

Measuring the Sustainability of Buffalo Farms and Factors Influencing this Sustainability in Samsun Province of Türkiye

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Abstract: Agricultural sustainability contributes to the food supply from national resources and prevents rural people from migrating to urban areas, especially in developing countries. This study seeks to assess the sustainability of buffalo farms and the factors influencing their sustainability, collecting data from a sample of 177 buffalo farmers. First, a sustainability index was developed to measure sustainability and compare large and small farms. The factors affecting sustainability were determined using an ordered probit model. According to the findings, large farmers had higher sustainability than small farmers. The factors affecting sustainability are education level, family size, farming land, land allocated to forage crops, number of buffaloes, membership in farmer organizations, and frequency of contact with extension personnel. The results suggested that to increase sustainability and to manage agricultural resources properly in buffalo farms, the support provided by the state should continue to grow, more awareness studies targeting consumers of buffalo products should be conducted to stimulate market growth, and farmer organizations and extension offices should continue to serve more effectively and actively in the region.

Keywords: Buffalo farming, sustainability, sustainable agriculture, animal husbandry.

1. INTRODUCTION

“Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs” [1]. From this definition, it follows that present generations have no right to reduce future generations' opportunities to meet their own needs, and that they should exercise the utmost care to protect natural resources and the environment in all economic development initiatives. If this is not done, land and natural resources will not be able to feed the human race indefinitely [2-4].

For development to continue sustainably, the aim should be for the present and future generations to live more prosperous lives. Therefore, scientific research should balance the present use of natural resources, especially agricultural lands, and the amount left for future generations. Here, the role of technology in development should be determined correctly over time, leading to a well-balanced developmental process.

Sustainable agriculture is considered a part of sustainable development. The technology used in

sustainable agriculture is a balanced, well-managed, and environmentally responsible production [5, 6]. The functional objectives of sustainable agriculture include interacting with animals in agricultural production, reducing off-farm inputs, using genetic resources effectively, determining adequate crop patterns, and applying the best farm management strategies [7]. To achieve these goals of sustainable agriculture, many farm-level practices must be implemented. Some of these practices can be listed as reducing the use of pesticides and chemical fertilizers, consciously performing irrigation using the most appropriate methods, including rotation in the farm and legume forage crops in the rotation, rotating grazing of pasture lands, consolidating land when necessary, using agricultural tools and machinery most appropriately, giving importance to plant and animal health and afforestation of erosion-prone lands in rural areas. The selection of these practices depends on the region's ecology, agricultural system, and socio-economic structure. The criterion here is that all practices aimed at protecting agricultural lands and other natural resources in the long term, and at using them without reducing their productivity, can be considered within the scope of sustainable agriculture [8-10].

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Samsun Province is located in the central Black Sea Region, with a surface area of 972,500 hectares, of which 375,922 hectares are cultivated agricultural land [11]. Most agricultural lands lie along and between the Yeşilırmak and Kızılırmak rivers, which provide irrigation water and flow into the Black Sea. In recent years, the importance of buffalo farming for the region has become increasingly recognized, and efforts have been undertaken to develop buffalo farming and increase its contribution to the national economy through various projects. Breeding experiments are conducted throughout these projects, and the most effective methods are identified and disseminated to farmers. The projects aim to increase buffalo's contribution to first farmers, and then the local and national economies, by providing farmers with practical training on how to develop their breeding systems, produce high-yielding new generations of buffalo, produce calves with high growth characteristics, develop improved production techniques, disseminate information, and continue these activities by sustainably using the natural resources [11].

Samsun province is one of the most important regions for buffalo farming in Turkey, and this activity has significant economic, ecological, and cultural value. The extensive wetlands formed by the Kızılırmak and Yeşilırmak deltas provide an extremely suitable environment for buffalo breeding. Since buffaloes prefer water and marshy areas, Samsun's natural environment has supported the development of this production activity [12].

From an economic standpoint, buffalo farming provides significant benefits to local and national economies, particularly in regions with a suitable climate and natural conditions. Buffalo milk has a higher fat and protein content than cow's milk and is preferred, especially in the production of cream, yogurt, and cheese. Samsun's buffalo cream is in demand both locally and nationwide due to its high quality [13, 14].

Buffaloes utilize hay and other harvest residues as feed; they are used as an energy source, especially in developing countries where agricultural mechanization is insufficient; they are relatively more resistant to various diseases and climate change; and they require fewer herders and less shelter. All of these factors contribute to the retention of the rural population by creating a sustainable income source for small family farms [12, 15, 16]. Environmentally, buffaloes have positive effects on wetland ecosystems. Maintaining a

suitable number of buffalo herds in wetlands significantly contributes to ecosystem conservation by maintaining a balance between animal and plant vegetation in the region. This is important for the ecological sustainability of the Samsun deltas [17].

All of the benefits mentioned above verify that buffalo farming should be considered as a strategic farming procedure for Samsun province regarding the efficient use of pastures and wetlands of the area, providing a viable income for thousands of rural families and raw materials for small agribusiness processing and serving buffalo meat and dairy products, contributing to sustainable rural development and protecting natural resources and the environment. For these reasons, buffalo farming should definitely be given top priority in regional and local development plans and strategies.

Literature shows that the sustainability of buffalo farming has been the subject of numerous studies worldwide. Since buffalo farming makes significant contributions to rural development, particularly in developing countries, this aspect has been studied by various scholars. The studies conducted in India [18-20] concluded that buffalo husbandry makes significant contributions to farmers' income and welfare, and therefore to sustainable development in rural areas, particularly for smallholder farmers. The study conducted in Egypt [21] suggested that feeding buffaloes with treated rice straw feed will increase meat production and, therefore, income and well-being of rural communities. According to a study by Nanda [22], buffalo farming has a vital role in the rural economic and social structures of Asian countries, particularly for the small and landless rural poor. Bangladesh is an Asian country where buffalo farming is a vital source of income for many farmers. Research conducted in this country concluded that the socio-economic status of buffalo farmers was improved through buffalo rearing practices, emphasizing that managerial practices should be given more importance [23, 24]. Another study in Bangladesh emphasized the benefits of buffalo programs for the development of buffalo farming in different districts of the country [25]. Thailand is another Asian nation that pays attention to buffalo farming. According to a study, government organizations, researchers, and other stakeholders should prioritize the production of cattle, particularly buffalo, to enhance farmers' livelihoods and create sustainable farming systems. Besides studies focused on the contributions of buffalo farming to rural

development in different countries, other studies focused on sustainable meat production [26-28] and on raising buffaloes for dairy production [29-32].

The review of the relevant literature indicates that specific studies focus on the development of buffalo farming as a rural livelihood, the enhancement of buffalo farmers' income and well-being, and the establishment of a sustainable farming system for the benefit of rural communities. Some other research focuses more on technical issues, such as more sophisticated methods for feeding and caring for buffaloes and techniques to increase milk and meat production. Nevertheless, the economic, social, and environmental aspects of sustainability in buffalo farms have not been thoroughly investigated by a significant number of researchers in this field. This region is experiencing a steady increase in demand for buffalo products, while the rural population is decreasing, and young people are abandoning farming. The development of a composite index with three dimensions of sustainability and elucidation of its influencing factors through an econometric model are typical components of the present study. Improvements in sustainability in buffalo husbandry will undoubtedly have a substantial impact on local and national economies. The results of this research will be essential for developing programs and implementing strategies and policies to improve the sustainability of buffalo husbandry in the region. Consequently, this study is expected to fill a critical gap in both science and application.

The present study aims to assess the sustainability of buffalo farms, which are mostly located in three districts of Samsun province along the Kizilirmak valley. The specific objectives include assessing the sustainability level, comparing the sustainability levels of larger and smaller buffalo farms, accounting for buffalo herd sizes, and identifying factors influencing the sustainability of buffalo farms in the region. Results are expected to provide policymakers, farmers' organizations, buffalo farmers, and academicians working in this field with useful information.

2. MATERIALS AND METHODS

2.1. Sampling Procedure

First, villages representing the Bafra, Ondokuz Mayıs, and Alacam Districts of Samsun Province, where buffalo farming is more widespread, were selected to represent buffalo farming in the province. Here, special attention was given to selecting villages

around the Kızılırmak Valley and Bird Paradise, located within the borders of Ondokuz Mayıs and Bafra Districts, and highly suitable for buffalo farming. In determining the villages, the opinions of provincial and district directorates of the Ministry of Agriculture and Forestry, the Buffalo Breeders Union, and academicians working on the subject at Ondokuz Mayıs University Faculty of Agriculture were consulted. The buffalo farmers in the six selected villages were identified as the research's accessible population, and the size of their buffalo herds and their names were obtained from the farmers' registration system. Farmers were categorized into three strata based on the frequency distribution of buffaloes: those with fewer than ten animals, those with ten to twenty animals, and those with more than twenty animals. The main objectives of stratified sampling are to improve the accuracy of estimates for the target population and to ensure that different groups are properly represented. Additionally, this approach reduces variance by allowing the primary population to be divided into homogeneous subgroups of strata. This makes it feasible to conduct a thorough investigation using smaller samples [33]. Yamane and Ersin's [34] stratified random sampling method was used to determine the number of farmers included in the sample. Accordingly;

$$n = \frac{N \sum N_h S_h^2}{N^2 D^2 + \sum N_h S_h^2} D^2 = \frac{e^2}{t^2} \quad (1)$$

Where,

n = Sample size,

N = Accessible population,

Nh = Size of each stratum,

Sh = Standard deviation within each stratum,

D^2 = Preferred variance from the mean of the accessible population,

e = The amount of error allowed,

t = The t-distribution value.

The sample size calculated by this formula was 177, distributed across three strata according to their proportions in the accessible population. The random numbers table was used to identify the farmers surveyed from each stratum. Given the likelihood that the selected respondent could not be found or would

refuse to participate in the survey, substitute farmers were selected from each stratum. More detailed information about this method can be found in Yamane and Ersin [34].

2.2. Data Collection

The questionnaire was prepared taking into account the nation's animal husbandry policies, socioeconomic factors, and the agricultural features of the research area, as well as local and international research. Additionally, by speaking with subject-matter experts, the survey's scientific validity was guaranteed. To assess the survey's reliability and comprehensibility, a pretest was conducted. Questions that were misinterpreted or susceptible to multiple interpretations were corrected. 'Cronbach's alpha internal consistency coefficient' was used to test the Likert-scale questions, and reliability was calculated as 84%. The data collection instrument was split into two sections. The first section included questions searching for information on various buffalo farming methods, while the second section focused on farmers' communication patterns and socioeconomic characteristics. Data were collected in the village's coffee shops, farmhouses, and meadows while the farmers were grazing their animals. The data collection period was August through December 2023.

2.3. Normalizing Data

The indicators included in the sustainability index were asked to farmers on a 'five-point Likert scale'. Initially, they were transformed to values between 0 and 1 using Formula 2 and Formula 3. With these values, economic, social, and environmental sustainability indices were easily comparable. Then, the values were multiplied by 100 to create a sustainability index ranging from 1 to 100, which was later divided into three ordered categories and used as the dependent variable of the ordered probit model. The main methods used to carry out the normalization process are "standard deviation from the mean," "distance to the highest value of the group," "distance to the mean," and "minimum-maximum normalization" (Min-Max method). The most commonly used minimum and maximum normalization methods in research were also used in the present study, and their general formulas are given below [35]:

$$NV = \left(\frac{X - \text{Minimum Value}}{\text{Maximum Value} - \text{Minimum Value}} \right) \times 100 \quad NV = \quad (2)$$

Normalized value, X = Real value of the indicator

Similarly, the following equation was used for indicators whose minimum score was considered more sustainable:

$$NV = \left(\frac{X - \text{Maximum Value}}{\text{Minimum Value} - \text{Maximum Value}} \right) \times 100 \quad NV = \quad (3)$$

Normalized value, X = Real value of the indicator

2.4. Data Analysis

Data collected from buffalo farms were coded appropriately and entered into the computer. The statistical methods used in data analyses were selected with the research objectives in mind. The study's variables were described using descriptive statistics, such as means, standard deviations, percentages, and frequencies. An independent-sample t-test was applied to compare the large and small buffalo farms. Finally, the "ordered probit" procedure was used to determine factors influencing the sustainability of buffalo farms in the region.

The dependent variable in the ordered probit model is the sustainability level of buffalo farms, which is divided into three categories (low, medium, and high). This level is obtained by dividing the farmers' scores on the sustainability index, which ranged from 0 to 100, into three categories according to the frequency distribution. Since the sustainability levels are low, medium, and high and naturally yield three increasing discrete values, the "ordered probit model" was the most appropriate. As Greene [36] explained, the basic principles and practical use of this model have been applied to address problems when the dependent variable represents a natural ordering [37-39]. The "ordered probit model" in the present study, where the dependent variable is coded as 0 = Low sustainability, 1 = Moderate sustainability, and 2 = High sustainability, can be explained with the following equations:

$$\begin{aligned} y^* &= \beta' x_i + \varepsilon, \quad \varepsilon \sim N(0,1) \\ y &= 0 \text{ if } y^* \leq 0, \\ y &= 1 \text{ if } 0 < y^* \leq \mu_1, \\ y &= 2 \text{ if } \mu_1 < y^* \leq \mu_2. \end{aligned} \quad (4)$$

In this case, the unobserved dependent variable's vector is denoted by y^* , β' is the coefficient vector, x_i is the independent variable vector, ε is the error terms vector showing a normal distribution $N(0,1)$, y is the observed values of the dependent variable of sustainability categories, and μ represents the threshold values showing the tendency to sustainability levels. There is a natural order among the dependent

variable categories when the threshold value is statistically significant. We can determine how much each independent variable increases or decreases the likelihood that participants fall into each category of the dependent variable by computing marginal effects. In an ordered probit model, marginal effects are calculated using the following formula [36]:

$$\frac{\partial P(R = y)}{\partial x_k} = \Phi \left[\mu_{j-i} - \sum_{k=1}^k \beta_k x_k \right] - \left[\mu_j - \sum_{k=1}^k \beta_k x_k \right] \beta_k \quad (5)$$

Here, $\partial P/\partial x_k$ shows the partial derivative of the probability calculated, depending on how x_k represents the independent variables. A positive marginal effect value of the independent variable x_k increases the probability of the subjects being in the category they belong to in the dependent variable. In contrast, a negative value of x_k decreases the same probability. The sum of the marginal effects calculated between the three categories of the dependent variable is equal to zero. The data collected in the study were first checked for model specification errors and parallel regression assumptions. It was clear that these assumptions were not violated in the checks made, and the data were suitable for additional analyses to achieve the objectives of this study.

3. RESULTS AND DISCUSSION

3.1. Measuring the Sustainability of Buffalo Farms

The research findings are presented in the order of the research objectives. Since the first objective was to determine the level of economic, social, and

environmental sustainability among the buffalo farms, the results are presented in Tables 1, 2, and 3, respectively. The items were measured on a five-point Likert scale, and responses were ranked in descending order by mean. A 5-point interpretive scale (Strongly Disagree (SD) = 0-1.49, Disagree (D) = 1.50-2.49, Neutral (N) = 2.50-3.49, Agree (A) = 3.50-4.49, and Strongly Agree (SA) = 4.50-5.00) was developed by the researchers.

Farmers agreed with seven of the items regarding the economic sustainability dimension and were neutral about three. The item with the highest mean was "I am thinking of making new investments in buffalo production" (mean = 4.12). In contrast, the item with the lowest mean was "I can continue production without the support provided to animal husbandry by the Ministry of Agriculture and Forestry" (Table 1). Given the higher means, it can be said that farmers are optimistic about the economic sustainability of buffalo farming, as they expect to make new investments and believe it will provide income for themselves and their families in the future. On the other hand, farmers believe that various supports should be given to buffalo farming. In this context, they stated that they are somewhat in favor of continuing production, even without government or other institutional support.

The research included 15 items as social sustainability indicators, and farmers stated that they strongly agreed with five, agreed with seven, and were neutral toward three. The indicator that farmers agreed with the highest mean was "We have good relations with our neighbors" (mean = 4.89), while the indicator

Table 1: Economic Sustainability of Buffalo Farms

#	Economic sustainability indicators	Mean	SD	Category
1.	I am thinking of making new investments in buffalo production.	4.12	0.870	A
2.	I think that buffalo farming will increase my income in the future.	3.85	0.988	A
3.	I think buffalo farming will provide a sufficient future for my children.	3.84	0.976	A
4.	I am thinking of increasing the number of buffalo and, therefore the income.	3.83	0.99	A
5.	I am considering increasing forage crop production by purchasing or renting land.	3.75	1.00	A
6.	If marketing opportunities improve, I can increase buffalo production.	3.74	0.07	A
7.	The demand for buffalo products is increasing, and this encourages buffalo farming.	3.71	1.13	A
8.	I can continue production without credit received from banks and cooperatives.	3.27	1.09	N
9.	I can continue production without the farming subsidies provided by the ministry.	3.05	1.18	N
10.	I can continue production without any support from the ministry.	3.02	1.27	N
	Mean	3.62	0.72	A

that farmers expressed their opinion with the lowest mean was “My children have the desire to become farmers” (mean = 2.68) (Table 2). These findings verify that farmers have good social relationships with their peers in the village and with other personnel employed by various organizations and serving rural people and farmers. Although farmers' social connections with their environment have suggested sustainability, farmer families are generally unhappy with living in rural areas and with agricultural work. Furthermore, farmers do not want their children to pursue agricultural careers.

Within the scope of environmental sustainability, farmers agreed with three of the 14 indicators included in the research, remained neutral on eight, and disagreed with two items (Table 3). The indicator that farmers agreed with most was “I care enough about animal rights” (mean = 4.19), while the indicator they remained neutral on was “We can take adequate adaptation measures against climate change” (mean = 2.48). Farmers protect their villages' water supplies and take care to prevent agricultural land from being utilized for housing or other purposes. They also stated that they can combat diseases sufficiently in plant production. However, there is an understanding that farmers do not adequately protect public pastures. The

weakest side they reported is their inability to carry out sufficient adaptation activities against climate change. These factors pose a threat to environmental sustainability in the region.

Table 4 and Figure 1 show the economic, social, environmental, and overall sustainability of buffalo farms. The data collected on the five-point Likert scale were made unitless, as stated in the materials and methods section of the research. They were interpreted by converting them into values between 0 and 1. A value of 0 indicates sustainability is at its lowest, and a value of 1 indicates it is at its highest. As seen in Table 4, the average sustainability of buffalo farms in the research area is around 66%. The social sustainability of the farms (76%) is higher than their economic sustainability (66%) and environmental sustainability (57%). Likewise, social sustainability's minimum and maximum values are higher than those of economic and environmental sustainability. An important finding is that environmental sustainability received the lowest value. A recent study in the region emphasized that

buffalo farmers should focus on milk production and adopt new technologies to enhance environmental sustainability [40].

Table 2: Social Sustainability of Buffalo Farms

#	Social sustainability indicators	Mean	SD	Category
1.	We have good relationships with our neighboring farmers.	4.89	0.41	SA
2.	We have good relations with the provincial and district directorate of the 'Ministry of Agriculture and Forestry'.	4.78	0.52	SA
3.	The village house where our family lives is in good condition.	4.77	0.51	SA
4.	We have good relationships with farmers' unions and farmers' cooperatives.	4.67	0.63	SA
5.	We have good relationships and communication with veterinarians and technicians who serve us.	4.51	0.62	SA
6.	We have a positive attitude towards tourists visiting the bird paradise, wetlands, and villages.	4.35	0.78	A
7.	The social security status of family members is good.	4.31	1.04	A
8.	There is a positive attitude and good relationships towards workers coming to our village from other regions.	4.02	1.16	A
9.	We have good relationships with the leading farmers in our location.	4.02	0.91	A
10.	There are good healthcare institutions around our region.	3.94	0.70	A
11.	There is a good transportation and communication network in our village.	3.72	1.05	A
12.	We have regular working hours during the day.	3.05	1.08	N
13.	My family members have a positive attitude toward animal husbandry.	2.94	0.98	N
14.	My children want to become farmers.	2.68	1.11	N
	Mean	4.03	0.49	A

Table 3: Environmental Sustainability of Buffalo Farms

#	Environmental sustainability indicators	Mean	SD	Category
1	I care enough about animal rights.	4.19	0.72	A
2	Sufficient precautions are being taken to prevent housing on agricultural land in the region.	3.83	1.68	A
3.	I think the water resources in this region are sufficiently protected.	3.82	1.01	A
4.	We can combat diseases sufficiently in plant production.	3.54	0.82	A
5.	I can spread enough animal manure on the agricultural land.	3.40	1.25	N
6.	I can combat poisonous weeds in grassland areas.	3.32	1.08	N
7.	We can combat diseases sufficiently in animal husbandry.	3.31	0.98	N
8.	I can produce enough forage crops on my farm.	3.27	1.33	N
9.	We perform pasture grazing by rotation.	3.21	0.84	N
10.	We do not allow animals to overgraze the pastures.	3.11	0.96	N
11.	Precautions are being taken against early grazing of pastures.	3.02	1.06	N
12.	We can carry out afforestation work on environmentally risky lands.	2.98	0.93	N
13.	Public pasture areas in the region are adequately protected.	2.49	0.96	D
14.	We can take adequate adaptation measures to adapt to climate change.	2.48	0.81	D
	Mean	3.30	0.55	N

Table 4: Economic, Social, Environmental, and Overall Sustainability of Buffalo Farms

Sustainability	N	Minimum	Maximum	Mean	Std. Dev.
Economic sustainability	177	0.30	0.90	0.661	0.158
Social sustainability	177	0.38	0.93	0.762	0.102
Environmental sustainability	177	0.29	0.86	0.575	0.111
Overall sustainability	177	0.34	0.89	0.666	0.100

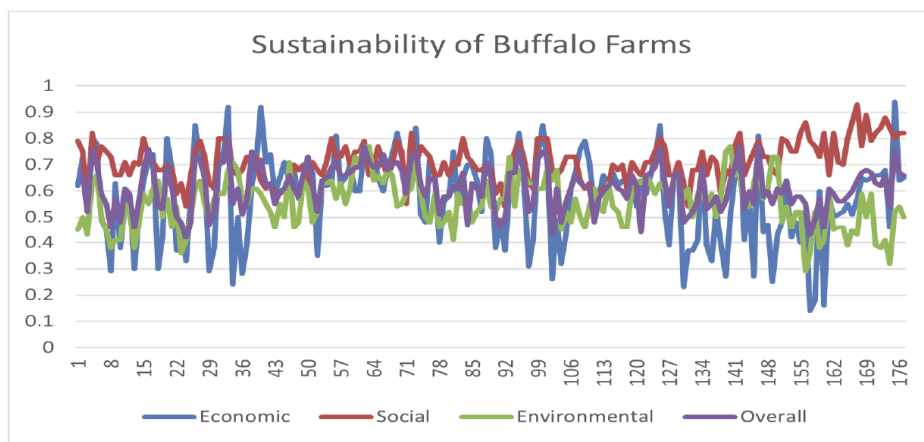


Figure 1: Sustainability of buffalo farms.

3.2. Comparison of Large and Small Farmers Regarding Sustainability

An independent sample t-test was used to compare buffalo farms by farm size. For this purpose, buffalo farms were divided into two groups according to the

number of buffalo they owned. Those with an average number of buffalo greater than 22 were included in the large farms group, and those with 22 or fewer were included in the small farms group. According to this separation, as seen in Table 5, there are 70 large farms and 107 small farms in the region. The

Table 5: Comparison of Sustainability by Farm Size

Sustainability	Farm Size	N	Mean	Std. Dev.	T	p
Economic sustainability	Large farms	70	77.86	8.58	9.820	≤0.01**
	Small farms	107	58.55	14.88		
Social sustainability	Large farms	70	80.53	7.23	4.79	≤0.01**
	Small farms	107	73.40	10.99		
Environmental sustainability	Large farms	70	62.01	10.85	4.49	≤0.01**
	Small farms	107	54.68	10.47		
Overall sustainability	Large farms	70	67.84	5.60	10.49	0.023*
	Small farms	107	57.25	7.16		

(**) (*) Significant at 0.01, and 0.05 levels, respectively.

sustainability scores here are obtained by multiplying the values in equations 2 and 3 by 100. In this context, the sustainability indices range from 0 to 100, and comparisons were performed using an independent-samples t-test. According to Table 5, all tests were statistically significant at the 0.05 Alpha level, indicating that large farms have better composite sustainability due to greater environmental, social, and economic sustainability.

As farm sizes increase in agriculture, farmers have the opportunity to increase yields. This can reduce fixed and variable costs per unit of production. In addition, farmers can have some, even minor, bargaining power in input and output markets as they increase the quantities of inputs and outputs with an increasing farm size [41, 42]. This situation can be strengthened when farmers form cooperatives and act together. Various studies indicate that larger farms increase productivity, the efficiency of the production process, the asset replacement ratio, and yield in plant and animal production [43]. They provide better certification of farm products [44], reduce fertilizer and pesticide use per hectare, demonstrate clear environmental benefits [45], increase labor productivity and net farm income [46], and contribute more to agricultural sustainability [47,48].

3.3. Factors Influencing the Sustainability of Buffalo Farms

To determine the factors affecting sustainability in buffalo farms in the research area, the sustainability index was first divided into three categories: low, medium, and high, taking into account the frequency distribution. In this context, 46 (26%) of the 177 farmers who participated in the research fell into the low level, 70 (39.5%) fell into the medium level, and 61 (34.5%)

fell into the high-level sustainability category. This was used as the dependent variable. The variables used in the model, their expected signs, and descriptive statistics are given in Table 6. The explanatory variables were either selected from various studies or prepared by the researchers, based on socioeconomic characteristics and farming structures in the locality [2, 4, 49, 50]. Among the explanatory variables, age of farmer, level of education, family size, monthly income, the amount of land owned, the amount of land allocated to forage crops, the number of animals owned, and membership in farmer organizations were considered as socioeconomic characteristics. The frequencies of travel, meeting with extension staff, participation in farm-related activities such as meetings, seminars, and symposiums, reading newspapers, watching television, listening to the radio, and internet use were considered as communication behavior variables.

Table 6 shows that the average age of farmers is 44.74 years, and 40% have at least a secondary education. The average family size was 5.52 people, and the monthly income per family was 19924 Turkish Liras. The average farmer owned 41.61 acres of agricultural land, and 21.43 acres were allocated to fodder crop production. The average farmer owned 22.52 buffalo, and 65% of the farmers were members of farmers' organizations. While 76% of farmers travel to the nearest town at least once a week, 37% stated that they meet with extension officers in the agricultural organization at least once a month. While 58% of farmers stated that they attend any meeting, seminar, conference, etc. related to agriculture at least once a month, 37% said they read newspapers at least once a week. 35% of farmers listened to the radio for about an hour daily, while 95% watched television, and 74% used the Internet daily.

Table 6: Definition of the Variables Used for the Ordinal Probit Procedure and Summary Statistics

Explanatory Variables	Code	mean	Std. Dev.	Expected sign
Age of farmer (Year, cont. var.)	AGE	44.74	11.26	-
Education 1 = Secondary and higher, 0 = Lower	EDU	0.40	0.49	+
Family size (Person, cont. var.)	FMLSZ	4.52	1.58	+
Income (Turkish Liras, cont. var.)	INCM	19924	10712	+
Land owned (Decares, cont. var.)	LAND	41.61	27.8	+
Fodder crop area (Decares, cont. var.)	FDCRPA	21.43	12.80	+
Number of buffaloes (Cont. var.)	NBBFL	22.52	12.3	+
Membership in farmers' organizations 1 = Member 0 = Not a member	MFO	.64	0.62	
Travels to the nearest towns 1 = At least once a week 0 = More seldom	TRNRTW	0.76	0.43	+
Extension contacts 1 = At least once a month 0 = More seldom	EXT	0.37	0.47	+
Participation in farming events 1 = At least once a month 0 = More seldom	PRFREV	0.58	0.68	+
Reading newspapers 1 = At least once a week 0 = More seldom	NWSP	0.37	0.48	+
Listening to the radio 1 = At least one hour a day 0 = More seldom	RADIO	0.35	0.48	+
Watching television 1 = Every day 0 = More seldom	TV	0.95	0.22	+
Using the Internet 1 = Every day 0 = More seldom	INTRNT	0.74	0.44	+
Dependent Variable (Sustainability level)	Count	Percent		
Lower sustainability	46	26.0		
Medium sustainability	70	39.5		
Higher sustainability	61	34.5		
TOTAL	177	100.0		

The ordered probit model examining factors affecting the sustainability of buffalo farms was significant at the 0.01 Alpha level, with a chi-squared value of 185.7 and 15 degrees of freedom. The threshold value was estimated as ($\mu_1 = 2.292$), and it was positive and statistically significant at 1%

probability level or better. This situation shows a natural order and an increase in the sustainability levels of buffalo farmers in the region.

Fifteen explanatory variables were included in the model, and their estimated coefficients were examined

using a t-test. Results indicated that 7 of the explanatory variables in the model were statistically significant at the 0.01 level or better. These were the farmers' level of education, family size, the amount of land owned, the amount of land allocated to forage crops, the number of animals owned, membership in farmer organizations, and the frequency of meeting with extension officers. On the other hand, the eight variables that were not statistically significant were the farmer's age, income level, frequency of traveling to the nearest town, participation in farm-related events such as meetings, symposiums, and seminars, frequency of reading newspapers, frequency of listening to the radio, and frequency of watching television.

According to the estimated marginal effects, farmers are less likely to fall into the low-level and medium-level sustainability categories as the magnitude of the statistically significant explanatory variables increases. In contrast, the probability of falling in the high sustainability category rises by the relevant percentage points, as shown in Table 7.

Among the significant explanatory variables, education is expected to contribute to sustainability. More educated people are expected to have better relationships and communication with communities outside their social systems. Therefore, they may have a more positive attitude toward agricultural sustainability. This finding is supported by earlier research on sustainable agriculture [2, 3, 51, 52]. Although we could not find any studies in the reviewed literature investigating the effect of family size on sustainability, this was statistically significant in this study. In particular, the employment of family members on the farm, their contributions to farming activities, and their continued residence in rural areas will be effective, especially for economic and social sustainability. Since there has been a significant migration from rural to urban areas, particularly among younger people, any activity, such as buffalo farming, can provide employment and help keep rural people in their original places of residence. The size of agricultural land, corroborated by the variable amount of farmland devoted to forage crops, is another factor

Table 7: Factors Influencing the Sustainability of Buffalo Farms, and their Marginal Effects

Variable	Coefficient	Standard error	P	Marginal effects		
				Lower level	Medium level	Higher level
Constant	-4.883	1.014	0.001			
AGE	0.072	0.009	0.450	-0.00056	-0.00203	0.00258
EDU	0.640**	0.169	0.002	-0.04929	-0.17844	0.22773
FMLSZ	0.209*	0.880	0.017	-0.01612	-0.05837	0.07449
INCM	0.202	0.117	0.086	-0.151D-05	-0.51D-05	0.72D-05
LAND	0.259*	0.082	0.002	-0.00200	-0.00723	0.00923
FDCRPA	0.324**	0.125	0.009	0.00249	-0.00903	0.01153
NBBFL	0.086**	0.014	0.001	-0.00667	-0.02416	0.03083
MFO	0.499*	0.266	0.041	-0.03580	-0.14444	0.18025
TRNRTW	0.237	0.294	0.419	-0.01729	-0.06847	0.08576
EXT	0.550*	0.248	0.027	-0.03822	-0.16197	0.20019
PRFREVE	0.279	0.215	0.195	-0.02153	-0.07794	0.09947
NWSP	0.014	0.283	0.950	-0.00111	-0.00402	0.00513
RADIO	-0.652	0.381	0.087	0.06172	0.15614	-0.21786
TV	0.224	0.566	0.691	-0.02078	-0.05495	0.07573
INTRNT	0.043	0.246	0.861	-0.00338	-0.01185	0.01523
μ1	2.292	0.257	0.001			

'Log-likelihood function': -99.0499
 'Restricted log-likelihood': -191.903
 'Chi-squared' (15) (p≤0.01): 185.706
 (**) (*) Significant at 0.01 and 0.05 levels, respectively.

that positively affects agricultural sustainability. While the labor and machinery costs per unit of product have the potential to decrease in larger land, the farmer can benefit from the advantages of buying and selling larger quantities of inputs and outputs, respectively. Forage crops constitute an essential input source for farmers engaged in animal husbandry. On the other hand, they protect agricultural land by preventing it from being used for tillage farming each year. This two-way contribution is positively reflected in both economic and environmental sustainability. This finding is supported by different researchers who stressed the importance of forage crops for sustainable agriculture [53-56].

Although there are many farmers' organizations in the region, one is directly related to buffalo farming: The Buffalo Breeders Union, whose membership significantly influenced sustainability. This union provides producers with various training and extension activities on buffalo breeding and feeding, thereby contributing to more conscious, sustainable production. Besides bringing together buffalo farmers to act cooperatively, it also organizes farm visits in various regions of the country that are successfully producing and marketing buffalo products. Consequently, this investigation concludes that sustainability is affected by membership in farmer organizations, a conclusion that is corroborated by prior research in this area [57-60].

The last variable affecting sustainability in buffalo farms in the research was the frequency of contact with agricultural extension personnel. There are provincial and district directorates of the Ministry of Agriculture and Forestry in Samsun province, including Bafra, 19 Mayıs, and Alaçam, where the research is focused. Extension personnel in these organizations regularly provide extension services to farmers on plant and animal production. In addition, when farmers need information or encounter problems during farming activities, they can visit these organizations to seek solutions. Therefore, this finding regarding the extension contact in this research is quite logical and is supported by earlier studies [61-63].

The statistical insignificance of age in the study is due to farming being predominantly carried out by relatively older individuals and to the disengagement of young people from agriculture. The insignificance of the income variable, on the other hand, can be explained by the fact that income is not used for sustainable agricultural practices and has an indirect impact through other structural variables, such as land area,

fodder crop production area, and the number of animals owned.

The study also concluded that variables indicating access to information sources, such as media exposure, travel frequencies, and participation in agricultural activities, were not statistically significant. These findings indicate that sustainability levels in buffalo farming are not significantly affected by passive access to information. Conversely, these findings show that producers' sustainability levels are more strongly influenced by structured, interactive mechanisms such as formal education and agricultural extension services.

4. CONCLUSION AND RECOMMENDATIONS

The study's findings led to the following conclusions and recommendations: First, the three dimensions of economic, social, and environmental sustainability were higher on large farms than on small farms. This finding confirms that state support can initially be targeted at large farmers to increase income and profits, as well as to implement measures to protect agricultural resources and the environment. The Ministry of Agriculture and Forestry has provided significant support to buffalo farming in the region. These supports aim to establish modern buffalo breeding enterprises that raise buffalo for breeding, increase the number of buffalo, particularly in areas with suitable and water conditions, to improve efficiency and quality in buffalo meat and milk production, and to create employment in rural areas and prevent migration. The support will undoubtedly contribute significantly to sustainability, and the ministry will achieve its objectives in this regard.

The findings of this study suggest that future agricultural policy should focus on expanding farm size and the area of fodder crops, which will increase the number of buffalo. Increasing the number of buffalo in the region and practicing breeding in accordance with recommendations from agricultural organizations will undoubtedly increase farmers' productivity and income. This means that farmers will invest more in modern agricultural technologies and create employment opportunities for their family members.

Extension services in buffalo breeding should be provided by the Ministry of Agriculture and Forestry and the farmers' organization, the Buffalo Breeders' Union. This union has close dialogue with farmers. They should cover topics in their extension programs, such as the basic principles of buffalo breeding, animal care

and feeding, and processing and marketing of buffalo products such as meat and milk. Improvements in these subjects will contribute to the economic sustainability of buffalo farming. In addition, increasing the area of fodder crops, rotating pastureland grazing, avoiding early and excessive grazing, and protecting land and water resources in the region should be covered in education and extension activities. These efforts will probably contribute to increasing environmental sustainability, which was the lowest in the present study.

This study is restricted to buffalo farmers in Samsun province; consequently, it may not represent the agricultural sustainability of other regions. The cross-sectional data collection method used in the research neglects the changes in sustainability over time. Lastly, reliance on producers' responses to assess sustainability may cause specific constraints.

Scientists aiming to investigate this issue in the future could address these limitations and conduct more efficient studies. For example, longitudinal data collection methods could be used to measure the changes in the sustainability of buffalo farms over time and establish causal relationships. Furthermore, planning the research to represent broader regions would increase the generalizability of the results.

ETHICAL STATEMENT

The data for this research were collected through questionnaires administered to adult farmers. Informed consent was obtained before administering the survey. The information they provided has no identifiable images or data. Farmers were assured that the information they provide will be used for scientific purposes only. No individual information will be shared with third parties. Therefore, no ethical report was required.

DATA AVAILABILITY STATEMENT

Data for this study are available upon request from the corresponding author.

CONFLICT OF INTEREST STATEMENT

All authors declare that they have no competing interests.

FINANCIAL SUPPORT STATEMENT

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