The effect of robotic milking systems on economic performance of dairy farms with a simulation model

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Abstract

The most remarkable technology brought to dairy farms by the digital transformation in agriculture is undoubtedly robotic milking systems (RMS). Knowing the economic impact of this technology is essential for farmers to adopt. For this purpose, in the study; a simulation model was created that gives possible economic analysis results as a result of the use of RMS by using the current economic analysis results of dairy farms. For the economic analysis of dairy farms, data obtained from face-to-face surveys from 148 dairy farms were used. Assumptions used in the simulation model for comparing RMS and conventional milking systems (CMS) were 8.66% increase in milk yield, 58.46% increase in investment costs, 36.66% increase in energy consumption, 1.33% increase in feed costs and 27.84% decrease in labor input. The economic analysis of the dairy farms was made again with these new input and output values obtained. While the simulation results show that the use of RMS is a preferable investment that increases profitability for 10-60 head and 121 + head groups; it shows that it will be an investment that negatively affects profitability for the 61-120 head group. The simulation model was used by taking the average values of the data belonging to the dairy farm groups. A dairy farmer considering an RMS investment can be able to obtain a result specific to his farm if he combines the simulation model with his own economic analysis results.

Keywords: *Robotic milking systems, Simulation model, Economic analysis.*

1. Introduction

Innovation in agriculture and the food sector is particularly important in countries such as Turkey, where agriculture has a high share of national gross domestic product (GDP) (Ben Hassen and El Bilali, 2021). The main element of innovation in the production process is the use of innovative technology. For this reason, it is extremely critical for the sustainability of livestock activities that farmers keep up with these changes by following new technologies and innovations (Yener Ögür, 2021).

The most important technological innovation in the dairy industry in recent years is undoubtedly robotic milking systems (RMS). In 1992, Lely, a Dutch company, installed the first milking robot as part of a project in its own coun-

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try (Schewe and Stuart, 2015). After the introduction of the first RMS, the adoption of the new technological innovation proceeded slowly and in 1996 only about 45 installations were used on commercial farms with the majority in the Netherlands. By the end of 2009, RMS was estimated to be deployed on more than 8,000 dairy farms in over 25 countries worldwide. The number rose to 10,000 by 2010 and to 30,000 in 2017 (Jiang *et al.*, 2017). Today, the number of RMS has risen to 50,000 (Simões Filho *et al.*, 2020).

Different simulation studies have been carried out to reveal the benefits and disadvantages of RMS. Dijkhuizen *et al.* (1997) examined the economic consequence of using this technology in place of a conventional parlor system on dairy farms. Some assumptions with respect to size of operation, general costs and tax rates were made to perform the study. Cooper and Parsons (1998) used a simulation model to test the benefits and drawbacks of robotic or fully automated milking systems. In their study, they used a three-phase discrete simulation model to study system performance under different management options and to analyze the effect of herd size, milk yield and calving pattern. As a result of the study, they presented the findings obtained under different scenarios. In their next study, Cooper and Parsons (1999) examined the economic and logistic results of dairy farms using robotic or fully automatic milking systems with this simulation model they established. They combined the A three-phase discrete simulation model with economic analysis of real farms with a herd size of 85-95 heads. As a result of the study, they revealed economic benefits and costs.

Veysset *et al.* (2001) applied a questionnaire to 44 dairy farms using RMS in their study. By using the survey results, simulations were carried out in three types of dairy farms with 60, 80 and 100 dairy cows. They interpreted the simulation results through economic factors. Hyde and Engel (2002) used Monte Carlo simulation methods to estimate the breakeven value for a RMS on a dairy farm. The analysis simulates several scenarios under three herd sizes, 60, 120, and 180 cows. As a result of the study, the breakeven values where the costs of production equal the revenues for a product, were $192,056, $374,538, and $553,671, respectively. Tranel and Schulte (2013) developed a partial budget spreadsheet tool, in order to assist dairy producers to make informed decisions on the economic variables associated with RMS. This tool they have developed reveals positive and negative impacts by making calculations on the economic assumptions about RMS. Generally, the technical features of milking robots and their effects on animal welfare were studied in Turkey and there are hardly any studies on their economic performance. Örs and Oğuz (2016, 2018) compared the economic performance of robotic milking system (RMS) and conventional milking system (CMS). In their study literature about economic comparison of RMS and CMS was reviewed by using the data from 33 studies carried out in 13 different countries from 1998 to 2017.

Although the use of RMS is increasing day by day in Turkey, question marks remain on the economic performance of these systems. The aim of the study is to simulate the economic performance results of dairy farms using robotic milking systems and to compare the results with their current economic situation. For this purpose, economic analyzes were carried out with the data collected through questionnaires from 148 dairy farms. The results of these economic analysis and the new results simulated with the economic performance assumptions of the RMSs are compared.

2. Materials and methods

2.1. *Materials*

The analysis was carried out through the 148 dairy farm data which were obtained through the interviews in Konya. Survey data span the period between May 2017 and November 2017. In addition to these data, previous research findings and publications were also used as a secondary material. In this study, $1 = 3.58 Turkish Liras calculated that was the average exchange rate of the dates of the field study was done.

2.2. *Methods*

2.2.1. *The method used in sampling*

As a research area, Konya province was selected according to the "judgment sampling method". By the presence of cattle and milk production, Konya is the first province in Turkey. In Konya the cattle number was 740.148 head and milk production were 1.018.917 tons (Turkish Statistical Institute). The main frame of dairy farms was determined as 4.209 establishments in 16 districts of Konya. The Neyman method from the stratified sampling method was used in the calculation of sample volume. According to the Neyman method, the equation that determines the sample volume was formulated as follows (Yamane, 1967).

$$n = \frac{[\Sigma(N_h S_h)]^2}{N^2 D^2 + \Sigma[N_h (S_h)^2]} \quad (1)$$

In formula; n = sample volume, N = total unit number belonging to the sampling frame, S = standard deviation of sample mean, S^2 = variance, D = d / t, d = derivation from the average, t = standard normal distribution value. The sample volume was determined by using the number of milking cows. The sample size was calculated for a confidence interval of 95% and an error margin of 5%. As a result, 150 dairy farms were determined as total sample volume.

2.2.2. *The method used in the economic analysis of dairy farms*

In the milk production cost and profitability calculations of the farms, they evaluated only by taking into account the dairy cattle production activity. The inputs and outputs of the dairy cattle farms used in calculations were given in Figure 1.

Total production costs of the dairy cattle farms were calculated separately as variable and fixed operating costs (Geetha and Lavanya, 2013; Oğuz and Bayramoğlu, 2015; Tapkı, 2019). In the research, the costs which were increasing or decreasing depending on the production volume were evaluated as variable costs and the costs not related to production amount were considered as fixed costs (Güneş, 2004; Hanrahan *et al.*, 2018). The items used in the variable and fixed cost calculations were shown in Figure 1.

The gross production value for dairy cattle was calculated by adding up the value of total milk, which was the main product, the increase in productive stock value (PSV) and farm fertilizer which were by-products (Aşkan and Dağdemir, 2016; Çetin, 2013; Kumawat *et al.*, 2014; Ramsbottom *et al.*, 2015). The increase in productive stock value (PSV) was calculated by taking into account factors that cause animal movements such as birth, death, changing age, buying, selling and consumption of animals. For this purpose, the following formula was used (Kıral *et al.*, 1999; Örs and Oğuz, 2019).

PSV = (year end stock value + value of the sold stock + value of the stock slaughtered) – (value of the stock at the beginning of year + value of the stock bought)

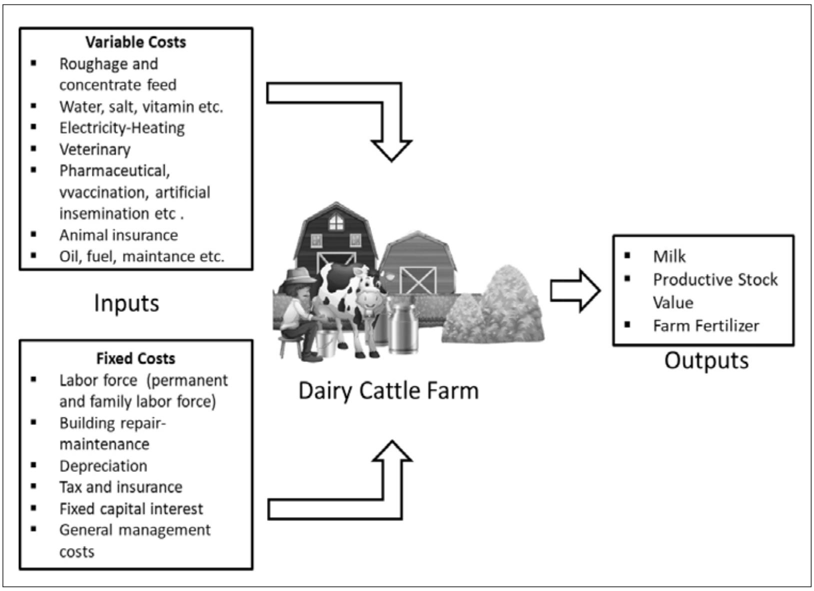
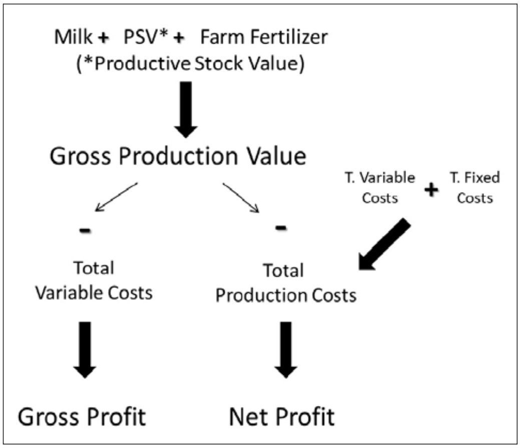


Figure 1 - Inputs and outputs scheme of dairy cattle farms.

Source: Research results.

Figure 2 - Gross and net profit calculation scheme of dairy cattle farms.



Source: Research results.

Gross profit was calculated by subtracting the variable costs from the gross production value while net profit was calculated by subtracting total production costs from gross production value (Açıl and Demirci, 1984; Demircan *et al.*, 2006; Hanrahan *et al.*, 2018; Ramsbottom *et al.*, 2015; Shoemaker *et al.*, 2008).

The relative sales value method was used to calculate the unit milk cost. In this method, the total production cost was distributed according to the contribution of each compound product to the gross production value and the cost of each product was divided by the amount of production and the unit costs are calculated (Kıral et al., 1999). The following formula was used to calculate the unit milk cost:

Unit Milk Cost = Milk Production Cost ($) / Total Milk Production Amount (kg)

2.2.3. *The method used in the economic simulation model of the robotic milking system*

For economic analysis of dairy farms, the data obtained from 150 dairy farms as a result of a face-to-face survey in the study of Örs and Oğuz (2019) were used. Two dairy farms already using milking robots had not been evaluated, and the data of 148 dairy farms had been used in the economic analysis. Since one milking robot for every 60 dairy cattle is recommended by the RMS manufacturers, economic analyzes were carried out by forming farm size groups as 10-60 head, 61-120 head and 121 head and above dairy cattle.

Table 1 - Assumptions used in the economic analysis of dairy farms using RMS.

Affected factor	*Percent change (%)*
Milk yield	8.66
Investment cost	58.46
Energy consumption	36.66
Feed cost	1.33
Labor input	- 27.84

For the economic performance assumptions of RMS, the results of Örs and Oğuz (2018)'s study in which 33 research results from 13 countries were analyzed were used. Assumptions used in the simulation model for comparing RMS and conventional milking systems (CMS) are; 8.66% increase in milk yield, 58.46% increase in investment costs, 36.66% increase in energy consumption, 1.33% increase in feed costs and 27.84% decrease in labor input (Table 1). These assumed percentage change values had been applied to the respective input and output items. The economic analysis of the dairy farms was made again with these new input and output values obtained.

Percentage change assumptions in the economic performance of the RMS and the affected input and output items were schematized in Figure 3 to form the main frame of the study.

2.2.4. *Paired samples t-test*

In the study, paired samples t-test was used to test whether there is a significant difference between the economic performances of dairy farms as a result of using CMS and RMS systems.

The parametric test performed to determine whether there is a statistically significant difference between the means of the data values obtained as a result of two consecutive measurements on the same data source is called the paired samples t-test. In order for the test to give reliable results, the data set should show a normal distribution. In the paired samples t-test, the effect size can be found by dividing the mean value by the standard deviation by using paired differences table (Can, 2018).

Net profits of CMS and RMS were used in paired samples t-test. Firstly, normality test was

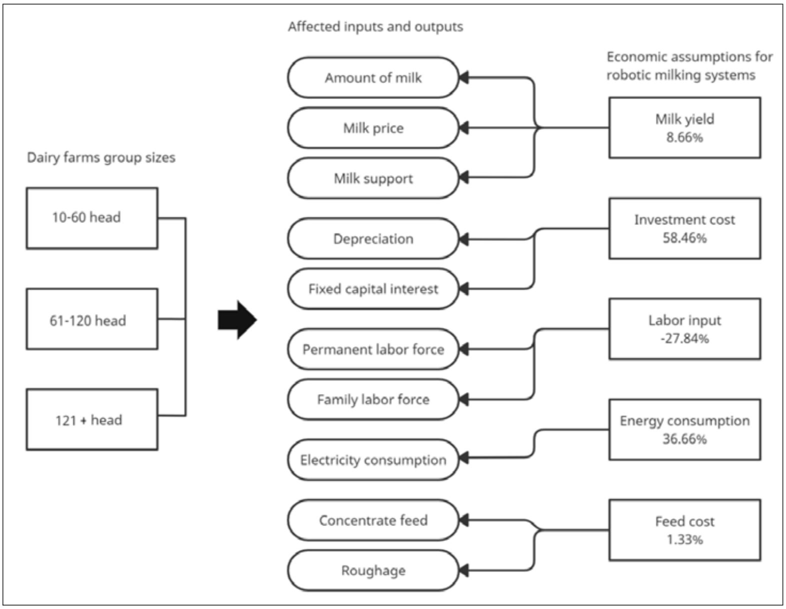


Figure 3 - The main frame of the study and the assumptions.

performed by using the package program. Data of all groups show normal distribution. Then, paired samples t-test was performed separately for each of the three groups. The effect size value (d) was evaluated above 1 as very large, 0.8 as large, 0.5 as medium and 0.2 as small effect (Green and Salkind, 2013).

3. Results

3.1. *General information about the dairy farms examined*

As a result of the analysis of the survey data, general information about dairy farms is presented in Table 2.

As a result of the study, the average economic performance indicators for dairy farms were calculated as gross production value (GPV) $428,967.56, gross profit $183,620.58, net profit $76,224.20 and unit milk cost $0.31/kg. Oguz and Yener (2018) calculated the GPV as $194,492.69, the gross profit as $90,257.46 and the unit milk cost as $0.31 in the Konya region. Özsayın (2019), calculated the average GPV as $53,583.48, gross profit as $23,302.29, net profit as $44,80.41 and unit milk cost as $0.30. Although the gross production value and profit values differ according to the size of dairy farms, unit milk costs were close to each other in all studies.

3.2. *Economic analysis of dairy farms with 10-60 head milking cows*

CMS and RMS economic analysis results for 10-60 head dairy farm group is presented in Table 3 comparatively.

As a result of the use of RMS, the increase in concentrate feed, roughage and energy costs in-

Table 2 - General information of the dairy farms.

Groups (head milking cows)	*Dairy farms (number)*	*Milking cows (head)*	*Gross production value ($)*	*Total production costs ($)*	*Gross profit ($)*	*Net profit ($)*	*Unit milk cost ($/kg)*
10-60	96	24	93,079.30	95,930.85	30,625.23	-2,851.55	0.39
61-120	39	97	415,375.08	362,831.98	166,442.17	52,543.10	0.34
121+	13	165	778,448.32	599,467.26	353,794.33	178,981.06	0.31
Total /Av.	148	95	428,967.56	352,743.36	183,620.58	76,224.20	0.35

creased the total variable costs from $62,454 to $63,471. Despite the decrease in the family labor force and permanent labor force, the total fixed expenses increased from $33,477 to $38,187 as a result of high depreciation, interest on fixed capital and general administrative expenses. With this increase in variable and fixed costs as a result of the use of RMS, the total operating costs increased from $95,931 to $101,658. With the increase in yield resulting from the use of RMS, there had been an increase in milk income and livestock support (including milk support). The total income of dairy enterprises increased from $102,771 to $119,759. Looking at the profitability values, the gross profit ranged from $30,625 to $45,470; net profit increased from -$2,852 to $7,283. This dairy farm group, which made a loss in terms of net profit, became profitable as a result of using RMS (Table 3).

When we look at the unit milk cost values, the unit milk costs before and after the support are very close to each other in the use of CMS and RMS. However, as a result of the use of RMS, there is an increase in the unit milk cost, even if it is less than 1 cent.

3.3. *Economic analysis of dairy farms with 61-120 head milking cows*

CMS and RMS economic analysis results for 61-120 head dairy farm group is presented in Table 4 comparatively.

As a result of the use of RMS, the increase in concentrate feed, roughage and energy costs increased the total variable costs from $248,933 to $254,106. Despite the decrease in the family labor force and permanent labor force, the total fixed expenses increased from $113,899 to $140,157 as a result of high depreciation, interest on fixed capital and general administrative expenses. With this increase in variable and fixed costs as a result of the use of RMS, the total operating costs increased from $362,832 to $394,263. With the increase in yield resulting from the use of RMS, there had been an increase in milk income and livestock support (including milk support). The total income of dairy enterprises increased from $459,560 to $490, 748. Looking at the profitability values, the gross profit ranged from $166,442 to $190,568. However, net profit including fixed costs decreased from $52,543 to $50,411 due to the high investment cost of the RMS system. Looking at net profit, this dairy farm group has lost profits as a result of using RMS (Table 4).

When we look at the unit milk cost values, the unit milk costs before and after the support are very close to each other in the use of CMS and RMS. However, similar to the first group, as a result of the use of RMS, there is an increase in the unit milk cost, even if it is less than 1 cent.

3.4. *Economic analysis of dairy farms with 121 head and above milking cows*

CMS and RMS economic analysis results for 121 head and over dairy farm group is presented in Table 5 comparatively. As a result of the use of RMS, the increase in concentrate feed, roughage and energy costs increased the total variable costs from $424,654 to $433,749. Despite the decrease in the family labor force and permanent labor force, the total fixed expenses increased from $174,813 to $208,726 as a result of high depreciation, interest on fixed capital and general administrative expenses. With this increase in variable and fixed costs as a result of the use of RMS, the total operating costs increased from $599,467 to $642,476.

With the increase in yield resulting from the use of RMS, there had been an increase in milk income and livestock support (including milk support). The total income of dairy enterprises increased from $861,007 to $921,068. Looking at the profitability values, the gross profit ranged from $353,794 to $401,277; net profit increased from $178,981 to $192,551. This dairy farm group, which makes a profit in terms of net profit, has increased its profits as a result of using RMS (Table 5).

When we look at the unit milk cost values, the unit milk costs before and after the support are very close to each other in the use of CMS and RMS. Similar to the first two groups, there is an increase in the unit milk cost after supports, although it is less than 1 cent as a result of the use of RMS, while unlike the first two groups, there is a decrease in the unit cost of milk before supports in this group.

Table 3 - CMS and RMS economic analysis results for 10-60 head dairy farm group.

CMS (10-60 head)		*RMS (10-60 head)*
$/Year		*$/Year*
	Costs	
	Variable Costs	
29,941.99	Concentrate Feed	30,340.21
26,467.48	Roughage	26,819.50
619.38	Water-Salt-Vitamin	619.38
727.28	Electricity-Heating	993.89
1,513.17	Veterinary-Pharmaceutical-Vaccination	1,513.17
839.07	Artificial Insemination	839.07
259.47	Animal Insurance	259.47
2,086.24	Oil-Fuel- Maintenance	2,086.24
62,454.07	*Total Variable Costs (A)*	*63,470.93*
	Fixed Costs	
12,134.25	Depreciation Expenses	17,405.89
2,853.40	Building Repair-Maintenance Expenses	2,853.40
2,612.92	Permanent Labor Force	1,885.49
7,505.02	Family Labor Force	5,415.62
51.05	Tax and Insurance	51.05
6,446.52	Fixed Capital Interest	8,671.38
1,873.62	General Management Costs (%3)	1,904.13
33,476.78	*Total Fixed Costs (B)*	*38,186.96*
95,930.85	*Total Production Costs (C) = (A+B)*	*101,657.90*
	Incomes	
72,369.33	Milk Value (D)	88,230.84
17,778.17	Productive Stock Value (E)	17,778.17
2,931.80	Farm Fertilizer Value (F)	2,931.80
9,691.98	Livestock Supports (G)	10,818.65
102,771.27	*Total Incomes (H) = (D + E + F + G)*	*119,759.46*
93,079.30	*Gross Production Value (I) = (D + E + F)*	*108,940.80*
30,625.23	*Gross Profit (J) = (I - A)*	*45,469.87*
-2,851.55	*Net Profit (K) = (I - C)*	*7,282.91*
53,760.86	Milk Production Amount (kg) (L)	58,416.55
74,586.42	Milk Production Costs (M) =(C x %D/100)	82,332.43
0.37	Milk Sales Price ($/kg)	0.39
0.388	*Unit Milk Cost (N) = (M / L)*	*0.394*
0.337	*Unit Milk Cost by Livestock Supports (P) = (M - G) / (L)*	*0.342*

**Grey colored cells are positively affected values; Black colored cells are negatively affected values.*

3.5. *Comparison of economic performance of dairy farm groups*

Table 6 was created by subtracting the economic performance results of CMS from the economic performance results of RMS. The difference values are presented in the table in dollars and percentages. When Table 6 is examined, it is seen that the use of RMS increases operating costs and total income at the same time. As a result of the use of RMS, there has been an increase in gross profit in all dairy farm groups; Net profit increased in dairy farm groups with 10-60 heads and 121 heads and above. In the group of dairy farms with 61-120 head milking cows, there was a decrease in net profit as a result of the use of RMS.

RMS and CMS economic performance dif-

Table 4 - CMS and RMS economic analysis results for 61-120 head dairy farm group.

CMS (61-120 head)		*RMS (61-120 head)*
$/ Year		*$/ Year*
	Costs	
	Variable Costs	
115,971.55	Concentrate Feed	117,513.97
99,038.51	Roughage	100,355.72
4,711.36	Water-Salt-Vitamin	4,711.36
6,310.70	Electricity-Heating	8,624.20
6,577.85	Veterinary-Pharmaceutical-Vaccination	6,577.85
5,470.56	Artificial Insemination	5,470.56
3,173.53	Animal Insurance	3,173.53
7,678.84	Oil-Fuel- Maintenance	7,678.84
248,932.90	*Total Variable Costs (A)*	*254,106.04*
	Fixed Costs	
48,098.88	Depreciation Expenses	70,583.21
12,245.65	Building Repair-Maintenance Expenses	12,245.65
16,507.95	Permanent Labor Force	11,912.14
3,834.16	Family Labor Force	2,766.73
635.22	Tax and Insurance	635.22
25,109.22	Fixed Capital Interest	34,390.56
7,467.99	General Management Costs (%3)	7,623.18
113,899.07	*Total Fixed Costs (B)*	*140,156.69*
362,831.98	*Total Production Costs (C) = (A+B)*	*394,262.73*
	Incomes	
338,323.08	Milk Value (D)	367,621.86
65,914.63	Productive Stock Value (E)	65,914.63
11,137.37	Farm Fertilizer Value (F)	11,137.37
44,184.73	Livestock Supports (G)	46,074.23
459,559.81	*Total Incomes (H) = (D + E + F + G)*	*490,748.09*
415,375.08	*Gross Production Value (I) = (D + E + F)*	*444,673.86*
166,442.17	*Gross Profit (J) = (I - A)*	*190,567.82*
52,543.10	*Net Profit (K) = (I - C)*	*50,411.13*
242,430.11	Milk Production Amount (kg) (L)	263,424.56
295,526.71	Milk Production Costs (M) =(C x %D/100)	325,945.85
0.39	Milk Sales Price ($/kg)	0.39
0.341	*Unit Milk Cost (N) = (M / L)*	*0.346*
0.290	*Unit Milk Cost by Livestock Supports (P) = (M - G) / (L)*	*0.297*

**Grey colored cells are positively affected values; Black colored cells are negatively affected values.*

ferences are presented in Figure 4. When we look at the graph given in dollars, it is seen that there is a greater difference in production costs, total income and gross profit in dairy farms with more animals in proportion to the size of the enterprises. However, the situation changes when net profit is taken into account. In the chart, the difference between the 10-60 head group and the 121 head and above group are very close to each other for net profit, while this difference is low and negative for the 61-120 head group.

When we look at the graph given as a percentage, we can talk about the opposite of the dollar graph. The percentage difference of the 10-60 head group with the fewest animals is much higher than the other groups. The percentage increase in gross profit and net profit values, espe-

Table 5 - CMS and RMS economic analysis results for 121 head and above dairy farm group.

CMS (121+ head)		*RMS (121+ head)*
$/ Year		*$/Year*
	Costs	
	Variable Costs	
196,092.18	Concentrate Feed	198,700.20
164,754.42	Roughage	166,945.65
10,249.25	Water-Salt-Vitamin	10,249.25
11,718.95	Electricity-Heating	16,015.12
13,472.28	Veterinary-Pharmaceutical-Vaccination	13,472.28
8,917.06	Artificial Insemination	8,917.06
6,414.18	Animal Insurance	6,414.18
13,035.67	Oil-Fuel- Maintenance	13,035.67
424,653.99	*Total Variable Costs (A)*	*433,749.41*
	Fixed Costs	
70,908.84	Depreciation Expenses	102,919.65
15,076.48	Building Repair-Maintenance Expenses	15,076.48
36,791.58	Permanent Labor Force	26,548.80
2,041.79	Family Labor Force	1,473.36
715.01	Tax and Insurance	715.01
36,539.95	Fixed Capital Interest	48,980.53
12,739.62	General Management Costs (%3)	13,012.48
174,813.27	*Total Fixed Costs (B)*	*208,726.32*
599,467.26	*Total Production Costs (C) = (A+B)*	*642,475.73*
	Incomes	
653,325.84	Milk Value (D)	709,903.86
106,789.86	Productive Stock Value (E)	106,789.86
18,332.62	Farm Fertilizer Value (F)	18,332.62
82,559.09	Livestock Supports (G)	86,041.57
861,007.41	*Total Incomes (H) = (D + E + F + G)*	*921,067.91*
778,448.32	*Gross Production Value (I) = (D + E + F)*	*835,026.34*
353,794.33	*Gross Profit (J) = (I - A)*	*401,276.92*
178,981.06	*Net Profit (K) = (I - C)*	*192,550.61*
446,815.21	Milk Production Amount (kg) (L)	485,509.41
503,112.98	Milk Production Costs (M) =(C x %D/100)	546,205.53
0.41	Milk Sales Price ($/kg)	0.41
0.315	*Unit Milk Cost (N) = (M / L)*	*0.314*
0.263	*Unit Milk Cost by Livestock Supports (P) = (M - G) / (L)*	*0.265*

**Grey colored cells are positively affected values; Black colored cells are negatively affected values.*

cially in the 10-60 head group as a result of the use of RMS, is much higher than other groups.

3.6. *Results of paired samples t-test*

It is investigated whether there is a significant difference between the CMS and RMS results of the Dairy farm groups and the effect size. The results of the paired samples t-test performed to determine the difference between the net profitability of CMS and RMS are given in Table 7.

As a result of the t-test, a significant difference ($t_{10\text{-}60}$ =-14.50, $p_{10\text{-}60}$ = .000; $t_{61\text{-}120}$ = 17.34, $p_{61\text{-}120}$ =. 000; t_{121+} = -8.03, p_{121+} =. 000) was observed between the average net profits of the current production ($\bar{X}_{CMS10\text{-}60}$ = 31,615.04; $\bar{X}_{CMS61\text{-}120}$ = 357,624.34; $\bar{X}_{CMS121+}$ = 890,481.49) and the average of the net profits after the economic simulation

Table 6 - Comparison of economic performance differences of dairy farm groups.

	10-60 head ($)	*10-60 head (%)*	*61-120 head ($)*	*61-120 head (%)*	*121 + head ($)*	*121 + head (%)*
Total Production Costs	5,727.05	5.97	31,430.75	8.66	43,008.47	7.17
Total Incomes	16,988.19	16.53	31,188.28	6.79	60,060.50	6.98
Gross Profit	14,844.64	48.47	24,125.65	14.49	47,482.59	13.42
Net Profit	10,134.46	355.40	-2,131.97	-4.06	13,569.55	7.58

model of the robotic milking system ($\bar{X}_{RMS10\text{-}60}$ = 86,878.12; $\bar{X}_{RMS61\text{-}120}$ = 539,328.29; $\bar{X}_{RMS121+}$ = 1,054,636.02) for all three groups. As a result of the test, the effect sizes of all groups ($d_{10\text{-}60}$ =1.48; $d_{61\text{-}120}$ = 2.78; d_{121+} = 2.23) were above 1 and this show that the difference is at a very large level.

4. Conclusions

In this study, RMS economic analysis results of dairy farm groups were created as a result of the simulation performed by combining real dairy farm economic analysis data and RMS assumptions. While the simulation results show that the use of RMS is a preferable investment that increases profitability for 10-60 head and 121 + head groups; It shows that it will be an investment that negatively affects profitability for the 61-120 head group.

As a result of the use of RMS in the study, it is seen that the net profit for the 10-60 head group increased at a very high rate, such as 355%, and turned from negative profitability to positive profitability. When the data is examined, it is seen that this increase is not due to the use of RMS alone. The most important factor affecting this increase is that most of the 10-60 head group enterprises sell uncooled raw milk. As a result of the use of the RMS system, these enterprises will sell the raw milk as chilled, and the increase in unit raw milk sales prices affects their revenues and therefore their net profits.

It is seen that it is not possible to cover the increased investment cost for the 61-120 head group as a result of the use of RMS with the income to be obtained with the current number of animals. According to the simulation result of this dairy farm group, the use of RMS will not be economically preferred. For 121 + head group, the use of RMS increases net profitability depending on the increase in milk yield. This shows that the RMS is economically preferable for the 121+ head group.

The paired samples t-test has shown that the net profit change that occurs as a result of the

Figure 4 - Economic performance difference graphs.

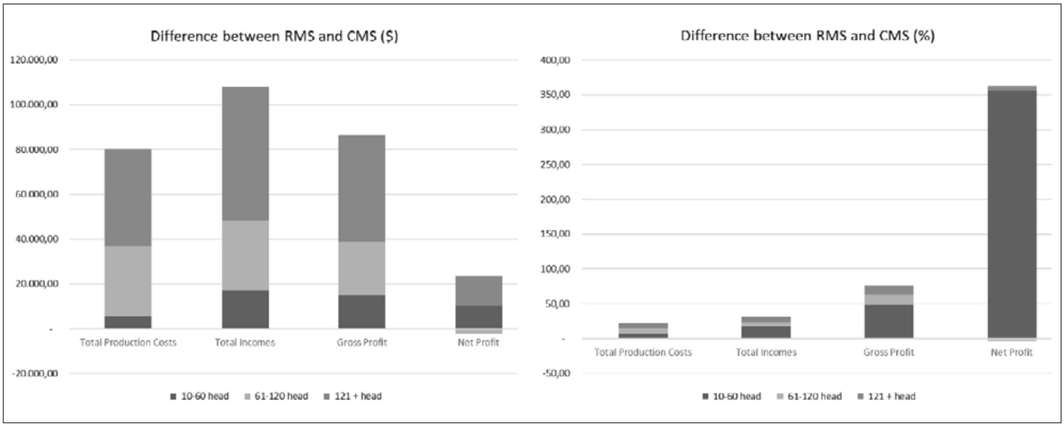


Table 7 - Paired samples t-test results for CMS and RMS.

Groups (heads)	*System*	*N*	*Mean*	*Std. Deviation*	*t*	*Sig.*
10-60	CMS	96	31.615,04	112.632,04	-14,50	.000
	RMS	96	86.878,12	134.716,59		
61-120	CMS	39	357.624,34	261.684,97	-17,34	.000
	RMS	39	539.328,29	288.935,99		
121+	CMS	13	890.481,49	473.741,65	-8,03	.000
	RMS	13	1.054.636,02	533.735,32		

dairy farm groups conversions from the CMS to the RMS is not a coincidence but is significant and the effect size of the change is very large. This shows that farmer's investment in this new technology will make a significant contribution to their profitability. But low enterprise income is a major barrier to enterprises access to technology (Ben Hassen and El Bilali, 2021; Yener Ögür, 2021). For this reason, businesses need to be supported economically in order to make RMS investments. The Eleventh Development Plan (2019-2023), prepared by the Presidency of the Republic of Turkey, presents priorities and policies on Digital Transformation and innovation in agriculture. Within the scope of these policies, economic support can be provided by the state for the dissemination of new technologies in agriculture.

Within the scope of the study, the simulation model was used by taking the average values of the data belonging to the dairy farm groups. A dairy farmer considering an RMS investment will be able to obtain a result specific to his farm if he combines the simulation model with his own economic analysis results. This simulation model created with this aspect can be used as an important tool for enterprises to decide on RMS investment.

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