Pastoralism
Research, Policy and Practice

TYPE Original Research
PUBLISHED 28 April 2026
DOI 10.3389/past.2026.15989

OPEN ACCESS

EDITED BY
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RECEIVED 03 December 2025
ACCEPTED 27 February 2026
PUBLISHED 28 April 2026

CITATION
Naghshbandi F, Abbasi E, Maghsoudi A, Masoudi A and Vaez Torshizi R (2026) Beyond pastoralism: challenges and strategic solutions in Iranian sheep farming.
Pastoralism 16:15989.
doi: 10.3389/past.2026.15989

Beyond pastoralism: challenges and strategic solutions in Iranian sheep farming

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Sheep farming in Iran has a long and significant history, and the country is widely recognised as one of the centres of sheep domestication. However, the structure and practices of sheep farming have undergone substantial changes over the past two decades, the underlying drivers of which have not yet been systematically examined. Therefore, this study investigates the major challenges facing the Iranian sheep industry and proposes strategic solutions to promote its sustainable development. To address these issues, this study employed the Delphi method to collect and synthesise expert perspectives in order to identify key areas requiring intervention and improvement. The findings highlight the need to strengthen rangeland management practices, implement genetic improvement programmes to enhance livestock resilience, and provide greater educational and technical support to farmers. The proposed policy framework emphasises the establishment of cooperatives to empower farmers through collective resource management, knowledge sharing, and improved market access. In addition, it advocates for supportive policies focused on the sustainable management of pasture and forage resources and the expansion of targeted training programmes for sheep farmers. These strategies aim to enhance the resilience, productivity, and long-term viability of the Iranian sheep sector, enabling it to adapt effectively to contemporary environmental, economic, and social challenges. Moreover, the proposed framework could serve as a reference model for other regions experiencing similar livestock management constraints, underscoring the value of shared learning and collaborative approaches to sustainable agricultural development. By comprehensively addressing structural and operational challenges, this study contributes to strengthening the sustainability of the Iranian sheep industry while supporting national food security and rural livelihoods.

KEYWORDS

climate changes, cultural factors, economics, rural livelihoods, sheep population

Introduction

Sheep (*Ovis aries*) were domesticated independently in southeastern Anatolia, Mesopotamia, and western Iran approximately 7,000 years before present (BP) (Jackson et al., 2020). This species has accompanied human societies throughout the development of diverse civilisations. Its high adaptability enables it to thrive across a wide range of terrains and climatic conditions. Through selective breeding driven by human needs and regional environmental conditions, 418 breeds have been developed worldwide (Rasali et al., 2006). Today, sheep constitute one of the most important small ruminant livestock species in both developed and developing countries. Although sheep generally adapt rapidly to new environmental conditions, several factors may cause fluctuations in their population, despite the substantial growth of the global human population (Figure 1).

These factors are rooted in cultural, infrastructural, economic, and climatic conditions. For example, certain religious traditions involve the ritual sacrifice of sheep (Brooke, 1987). Infrastructural and economic challenges include insufficient government support for shepherds, which limits their ability to cover the costs of sheep husbandry, and the absence of consistent and structured breeding programmes. Climatic factors, including climate change, pasture degradation, harsh winters, and extreme weather events, further exacerbate these challenges (Wanjala et al., 2023). In addition, increased predator density has been identified as a contributing factor affecting sheep populations (Paterson et al., 2021).

Iran is recognised as one of the original centres of sheep domestication. Its diverse climate and geography have contributed to the development of 27 breeds of indigenous sheep over thousands of years. The majority of sheep production in Iran takes place within rural and nomadic systems, while only a small proportion is managed using industrial farming systems. Consequently, the national sheep population is highly susceptible to external environmental, economic, and social factors. According to official statistics, Iran has experienced a notable decline in its sheep population in recent years (Figure 2).

The primary objective of sheep production is meat, followed by milk and wool. These production goals are closely linked to effective reproductive and breeding management. Inadequate management systems may lead to reproductive disorders, including abortions caused by infectious diseases, which result in reduced meat and milk production, delayed breeding cycles, and significant economic losses (Ali et al., 2019). In southeastern Iran, abortion in Baluchi sheep has been associated with *Brucella melitensis*, *Coxiella burnetii*, and *Salmonella abortusovis*, as determined by molecular diagnostic techniques (Mahdavi Roshan et al., 2018). In northeastern Iran, *Mycoplasma ovipneumoniae* and *Mycoplasma arginini* have been confirmed as the etiological agents of pneumonia in sheep (Daee et al., 2020).

Effective grazing and pasture management represent additional critical challenges. From a global perspective, environmental changes, including climate change and global warming, contribute to pasture degradation, reduced vegetation density and thermal stress, which affect both forage resources and livestock (Sawyer and Narayan, 2019). At the regional level, the uncontrolled conversion of pastureland into cultivated agricultural land reduces available grazing areas further (Gebresamuel et al., 2022). These pressures create harsh production environments in which breeders struggle to provide adequate feed and nutrition, ultimately reducing profit margins and, in some cases, forcing producers to exit the sector (Tüfekci and Çelik, 2021). Nevertheless, small ruminants naturally depend on grazing systems, which support animal welfare and hoof health. Pasture-based feeding systems may also offer nutritional advantages compared with forage silage under certain conditions (Masters and Thompson, 2015).

Another important issue is the shift in human lifestyles from nomadism towards urbanisation. This transition has generated labour shortages in pastoral systems, contributed to rural poverty, and reduced purchasing power for animal products in some communities. For producers, financial constraints limit the adoption of advanced technologies that could improve breeding efficiency and overall productivity (Alders et al., 2021). Although localised increases in sheep numbers may occur in certain regions, the overall national trend indicates a decline in the sheep population (FAOSTAT, 2023).

A further challenge relates to the lack of consensus among experts and researchers regarding the primary causes of population decline and the most effective policy responses. To address these issues, the present study employs the Delphi method to formulate a comprehensive policy package for the development of the sheep breeding industry in Iran. The objectives of the study are:

1. To describe the challenges associated with the decline in the sheep population;
2. To identify solutions for controlling the decline in the sheep population;
3. To classify the extracted challenges and solutions;
4. To propose a policy package for the development of the sheep breeding industry in Iran.

These objectives are achieved by reaching consensus among a panel of experts. Panel members respond to open-ended questions, review summarised responses, rank the importance of compiled items, and indicate their level of agreement with each proposed statement through iterative rounds (Powell, 2003).

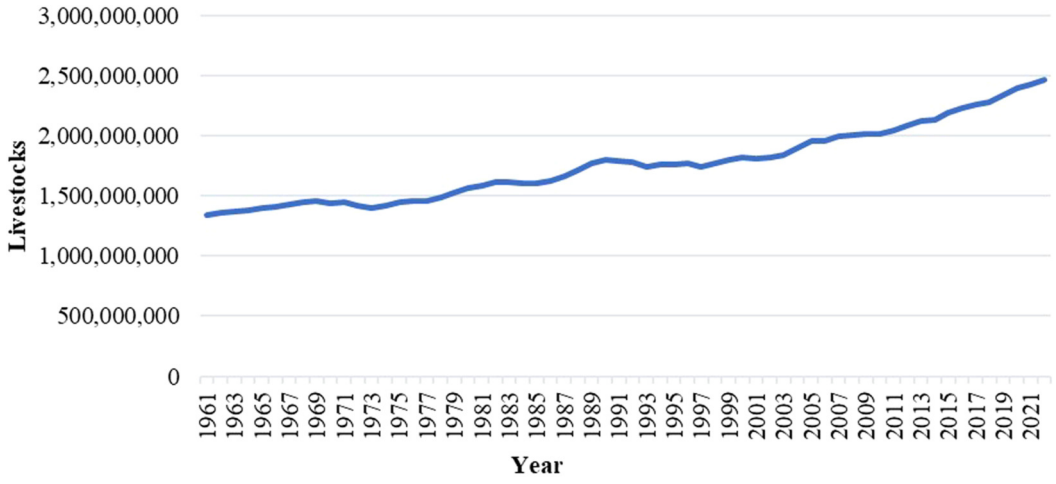

FIGURE 1
Sheep population worldwide (FAOSTAT, 2023).

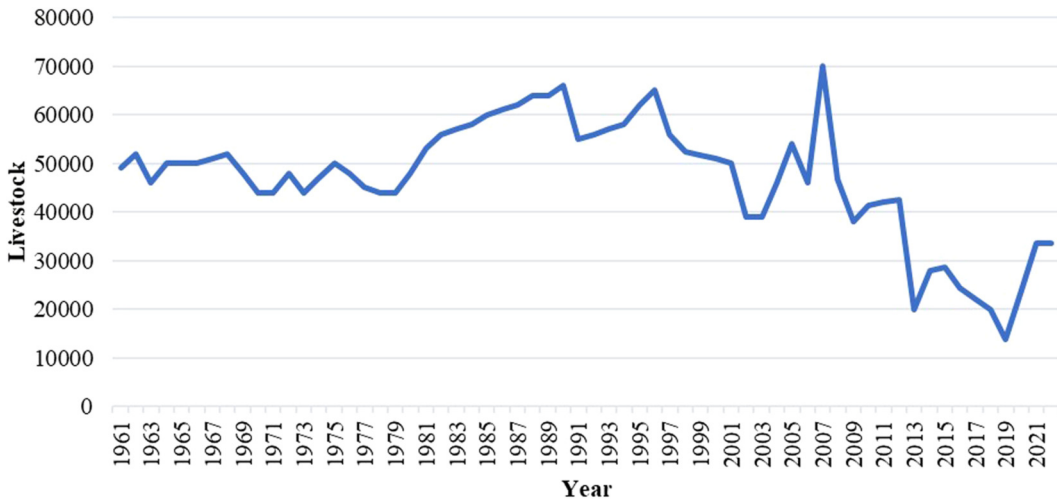

FIGURE 2
Sheep population in Iran (FAOSTAT, 2023).

The present study adopts a qualitative research paradigm. It is applied and descriptive in terms of its methodological approach. Given the novelty of the topic and the limited number of previous studies addressing the specific challenges and solutions related to the decline in the population of sheep in Iran, the classical three-round Delphi technique was employed. The core features of the Delphi method include multiple rounds of questionnaires, structured feedback, the opportunity for participants to revise their responses, and the anonymity of responses (Thangaratinam and Redman, 2005).

Materials and methods

The present study employed a mixed-methods design, integrating qualitative and quantitative approaches within a Delphi framework. To collect the required data, a panel of experts in sheep breeding was recruited from three sectors: academia, industry, and governmental administration. All participants had more than 20 years of experience working professionally with sheep breeding and were involved in administrative departments responsible for macro-level decision-making within the country (n = 18). A

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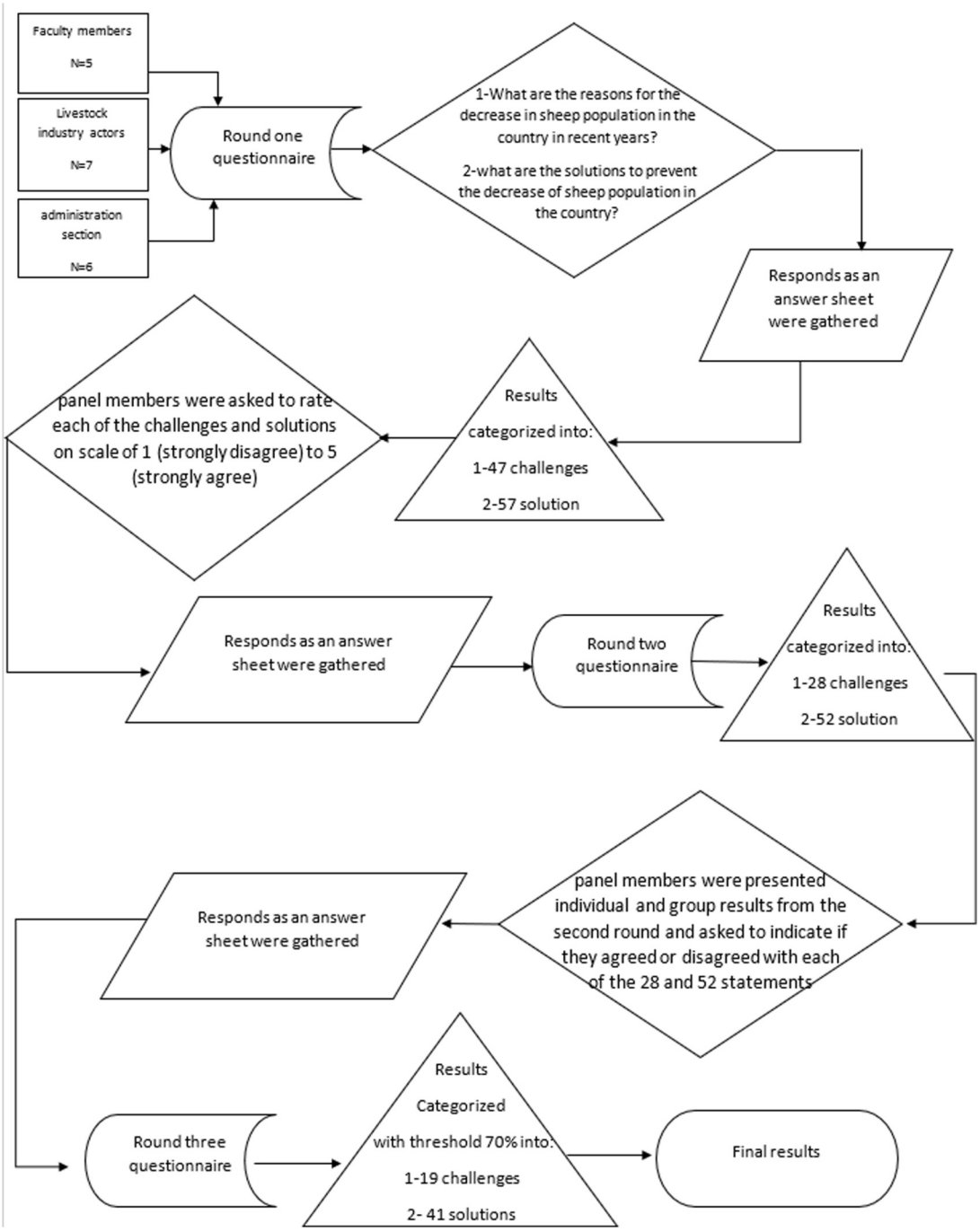

FIGURE 3
Flowchart of the Delphi technique procedure.

representative panel of 13 members can provide a reliability coefficient of 0.90 (Harder et al., 2010), indicating that the panel size in the present study was adequate to ensure methodological reliability.

The researchers administered a series of three questionnaire rounds by mail. In the first round, participants were asked to respond to two open-ended questions: (1) What are the reasons for the decrease in the sheep population in the country in recent years? and (2) What are the solutions to prevent the decrease in the sheep population in the country? The responses were analysed and consolidated into 47 challenge statements and 57 solution statements (Figure 3).

In the second round, panel members were asked to evaluate each of the identified challenges and solutions using a five-point Likert-type scale (1 = strongly disagree, 2 = disagree, 3 = uncertain, 4 = agree, and 5 = strongly agree). Participants were also invited to revise, refine, or comment on the listed items to ensure that the statements accurately reflected their perspectives.

Based on the results of the second round and the comments provided by participants, the third-round questionnaire was developed. At this stage, the list of challenges and solutions was refined and reduced to 28 and 52 items, respectively. The third round aimed to achieve consensus. Panel members were provided with both individual and aggregated group results from the second round and were asked to indicate whether they agreed or disagreed with each of the 28 challenge statements and 52 solution statements. The level of agreement required for consensus was determined *a priori* at 70%. Items that did not receive agreement from at least 70% of panel members were excluded from the final list of challenges and solutions. As noted by McCampbell and Stewart (1992), consensus in the majority of Delphi studies is typically achieved by the third round. Finally, the confirmed challenges and solutions were categorised according to the conceptual similarity of their components.

Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki. The research design involved a three-round Delphi process using structured questionnaires administered to expert participants. Participation was entirely voluntary, and informed consent was obtained from all participants prior to their inclusion in the study. Participants were informed of the study's objectives, the iterative nature of the Delphi process, and their right to withdraw at any time without penalty. The anonymity and confidentiality of all responses were strictly maintained throughout the study, and no personally identifiable information was collected. Written informed consent was obtained for the publication of any potentially identifiable images or data included in this article.

Results

Personal and professional characteristics of the respondents

A total of 18 sheep production experts participated in the Delphi rounds of this study. The panel was intentionally composed to represent the academic, industrial, and administrative sectors, and included faculty members (n = 5), livestock industry practitioners (n = 7), and administrative experts (n = 6). The faculty members had a mean age of 55 years and a mean professional experience of 28 years, and all held a Doctor of Philosophy (PhD) degree in animal science. The livestock industry practitioners had a mean age of 49 years and had the most professional experience on average among the groups (30 years). Their educational backgrounds included bachelor's or master's degrees in animal science. The administrative sector experts had a mean age of 51 years and a mean professional experience of 24 years; their educational backgrounds included master's or PhD degrees in animal science. Overall, the panel represented a mature and highly experienced group of experts with substantial academic training in animal science—particularly in animal breeding and genetics, ruminant nutrition, and animal physiology—and extensive experience in the sheep production sector. The mean age, mean professional experience, educational level, and number of respondents in each group are presented in Table 1.

Findings from the first round of the study

The first objective of the study was to identify the challenges associated with the recent decline in the Iranian sheep population and propose potential solutions to prevent further reductions. In the first Delphi round, two open-ended questions were posed to the panel members: (1) What are the challenges contributing to the decline in the sheep population? and (2) What are the solutions for controlling the decline in the sheep population?

The response rate in this round was 100%. Based on the responses from the 18 participants, an initial list of challenges and solutions was generated.

TABLE 1 Professional characteristics of the panel of experts.

Group	Average age (year)	Average experience (years)	Level of education	Number
Faculty members	55	28	PhD	5
Livestock industry actors	49	30	BSc/MSc	7
Experts in the administration section	51	24	PhD/MSc	6

Findings from the second round of the study

In the second round, the panel members were asked to rate each of the 47 challenges and 57 solutions identified in the first round using a five-point Likert-type scale. All panel members participated in this round, resulting in a 100% response rate.

The results indicated that 28 challenge items had a mean score greater than 3, whereas 19 items had mean scores below 3. Regarding the proposed solutions, 52 items had mean scores above 3, while 5 items had mean scores below 3. Consequently, the 52 solution items with mean scores above 3 were retained for the third round, and the remaining items were excluded.

Findings from the third round of the study

In the third round, panel members were asked to indicate dichotomously whether they agreed or disagreed with each of the remaining challenge and solution statements. To facilitate consensus building, participants were also invited to provide comments in cases of disagreement or where further clarification of an item was needed. All panel members responded, resulting in a 100% response rate. For the challenges, 9 items received less than 70% agreement and were therefore excluded. The remaining 19 items met the predefined consensus threshold and were retained for subsequent classification. For the solutions, 11 items received less than 70% agreement and were excluded, while 41 items achieved the required level of agreement and were retained for classification (Tables 2, 3).

The secondary objective of the study was to classify the confirmed challenges and solutions. As shown in Table 4 and Figure 4, the challenges identified in the third round were categorised into the following domains: ecological, communication, economic, supportive, lifestyle, educational, and animal breeding. The solutions were categorised into educational and extension, genetic improvement, facilitation and support, human resources, fodder supply management, branding, and international interaction (Table 5, Figure 5).

Discussion

Based on the findings, the discussion is organised into two main sections: challenges and solutions. In the challenges section, 19 items were identified and categorised into the following domains: ecological, communication, economic, supportive, lifestyle, educational, and animal breeding. In parallel, the confirmed solutions were categorised into education and extension, genetic improvement, facilitation and support, human resources, fodder supply management, branding, and international interaction.

Across these categories, several challenges demonstrated strong interrelationships despite being classified under different domains. For example, within the ecological, supportive, and lifestyle domains, the following challenges showed high levels of agreement (93%, 83%, and 80%, respectively): drought, decreased pasture quality and unstable breeding conditions due to changing rainfall patterns; lack of development of side professions related to sheep by-products; and changes in villagers' lifestyles accompanied by declining interest in labour-intensive occupations such as sheep breeding. Although categorised separately, these factors are closely interconnected in practice.

Increasing drought stress, together with the reduction of natural pastures and water resources, threatens the sustainability of extensive sheep production systems. These pressures directly affect sheep nutrition, health status, and overall farm productivity (Scocco et al., 2016). Comparable findings have been reported in fat-tailed lambs subjected to feed restriction, where nutritional stress significantly influenced growth performance and metabolic parameters (Moghaddam et al., 2021).

The development of complementary or side businesses could provide sheep farmers with alternative income streams and enhance their economic resilience. By-products such as wool, hides, and manure can be processed and marketed, contributing to a more diversified and sustainable production model while creating additional employment opportunities within rural communities (Hatziminaoglou and Boyazoglu, 2011; Lal et al., 2020). Furthermore, sheep production is inherently labour-intensive, requiring continuous management of herding, feeding, and animal care. Declining interest in such occupations has led to shortages of skilled and motivated labour, thereby reducing production efficiency. Labour-intensive activities such as sheep rearing often generate lower incomes compared with emerging opportunities in other sectors, making them less attractive to rural populations seeking more stable and profitable livelihoods (Dorji et al., 2017).

To address these challenges, experts have proposed several supportive and structural solutions, including recognising shepherding as a high-risk occupation and providing appropriate insurance and social services; promoting rural production and consumption patterns to strengthen local economies; establishing local markets for rural products; allocating low-interest financial facilities to sheep breeders; guaranteeing government purchase of livestock products (similar to wheat procurement policies); utilising the capacity of nomadic communities for pasture management and border protection alongside livestock

TABLE 2 Challenges associated with Iran's sheep development.

Rank	Items	Agreement[a] (total)	Mean[b] (total)	Frequencies[c]
1	A lack of a strong organisation to support sheep breeders (a lack of unions and cooperatives)	93	3.83 ± 1.11	38.88
2	Droughts and decreases in the quality of pastures, due to an unstable climate and changing rainfall patterns	93	4.00 ± 1.41	88.89
3	Insufficient income to cover the costs of breeding sheep and their product, meaning it is difficult to attract new investors	89	4.28 ± 0.57	33.33
4	A lack of development of side professions for sheep by-products	83	3.46 ± 0.98	16.66
5	No guaranteed purchase of sheep products by the government, with the presence of brokers and middlemen reducing the breeders' profits (there is no guaranteed purchase process for wheat)	83	4.33 ± 1.13	66.66
6	Extreme market fluctuation and uncertainty about future investment prospects for this profession	83	4.09 ± 0.94	50.00
7	Smaller final benefits compared to other businesses in sheep breeding	83	3.99 ± 1.13	72.22
8	Changes in lifestyle among villagers due to a lower interest in strenuous jobs, such as sheep breeding	80	3.90 ± 1.10	77.77
9	A destruction of pastures and shepherds becoming dependent on production factors and manufactured forage	80	4.16 ± 0.76	33.33
10	A disconnection among the three aspects of livestock farming within the country (university, industry, and performance)	78	3.59 ± 1.29	22.22
11	Illiteracy and a lack of education programmes for breeders	78	3.33 ± 1.07	50.00
12	A lack of young and interested workers in animal husbandry within villages (as the main centres for sheep breeding)	76	3.94 ± 0.90	77.77
13	Non-allocation of subsidised production factors allocated to the small ruminant sector (with major allocation of imported inputs to dairy cattle and poultry)	76	3.23 ± 1.28	77.77
14	Pasture utilisation problems due to poor interaction between natural resources and pasture-dependent pastoralists	76	3.21 ± 1.13	50.00
15	The new generations of employees in related organisations are unaware of sheep-related issues	76	3.20 ± 1.10	22.22
16	Lower efficiency of national sheep breeds for breeding in closed industrial situations	74	3.15 ± 1.15	66.66
17	A transformation of sheep breeding from a multi-product system (meat, milk, wool, leather) to a single-product system (meat)	72	3.38 ± 1.14	5.55
18	A lack of increase in Iranians' household incomes over the past 25 years, which is insufficient to purchase sheep meat	72	4.11 ± 0.76	33.33
19	A lack of a comprehensive breeding plan, which has led to the destruction of sheep breeds	70	3.63 ± 1.34	38.88
20	An absence of an integrated production chain from farm to table	-	3.89 ± 0.96	16.66
21	A lower population of villagers and an increase in urbanisation	-	3.77 ± 0.96	55.55
22	The increase of a meat import-based criminal organisation despite the ample supply of sheep meat in the country	-	3.63 ± 1.24	55.55
23	A lack of interested and skilled shepherds in the country	-	3.59 ± 0.98	61.11
24	The weak social status of the sheep farming profession	-	3.57 ± 1.10	5.55
25	Government subsidies to broiler meat, which is a serious and cheaper competitor to red meat	-	3.53 ± 1.25	38.88
26	A lack of insurance and social services for animal breeders	-	3.36 ± 1.23	27.77
27	A lack of demand for sheep wool due to the textile industry's collapse (loss of a part of the market for sheep products)	-	3.20 ± 1.10	44.44
28	Small ownership systems and small herd size	-	3.05 ± 1.24	38.88

(*Continued*)

TABLE 2 Continued

Rank	Items	Agreement[a] (total)	Mean[b] (total)	Frequencies[c]
29	Climate change (some of the climates that were stable in past have become unstable, and *vice versa*, affecting the locations where local breeds mate	-	-	83.33
30	Long travel time between the locations of sheep breeders and service providers(educational, health, veterinary, production factors, and so on)	-	-	83.33
31	Lower efficiency of sheep breeding systems (it is different from low sheep efficiency)	-	-	66.66
32	Smuggling live animals to Arab countries	-	-	55.55
33	Persuading traditional herdsmen to decrease the number of native sheep and encouraging the production of high-yield livestock by pertinent organisations	-	-	50.00
34	Exclusion of sheep skins and leather from the market due to the growing imports and use of synthetic leather (loss of a portion of the market for sheep products)	-	-	50.00
35	Exclusion of sheep leather from sales list due to government restrictions on row sales and sharp declines of import salambor products (loss of a portion of the market for sheep products)	-	-	44.44
36	No access to permanent veterinary services due to the-shortage of professional small ruminant veterinarians	-	-	33.33
37	A lack of proper infrastructure in sheep breeding locations (mechanisation, electricity, purification of water, telecommunications, and internet) in comparison to cattle and poultry farms	-	-	27.77
38	Spread of contagious diseases due to expensive high-quality drugs and low-quality national drugs	-	-	27.77
39	Social media trends promoting white meat over red meat	-	-	27.77
40	Decrease in consumption of red meat due to social media trends and nutrition education	-	-	27.77
41	Decrease in the desire to consume red meat due to the growing dietary changes in the consumer population	-	-	16.66
42	Increase in the number of health centres with campaigns opposing red meat and sheep with fat tails	-	-	11.11
43	A change in taste due to propaganda against sheep with fat tails (the majority of local breeds have fat tails)	-	-	11.11
44	A change in nomadic breeding (migration, which used to take up to 3 months, is now done by truck, putting more pressure on summer and winter pastures)	-	-	11.11
45	The development of machine-made carpet industries and a decrease in domestic customers for hand-woven carpets, along with a lack of customers for sheep's wool	-	-	11.11
46	Ability to extract vegetable oil and strong advertising against animal fat	-	-	5.55
47	Sheep populations have not declined; rather, the data have become more reliable	-	-	5.55

[a]Expert panel agreement (percentage) per item.
[b]Average of each item in the second round.
[c]The expert panel percentage in the first round.

production; and preventing pasture degradation and land-use conversion.

Within the communication and economic domains, two major challenges received particularly high levels of agreement (93% and 89%, respectively): the absence of strong organisations to support sheep breeders (including unions and cooperatives) and insufficient income relative to production costs, which discourages new investment.

In the absence of effective cooperatives or professional unions, individual breeders often lack the collective bargaining power to negotiate favourable prices for outputs (e.g., meat and wool) or inputs (e.g., feed and veterinary services). This weakens their market position and reduces profitability. Organised structures can facilitate knowledge exchange, resource sharing, and the dissemination of best practices. Moreover, cooperatives can

TABLE 3 Solutions associated with Iran's sheep development.

Rank	Items	Agree[a] (total)	Mean[b] (total)	Frequencies[c]
1	Training breeders to document the identity and information of their herds	100	3.642 ± 1.294	27.77
2	Creating a local market for the consumption of rural products (small-scale marketing)	100	3.533 ± 1.247	50.00
3	Promoting rural livestock products in schools and textbooks to establish the importance of small ruminants in children's minds	100	3.417 ± 1.195	38.88
4	Providing permanent veterinary services oversights in the small ruminant sector	100	3.083 ± 1.367	66.66
5	Increasing the knowledge and interest of breeders and other individuals in sheep breeding	93	3.458 ± 1.097	94.44
6	Using superior genetics to produce inexpensive meat in a closed breeding system	93	3.450 ± 1.249	5.55
7	Synthesising new breeds to increase lamb productivity and breeding performance	89	4.458 ± 0.616	5.55
8	Forming core herds and transferring genetic material to civilian herds	89	4.242 ± 0.808	55.55
9	Improving the viewpoint of government decision-makers on the small ruminant sector	89	4.117 ± 1.162	44.44
10	Recruitment of caring and skilled employees in the performance department	89	3.875 ± 1.249	22.22
11	Using traditional products based on animal products in cinema, television and environmental advertising	89	3.692 ± 1.381	27.77
12	Development of sheep food processing industries	89	3.675 ± 1.138	16.66
13	Preventing blind breeding and arbitrary hybridisation between sheep breeds	89	3.608 ± 1.338	83.33
14	Increasing educational-extensional activities to improve the level of breeding awareness in order to increase the productivity of rural-nomadic production units	89	3.600 ± 1.200	72.22
15	Development of agricultural academies and principled sheep breeding training in these centres	89	3.333 ± 1.227	77.77
16	Allocation of appropriate and low-interest facilities to sheep breeders	87	4.183 ± 1.023	55.55
17	Improving breeding management in civilian herds	87	4.050 ± 0.840	11.11
18	Limiting the introduction of genetic material and the risks that this poses to local breeds	87	3.550 ± 1.249	77.77
19	Preventing the destruction of pastures and changes to the use of agricultural land	87	3.525 ± 1.150	11.11
20	Improving terminal crossbreeding	85	3.808 ± 0.878	5.55
21	Providing educational content to improve the knowledge levels of educators	85	3.775 ± 1.283	5.55
22	Forming rural cooperatives and unions, and pooling people's capital to form large herds	85	3.683 ± 1.195	88.88
23	Developing an artificial insemination programme in order to use superior genes	85	3.483 ± 1.199	5.55
24	Classifying the shepherd's job as a hard job, and allocating appropriate insurance and social services	83	4.208 ± 1.183	66.66
25	Guaranteed purchase of animal products by the government (similar to the guaranteed purchase of wheat)	83	3.900 ± 1.339	5.55
26	Continuous monitoring of the country's livestock population, and preventing unnecessary meat imports when there is sufficient livestock in the country	83	3.825 ± 1.098	66.66
27	Employing nomads in pasture management (e.g., border and environmental protection) in addition to sheep farming	83	3.550 ± 1.425	16.66
28	Development of textile products from livestock (e.g., carpets with natural fibres)	83	3.525 ± 1.200	11.11
29	Pasture management improvement (for example, by cancelling grazing licences for those individuals who are no longer engaged in livestock farming, and renting pastures instead)	83	3.417 ± 1.195	83.33
30	Development of intermediate and related jobs to improve the levels of sheep breeding (such as rice farming in Gilan)	83	3.292 ± 1.353	22.22
31	Creation of ideas at the university level for using local and traditional products, such as sheep's wool	83	3.292 ± 1.263	16.66

(*Continued*)

TABLE 3 Continued

Rank	Items	Agree[a] (total)	Mean[b] (total)	Frequencies[c]
32	Branding of "Kaleh Va Pache" as a traditional food, similar to the branding of pizza (in Iran, pizza has become a popular non-traditional dish)	83	3.183 ± 1.367	27.77
33	Oversease farming to provide cheap fodder and supply for small ruminant breeders	80	3.442 ± 1.335	44.44
34	Improving relationships with Arab countries and exporting sheep meat instead of live animals	80	4.367 ± 1.092	61.11
35	Issuing export certificates to breeders to increase their financial base	80	4.258 ± 1.179	22.22
36	Issuing national IDs and placing them on the products in order to rank the products of the growers	76	3.558 ± 1.294	11.11
37	Development of comprehensive local programmes (HUBs) for each of the sheep breeding centres in the country according to regional conditions	76	3.683 ± 1.145	77.77
38	The option for the children of sheep breeders to pursue studies in animal science without taking an entrance exam	76	3.225 ± 1.383	16.66
39	Encouraging rural people to consume their products (villagers do not want to imitate urban life)	72	3.558 ± 1.247	55.55
40	Establishing breeding programmes to increase lamb production per year	70	4.175 ± 0.707	5.55
41	Branding organic meat	70	4.058 ± 1.305	16.66
42	Direct involvement of the government in selling live animals and animal products to remove middlemen and brokers	-	3.925 ± 1.383	83.33
43	Construction of slaughterhouses in the provinces adjacent to the Persian Gulf and the Oman Sea, funded by Arab countries	-	3.850 ± 1.295	27.77
44	Branding in the textile sector	-	3.833 ± 1.215	27.77
45	Setting meat prices to reflect the costs of sheep breeding	-	3.817 ± 1.487	55.55
46	Providing subsidies to local breeders	-	3.592 ± 1.294	50.00
47	Allocating subsidised production factors to the small ruminant sector	-	3.508 ± 1.501	94.44
48	Persuading famous Iranians (celebrities) in the country to use clothes made from natural fibres	-	3.383 ± 1.447	33.33
49	Persuading famous Iranians (celebrities) to use traditional clothes made from natural fibres obtained from sheep's wool (when they intend to attend official events and festivals, and so on in other countries)	-	3.342 ± 1.353	38.88
50	Using the expertise of the Agricultural Jihad Organisation in cities for the centralised collection of sheep products, including wool and skins	-	3.250 ± 1.295	11.11
51	Allocation of barren lands from national lands to animal science graduates to build sheep breeding farms	-	3.167 ± 1.305	11.11
52	Gathering small herds in order to create larger herds under single management	-	3.142 ± 1.110	50.00
53	Industrialising the breeding of small ruminants -Concentrated breeding instead of nomadic breeding	-	-	88.88
54	Preventing preformatting breeding projects under government supervision due to the lack of government budget continuity	-	-	38.88
55	Improving the lifestyle of villagers who have travelled to big cities to study and developed a desire to return to their villages	-	-	33.33
56	Allocating subsidies to famous people (celebrities) instead of giving subsidies to producers or consumers	-	-	16.66
57	Population reduction is appropriate state for the country sheep industry	-	-	16.66

[a]Expert panel agreement (percentage) per item.
[b]Average of each item in the second round.
[c]The expert panel percentage in the first round.

TABLE 4 Categorised challenges related to the decrease in sheep population.

Category	Challenges
Ecological challenges	- Droughts and decreases in the quality of pastures due to an unstable climate caused by changing rainfall patterns
	- Destruction of pasture and shepherds becoming dependent on production factors and manufactured forage
Communication challenges	- Lack of strong organisations to support sheep breeders (lack of unions and cooperatives)
	- Disconnection between the three aspects of livestock farming within the country (university, industry, and performing)
	- Pasture utilisation problems due to poor management of natural resources and pasture-dependent pastoralists
Economic challenges	- Insufficient income from sheep product breeding costs, therefore unable to attract new investors
	- Extreme market fluctuations and uncertainty regarding future investment prospects for this profession
	- Smaller final benefits compared to other businesses in sheep breeding
	- A lack of increase in Iranians' household incomes over the past 25 years, which is insufficient to purchase sheep meat
Support challenges	- No guaranteed purchase of sheep products by the government, with the presence of brokers and middlemen reducing the breeders' profits (there is no guaranteed purchase process for wheat)
	- A lack of development of side professions for sheep by-products
	- Non-allocation of subsidised production factors allocated to the small ruminant sector (with major allocation of imported inputs to dairy cattle and poultry)
Lifestyle challenges	- Changes in lifestyle among villagers due to a lower interest in strenuous jobs, such as sheep breeding
	- Lack of young and interested workers in animal husbandry within villages (as the main centres for sheep breeding)
Educational challenges	- Illiteracy and a lack of education programmes for breeders
	- The new generations of employees in related organisations are unaware of sheep-related issues
Animal breeding challenges	- Lower efficiency of national sheep breeds for breeding in closed industrial situations
	- A transformation of sheep breeding from a multi-product system (meat, milk, wool, leather) to a single-product system (meat)
	- A lack of a comprehensive breeding plan, which has led to the destruction of sheep breeds

provide financial support mechanisms to help breeders manage risks during economic or environmental crises, thereby promoting long-term sustainability (Valiev and Khafizov, 2021).

When revenues fail to offset production costs, the financial viability of sheep farming is undermined. Under these conditions, existing producers struggle to sustain operations, and potential investors are discouraged from entering the sector. This investment gap hinders modernisation, limits the adoption of advanced technologies and improved breeding strategies, and ultimately reduces sector productivity and competitiveness. As a result, breeders may lose motivation to continue their activities (Akcaoz et al., 2021).

Proposed solutions to these economic and organisational challenges include forming rural cooperatives and unions to pool capital and establish larger herds; cultivating offshore to provide small ruminant producers with low-cost fodder; strengthening trade relations with Arab countries and prioritising meat export over live animal export; and issuing export certificates to qualified breeders to enhance their financial capacity and market access.

Finally, two closely related challenges were identified in the educational and animal breeding domains encompassed: low literacy levels among some breeders and the absence of systematic training programmes, and the relatively low efficiency of certain national sheep breeds under closed, industrial production systems.

Effective sheep breeding programmes depend on accurate record keeping related to performance traits, genetics, health status, and growth parameters (Abbasi et al., 2012). Limited literacy and inadequate training hinder the maintenance of such records and constrain evidence-based decision-making in selective breeding. The absence of structured educational programmes also reduces breeders' awareness of best practices in disease prevention, nutrition, reproductive management, and genetic improvement, thereby limiting productivity gains (Nel et al., 2023).

If indigenous breeds demonstrate lower performance in industrial systems, producers may shift towards commercial breeds that are better adapted to intensive conditions. This trend could accelerate the erosion of native genetic resources and reduce overall genetic diversity, thereby weakening long-term resilience to environmental change and disease challenges. While many indigenous breeds perform well under extensive grazing systems, they may exhibit reduced productivity, elevated

FIGURE 4
Sunburst chart of challenges.

stress responses, and increased health risks in closed housing systems characterised by different feeding and management regimes (Wanjala, 2024).

To address these issues, experts have proposed enhancing breeders' knowledge and encouraging greater participation in sheep production; utilising superior genetic resources to improve meat production efficiency in closed systems; expanding artificial insemination programmes to disseminate elite genes; establishing nucleus herds and transferring genetic material to commercial flocks; and preventing unplanned crossbreeding and indiscriminate hybridisation among sheep breeds. These findings are consistent with previous research highlighting the importance of structured breeding programmes in improving growth performance and carcass traits in native sheep populations (Lee et al., 2019).

TABLE 5 Categorised solutions for preventing a decrease in the sheep population.

Category	Solutions
Education and Extension	- Training breeders to document the identity and information of their herds
	- Promoting rural livestock products in schools and textbooks to establish the importance of small ruminants in children's minds
	- Increasing the knowledge and interest of breeders and other individuals in sheep breeding
	- Using traditional products based on animal products in cinema, television and environmental advertising
	- Creation of ideas at the university level for using local and traditional products, such as sheep's wool
	- Encouraging rural people to consume their products (villagers do not want to imitate urban life)
	- The option for the children of sheep breeders to pursue studies in animal science without taking an entrance exam
	- Increasing educational-extensional activities to improve the level of breeding awareness in order to increase the productivity of rural-nomadic production units
	- Development of agricultural academies and principled sheep breeding training in these centres
Genetic improvements	- Using superior genetics to produce inexpensive meat in a closed breeding system
	- Synthesising new breeds to increase lamb productivity and breeding performance
	- Forming core herds and transferring genetic material to civilian herds
	- Preventing blind breeding and arbitrary hybridisation between sheep breeds
	- Establishing breeding programmes to increase lamb production per year
	- Limiting the introduction of genetic material and the risks that this poses to local breeds
	- Improving terminal crossbreeding
	- Developing an artificial insemination programme in order to use superior genes
	- Improving breeding management in civilian herds
Facilitation and support	- Creating a local market for the consumption of rural products (small-scale marketing)
	- Development of sheep food processing industries
	- Allocation of appropriate and low-interest facilities to sheep breeders
	- Development of textile products from livestock (e.g., carpets with natural fibres)
	- Guaranteed purchase of animal products by the government (similar to the guaranteed purchase of wheat)
	- Continuous monitoring of the country's livestock population, preventing unnecessary meat imports when there is sufficient livestock in the country
	- Development of comprehensive local programmes (HUBs) for each of the sheep breeding centres in the country according to regional conditions
	- Classifying the shepherd's job as a hard job, and allocating appropriate insurance and social services
	- Employing nomads in pasture management (e.g., border and environmental protection) in addition to sheep farming
Human resources	- Providing permanent veterinary services oversights in the small ruminant sector
	- Issuing national IDs and placing them on the products in order to rank the products of the growers
	- Improving the viewpoint of government decision-makers on the small ruminant sector
	- Recruitment of caring and skilled employees in the performance department
	- Forming rural cooperatives and unions, and pooling people's capital to form large herds
	- Development of intermediate and related jobs to improve the levels of sheep breeding (such as rice farming in Gilan)
Fodder supply management	- Oversease farming to provide cheap fodder and supply to small ruminant breeders
	- Preventing the destruction of pastures and changes to the use of agricultural lands
	- Pasture management improvement (for example, by cancelling grazing licences for those individuals who are no longer engaged in livestock farming, and renting pastures instead)

(*Continued*)

TABLE 5 Continued

Category	Solutions
Branding	- Branding of "Kaleh Va Pache" as a traditional food, similar to the branding of pizza (in Iran, pizza has become a popular non-traditional dish)
	- Branding organic meat
International interactions	- Improving relationships with Arab countries and exporting sheep meat instead of live animals
	- Issuing export certificates to breeders to increase their financial base

FIGURE 5
Sunburst chart of solutions.

Conclusion

This study identified the key environmental and socio-economic challenges that threaten the sustainability of Iran's sheep industry, including drought, rangeland degradation, low profitability, and weak institutional support. By applying the Delphi method, expert consensus was achieved on a set of practical and policy-oriented solutions to address these challenges.

To operationalise the findings, rural sheep cooperatives should be legally strengthened to enhance their collective marketing capabilities, improve their access to financial resources, and facilitate structured export mechanisms. Concurrently, the development of a national climate-resilient rangeland and forage management programme is essential to prevent land degradation and stabilise feed resources. In addition, a coordinated breeding and training strategy is required to enhance breeders' knowledge, expand artificial insemination services, establish nucleus herds, and preserve indigenous genetic resources while improving overall productivity.

The effective implementation of these measures depends on close collaboration between government agencies, industry stakeholders, and educational institutions. The adoption of these integrated strategies could contribute to the revitalisation, resilience, and long-term sustainability of Iran's sheep sector. Furthermore, the proposed framework could serve as a practical policy model for other developing countries facing comparable structural, economic, and environmental challenges in their livestock industries.

As with any research, this study has limitations that should be acknowledged. In the second Delphi round, items with mean scores below 3 were excluded, and in the third round, items that did not achieve at least 70% agreement were omitted. Although this threshold-based approach is methodologically consistent with Delphi procedures, it may have resulted in the exclusion of nuanced or contested issues that could still hold policy relevance. This limitation reflects an inherent methodological trade-off in consensus-based research and should be considered when interpreting the findings.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The research design involved a three-round Delphi process using structured questionnaires administered to expert participants. Participation was entirely voluntary, and informed consent was obtained from all participants prior to their inclusion in the study. Participants were informed of the study's objectives, the iterative nature of the Delphi process, and their right to withdraw at any stage without penalty. The anonymity and confidentiality of all responses were strictly maintained throughout the study, and no personally identifiable information was collected. Written informed consent was obtained for the publication of any potentially identifiable images or data included in this article.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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