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Comparing Predictive Performances of MARS and CHAID Algorithms for Defining Factors Affecting Final Fattening Live Weight in Cultural Beef Cattle Enterprises

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AA conceived and designed the study and collected the data. EE analysed the data statistically. MMT interpreted the data and wrote the article. YEE helped in interpreting the data.

Key words
Final fattening weight, Cultural beef cattle, MARS, CHAID, Data mining, Production economics.

ABSTRACT

This study was conducted to define vital factors on final fattening live weight (FFW) on cultural beef cattle enterprises from Eastern region of Turkey. Predictive performances of Multivariate Adaptive Regression Splines (MARS) and Chi-Square Interaction Detector (CHAID) were evaluated comparatively in the definition of significant factors and interaction effects between the factors. Before the definition process, the data on socio-economic (age, province, educational level, experience, social security, lands and the reason at ranching of the animal breeders) and biological factors (sex, first live weight before fattening and fattening period of the beef cattle) were recorded from the related beef cattle enterprises. For the statistical evaluation of MARS algorithm, the package "earth" of the R software was employed based on the smallest GCV value. In the CHAID algorithm, minimum enterprise numbers in parent and child nodes were set at 4 and 2 for ensuring strong predictive accuracy with the Bonferroni adjustment. MARS algorithm gave a very good performance in the prediction of final fattening weight according to goodness of fit criteria *i.e.* R^2 (0.983) and SD_{RATIO} (0.114). Very strongly significant Pearson correlation coefficient (r=0.992) between observed and predicted FFW values in the MARS were found for the cultural beef cattle enterprises, respectively ($P<0.01$). The respective model evaluation criteria for CHAID algorithm were estimated as 0.671 R^2 and 0.574 SD_{RATIO}. Whereas, the respective correlation coefficient for CHAID algorithm was 0.819 ($P<0.01$). MARS outperformed CHAID algorithm in predictive quality. In the CHAID algorithm, the first live weight, farmer's age, pasture land, SOCSEC, fattening period and sex of the beef cattle were found for FFW as the influential predictors, whereas main and interaction effects of all the predictors handled here were found significant in the MARS. In conclusion, the results represented that MARS may submit meaningful hints to enterprises in the description of noticeable factors on FFW for further studies to be conducted under similar conditions.

INTRODUCTION

Turkey is a country that makes a traditional production for red meat from beef cattle in order to meet essential protein needs for healthy nourishment of the current and next generations. To supply increasing demand for red meat in Turkey, beef cattle production had a significant share with the existence of the native, crossbred and exotic beef cattle breeds. Among these, cultural beef cattle breeds are prominent gene sources and can be mated with indigenous beef cattle breeds to produce heavier crossbred offspring in live weight trait with a high heritability. With the recent biotechnological developments, native beef breeds have been inseminated artificially by using qualified sperms of the cultural breeds for producing superior offspring, which is a great effort to progress rural economy. In beef cattle rearing, FFW, an economically considerable trait affected by genetic and environmental factors, is influenced by first fattening weight influencing profitability and efficiency of the beef cattle production (Demircan, 2008). Several important factors (breed, gender, age, season, first live weight before fattening, fattening period, feeding regime,

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health status, housing system *etc*.) on FFW in beef cattle production were mentioned by previous authors (Demircan, 2008; Aytekin *et al*., 2017). However, more comprehensive knowledge on the effect of socioeconomic factors on FFW for the beef cattle enterprises is still needed together with biological factors addressed above (Abo-Elfadl *et al*., 2015). Demircan *et al*. (2007) studied the impact of season on fattening performance and profitability in beef cattle enterprises. A straightforward explanation of efficient predictors on FFW is affiliated with taking proper and robust statistical methodologies *i.e.* artificial intelligence algorithms (Aytekin *et al*., 2017).

Some documentations were present on FFW in respect of different beef cattle breeds *i.e.* Indigenous, Brown Swiss, Simmental, Holstein Fresian *etc*. (Koknaroglu *et al*., 2005; Aydın *et al*., 2014; Sarma *et al*., 2014; Abo-Elfadl *et al*., 2015; Muižniece and Kairiša, 2016; Aytekin *et al*., 2017). Demircan (2008) reported a significant influence of first fattening weight on sustainability of the beef cattle production in feedlots. Dadi *et al*. (2017) evaluated fattening performance in commercial beef cattle production. Gozener and Sayili (2015) reported significant predictors for live weight gain in beef cattle enterprises. Abo-Elfadl *et al*. (2015) recommended a simultaneously investigation of economic, biological and social predictors affecting FFW to increase efficiency of the beef cattle production.

Statistical analysis of describing influential factors in regard to final fattening weight is important to be concurrently made by robust data mining techniques *i.e.,* CHAID (Akin *et al*., 2017a, b, c, d), CART (Kowalchuk *et al*., 2017; Akin *et al*., 2017d), Exhaustive CHAID (Akin *et al*., 2017d), MARS, multilayer perceptron (MLP) and Radial basis function (RBF) *etc*. However, use of the abovementioned techniques to capture operative factors on FFW is still rare (Aytekin *et al*., 2017). Among these, the first three algorithms are tree-based algorithms that are more easily interpretable visually, whereas MARS can provide an opportunity of making more accurate elucidation on non-linear and interaction effects significantly affecting FFW. The significant biological, socio-economic factors and their high interaction effects in terms of FFW may be exhibited concurrently through MARS algorithm. Hence, an attempt was made in the current study to define noticeable factors on FFW for cultural beef cattle enterprises from Eastern region of Turkey by comparatively using MARS and CHAID in the characterization of significant factors and interaction effects between these considerable factors with the aim of improving productivity of the cultural beef cattle production for the future.

MATERIALS AND METHODS

Data collection and sampling

The questionnaire study was conducted on 145 cultural beef cattle enterprises in Erzurum, Igdir, Kars and Agri provinces of Turkey to describe factors affecting the FFW per enterprise.

Variable structure

FFW was evaluated as a target trait or response variable. Several categorical predictors were sex of the beef cattle (male and female), farmer's province (Erzurum (44.1%), Igdir (12.4%), Kars (22.8%) and Agri (20.7%)), farmer's age (year), farmer's educational degree (illiterate-primary school (49%), secondary school (31.7%), high school (15.9%), and college (3.4%)), farmer's social security status (available (81.4%) and unavailable (18.1%)). Some continuous predictors were expressed as mean ± standard deviation; namely, farmer's experience in animal production (year, 26.4±11.7), farmer`s irrigated land (da, 96±88.6), farmer`s dry land (da, 142±104.8), farmer`s pasturage land (da, 75±27.1), the first live weight before fattening (kg, 283±99.9), and fattening period (day, 174±70.4).

Statistical analysis

CHAID algorithm just runs for nominal or ordinal categorical independent variables. Therefore, continuous predictors are transformed into ordinal predictors before identifying the following algorithm. For a known set of break points a_1, a_2,……,a_{K-1} (in ascending order), a known x is mapped into category *C(x)* as follows:

$$C\,(x) = \begin{cases} 1 & x \leq a_1 \\ k+1 & a_k < X \leq a_{k+1}, k = 1, \ldots, K-2 \\ K & a_{K-1} < X \end{cases}$$

When K is the preferred number of bins, for the approximation of the break points x_i frequency weights are unified in calculating the ranks. In the event of being ties, the average rank is employed. The rank and the respective values in ascending order can be defined as:

$$\left\{r_{(i)}, x_{(i)}\right\}_{i=1}^{n}$$

For k = 0 to (K−1), set:

$$I_k = \left\{ i\colon \left[r_{(i)} \frac{K}{N_f + 1} \right] = k \right\}$$

Where, *(x)* displays the floor integer of x. If I_k is not empty, $i_k = \max\{I : I \epsilon I_k\}$, the adjustment on behalf of the break points is done by becoming equal to the x values corresponding to the i_k, excluding the largest (Breiman *et al*., 1984).

Bonferroni adjustment was taken a basis for CHAID algorithm in estimating Adjusted P values of F values. The CHAID tree based algorithm with an automatically pruning process in removing needless nodes in the decision tree uses F significance test. This pruning (pre-pruning) used in CHAID is different from the post-pruning used e.g. in CART, in which a too complex tree grown at an earlier stage of the analysis is then pruned back by eliminating redundant nodes at a later stage.

MARS as a-non parametric regression methodology was executed to improve a helpful prediction model which ascertains interaction effects of imperative factors in the representation of the momentous factors in FFW as a response continuous variable.

The MARS algorithm was employed here:

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

Where, $\acute{y}$ is the predicted FFW value as a 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 for the m^{th} component of the k^{th} product, K_m is the parameter on limiting the order of interaction.

The maximum number of basis functions in the MARS analysis was 100 and the three-order interactions were considered based on the lowest GCV. After building the most complex MARS model, the basis functions that decrease the quality of the model performance were removed from the prediction equation in pruning process depending upon generalized cross-validation error (GCV):

$$GCV(\lambda) = \frac{\sum_{i=1}^{n}(y_i - y_{ip})^2}{\left[1 - \frac{M(\lambda)}{n}\right]} \ldots\ldots\ldots (2)$$

Where, n is the number of training cases, y_i is the observed FFW value, y_{ip} is the predicted FFW value, $M(\lambda)$ is a penalty function related to the complexity of the model containing λ terms.

We have used a cross validation of 10 for both algorithms. Obtaining the least difference between the cross validation cost and resubstitution cost estimated for learning sample was important for the best solution in the CHAID in the IBM SPSS software. MARS was also specified by V tenfold cross validation together with penalty=2 to prevent overfitting performance in R software. Previous simulation studies suggested penalty values of 2 to 4. We performed the best estimation in penalty=2.

Goodness of fit criteria for computing predictive accuracy of the CHAID and MARS algorithms are formulated below:

Coefficient of determination

$$R^2 = \left[1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}\right] \ldots\ldots\ldots (3)$$

Standard Deviation Ratio

$$SD_{RATIO} = \sqrt{\frac{\frac{1}{n-1}\sum_{i=1}^{n}(\varepsilon_i - \acute{\varepsilon})^2}{\frac{1}{n-1}\sum_{i=1}^{n}(Y_i - \bar{Y})^2}} \ldots\ldots\ldots (4)$$

Pearson's correlation coefficient between actual and predicted FFW scores (5).

Where, Y_i the observed FFW (kg) value associated with i^{th} cultural beef enterprise, $\hat{Y}_i$ is the predicted FFW of i^{th} cultural beef enterprise, $\bar{Y}$ is arithmetic mean of the FFW values associated with all the cultural beef enterprises, ε_i is the individual residual value of i^{th} cultural beef enterprise, $\acute{\varepsilon}$ is arithmetic mean of the residual values, and n: number of total cultural beef enterprises. The individual residual value of each cultural beef enterprise is found as $\varepsilon_i = Y_i - \hat{Y}_i$.

RESULTS AND DISCUSSION

CHAID algorithm results

Figure 1 presented the regression tree diagram built by CHAID algorithm in the prediction of FFW for cultural beef cattle enterprises. The predicted FFW scores were significantly correlated with the real FFW in the cultural beef cattle enterprises (r=0.819, P=0.000). In addition, SD_{RATIO} for CHAID algorithm was estimated as 0.574.

CHAID regression tree diagram presented that the first fattening weight before fattening was the most influence predictor on FFW (Adjusted P= 0.000, F=56.050, df1=3 and df2=141). At top of the regression tree diagram, a root node (Node 0) containing all the enterprises in the study generated an overall average of 488.393 kg in the FFW per enterprise.

The root node was unsurprisingly split into four smaller subgroups (Nodes 1-4) by the first fattening weight before fattening, as a good predictor, respectively. The averages of the FFW from Node 1 to Node 4 subgroup increased as a result of increasing first live weight before fattening. The present findings were consistent with those reported by Demircan (2008) who emphasized the importance of the first live weight in the beef cattle production.

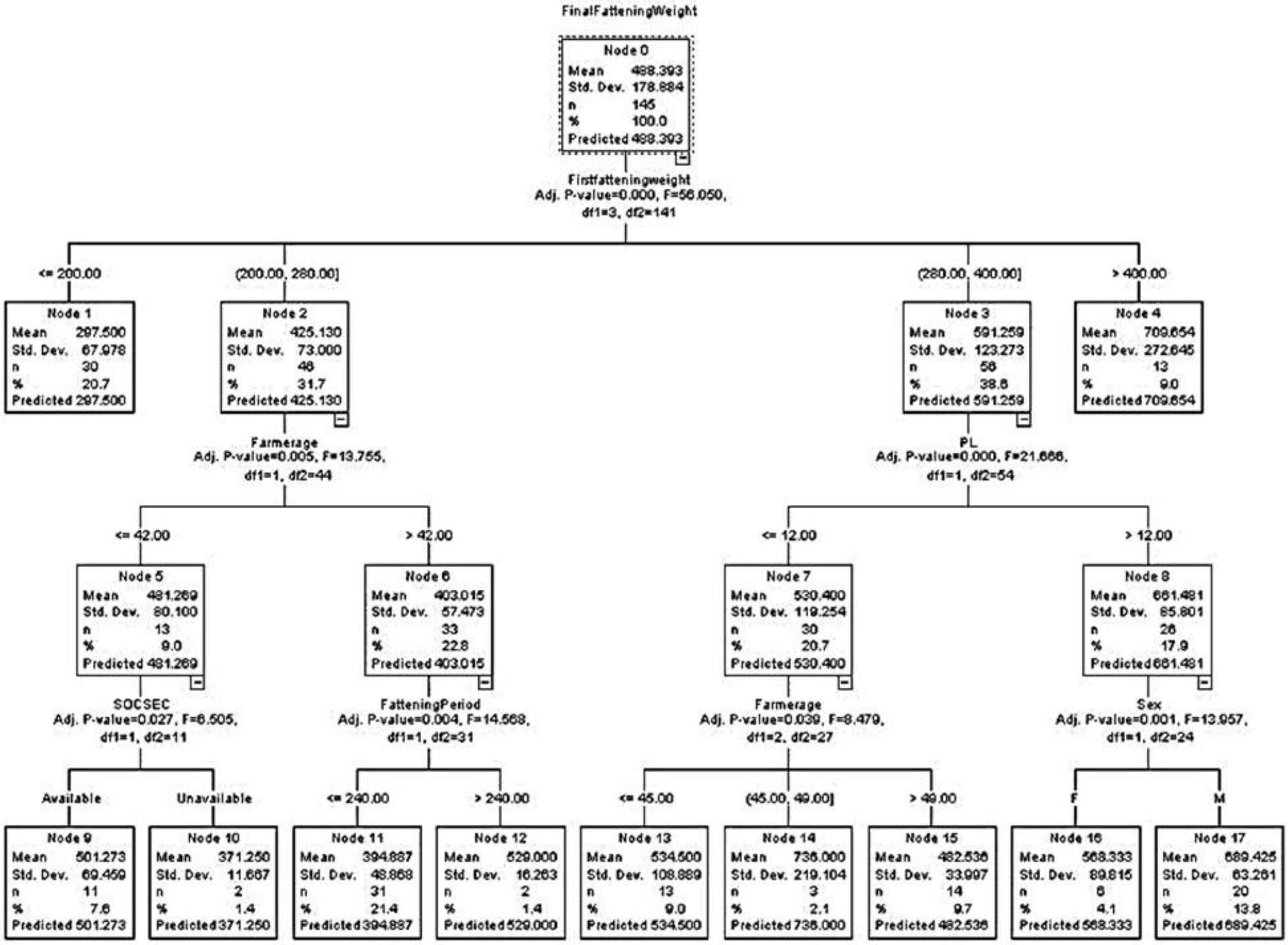

Fig. 1. The regression tree diagram of the CHAID algorithm in the FFW.

Node 1 was the subgroup of enterprises that reared cultural beef cattle with 200 or lighter fattening weights and in the first group, an average FFW of 297.500 kg was predicted.

It was reported that fattening period was a significant source of variation in FFW for the beef cattle production (Abo-Elfadl *et al*., 2015; Aytekin *et al*., 2017). When Node 3 (the subgroup of enterprises rearing cultural beef cattle with 280 < initial live weight ≤ 400 kg) was examined, the effect of PL on the FFW in the beef cattle could be changed by levels of farmer's age, and sex of the beef cattle. These results obtained for Nodes 2, 5, 6, 11 and 12 were in disagreement with those given in earlier publications (Abo-Elfadl *et al*., 2015; Aytekin *et al*., 2017). For Node 3, the heaviest mean FFW of 736 kg in the CHAID analysis was obtained by enterprises' age ranging from 46 to 49 with PL ≤ 12 da and reared the beef cattle with the first live weight of (280, 400] kg. Abo-Elfadl *et al*. (2015) reported that socio-economic and biological factors conjointly influenced FFW in assuring better level of the beef cattle production.

Sex had an important effect on FFW performance (Demircan *et al*., 2007; Dadi *et al*., 2017). However, sex factor was determined to be a significant factor for only enterprises rearing cultural beef cattle with 280 < initial live weight ≤ 400 kg, having PL > 12 da. This also confirmed the declaration of Abo-Elfadl *et al*. (2015).

No significant predictors affecting the FFW for enterprises that reared cultural beef cattle with the first live weight heavier than 400 kg were noted (Node 4). The data might be a principal hint in practice for cultural beef cattle enterprises in the region handled here.

MARS algorithm

MARS algorithm produced a prediction model estimating the smallest GCV and the respective results are summarized in Table I. The R^2 value of 0. 9832 estimated for the MARS predictive model indicated that the constructed model explained just about all of the variability in the FFW in cultural beef cattle enterprises. A very strongly correlation of 0.992 was found between the observed and predicted FFW scores ($P<0.001$). The respective SD ratio gave a very good fit with 0.114. According to the goodness of fit criteria, MARS showed a very good fit and outperformed CHAID in the predictive accuracy of FFW.

Table I.- Results of MARS algorithm for the final fattening live weight in cultural beef cattle.

Basis functions	Coefficients
Intercept	384.87911
EDUL_highschool	7.11997
max(0, 20-EFAP)	15.91426
max(0, EFAP-20)	0.79740
max(0, 200-DLF)	0.47125
max(0, DLF-200)	-2.94026
max(0, 120-FATPERIOD)	0.17154
max(0, FATPERIOD-120)	-0.88915
max(0, FIRSTLIVEWEIGHT-200)	-0.46506
max(0, 350-FIRSTLIVEWEIGHT)	0.10874
max(0, FIRSTLIVEWEIGHT-350)	0.29996
EDUL_COLLEGE * max(0, 350-FIRSTLIVEWEIGHT)	1.81014
EFAP * max(0, DLF-200)	0.09148
APAP_HOME&TRADE * max(0, DLF-200)	0.85320
max(0, 200-DLF) * SEXM	-0.21121
max(0, FIRSTLIVEWEIGHT-200) * SEXM	0.37258
max(0, FIRSTLIVEWEIGHT-350) * SEXM	-3.10924
max(0, 47-FARMERAGE) * max(0, FATPERIOD-120)	-0.07735
max(0, FARMERAGE-47) * max(0, FATPERIOD-120)	0.00503
max(0, 50-FARMERAGE) * max(0, FIRSTLIVEWEIGHT-200)	0.00877
max(0, FARMERAGE-50) * max(0, FIRSTLIVEWEIGHT-200)	-0.02602
max(0, EFAP-20) * max(0, DLF-13)	-0.01879
max(0, EFAP-20) * max(0, 13-DLF)	-0.20737
max(0, 18-EFAP) * max(0, 350-FIRSTLIVEWEIGHT)	0.02416
max(0, EFAP-18) * max(0, 350-FIRSTLIVEWEIGHT)	0.02441
max(0, EFAP-20) * max(0, FIRSTLIVEWEIGHT-300)	-0.02521
max(0, EFAP-20) * max(0, 300-FIRSTLIVEWEIGHT)	-0.02456
max(0, 38-ILF) * max(0, FATPERIOD-120)	-0.00307
max(0, ILF-38) * max(0, FATPERIOD-120)	0.00084
max(0, 40-DLF) * max(0, FIRSTLIVEWEIGHT-200)	0.00677
max(0, DLF-40) * max(0, FIRSTLIVEWEIGHT-200)	0.00947
max(0, 200-DLF) * max(0, FIRSTLIVEWEIGHT-300)	0.00787
max(0, 200-DLF) * max(0, 300-FIRSTLIVEWEIGHT)	-0.00412
max(0, 25-PF) * max(0, FIRSTLIVEWEIGHT-200)	-0.01456
max(0, PF-25) * max(0, FIRSTLIVEWEIGHT-200)	0.00667
max(0, FATPERIOD-120) * max(0, FIRSTLIVEWEIGHT-300)	-0.06258
max(0, FATPERIOD-120) * max(0, 300-FIRSTLIVEWEIGHT)	-0.00298
max(0, FATPERIOD-120) * max(0, FIRSTLIVEWEIGHT-270)	0.06257
max(0, 180-FATPERIOD) * max(0, 350-FIRSTLIVEWEIGHT)	-0.00719
max(0, FATPERIOD-180) * max(0, 350-FIRSTLIVEWEIGHT)	0.01533
PROVINCE_IGDIR * max(0, FIRSTLIVEWEIGHT-350) * SEXM	-4.29574
EDUL_secondaryschool * max(0, FIRSTLIVEWEIGHT-350) * SEXM	3.43052
PROVINCE_ERZURUM * max(0, 47-FARMERAGE) * max(0, FATPERIOD-120)	0.11606
PROVINCE_KARS * max(0, DLF-40) * max(0, FIRSTLIVEWEIGHT-200)	0.00518
max(0, FARMERAGE-47) * APAP_TRADE * max(0, FATPERIOD-120)	-0.17463
max(0, 40-FARMERAGE) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	0.35752
max(0, FARMERAGE-40) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	0.04758
EDUL_highschool * max(0, FATPERIOD-120) * max(0, 300-FIRSTLIVEWEIGHT)	-0.00664
EDUL_COLLEGE * max(0, 18-EFAP) * max(0, 350-FIRSTLIVEWEIGHT)	-0.40413

Basis functions	Coefficients
max(0, 25-EFAP) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	-0.07910
max(0, EFAP-25) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	-0.01070
APAP_TRADE * max(0, FATPERIOD-120) * max(0, 300-FIRSTLIVEWEIGHT)	0.01324
max(0, 20-ILF) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	0.02673
max(0, ILF-20) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	0.00389
max(0, FARMERAGE-47) * max(0, FATPERIOD-120) * max(0, FIRSTLIVEWEIGHT-250)	0.00096
max(0, FARMERAGE-47) * max(0, FATPERIOD-120) * max(0, 250-FIRSTLIVEWEIGHT)	-0.00050
max(0, 50-ILF) * max(0, 40-DLF) * max(0, FIRSTLIVEWEIGHT-200)	0.00066
max(0, ILF-50) * max(0, 40-DLF) * max(0, FIRSTLIVEWEIGHT-200)	-0.00074
max(0, 40-DLF) * max(0, PF-20) * max(0, FIRSTLIVEWEIGHT-200)	-0.00029
max(0, 40-DLF) * max(0, 20-PF) * max(0, FIRSTLIVEWEIGHT-200)	-0.00119
EDUL_secondaryschool * DLF * max(0, FIRSTLIVEWEIGHT-350) * SEXM	-0.45972
max(0, 40-FARMERAGE) * EDUL_highschool * max(0, FIRSTLIVEWEIGHT-200) * SEXM	-0.32736
max(0, FARMERAGE-40) * max(0, PF-10) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	-0.00194
max(0, FARMERAGE-40) * max(0, 10-PF) * max(0, FIRSTLIVEWEIGHT-200) * SEXM	-0.00213
EDUL_secondaryschool * max(0, ILF-50) * max(0, 40-DLF) * max(0, FIRSTLIVEWEIGHT-200)	0.00029
EFAP * max(0, ILF-50) * max(0, 40-DLF) * max(0, FIRSTLIVEWEIGHT-200)	0.00004

PROVINCE, this presents province where farmer lives, (Erzurum, Agri, Igdir and Kars); FARMERAGE, age of Farmer; EDUL, education level (illiterate, primary_school, secondary_school, high_school and college); SOCSEC, social security available and unavailable; APAP, the aim in performing animal production, to meet home's needs (home), to trade (trade), home and trade (home&trade); EFAP, experience of farmer in animal production; ILF, irrigated land (da) of farmer; DLF, dry land (da) of farmer; PF, pasturage (da) of farmer; FATPERIOD, fattening period (day) of male crossbred beef cattle; FIRSTLIVEWEIGHT, the first live weight before fattening (kg).

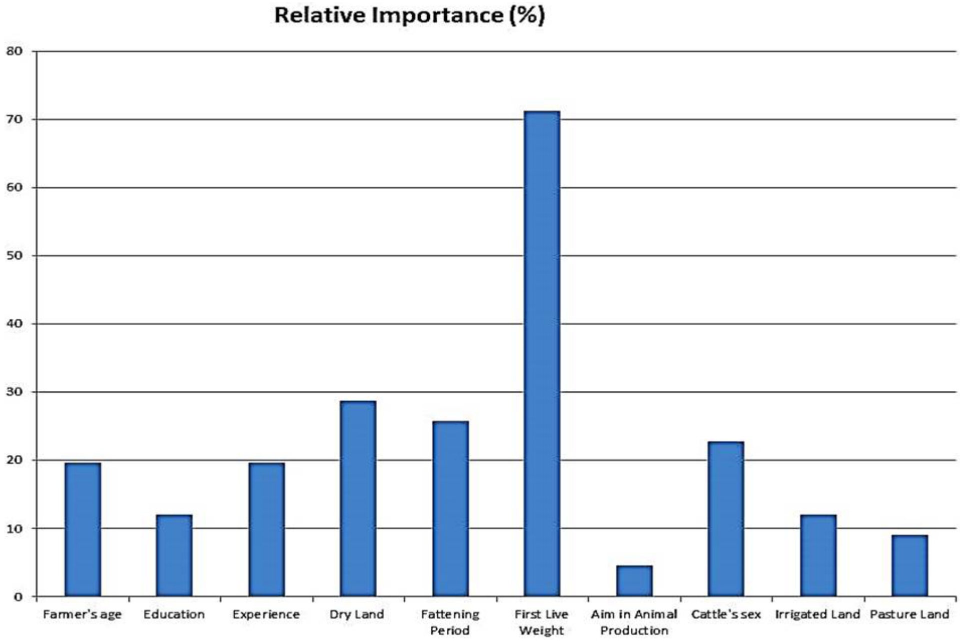

Fig. 2. Relative importance values of the influential predictors in MARS.

Pearson correlations of CHAID and MARS algorithm (0.819 vs. 0.992) showed the predictive superiority of MARS algorithm in the FFW (P<0.05). The present MARS results were a bit better compared with those reported by Aytekin *et al.* (2017) in the FFW. The achieved results were in accordance with those obtained by Demircan (2008) and Muižniece and Kairiša (2016) who declared the significance of the first live weight before fattening in beef cattle production. Relative importance values of the influential predictors in MARS are presented in Figure 2. The most influential four predictors were first live weight > dry land > fattening period > cattle's sex (Fig. 2).

Some former authors said that fattening period was a significant source of variation in FFW for the beef cattle production (Abo-Elfadl *et al*., 2015; Aytekin *et al*., 2017). As an important source of variation in FFW was reported to be sex of the beef cattle reared (Demircan *et al*., 2007; Dadi *et al*., 2017); however, it was observed in our study that the effect of sex factor on FFW could be changed based upon DLF, the first live weight before fattening, farmer's province, educational level, age, EFAP, ILF, and PF, which supported the declaration of Abo-Elfadl *et al*. (2015), who highlighted that socio-economic and biological predictors affected FFW in assuring better production level of the beef cattle. In disagreement with those obtained in our study, Kocak *et al*. (2004) declared the effect of fattening season on fattening performance in Holstein young bulls. Papa and Kume (2010) informed that crossbred cattle's genetic levels had a significant influence on FFW.

Malole *et al*. (2014) addressed the ration factor for live weight gain at the end of fattening. Previous authors reported that farmer's age, educational degree, and number of animals in cattle breeding enterprises in Turkey were prominent factors in cattle breeding (Uzal and Uğurlu, 2006; Han and Bakır, 2009; Aydın, 2011; Aksoy and Yavuz, 2012; Er and Özçelik, 2016).

The large variation in literature were attributable to social factors (farmer's educational degree, age, province and social security situation), biological and economic factors (season, cattle's breed, cattle's sex, first live weight before fattening, and fattening period), managerial conditions, main and interaction effects of these factors as well as, to statistical analysis techniques *etc*.

CONCLUSION

In the study, we found predictors affecting FFW in the cultural beef cattle with the help of MARS and CHAID algorithms. Results showed that MARS outperformed CHAID in the predictive accuracy of FFW. In the CHAID algorithm, the first live weight, farmer's age, pasture land, SOCSEC, fattening period and sex of the beef cattle were found for FFW as the influential predictors, whereas main and interaction effects of all the predictors handled here were found significant in the MARS. In this respect, we advised that social-economic and biological factors in FFW of the cultural beef cattle should be assessed conjointly by MARS algorithm, which is used without requiring any distributional assumption regarding influential predictors. It was concluded that implementation of MARS algorithm may be recommended for future similar studies.

Statement of conflict of interest

Authors have declared no conflict of interest.

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