the first live body weights of the lambs are the significant traits affecting growth, survivability and mortality of them. To preciously estimate genetic parameters and genetic improvement and to predict genetic merit of animals in relation to the more heritable quantitative traits in a flock, it is unescapable to reveal the influential non-genetic factors (Bytyq *et al.*, 2015) with the use of robust statistical approaches *viz*. Classification and regression tree (CART), Chi-square automatic interaction detector (CHAID), artificial neural networks (ANNs), and multivariate adaptive regression splines (MARS) data mining algorithms. Mass selection suitable for more heritable traits is a selection method on being directly selected superior animals in quantitative traits with the scope of the genetic improvement.

Several earlier investigators stated that growth-related quantitative traits can be influenced by non-genetic factors *i.e.* birth type, dam age, dam weight at lambing, lambing year, birth weight and farm. Breeding systems i.e. inbreeding and crossbreeding also affect the growth traits. Farm, dam's lambing year and age are non-genetic factors interacted with genetic factors for long-term breeding program. Considering the mentioned points, it is necessary to define and control the influential non-genetic factors for forceful breeding strategies.

Esenbuga and Dayioglu (2002) reported the data on the influence of non-genetic factors on growth characteristics of Awassi and Morkaraman sheep breeds. Petrovic' *et al*. (2015) evaluated the effect of genetic and non-genetic factors on weights at various periods of the lambs belonging to Pirot × Württemberg and Sjenica × Württemberg crossbreds. High daily weight gains are desirable and crossbreeding systems are the most influential solution to improve the profitability of lamb meat production, to develop rural economy and to increase labour efficiency in farms in the event that there is lack of genetic variation in traits.

Fathala *et al*. (2014) evaluated growth performance of Edilbai × Romanov F1 crossbred lambs in Russia-Moscow region. Kopuzlu *et al*. (2014) reported the influence of sex, birth type, lambing year, and herd type on birth weight, weights at the beginning of grazing season and at the end of grazing season *etc*. in Morkaraman sheep. Korkmaz and Emsen (2016) studied the influence of genotype, litter size and sex on birth weight, weaning weight and survivability of the Morkaraman and Romanov × Morkaraman crossbred lambs under semi intensive conditions.

Morkaraman is a multifaceted indigenous sheep breed that has fat-tailed structure but has twin reproduction at lower proportion. The indigenous breed is also of great importance in the conservation of local gene sources in Turkey. Romanov is one of the most productive sheep breeds in reproductive efficiency, rapid growth and high survival rate. As from the year 2004 in Turkey, the fat-tailed sheep breeds have been crossbred with the Romanov prolific breed (Korkmaz and Emsen, 2016). As the indigenous breed, Morkaraman has high adaptability under harsh conditions and zoonotic diseases at regions where they live in Turkey. In obtaining higher survival rate, it is logical to evaluate growth and reproductive performances of Romanov x Morkaraman F1 crossbred (Korkmaz and Emsen, 2016). Isik and Kaya (2011) studied weights at the start and end of grazing period for Tuj lambs. There is still lack of describing factors affecting pasture revenue in Morkaraman and the crossbred sheep, which is significant in developing rural economy. Hence, this study was conducted on Morkaraman breed and Romanov x Morkaraman F1 Crossbreed sheep in order to find factors affecting pasture revenue with the aid of MARS data mining algorithm as a non-parametric regression method.

MATERIALS AND METHODS

The present study was performed on indigenous Morkaraman breed and Romanov × Morkaraman F1 Crossbreed sheep maintained at Research and Application Farm of Atatürk University, Erzurum province of Turkey. The data were recorded on the dam age, genotype, birth weight, year, sex and birth type at lambing, weaning weight, weaning age, grazing period and weight at the end of the grazing period on pasture revenue, of great economic importance, which is defined as the obtained revenue per lamb from weaning period to the end of the grazing period. The collected data are crucial for efficient breeding strategies.

MARS data mining algorithm was suggested by Friedman (1991) with the intention of describing the non-linear relationships between a set of predictors and responses. Within the scope of the MARS algorithm, no assumptions about functional relationships between responses and predictors are needed. It is a nonparametric regression technique based on a divide-and -conquer strategy where the training data sets are split into separate piecewise linear segments (splines) of various gradients (slope). The splines are connected smoothly to each other as well as basis functions as piecewise curves permit ones to adaptably construct linear and non-linear effects. The connection point between the pieces is called as “knots”. The candidate knots were placed at random location within the range of each predictor. MARS generates basis functions by taking into consideration all potential candidate knots and interaction effects between predictors in a stepwise procedure. To define a pair of the basis functions, the forward procedure sets up the candidate knots at random location within the range of each predictor. The predictive model built by MARS data mining algorithm at each stage specifies the knots and their pairs of basis functions to decrease error variance. Until the complicated model is achieved, the procedure of involving the basis functions continues. The redundant functions insignificantly contributing to the MARS are deleted by the backward procedure in the MARS (Zhang and Goh, 2016).

Finally, the following MARS model was applied in the current study (Aksoy *et al*., 2018):

$$\hat{Y} = \beta_0 + \sum_{m=1}^{M} \beta_m \prod_{k=1}^{K_m} h_{km}\left(X_{v(k,m)}\right)$$

Where, $\hat{Y}$ is the predicted value of the response variable, β_0 is a constant, $h_{km}(X_{v(k,m)})$ is the basis function, in which $v(k,m)$ is an index of the predictor employed in the m^{th} component of the k^{th} product and K_m is the parameter limiting the order of interaction (Ertürk *et al*., 2018).

The maximum number of basis functions in the current analysis was 200 and no interaction effects were used for MARS. After building the most complex MARS model, the basis functions which did not contribute much to the model performance were eliminated in the process of the so-called pruning based on the following generalized cross-validation error (GCV):

$$\mathrm{GCV}(\lambda) = \frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{\left[1 - \frac{M(\lambda)}{n}\right]^2}$$

Where, n is the number of training cases, Y_i is the observed value of a response variable, $\hat{Y}_i$ is the predicted value of a response variable and Mλ is a penalty function for the complexity of the model with λ terms.

Formulas of the model evaluation criteria for estimating their predictive performance of the MARS algorithms are given below:

Coefficient of determination

$$R^2 = \left[1 - \frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{\sum_{i=1}^{n}\left(Y_i - \bar{Y}\right)^2}\right]$$

Adjusted coefficient of determination

$$R^2_{ADJ} = \left[1 - \frac{\frac{1}{n-k-1}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{\frac{1}{n-1}\sum_{i=1}^{n}\left(Y_i - \bar{Y}\right)^2}\right]$$

Pearson correlation coefficient between actual and predicted values in pasture revenue (TL, Turkish Liras).

Where, Y_i is the real pasture revenue (TL) (kg) value of i^{th} lamb, $\hat{Y}_i$ is the predicted pasture revenue (TL) of i^{th} lamb, $\ddot{Y}$ is the average of the pasture revenue (TL) values of lamb, ε_i is the residual value of i^{th} lamb, *k* is the number of terms in the MARS model, and n is total lamb number. The residual value of each lamb is expressed as $\varepsilon_i = Y_i - \hat{Y}_i$.

Relative importance estimates of the significant predictors in the MARS were made according to residual sum of squares (RSS) and GCV criteria. Also, nsubsets counts the number of the model subsets that contain the predictor, and are the subsets of terms produced by means of the pruning pass. RSS criterion first calculates the decrease in the RSS for each subset relative to the previous subset. GCV criterion is the same, but employing the GCV instead of the RSS.

Heteroscedasticity problem was tested by White test. To remove the problem, pasture revenues were converted logarithmically. To find predictors affecting pasture revenue, the following non-linear regression model was adopted:

$$\text{Ln(Pasture Revenue)} = \alpha + \beta_1 \text{(Breed)} + \beta_2 \text{(Sex)} + \beta_3 \text{(Concentrate feed)} + \beta_4 \text{(Grazing period)} + \beta_5 \text{(Weaningage)} + \beta_6 \text{(Weaning Weight)}$$

The MARS model with the lowest GCV, SD_{RATIO} and the greatest coefficient of determination (R^2), adjusted coefficient of determination (R^2_{ADJ}), and Pearson coefficient (r) between actual and predicted values in pasture revenue was considered as the best one. All the statistical evaluations were performed through R package program (R Core Team, 2014; Milborrow, 2011).

RESULTS AND DISCUSSION

The relationship between pasture revenue as lamb selling revenue and some predictors was examined through non-linear regression model. The achieved results are summarized in Table I. The specified model produced 0.644 R^2, 0.627 Adjusted R^2. Morkaraman breed positively affected pasture revenue. Pearson’s correlation coefficient between actual and estimated pasture revenue values was 0.791 (P<0.01). The inverse relationship between grazing period and pasture revenue was noted. In the studied region, grass yield decreased since pasture dried after midsummer and thus lambs were adversely influenced due to fasting. Besides, there was a negative relationship between pasture revenue and weaning weight. In the study of Ptáček *et al*. (2015), there was a significant relationship between growth performance and sex of lambs and ewe's age.

Table I.- Results of regression analysis.

Predictor	β	SE	t-value	P value
Intercept	6.535	0.457	14.292	0.000
Breed	0.159	0.094	1.689	0.094
Sex	-0.004	0.075	-0.059	0.952
Concentrate feed	0.079	0.010	7.567	0.000
Grazing period	-0.022	0.002	-10.390	0.000
Weaning age	0.002	0.004	0.659	0.511
Weaning weight	-0.092	0.019	-4.936	0.000

R^2=0.644; F(6,122) = 36.8, P = 0.000; White Test = 45.114, P = 0.008; Ramsey Reset Test = 0.847, P = 0.431.

This is the initial documentation on predicting pasture revenue from systematic environmental factors with the use of MARS data mining algorithm that has no interaction effects. The MARS algorithm's prediction equation showing predictors affecting pasture revenue as an indication of the profitability of small ruminant enterprises was written below with 0.968 R^2, 0.928 Cross-validation R^2, 97.7 GCV with the selected 17 terms. Highly significantly correlation of 0.984 was found between the real and the predicted pasture revenue values (P<0.01). Approximately all the variation in pasture revenue was explained by these 17 terms selected in the MARS solution. Insignificant contribution of birth type, sex, dam's age, and lambing year to pasture revenue in the MARS was noted, which supported the explanations of Esenbuga and Dayioglu (2002) who reported the insignificant effect of the mentioned environmental factors on weights at increasing age of lambs. Also, the effect of genotype on pasture revenue was non-significant, meaning that the constructed MARS model could be used for both genotypes evaluated in the study. The MARS algorithm had greater predictive accuracy compared to the multiple regression analysis here, and presented the cut-off values in order to more easily comment on the achieved outputs with the aid of its maximum functions instead.

There was not any change in pasture revenue for the lambs whose birth weight was 4.4 or lighter as the second term was examined below. When grazing period was longer than 173 days, more increase in pasture revenue per lamb would be expected. As one day increased in grazing period, the pasture revenue increasing of 7.55 TL would be expected per lamb. This cut off value may be gained importance in practice for small ruminant enterprises due to the importance value of age in the end of grazing period. If grazing period is 173 or shorter, no positive effect of grazing period on pasture revenue would not be found. MARS results revealed that grazing period also named age at the end of grazing period was needed to be longer than 173 days at least in order to gain pasture revenue. Shalloo *et al*. (2004) found similar results in the study used to Teagasc Lamb Production Model. According to this model, short grazing period reduces economic income.

The weaning weight of 18.6 kg would provide a contribution of 46.92 TL to pasture revenue. The weaning weight of 20.9 kg will provide 9.315 TL to pasture revenue. The weaning weight of 21.9 kg will make an adverse contribution of 10.44 TL to it. The MARS terms 5-7 reflected that the weaning weights of 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0, 20.5, 21.0 and 21.5 kg would make the contributions of 79.56 TL, 69.36 TL, 59.16 TL, 48.96 TL, 40.38 TL, 32.205 TL, 24.03 TL, 15.855 TL and 7.34 TL with a decreasing trend to the pasture revenue. Average weaning weight of the lambs (15.7 kg) contributed the pasture revenue of 106.08 TL to it. Suryanarayan *et al.* (2007) informed that the concentrate feeding though costly could be promoted at the field level for rapid weight gain under semi-intensive system. Arulnathan and Bandeswaran (2013) reported that the average daily gain and net profit was higher (1385) in lambs maintained in Gr-I (stall feeding) than Gr-II (1014) (Grazing + Concentrate feeding) and Gr-III (926) (grazing alone).

When the terms 3 and 4 regarding weaning age, as the beginning of grazing period, in the MARS equation were examined, the weaning ages of 64 days or shorter didn't affect pasture revenue because max (0, WWage – 64) = 0 and max (0, WWage – 67) = 0 for 64 days or shorter in weaning age. For the weaning age of 67 days, the effect of the term 4 on pasture revenue was unavailable, where in the term 3 (- 16.4 * max(0, WWage - 64)), the contribution (-16.4*max(0, 67-64)=-16.4*max(0,3)=-16.4*3) of the third term to pasture revenue for the weaning age of 67 days was -49.2 TL. When intercept of 142 TL were added to corresponding revenues, the corrected revenue ranged from 125.6 TL to -68.9. The most revenue was possible with weaning age of 65 days. Late weaning age adversely affected the pasture revenue.

The terms 8 and 9 of the MARS was connected with weight at the end of grazing period. When weight at the end of grazing period was 26.2 kg or lighter, no contribution of the weight at the end of grazing period to pasture revenue was found. In the handled farm, the final fattening weight of 26.2 kg might be a significant cut off value affecting the pasture revenue. For the lambs heavier than 26.2 kg, the term 8 was ineffective, and then only the term 9 (21.3 * max(0, W_EGRAZING - 26.2)) provided the contribution to the pasture revenue. Logically, the heavier than 26.2 at the end of grazing period, the more revenue was. For example, for the lamb with the weight of 32.2 kg at the end of the grazing period, the contribution of 32.2 kg to the pasture revenue was (21.3 * max(0, 32.2-26.2)=21.3*max(0, 6)=21.3*6=127.8 TL.

Pasture revenue= 142 - 19.5 * max(0, BW -4.4) - 16.4 * max(0, WWage - 64) + 11.5 * max(0, WWage - 67) + 4.05 * max(0, WW - 18.6) + 20.4 * max(0, 20.9 - WW) - 23.8 * max(0, WW - 20.9) - 20 * max(0, 26.2 - W_EGRAZING)+ 21.3 * max(0, W_EGRAZING - 26.2) - 3.39 * max(0, 163 - EGRAZING_age) + 1.14 * max(0, EGRAZING_age - 163) - 4.55 * max(0, EGRAZING_age - 175) + 4.01 * max(0, EGRAZING_age - 190) + 1.11 * max(0, EGRAZING_age - 249) - 8.19 * max(0, GRAZINGPERIOD - 165) + 1.43 * max(0, 173 - GRAZINGPERIOD) + 7.55 * max(0, GRAZINGPERIOD -173).

The evaluation of importance of the predictors in relation to the MARS is depicted in Table II. The greatest importance order was obtained for age at the end of grazing period (100%), followed by weight at the end of grazing period, weaning age, birth weight and grazing period (Table II). The results in Table II confirmed those reported by Esenbuga and Dayioglu (2002), who recorded non-significant effect of non-genetic factors on the weights as animals aged.

Table II.- The importance estimates of the influential predictors.

	NSUBSETS	GCV	RSS
Endgrazing age	16	100.0	100.0
Weight endgrazing	15	76.2	75.4
Weaning weight (WW)	14	64.4	62.9
Weaning age (WW age)	9	20.4	20.0
Birth weight (BW)	5	5.6	8.0
Grazing period	4	6.5	7.7

The variation in literature was attributable to genetic and non-genetic factors, and botanically various pastures, different statistical implementations *etc*. Howes *et al.* (2015) mentioned that ruminants in pasture grazing system yielded more desirable fatty acids. It is known that those fed with pasture based diets are more preferred by consumers, who are conscious of antioxidants of natural plants, to meet increasing demand for lamb meat in Turkey. Natural grazing pasture is a cheaper alternative to concentrate feed based diets (Smeti *et al*., 2014). More sophisticated studies on assessing the effect of concentrate and pasture based systems on fatty acid compositions of lamb meats are still required for the aim of describing optimal conditions.

CONCLUSION

The current work presented obvious evidence for superior performance of MARS algorithm in order to describe effectual factors on pasture revenue. In this respect, it was concluded that the MARS may be a valuable tool to ascertain optimum points of predictors affecting pasture revenue within the scope of improving lamb productivity.

Statement of conflict of interest

Authors have declared no conflict of interest.

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