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Challenges, Economics, and Sustainability of Sheep and Goat Farming in Drylands

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Abstract: This study finds that in northern Jordan, breeder indicators present challenges to the sustainability and growth of sheep and goat farming, while economic indicators suggest a combination of financial stability alongside hurdles related to profitability and resource ownership. Breeder age plays a role in the management of livestock herds, due to factors such as experience, resources, or adherence to traditional practices. Experience significantly affects breeders' decisions on male insemination replacements, likely due to skill. Crop cultivation influences breeders' returns by reducing feeding costs, while strategic lamb sales management boosts individual animal profitability. Winter raises animal mortality due to cold stress. Other animals in herds increase kid mortality by spreading diseases. Breeder experience significantly affects lamb survival, stressing its role in care. Increasing sheep proportion enhances lamb production and reduces lamb mortality while managing rams and selling lambs positively affects herd health and productivity. A larger goat herd proportion positively correlates with kids sold but inversely with breeding males and overall kids, implying trade-offs affecting herd productivity and mortality rates. Sheep herds (92.5%) show slightly better reproductive success than goats (90.6%), implying superior long-term viability. Flock excels in birth, survival, and sales, but low sheep and lamb%. Improvement is needed for sustainability, and the potential is high. Goat breeding shines in birth, sales, and overall success, but needs attention to kid survival and other sustainability issues. In conclusion, despite challenges, there are promising opportunities to enhance sheep and goat farming in Jordan. Effective management, informed by breeders' experience and economics, is crucial. Empowering small-scale herders and implementing targeted interventions like winter mortality solutions and selective breeding is vital for sustainable growth.

Keywords: sustainability; smallholder; sheep; goat; Jordan

1. Introduction

Sheep and goat breeding is an economic and vital sector in many countries, facing challenges including climate change and the decreasing diversity of animal genetic resources. It is necessary to conduct a sustainability study for this sector to ensure its vital role. Prioritizing training and investment for smallholder farmers, emphasizing data recording for sustainable management and conservation of indigenous ovine genetic resources, was reported by [1].

In Jordan, goat production is vital for food security, socioeconomics, and cultural needs in rural households, with a focus on meat. Goats are preferred for their ease of rearing and efficiency in utilizing low-quality roughage. Unique biological abilities enable successful raising in areas with poor grass vegetation but constraints like diseases, and water shortages persist [2]. The sheep and

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goat farming sector encounters challenges, yet sustainable management offers avenues for improvement [3]. This research is pivotal because it emphasizes the importance of the sector to the Jordanian economy and rural society, while also identifying challenges it faces. This knowledge can inform the development of policies and programs aimed at enhancing sustainability within this sector.

Sustainability assessment of sheep and goat farms involves selecting the best tool and indicators for measuring sustainability, taking into account the specificities of farm systems, their production objectives, and their classification [4]. Improving rural goat production is crucial for sustainability, and the use of scoring schemes and mating strategies enhances production traits in traditional farming systems [5].

Assessing the main characteristics, variations and prospects of sheep and goat herds in Mafraq Governorate is essential for their sustainability, which represents approximately 37.4% of sheep and 18% of goats in Jordan [6]. The various indicators, which include the social, economic, and productivity dimensions of these farms, have been classified into three main groups. This evaluation aims to ensure the efficiency and sustainability of sheep and goat farming systems. This study aims to evaluate the sustainability of smallholder sheep and goat farming in Mafraq Governorate, Jordan, using a multivariate assessment tool based on criteria about sustainable production.

2. Materials and Methods

2.1. Survey Data

The study conducted in 2021/2022 in northern Jordan's Mafraq Governorate, focused on 53 traditionally managed sheep and goat farms. These farms, registered with the Mafraq Agriculture Directorate, practiced dual-purpose production (milk and live meat) using communal pastures and semi-concentrated feed. Data collection involved a questionnaire covering breeder information, farm economics, and herd composition (Figure 1).

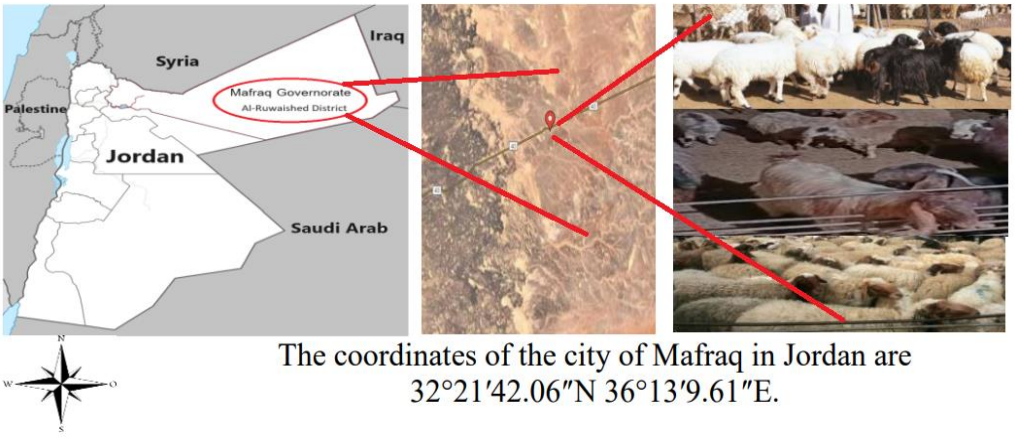

Figure 1. shows herds of sheep and goats in Mafraq Governorate on a map of Jordan, in addition to the area's coordinates.

2.2. Statistical Analysis

Linear models were used to analyze the study sample data, with variance and correlation tests to evaluate the relationships between the studied variables using [7]. Analysis of variance was used for total revenues and revenues/ animal for sheep and goat breeders following the linear model (1):

$$Y_{ijklmn} = \mu + LO_i + LC_j + FC_k + B_1LS_l + B_2KS_m + e_{ijklmn}$$

Where, Y_{ijklmn}=the total revenues or revenues/ animal of ijklmnth obsevations; LO_i=land ownership (1=land owner, and 2=land tenant); LC_j=land cultivation (1=farmer, and 2=no farmer); FC_k=fodder cultivation (1=plant fodder, and 2=not plant fodder); LS_l=lamb sales%; KS_j=kid sales%; B_1 and B_2=

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coefficients of regression of lamb sales% and kids sales%, respectively. e_{ijklm}=random error of ijklth observations with mean=0 and variance=$I\sigma_e^2$.

Analysis of variance was used for the flock size of sheep and goat breeders following the linear model (2):

$$Y_{ijkl} = \mu + EL_i + B_3EX_j + B_4AB_K + (\mathrm{EL} \times \mathrm{EX})_{ij} + (\mathrm{EL} \times \mathrm{AB})_{ik} + (\mathrm{AB} \times \mathrm{EX})_{jk} + e_{ijkl}$$

Where, Y=the flock size of ijklth observations; μ=overall mean; EL_i=education level (1=uneducated, 2=primary, and 3=basic); EX_j=experience/ years (range=10-30); AB_k=age of breeder/ years (range=40-76); B_3 and B_4= coefficients of regression of experience and age of breeder, respectively. $(EL\times EX)_{ij}$=the interaction between education level and experience; $(EL\times AB)_{ik}$=the interaction between education level and age of breeder; $(AB\times EX)_{jk}$=the interaction between age of breeder and experience. The symbols in the model (1) depict the rest.

Analysis of variance was used for lamb mortality%, kids mortality%, and mortality age/ month of sheep and goat herds following the linear model (3):

$$Y_{ijklmn} = \mu + OA_i + MM_j + LE_k + B_5EX_l + B_6WA_m + e_{ijklmn}$$

Where, Y=the lamb mortality%, kids mortality%, or mortality age of ijklmnth obsevations; OA_i=other animals (1=other animals exist, and 2=none, except sheep and goats); MM_j=mortality months (1=December =<, and 2=January =>); WA_m=weaning age /day (range=45-90); Remaining symbols displayed in the prior models.

Chi-square analysis examined the male replacement (mating) schedule in a herd of sheep and goats. Spearman rank correlation coefficient was computed for some economic indicators (Breeder experience, Level of education, Land ownership, Land cultivation, and Fodder cultivation) on breeders of sheep and goats. Pearson's correlation coefficient was estimated to explore the relationship between sheep% and goat% herd compositions.

2.3. Herd Vitality

To evaluate herd viability, overall reproductive success was considered, which is affected by both sheep and goat herds' birth and survival rates [8,9]. Reproductive Success = Birth rate × Survival rate (model 4).

2.4. Sustainability Evaluation

Performance indicators for sheep flock, including %sheep, %ewes birth, lambs%, lamb survival%, and lamb sales%; and goats flock, including goats%, doe birth%, kids%, kid survival%, and kid sales%. The data is categorized into three levels: average, above average "+", and below average "-", with corresponding numerical values. The sustainability rating is indicated by symbols: "-" indicates a negative rating, and "+" indicates a positive rating [10,11].

3. Results and Discussion

3.1. Breeders Indicators

The average age of sheep and goat farmers is 58.72±1.11 years, indicating a notable absence of interest among younger individuals and presenting a sustainability challenge. The family size is 7.34±0.22 members, with 4.25±0.19 males and 3.09±0.15 females, reflecting a standard family structure. Breeders have an average of 19.92±0.98 years of experience, aligning with their age and as a positive sign for sustainability. Education levels illustrate that 11.3%, 49.1%, and 39.6% fall into the uneducated, primary, and basic categories, respectively, indicating a deficiency in university education that could affect the ongoing viability of sheep and goat farming in Jordan.

Social background, including age, family farming history, experience, and education, significantly affects small ruminant dairy farming in Greece [12]. Similar trends hold in Nigeria [13]. India exemplifies regional variations, with sheep and goat farmers typically above 40, often from medium-sized families, and lacking formal education in many cases [14]. These cases highlight the widespread influence of socio-demographic factors within the industry.

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3.2. Economic Metrics

On average, annual fixed costs were around 6560.98±187.82 Jordanian dinars (JD), while variable costs were around 553.77±36.51 JD. Total assets and debts hovered around 6375.85±197.69 JD and 185.75±39.22 JD, respectively, with debts representing a mere 3.33±0.78% of total assets, showcasing the sustainable nature of this practice. Additionally, annual revenue from sheep and goat farming reached 1599.06±65.79 JD, translating to an average of 42.64±1.06 JD per animal. These findings suggest that sheep and goat farming in northern Jordan offers a viable and sustainable source of income.

Studies on goat production in Mexico, Greece, and the UK highlight the complex challenges and opportunities in small ruminant farming. While short-term viability is promising in Mexico [15], long-term sustainability faces hurdles due to high costs. In Greece, factors like labor, loans, feed, education, and age significantly affect goat farmer revenue [16]. Similarly, efficient land use, animal health, and record keeping are crucial for UK sheep farm profitability [17]. These studies underline the multifaceted nature of challenges and opportunities in small ruminant farming globally.

The values were 67.92, 66.04, and 52.83% for sheep and goat farmers who own land, grow crops, and grow green fodder, respectively. These percentages exceed 50% in raising sheep and goats in northern Jordan; this is a positive indicator. In contrast, the values were 32.08, 33.96, and 47.17% for breeders who rent land and do not grow crops or grow green fodder.

Bundelkhand goats offer income potential for dry region breeders, but face shrinking, degraded grazing land. Efforts to restore this land promise a sustainable future for both [18,19].

Table 1 shows that all correlations for economic indicators were positive and statistically significant (P<0.01). That is, there are strong positive relationships between all indicators, and this indicates that breeders with greater experience tend to have a higher cultural level, land ownership, cultivation of land and fodder, and are better off economically. The strongest association is between land ownership and land cultivation, which indicates that farmers who cultivate land tend to own more land.

Table 1. Spearman correlation coefficients for some economic indicators on breeders of sheep and goats. Prob > |r| under H0: Rho= 0; N= 53.

Indicators	Level of education	Land ownership	Land cultivation	Fodder cultivation
Experience of breeder/ Years	0.89**	0.80**	0.82**	0.86**
Level of education		0.79**	0.83**	0.84**
Land ownership			0.96**	0.73**
Land cultivation				0.76**

Ugandan goat farms hold promise for rural lives, dominated by older men with small lands. While goats offer income and cultural value, low earnings and high taxes hold them back. Women manage production, despite men owning most goats. Empowering women/youth is key to unlocking their potential for a brighter future [20].

Crop cultivation significantly boosts (P<0.01) annual returns for sheep and goat breeders, likely due to reduced feeding costs through the utilization of crop residues. Additionally, the percentage of male lamb sales from ewes significantly affects (P<0.05) per-animal return, emphasizing the importance of strategic lamb sales management in maximizing individual animal profitability (Table 2).

Table 2. Analysis of variance for annual return and revenue/ animal of sheep and goat breeders in northern Jordan (Model 1).

S.O.V	DF	Mean Square

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		Annual return	Pr>F	Revenue/ Animal	Pr>F
Land ownership	1	7799.690	0.84	37.38126	0.43
Land cultivation (Crops)	1	1608904.51	0.01	0.06169	0.97
Fodder cultivation	1	491148.42	0.12	3.86538	0.80
Lamb sales%	1	610598.72	0.08	245.27786	0.04
Kids sales %	1	263846.88	0.26	2.15647	0.85
Random Error	47	203462.91		59.78057	

In New Zealand, sheep production has increased despite declining sheep numbers, highlighting ongoing profitability concerns. Future challenges like changing land use and climate change could affect farmers' profits [21].

3.3. Herd Management Pointers

The average size of the total herds was 503.74±12.66 heads. As for the Awassi sheep herd, it amounted to 56.48±1.17%, compared to 43.52±1.17% for the local goat herd out of the total average size of the studied herds. The average age of weaning and mortality was 70.32±1.42 days and 8.93 months in the studied herds. The percentage of breeders who replace males for insemination every two years reached 71.70%, compared to 28.30% who do not. The animal mortality rate in (December until May) was 58.49 compared to 41.49 in (June until January). Other animals were found in some of the herds of sheep and goat breeders, amounting to 73.58%, compared to 26.42% when there were no other animals.

In northern Jordan, breeder age ($P<0.05$) positively correlated with herd size (Table 3). Breeders over 58.72±1.11 years old managed larger herds (7.21±1.12 heads/year), potentially due to economic, social, or traditional factors.

Table 3. Analysis of variance for herd size of sheep and goat breeders in northern Jordan (Model 2).

S.O.V	DF	Mean Square	Pr>F
Education Level	2	14045.57	0.17
Experience/ years	1	16676.19	0.14
Age of Breeder/ years	1	31574.82	0.04
Experience × Education Level	2	12673.41	0.20
Age of Breeder × Education Level	2	12450.66	0.20
Age of Breeder × Experience	1	12712.96	0.20
Random Error	43	7685.23	

Livestock subsidy removal in Jordan's Northern Badia halved animal numbers, raising prices, with proposed solutions like cooperatives, training, income diversification, and requiring effective strategies [22]. In Jordan, sheep and goat herds (avg. 297 animals) yield 30% profit (17,104 JOD) with 13,067 JOD variable costs as shown by [23]. West African urban areas raise sheep and goats for diverse purposes, valuing sheep more due to location and preference. Sheep breeders there exhibit greater openness to improvement programs, suggesting potential for further gains [24].

Breeder experience (years) significantly affects ($p<0.05$) their male replacement decisions (Table 4), likely reflecting factors like knowledge, skill, and risk tolerance gained through experience.

Table 4. Chi-square analysis of the male replacement (mating) schedule in a herd of sheep and goats in northern Jordan.

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Tables	DF	Values	Prob.
Males Replacement × Mortality Age /month	10	16.16	0.09
Males Replacement × Lamb Mortality %	27	22.61	0.70
Males Replacement × Kids Mortality %	14	12.58	0.55
Males Replacement × Breeder Experience /years	9	19.07	0.02
Males Replacement × Level of Education	2	0.10	0.95

Males Replacement: 1= replacement, 2= No replacement; Level of Education: 1= uneducated, 2= primary, and 3= basic.

Traditionally, farmers believe isolating female sheep/ goats triggers ovulation ("male effect") due to introducing replacement males, not isolation itself [25]. This aligns with West African practices of frequent male replacement and separate rearing. Understanding both traditional knowledge and science can improve animal husbandry [26]; while high flock replacement driven by lamb demand, not ewe age, leads to lower production [27].

Sheep and goat mortality is highest in December/January ($p<0.01$, Table 5) likely due to winter cold. Sharing enclosures with other animals increases infant mortality ($p<0.01$), possibly due to disease transmission. Breeder experience improves lamb survival ($p<0.05$), highlighting the value of practical care.

Table 5. Analysis of variance for lamb mortality %, kids mortality %, and mortality age/ month of sheep and goat breeders in northern Jordan (Model 3).

S.O.V	DF	Mean Square					
		Lamb mortality%	Pr> F	Kids mortality%	Pr> F	Mortality age/ month	Pr> F
Other animals	1	1.51987	0.38	1.09900	0.01	3.42165	0.61
Mortality Months	1	3.99646	0.15	0.13142	0.36	286.34653	0.01
Level of education	2	3.04641	0.21	0.04281	0.76	1.52911	0.89
Experience/ years	1	7.16296	0.04	0.06118	0.53	8.36724	0.42
Weaning age /day	1	1.72492	0.35	0.47220	0.09	21.61732	0.20
Random Error	46	1.93972		0.15905		13.14442	

High mortality rates affect young small ruminants, reaching 3.2-14.2% in goats. Poor management, improper age mixing, inadequate vaccination, and low birth weight are all contributing factors. Research emphasizes improved husbandry practices, proper vaccination, and better care for young animals as key to reducing these losses [28,29]. In addition, the maternal bond of the ewe greatly influences the survival of lambs and is influenced by stress, nutrition, and well-being [30]. Environmental factors also play a role in kid mortality, but proper management can mitigate these challenges [31]. Furthermore, studies reveal variations in disease prevalence across different regions, highlighting the need for targeted control measures [32].

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Overall, these studies underscore the multifaceted nature of raising healthy young sheep and goats, highlighting the need for a combination of improved animal husbandry practices, and consideration of environmental factors.

For sheep, Table 6 shows that higher lambing ewes rates are associated with fewer rams and non-lambing ewes, suggesting that ram competition can hinder flock fertility. Increased lambing of ewes leads to more lambs, but higher ram numbers can decrease lambing due to mating competition. More sheep means more lambs sold, but fewer lambs kept, suggesting effective flock management. A high sheep count lowers lamb mortality, boosting sales of lambs and suggesting good herd management.

Table 6. Pearson Correlation Coefficients for sheep % (above diagonal) and goat% (below diagonal) herd composition. Prob>|r| under H0: Rho=0. N=53.

Herds	Rams %	Ewe not lambing %	Ewe lambing %	All lambs %	Lamb sales %	Lamb mortality %
Sheep%	-0.08	-0.18	0.21	-0.06	0.42**	-0.50**
Rams%		-0.06	-0.42**	-0.44**	0.18	0.26
Ewes not lambing%			-0.88**	-0.15	-0.01	-0.03
Ewes lambing%				0.33*	-0.06	-0.11
All lambs%					-0.75**	-0.21
Lamb sales%						-0.47**
	Bucks %	**Non-kidding doe %**	**Kidding doe %**	**All kids %**	**Kids sales %**	**Kids mortality %**
Goats%	-0.38**	-0.03	0.17	-0.33*	0.35**	0.07
Bucks%		0.15	-0.56**	0.035	-0.29*	0.043
Non-kidding doe %			-0.90**	0.10	-0.13	-0.19
Kidding doe %				-0.07	0.24	0.12
All kids%					-0.06	-0.77**
Kids sales%						-0.55**

Non-sign: not significant; *: significant (P<0.05); **: high significant (P<0.01). .

No strong associations were found between specific ewe reproductive traits and ram sexual performance scores [33]. This suggests that selecting rams based solely on high sexual performance scores is unlikely to improve ewes' reproductive outcomes directly. Low birth weight is linked to a poor environment. Selecting lambs with higher weaning weight promotes growth, survival, and ewe reproduction [34]. Despite maternal influence decreasing with age, selecting larger lambs improves both ewe size and maternal ability due to a positive genetic link, making it a win-win for breeders [35].

For goats, Table 6 illustrations that more females lead to increased kid production, while fewer males may also boost output. However, selling kids reduces herd size. Balancing female numbers and sales is crucial. Excess males harm kid and female sales, emphasizing herd management equilibrium. Kidding goats are more disease-prone, affecting their reproductive rate. Higher mortality decreases kid production and sales, stressing the need for healthcare investment.

Heavier kids are born to heavier does, suggesting that feeding goats during critical reproductive periods can improve the health and growth of both mothers and offspring [36]. Improving data recording and animal management for phenotypic selection of traits is an important suggestion by [37]. They also emphasize the importance of better environmental conditions for raising kids to

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enhance survival rates. There are positive correlations between the first kidding period and initial milk production in animals, suggesting that reproductive performance should be considered in selection criteria [38]. Rainy seasons, older bucks (greater than 5 years old), longer mating periods (at least 21 days), and the presence of multiple males (4 or more) were all found to significantly increase birth rates in Mexican goats [39]. High pre-weaning mortality is a significant problem in Gala goats, hindering the development of replacement stock [40]. The study found that the age and sex of the kids were risk factors for mortality. Improved animal health practices could significantly reduce mortality rates and boost overall production in Gala goat herds.

3.4. Sustainability Assessment

Overall, reproductive success was assessed to evaluate herd viability. Sheep had a reproductive success rate of 92.5% and goats had a rate of 90.6% (model 4). This suggests that sheep herds may have better long-term viability than goat herds based on these rates alone. However, other factors such as disease resistance, environmental conditions, and management practices also influence herd sustainability. Variations within herds and the specific context must be considered for a reliable conclusion about herd permanence. Therefore, a more comprehensive analysis incorporating additional information is necessary.

Intensive production methods can address challenges like heat stress and disease in sheep and goats, aiming for sustainable and ethical farming practices. Achieving this requires collaboration across science, policy, and farming [41]. Compared to cattle, smaller ruminants better adapt to harsh environments, requiring fewer resources. To enhance their sustainability, prioritizing reducing emissions, ensuring animal welfare, and boosting farm profitability is crucial [42]. Ultimately, sustainable meat production involves utilizing digital tools and embracing agro ecological principles to optimize animal and environmental health [43].

Table 7 indicates a mixed sustainability assessment in sheep farming. The sheep% and lambs% receive negative evaluations, but the ewe's birth%, lambs' survival%, and lamb sales% are deemed above average. This variation in performance across indicators suggests a need for improvements to enhance overall sustainability. The sheep flock is performing well, with some indicators needing additional attention to achieve continuous improvement and increase sustainability.

Table 7. presents performance indicators for the sheep within the flocks.

Indicators	**Sheep**				
	Sheep %	**Ewes birth %**	**Lambs %**	**Lamb survival %**	**Lamb sales %**
Averages	56.5	95.4	25.3	96.9	18.0
Above average	47.2	60.4	37.7	75.5	56.6
Below average	52.8	39.6	62.3	24.5	43.4
Sustainability assessment	-	+	-	+	+

Sheep grazing can be sustainable if managed with site-specific densities, minimizing harm to the environment, boosting biodiversity, and protecting ecosystems [44]. A study by [45] identified 37 sustainability indicators that encompass productivity, stability, equity, and all 3 pillars of sustainability: social, economic, and environmental. Economic sustainability related to on and off-farm sheep activities, while social factors like generational turnover and farmer perceptions were key. They noted a trade-off between economic and environmental indicators, indicating higher economic sustainability often meant lower environmental sustainability. Maintaining genetic diversity is crucial for sustainable sheep farming, according to [46]. Diverse flocks benefit from improved production, reproduction, and adaptability. While traditional breeding methods and modern genomics can be helpful tools, successful strategies aid in considering the specific context of each farming operation. In Jordan, a three-pronged approach has been proposed to ensure the continued

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success of the small ruminant sector. This strategy outlined by [47], focuses on developing emergency response plans to mitigate extreme weather events, revamping farmers' skills, and establishing agricultural cooperatives.

Table 8 shows the sustainability assessment of the goat herd, as sustainability is good in the birth of mothers and the percentage of births and their sales. However, it could be bad for the goat herd and the survival of the young. Some indicators must be reviewed for the success of the breeding process. There is a good performance in some indicators, which supports the continued success of goat breeding.

Table 8. presents performance indicators for the goats within the flocks.

Indicators	Goats				
	Goats %	Doe birth %	Kids %	Kid survival %	Kid sales %
Averages	43.5	95.4	23.4	94.9	17.9
Above average	45.3	54.7	52.8	47.2	69.8
Below average	54.7	45.3	47.2	52.8	30.2
Sustainability assessment	-	+	+	-	+

Goat farming faces sustainability challenges including climate change, rising fodder and fuel prices, environmental degradation, and genetic erosion [48]. Sustainable African goat farming empowers women, feeds families, and protects the environment, tackling gender inequality, climate change, and rural food insecurity [49]. It is crucial to address the marketing and value hurdles faced by Turkey's goat meat to ensure a sustainable future driven by increasing consumer demand [50].

4. Conclusions

Empowering small-scale herders through training, incentives, and targeted interventions like winter mortality solutions and selective breeding is vital for the sustainability of sheep and goat farming in Jordan. These measures have significant policy implications and offer practical strategies for securing the industry's future.

The interaction between breeder indicators, economic metrics, herd management pointers, and sustainability assessment in sheep and goat farming in northern Jordan underscores how breeders' demographics, economics, and management practices shape industry viability. Older, experienced breeders typically show greater economic stability, influencing decisions like male replacement and crop cultivation. Effective management practices contribute to reproductive success, affecting sustainability. Decisive and efficient management is essential for ensuring industry sustainability and economic viability.

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