Gorgan University of Agricultural Sciences and Natural Resources

Environmemtal Resources Research (ERR)

Print ISSN: 2783-4832
Online ISSN: 2783-4670

# Managing drought on rangelands: adaptive strategies as perceived by pastoralists in Jiroft county

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**Article Info**

**Article type:**
Research Article

**Article history:**
Received: November 2022
Accepted: June 2023

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**Keywords**:
Arid land
Ecosystem
Drought
Shrubland

**Abstract**

Drought poses a significant challenge to pastoralists in arid and semi-arid regions, necessitating a reassessment of drought management strategies on rangelands. This study aimed to identify optimal strategies for drought management on rangelands based on the perceptions of nomadic and rural pastoralists in Jiroft County, Kerman Province. Data were collected through the administration of questionnaires. The findings, determined through multiple regression analysis, underscore the utmost significance of specific management strategies for pastoralists during drought conditions. Notably, water management ($P<0.0001$), forage management ($P<0.001$), and income diversification ($P<0.05$) emerged as crucial elements in effective drought management. Principal Component Analysis (PCA) further revealed that employing suitable irrigation techniques, engaging in recreational activities, purchasing forage, and efficiently storing water are critical sub-criteria for enhancing drought management strategies. Nomadic pastoralists identified moving livestock to rangelands with better conditions and changing livestock types as important drought management strategies. Given the reluctance of rural and nomadic pastoralists to reduce their livestock numbers during drought periods, the implementation of such strategies requires governmental arrangements and financial support. The findings emphasize pastoralists' preference for reactive drought management methods over preventive strategies, underscoring the need to raise awareness among pastoral communities about the risks associated with drought. Overall, the indigenous knowledge held by pastoralists has the potential to enhance existing management plans aimed at mitigating the consequences of drought.

**Cite this article:** Khosravi Mashizi, Azam; Sharafatmandrad, Mohsen. 2023. Managing drought on rangelands: Adaptive strategies as perceived by pastoralists in Jiroft County. *Environmental Resources Research*, 11(2), 167-178.


DOI: 10.22069/ijerr.2024.20994.1396
Publisher: Gorgan University of Agricultural Sciences and Natural Resources

## Introduction

Drought is a prevalent and recurring natural phenomenon, manifesting in various climates. Regions characterized by arid and semi-arid conditions, which exhibit significant fluctuations in rainfall, are particularly susceptible to drought (Karrous & Elmouidm, 2008). The repercussions of drought span across multiple domains, including social, economic, and environmental aspects, and these consequences can differ from one location to another (Nafarzadegan et al., 2012), contingent on the specific region (Brown et al., 2017).

Drought can have detrimental effects on natural resources, particularly rangelands. Macon et al. (2016) showed that drought reduced rangeland forage production by 80% in California. Rangelands cover a significant part of Iran. These ecosystems are generally fragile lands prone to degradation and drought. Hence, recognizing the consequences of drought is the first step to cope with it in rangelands. Padiab et al. (2009) investigated the impacts of drought on rangelands around Hamoon wetland in Sistan region and reported that 200,000 hectares of rangelands around the wetland and 15,000 hectares of rehabilitated reeds in the wetland bed have experienced adverse effects due to decreased rainfall and reduced water inflow to the lake in 2000-2001.

As drought may cause severe damage to the human communities, rangeland managers seek solutions to help mitigate the impacts of drought based on the ecological, social and economic impacts of the past droughts (Kelley et al., 2016). Drought management programs should aim to mitigate drought impacts, adapt to drought variability, and recover from drought (Moghaddas Farimani et al. 2017). Drought management is a crucial tool for minimizing drought risk and expediting drought recovery. Many drought management programs have failed due to their neglect of the interactions between humans and the environment (Urquijo-Reguera, 2022). Local stakeholders as the main exploiters of ecosystems can play important role to help mitigate the impacts of drought on ecosystems (Singh and Chudasama, 2017). The pastoralists all around the world have endured recurrent drought which negatively affect their economy from rangelands (Smart et al., 2021). Accumulated financial losses and psychological stress caused by drought affect the emotional and social dynamism of pastoralists' families (Wilmer and Fernández-Giménez, 2016).

As frequency and severity of future droughts are largely unpredictable, awareness of pastoralists' flexibility is one of the key features of drought management (Fazey et al., 2010). Pastoralism is highly dynamic and complex (Rhoades et al., 2014) and their perceptions of drought adaptation strategies are different. They choose different strategies based on their needs and goals (Wilmer and Fernández-Giménez, 2015). According to Wilmer et al. (2016), effective drought management should take into account the perceptions of those directly affected, and successful drought management necessitates learning from individuals on the 'front line' of rangeland drought who have endured recurrent drought.Wilmer and Fernández-Giménez (2015) also examined the US rangeland stakeholders' attitude on drought management and concluded that future plans are likely to be more successful if they are designed based on the complex experiences of pastoralists. Moghaddas Farimani et al. (2017) introduced the most effective drought coping strategies based on pastoralists' experiences in Fars province, Iran, as reducing stocking rates and gradually phasing out inefficient, old, and sick livestock. As drought stands as one of the most existential natural disasters threatening pastoralists in arid and semi-arid regions, it becomes imperative to reevaluate managerial strategies for drought on rangelands. While drought is a complex phenomenon, this study aims to explore the most effective drought management strategies by tapping into the experiences and perceptions of rural and nomadic pastoralists who have endured prolonged drought in their rangelands.

## Materials and methods

### *Study Area*

This study was conducted in Jiroft County, Kerman Province, south east of Iran (57º01′ to 57º35′ E and 28º40′ to 29º 21′N, Figure 1). The average annual rainfall varies between 136 to 466 mm. The region has

experienced frequent droughts. In recent years, wet spells have decreased and dry spells have increased (Bigneh and Ekhtesasi, 2013).

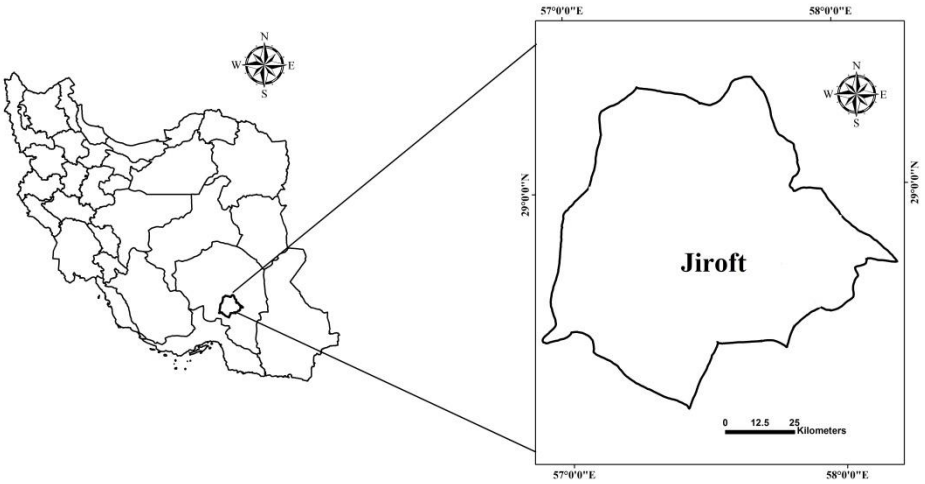


**Figure 1.** Location of the study area

***Methods***

This study is a descriptive-analytical research. Questionnaires were employed to collect pastoralists' opinions in two parts. The first part gathered personal information, including gender, age, income, level of education, and employment status. The second part assessed the importance of drought management strategies using a five-point Likert scale ranging from 1=very low to 5 = very high. Criteria and sub-criteria for drought management were determined based on previous studies (Table 1). The questionnaire's validity was confirmed by university professors and experts, and necessary corrections were made in multiple stages. Cronbach's alpha was used to observe the principles and techniques of work and measure the degree of questionnaire reliability.

The required sample size was determined based on the following equation:

$$n=\frac{Z^2 p(1-p)}{d^2}$$

where n is the sample size, Z is the statistic corresponding to level of confidence, P is the expected prevalence that can be obtained from same studies or a pilot study conducted by the researchers, and d is precision (corresponding to effect size). Thus, 100 local adults with sufficient experience in pastoralism were randomly selected for interview.

***Data Analysis***

Multiple regression tests and Principal Component Analysis (PCA) were used to analyze the data and determine the most important criteria and sub-criteria of drought management (Curz-Cardenas et al., 2014). The multiple regression tests showed the contribution of drought management criteria (forage management, grazing management, flock management, water management and income diversification during drought) (Kalantari, 2010). Before running the multiple regression tests, Kolmogorov–Smirnov normality test was used to check data for normal distribution. IBM SPSS Statistics V22.0 was used for both descriptive and analytical data analysis.

**Table 1.** Criteria and sub-criteria for drought management

| Criteria | Sub-criteria |
|---|---|
| Forage management (Treydte et al., 2017) | Sowing of forage plants (Guo et al., 2022) |
| | Planting of drought tolerant species for rangeland rehabilitation (Abu-Zanat et al., 2020) |
| | Planting of fast growing species for rangeland rehabilitation (Abu-Zanat et al., 2020) |
| | Forage purchase (Vrieling et al., 2016) |
| | Fodder storage in years with normal rainfall (Vrieling et al., 2016) |
| | Conservation of species diversity (Wen et al., 2021) |
| Grazing management (Liebig et al., 2014) | Reducing grazing time (Liebig et al., 2014) |
| | Implementing rotational grazing (Hughes, 2017) |
| | Implementing rangeland rest (Moghaddas Farimani et al., 2017) |
| | Moving livestock to rangelands with better condition |
| Flock management (Mengistu, 2016) | Reducing livestock numbers (Moghaddas Farimani et al., 2017) |
| | Changing livestock type (Mengistu, 2016) |
| | Breeding yearlings (Haigh et al., 2019) |
| | Keeping livestock of various breeds (Mengistu, 2016) |
| Income diversification (Aliyar et al., 2022) | Developing recreation (Bakhtiari et al., 2018) |
| | Developing hunting (Kachergis et al., 2014) |
| | Developing handicrafts (Aliyar et al., 2022) |
| Water management (Rahaman et al., 2019) | Controlling water loss (Singh et al., 2021) |
| | Harvesting rainwater and snowmelt (Rahaman et al., 2019) |
| | Promoting and teaching the correct techniques of water distribution and consumption (Lankford et al., 2020) |
| | Identifying and making proper use of other available sources for water required by livestock (Moghaddas Farimani et al., 2017) |

## Results

The personal information of respondents is summarized in Table 2. Approximately 71% of respondents were male, while 29% were female. The majority of respondents (94%) had a high school education or less, with six percent holding a 4-year college degree. In terms of age distribution, 19% of respondents were aged 30-40, 33% were aged 40-50, 35% were aged 50-60, and 13% were aged over 60 years. Among the respondents, 56% identified as rural pastoralists, while the remaining 44% identified as nomadic pastoralists. The income of 59% of responders was less than 5,000,000 Rials per month. Additionally, 36% reported an income ranging from 5,000,000 to 10,000,000 Rials per month, and 11% reported an income exceeding 10,000,000 Rials per month.

**Table 2**. Personal information of pastoralists participated in the study.

| Variable | Value | Frequency | Frequency (%) |
|---|---|---|---|
| Age | 30-40 | 25 | 19 |
| | 40-50 | 44 | 33 |
| | 50-60 | 46 | 35 |
| | 60< | 18 | 13 |
| Income (Rials/month) | <5000000 | 44 | 33 |
| | 5000000-10000000 | 74 | 56 |
| | 10000000< | 11 | 11 |
| Education | Less than high school | 79 | 59 |
| | High school | 46 | 35 |
| | 4year college degree | 8 | 6 |
| Gender | Female | 38 | 29 |
| | Male | 95 | 71 |
| Pastoralism type | Rural | 75 | 56 |
| | Nomadic | 58 | 44 |

**Table 3.** Mean importance of each of the sub-criteria for drought management

| Sub-criteria | Rural | | Nomadic | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Planting of forage plants | 3.97 | 1.2 | 3.04 | 0.98 |
| Planting of drought tolerant species for rangeland rehabilitation | 2.46 | 0.78 | 2.37 | 0.75 |
| Planting of fast growing species for rangeland rehabilitation | 3.89 | 0.78 | 3.24 | 0.67 |
| Forage purchase | 4.12 | 0.46 | 4.65 | 0.89 |
| Fodder storage in years with normal rainfall | 2.23 | 0.32 | 1.38 | 0.38 |
| Conservation of species diversity | 2.38 | 0.98 | 2.86 | 0.67 |
| Reducing grazing time | 3.12 | 0.52 | 3.05 | 1.24 |
| Implementing rotational grazing | 3.89 | 0.67 | 3.24 | 1.23 |
| Implementing rangeland resting | 2.35 | 0.34 | 2.53 | 0.49 |
| Moving livestock to rangelands with better condition | 2.38 | 0.68 | 4.06 | 0.35 |
| Reducing livestock numbers | 1.61 | 1.20 | 1.59 | 0.36 |
| Changing livestock type | 2.24 | 0.57 | 2.35 | 0.67 |
| Breeding yearlings | 3.25 | 0.56 | 2.34 | 0.31 |
| Keeping livestock of various breeds | 3.37 | 1.20 | 3.56 | 0.97 |
| Developing recreation | 4.38 | 0.37 | 3.68 | 0.65 |
| Developing hunting | 2.38 | 1.23 | 2.98 | 0.66 |
| Developing handicrafts | 3.58 | 0.38 | 3.84 | 0.90 |
| Controlling water loss | 3.98 | 0.32 | 4.12 | 0.12 |
| Harvesting rainwater and snowmelt | 4.86 | 0.03 | 4.03 | 0.58 |
| Promoting and teaching the correct techniques of water distribution and consumption | 4.21 | 0.17 | 3.15 | 1.30 |
| Identifying and making proper use of other available sources for livestock water | 3.24 | 1.23 | 4.65 | 0.17 |

Forage purchase was the most important sub-criteria of forage management for rural and nomadic pastoralists with mean values of 0.46 ± 0.46 and 4.65±0.89 respectively. Implementing rotational grazing (3.89±0.67) and moving livestock to rangelands with better condition (4.12±0.46) were the most important sub-criterion for grazing management based on rural and nomadic pastoralists respectively. Among the flock management sub-criteria, keeping livestock of various breeds held the highest importance for both rural and nomadic pastoralists, with mean values of 3.37±1.20 and 3.56±0.97, respectively.The most important sub-criteria of income diversification were developing recreation for rural pastoralists with mean value of 3.38±0.37 and developing handicrafts for nomadic pastoralists with mean value of 3.84±0.90. The most important sub-criteria of water management were harvesting rainwater and snowmelt for rural pastoralists with mean value of 4.86± 0.03 and identification and proper use of other available sources for livestock water for nomadic pastoralists with mean value of 4.65 ± 0.17 (Table 3).

The PCA results revealed that, for rural pastoralists, promoting and teaching the correct techniques of water distribution and consumption, developing recreation, forage purchase, and harvesting rainwater and snowmelt were the most important sub-criteria of drought management. In contrast, for nomadic pastoralists, the key sub-criteria included identifying and making proper use of other available sources for livestock water, developing recreation, forage purchase, moving livestock to rangelands with better conditions, and changing livestock type (Table 4).

**Table 4.** The most important sub-criteria for drought management based on PCA

| Sub-criteria | Rural | | Nomadic | |
|---|---|---|---|---|
| | PCA1 | PCA2 | PCA1 | PCA2 |
| Planting of forage plants | 0.202 | 0.038 | 0.213 | 0.029 |
| Planting of drought tolerant species for rangeland rehabilitation | 0.113 | 0.096 | 0.130 | 0.077 |
| Planting of fast growing species for rangeland rehabilitation | 0.134 | 0.137 | 0.239 | 0.067 |
| Forage purchase | **0.389** | 0.195 | **0.459** | 0.485 |
| Fodder storage in years with normal rainfall | 0.032 | 0.021 | 0.035 | 0.013 |
| Conservation of species diversity | 0.123 | 0.312 | 0.132 | 0.049 |
| Reducing grazing time | 0.032 | 0.037 | 0.035 | 0.064 |
| Implementing rotational grazing | 0.074 | 0.018 | 0.038 | 0.087 |
| Implementing rangeland resting | 0.031 | 0.237 | 0.031 | 0.019 |
| Moving livestock to rangelands with better condition | 0.037 | 0.234 | **0.358** | 0.438 |
| Reducing livestock numbers | 0.098 | 0.138 | 0.068 | 0.087 |
| Changing livestock type | 0.123 | 0.023 | 0.238 | **0.758** |
| Breeding yearlings | 0.137 | 0.038 | 0.237 | 0.035 |
| Keeping livestock of various breeds | 0.139 | 0.223 | 0.133 | 0.012 |
| Developing recreation | **0.454** | 0.213 | **0.432** | 0.234 |
| Developing hunting | 0.221 | 0.132 | 0.234 | 0.123 |
| Developing handicrafts | 0.237 | 0.231 | 0.239 | 0.137 |
| Controlling water loss | 0.298 | 0.138 | **0.492** | 0.123 |
| Harvesting rainwater and snowmelt | 0.192 | **0.438** | 0.253 | 0.035 |
| Promoting and teaching the correct techniques of water distribution and consumption | **0.447** | 0.135 | 0.231 | 0.137 |
| Identifying and making proper use of other available sources for livestock water | 0.237 | 0.190 | **0.482** | 0.121 |
| Eigenvalue | 8.96 | 1.27 | 8.93 | 1.46 |
| Variance | 64.06 | 9.13 | 63.08 | 10.48 |

According to the results, all five management criteria were found to be effective in drought management, with a coefficient of determination ($R^2$) of 84% at 99% confidence level. Additionally, the multiple correlation coefficient was 92% based on rural pastoralists (see Table 5). According to Table 6, all five independent variables (forage management, flock management, grazing management, water management and income diversification) were effective in predicting the dependent variable (drought management) at 99% confidence level. Standardized (regression) coefficient (Beta coefficient) was used to assess the importance and role of independent variables in predicting the dependent variable. Based on rural pastoralists, water management had a greater contribution than other variables in predicting drought management. Hence, drought management can increase by 0.38 units with 1-unit increase in water management.

**Table 5.** The relationship between drought management criteria based on multiple regression for rural pastoralists.

| | df | Sum of squares | F | sig | $R^2$ | R |
|---|---|---|---|---|---|---|
| Regression | 4 | 2.490 | 3.952 | 0.001 | 0.84 | 0.92 |
| Residual | 129 | 0.63 | | | | |
| Total | 133 | | | | | |

**Table 6.** The relative importance of variables and their impact on drought management for rural pastoralists.

| Drought management criteria | Standard B | t | p-value |
|---|---|---|---|
| Forage management | 0.365 | 4.35 | 0.001 |
| Grazing management | 0.265 | 3.02 | 0.03 |
| Flock management | 0.213 | 2.86 | 0.04 |
| Income diversification | 0.331 | 3.98 | 0.001 |
| Water management | 0.386 | 5.32 | 0.000 |

According to the results, all five management criteria were effective on drought management, so that the coefficient of determination ($R^2$) was 84% at 99% confidence level. Also in this analysis, the rate of multiple correlation coefficient was 92% based on nomadic pastoralists (Table 7). According to Table 8, all five independent variables (forage management, flock management, grazing management, water management, and income diversification) were statistically significant predictors of the dependent variable (drought management) at 95% confidence level. Among rural pastoralists, the water management variable had the most substantial contribution to predicting drought management. Hence, drought management can increase by 0.36 units with 1-unit increase in water management.

**Table 7.** The relationship between criteria based on multiple regression for nomadic pastoralists

| | df | Sum of squares | F | sig | R2 | R |
|---|---|---|---|---|---|---|
| Regression | 4 | 3.856 | 6.76 | 0.000 | 0.90 | 0.95 |
| Residual | 129 | 0.57 | | | | |
| Total | 133 | | | | | |

**Table 8.** The relative importance of variables and their impact on drought management for nomadic pastoralists

| Drought management criteria | Standard B | t | p-value |
|---|---|---|---|
| Forage management | 0.350 | 5.62 | 0.001 |
| Grazing management | 0.219 | 3.62 | 0.04 |
| Flock management | 0.313 | 4.86 | 0.01 |
| Income diversification | 0.281 | 3.58 | 0.04 |
| Water management | 0.360 | 6.32 | 0.000 |

## Discussion

Our results showed that water management, forage management and income diversification were the most important strategies for drought management. Safaei et al. (2020) emphasized on the importance of water management during drought in arid and semi-arid ecosystems. Moghaddas Farimani (2017) also showed that fodder scarcity during drought is one of the most important challenges for pastoralists in rangeland. Flock management was also the most important management strategies during drought for nomadic pastoralists. Since goats tolerate low forage rangelands more than other livestock types, pastoralists can increase the proportion of goats in the herd in drought years (Zhang et al., 2013). The reduction or absence of rainfall, diminished hydrological flows, and declining soil moisture levels are the most significant indicators of drought, with far-reaching economic and social impacts on communities (Nafarzadegan et al., 2012). Since, the highest water consumption is in agriculture section in Iran, water management was more important for the rural pastoralists than nomadic ones. Drought can reduce the sustainable production of natural ecosystems such as rangelands. Precipitation is the most important climatic factor for plant growth and soil moisture (Engda et al., 2016). Therefore, precipitation is the main limiting

factor of forage production. The findings from Noori et al. (2010) revealed a significant relationship between rangeland production and precipitation, with the lowest rangeland production occurring in years with low precipitation. Rangelands are composed of diverse plant species with different water requirements (Karimi et al. 2015). Therefore, plants' dependence on rainfall is different based on their growth form, root system as well as the temporal and spatial distribution of precipitation. Determining grazing capacity based on forage supply in arid rangelands is hard because of fluctuations in annual forage production (Moghaddam, 1998). In general, pastoralists encounter three crises related to forage shortages during drought: (1) a shortage and decline in rangeland forage or cultivated forage, (2) a reduction in forage storage for autumn and winter, and (3) the impacts of drought on crop storage and diminished plant growth in the subsequent growing season (Kachergis et al., 2014). Pastoralists also consider income diversification and reducing dependence on rangelands as important management strategies. Derner et al. (2014) and Kachergis et al. (2014) concluded that income diversification is a climate-independent strategy that can be employed to address drought. For nomadic pastoralists, the decrease in forage production and financial pressure are the most significant consequences of drought (Bagheri et al., 2012). Therefore, purchasing forage may prevent the reduction of livestock production and income.

Promoting and teaching correct techniques for water distribution and consumption, developing recreation, purchasing forage, and harvesting rainwater and snowmelt are the most crucial sub-criteria for drought management among rural pastoralists. Tingsanchali and Piriyawong (2018) assessed drought risk based on surface water irrigation systems and demonstrated that 83 billion cubic meters of the total renewable water resources are annually consumed in the agriculture sector, with 65% lost due to the use of traditional and incorrect irrigation methods (Mamoudian, 2008; Aryanfar et al., 2020). Adopting modern irrigation systems not only alleviates plant stress but also provides the required amount of water with minimal loss, thereby improving agricultural growth and development (Ghasemizadeh and Salemi, 2009). Thomas et al. (2013) emphasized that social and organizational networks, along with improved communication mechanisms with the media and the public, can significantly enhance adaptive capacity and result in fewer economic losses during drought. Recreation development serves as a viable source of income for villagers (Zhang et al., 2020) and can enhance the livelihoods of local people while reducing income dependence on rangelands. However, previous studies indicate a decrease in tourist numbers during drought (Bakhtiari et al., 2018), as drought can diminish the aesthetic value of natural landscapes by depleting water resources and damaging vegetation. Furthermore, the sale of handicrafts may decline due to reductions in agricultural and livestock production.

Nomadic pastoralists regard moving livestock to rangelands with better conditions and changing livestock types as crucial strategies for drought management. These findings align with the results of Mazaheri and Safari (2009) and Derner et al. (2014). Altering livestock composition, preventing livestock grazing in degraded rangelands with lower production potential, and relocating livestock to high-potential rangelands are essential aspects of drought management (McAllister et al., 2009, Coppock, 2011). Rangeland size can influence flock management strategies, with larger rangelands offering ecological and economic benefits such as forage heterogeneity and increased capital and forage storage (McAllister et al., 2009). However, previous studies have indicated that adaptive grazing management is one of the best strategies for drought management due to the temporal and spatial heterogeneity of forage (Derner et al., 2016).

## Conclusion

In this study, it was observed that rural and nomadic pastoralists showed limited interest in altering the number of their livestock. Implementing such a strategy necessitates financial assistance from the government,

possibly through insurance or incentive programs. Additionally, both rural and nomadic pastoralists placed the least emphasis on preventive practices for drought, such as fodder storage during years with normal rainfall. The results of Kachergis et al. (2014) showed that most pastoralists use reactive drought management techniques such as forage purchase and fewer pastoralists use prevention strategies defined in their drought management plans such as forage stock. Given the destructive impacts of drought on ecosystems, pastoralists need to be prepared to cope with drought. Therefore, it is essential to educate young pastoralists about drought risks, with a focus on preventive practices. In general, this study suggests that leveraging the indigenous knowledge of pastoralists could enhance existing management plans for the development of drought coping strategies. Various strategies must be implemented for drought management because what may be the 'best' management strategy during one drought may not be the most effective strategy in the next drought (McAllister et al., 2009). Therefore, operations with a broader range of management options during a drought may possess greater resilience to withstand drought conditions.

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