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Unveiling smallholder farmers' risk perception, vulnerability, and adaptation strategies to climate change: A gendered perspective

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Abstract

Climate change increasingly threatens the livelihoods of smallholder farmers by reducing agricultural productivity and intensifying food insecurity, particularly in arid and semi-arid regions. Although gender is widely recognized as an important dimension of climate vulnerability, empirical evidence remains limited regarding how gender shapes farmers' risk perception, vulnerability, and adaptation in Middle Eastern agricultural systems. This study examined gender differences in climate change risk perception, vulnerability, and adaptation strategies among smallholder farmers in Tehran Province, Iran. A cross-sectional survey of 350 male- and female-headed farming households was conducted using a multistage stratified random sampling design. Vulnerability was assessed using the IPCC framework, which conceptualizes vulnerability in terms of exposure, sensitivity, and adaptive capacity. Independent-samples *t*-tests and composite vulnerability indices were used to compare gender groups. The results showed no significant gender differences in perceived climate change impacts or overall vulnerability. Both groups identified increasing temperatures, rainfall variability, drought, and water scarcity as the principal climate-related challenges. Although male-headed households exhibited significantly higher sensitivity, they also demonstrated greater adaptive capacity, resulting in comparable overall vulnerability. Likewise, no significant gender differences were observed in the adoption of major on-farm and off-farm adaptation strategies. These findings suggest that climate vulnerability and adaptation are shaped primarily by the interaction of environmental and socioeconomic conditions rather than by gender alone in the study area. The study contributes empirical evidence from an underrepresented semi-arid context and highlights the importance of context-specific, multidimensional vulnerability assessments for informing evidence-based climate adaptation policies.

Keywords: Adaptation strategies, Climate change perception, Climate vulnerability, Gender, Iran. Smallholder farmers.

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1. Introduction

Agriculture remains a cornerstone of economic development in many developing countries, contributing approximately 10.7% of global GDP and employing nearly 30% of the labor force (World Bank, 2024). In rural areas, smallholder agriculture provides the primary source of income, employment, and food security. Because smallholder livelihoods depend heavily on climate-sensitive natural resources, they are particularly vulnerable to climate change. Rising temperatures, changing precipitation patterns, and the increasing frequency and intensity of droughts, pests, and crop diseases are already reducing agricultural productivity and threatening rural livelihoods (IPCC, 2021). These climatic pressures further intensify water scarcity, infrastructure damage, livelihood insecurity, poverty, and climate-induced migration, especially in dryland agricultural systems (Ajjur & Al-Ghamdi, 2021; Keshavarz et al., 2013).

Understanding how farmers respond to climate change requires examining not only their exposure to climatic hazards but also how they perceive climate-related risks and the resources available for adaptation. Risk perception refers to farmers' subjective assessment of the likelihood and consequences of climate-related threats and constitutes an important precursor to adaptation decisions (Oluwatusin, 2014). However, differences in adaptation cannot be explained by risk perception alone because farmers vary considerably in their capacity to anticipate, cope with, and recover from climatic shocks. Accordingly, this study adopts the Intergovernmental Panel on Climate Change (IPCC) vulnerability framework, which conceptualizes vulnerability as the interaction among exposure to climatic hazards, sensitivity of livelihood systems, and adaptive capacity, or the ability to adjust and respond effectively (IPCC, 2021). This framework provides a comprehensive basis for identifying the multiple social and environmental factors that shape climate vulnerability.

Within this framework, gender represents a key social determinant of vulnerability rather than merely a demographic characteristic. Gender influences access to productive resources, land ownership, agricultural inputs, financial services, climate information, extension support, decision-making authority, and social networks, all of which affect exposure, sensitivity, and adaptive capacity (Daoud, 2021). Consequently, men and women may experience climate risks differently and adopt different adaptation strategies even when they are exposed to similar climatic conditions. Nevertheless, empirical evidence suggests that these differences are highly context-specific and shaped by institutional, socioeconomic, and cultural conditions rather than by gender alone (Thompson-Hall et al., 2016). Therefore, gender should be understood as an analytical lens through which vulnerability is examined instead of assuming that one gender is inherently more vulnerable than the other.

Iran provides an important context for examining these relationships. Located largely within arid and semi-arid climatic zones, the country is experiencing increasing temperatures, declining precipitation, recurrent droughts, and severe water scarcity, all of which threaten agricultural sustainability (Statistical Center of Iran, 2023). Although previous studies have investigated drought adaptation, water management, or agricultural vulnerability in Iran (e.g., Keshavarz et al., 2013; Karimi et al., 2018), these dimensions have generally been examined separately. Moreover, relatively little empirical research has simultaneously investigated farmers' risk perception, multidimensional vulnerability, and adaptation strategies from a gender perspective, particularly within the Middle East.

This research specifically focuses on smallholder farmers in Tehran Province, where peri-urban rural communities experience the combined pressures of climate change and rapid urban expansion. Competition over water resources, land-use change, and increasing livelihood diversification distinguish these agricultural systems from more remote rural areas and may alter both vulnerability and adaptation processes. Despite their growing importance for regional food production and rural livelihoods, gendered climate responses among smallholder farmers in these peri-urban environments remain insufficiently understood.

This study contributes to the literature in three respects. First, it integrates farmers' climate risk perception with the IPCC vulnerability framework to examine how perceived risks are associated with exposure, sensitivity, adaptive capacity, and adaptation behavior. Second, it provides a gender-disaggregated assessment that advances understanding of whether and how gender shapes climate vulnerability under shared environmental conditions rather than assuming predetermined gender differences. Third, it generates empirical evidence from peri-urban smallholder farming systems in Iran, an underrepresented context within the broader climate adaptation literature, thereby providing insights relevant to other semi-arid regions facing similar environmental and socioeconomic challenges.

Accordingly, this study addresses the following research questions: (1) How do male- and female-headed smallholder households differ in their perceptions of climate change risks?, (2) How do exposure, sensitivity, and adaptive capacity vary between male- and female-headed households?, and (3) What on-farm and off-farm adaptation strategies are employed by these groups in response to climate change? Answering these questions contributes to a better understanding of the gendered dimensions of climate vulnerability and provides evidence to support context-specific and gender-responsive adaptation policies for smallholder agriculture in Iran and comparable semi-arid regions.

2. Material and methods

2.1. Study setting

The study was conducted in rural areas of Tehran Province, northern Iran (34°53′–36°07′ N, 50°20′–53°09′ E), covering approximately 13,842 km² (Fig. 1). Tehran Province was selected because it combines pronounced climatic heterogeneity with rapid urban expansion, making it a suitable setting for examining how climate variability and socioeconomic conditions jointly influence smallholder farmers' vulnerability and adaptation. Although only about 5.4% of the province's population resides in rural areas, agriculture remains an important livelihood, particularly for smallholder households engaged in cereal cultivation, horticulture, orchards, and mixed crop–livestock production (Statistical Center of Iran, 2023; Ministry of Agriculture Jihad, 2022).

The province exhibits considerable agro-climatic variation resulting from substantial differences in elevation and topography. Based on long-term climatic normals (1991–2020) obtained from the Iran Meteorological Organization (IRIMO), mean annual temperature ranges from approximately 16 to 18 °C, while annual precipitation generally decreases from the northern mountainous areas to the southern plains, varying between 200 and 300 mm (IRIMO, 2021). Northern areas experience relatively cool and wetter conditions, whereas the southern and south-western plains are characterized by warmer and drier climates.

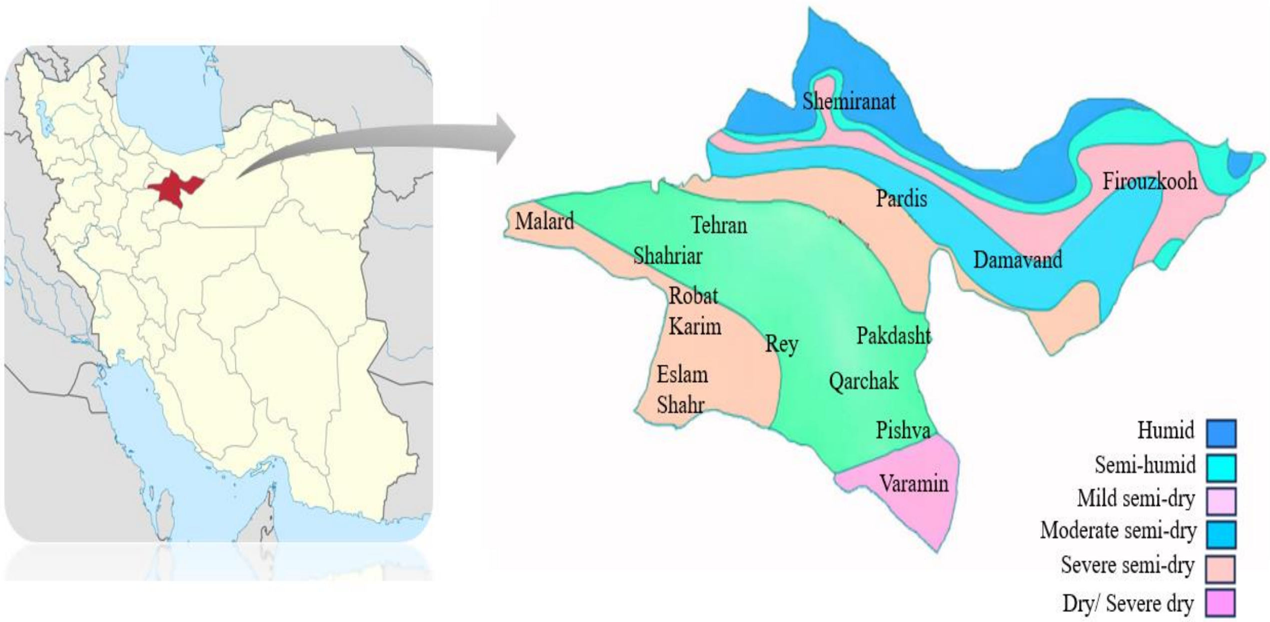

Fig.1. Geographical location and climate of Tehran Province.

Long-term climate records further indicate increasing mean and extreme temperatures together with declining and more variable precipitation across the province (IRIMO, 2021). These trends have increased the frequency and severity of droughts, intensified water scarcity, and placed growing pressure on agricultural production systems that depend largely on groundwater and surface-water irrigation. Combined with rapid population growth, urban water demand, and groundwater over-extraction, these climatic changes have substantially increased the vulnerability of rural livelihoods (Parhizkari et al., 2022).

To account for this climatic heterogeneity, the study area was stratified using the De Martonne aridity index, a widely applied climatic classification that integrates long-term precipitation and temperature to distinguish agro-climatic conditions. Based on the 1991–2020 climatic averages, rural areas of Tehran Province were classified into humid/semi-humid, semi-arid, and arid climate zones (Fig. 1). This stratification provided an objective basis for the multi-stage sampling design and enabled comparison of farmers' risk perceptions, vulnerability, and adaptation strategies across distinct climatic environments.

2.2. Research approach, sampling and research instruments

A cross-sectional household survey was conducted to investigate gender differences in climate change risk perception, vulnerability, and adaptation among smallholder farmers in rural Tehran

Province, Iran. For the purposes of this study, a farmer was defined as an adult household head or principal agricultural decision-maker whose primary livelihood during the previous agricultural season was crop and/or horticultural production. Some households also practiced small-scale livestock rearing as a complementary activity; however, livestock-only producers, beekeepers, and non-agricultural households were excluded to ensure comparability of production systems. Accordingly, both male- and female-headed households represented similar agricultural production systems, allowing meaningful gender-based comparisons. The target population consisted of approximately 8,500 registered smallholder farming households (Ministry of Agriculture Jihad, 2022). The required sample size was determined using the finite population sample size formula (Australian Bureau of Statistics, 2023), assuming a 95% confidence level, 5% margin of error, and p = 0.50, resulting in a minimum sample of 350 households.

A multistage stratified random sampling procedure was employed. First, rural areas were stratified into humid/semi-humid, semi-arid, and arid climatic zones using the De Martonne aridity index calculated from long-term climatic data (1991–2020). This climate-based stratification ensured representation of the province's major agro-climatic conditions and supported comparisons across different levels of climatic exposure. Second, 13 sub-counties and 39 villages were selected proportionally from the three climatic strata. Finally, farming households were randomly selected from official village household lists. The final sample comprised 268 male-headed households (76.6%) and 82 female-headed households (23.4%). This distribution reflects the actual gender composition of registered farm household heads in the study area and resulted from proportional random sampling rather than predetermined quotas. Female-headed households were defined as households in which women served as the principal agricultural decision-makers and managers, typically owing to widowhood, divorce, separation, or the long-term absence of a male household head. Their farming activities primarily involved crop and horticultural production similar to those of male-headed households, thereby minimizing potential bias arising from differences in agricultural specialization.

Data were collected through a structured questionnaire consisting of four sections. The first gathered respondents' socio-demographic and farm characteristics. The second measured perceived climate change impacts using five-point Likert-scale items assessing perceived changes in temperature, precipitation, drought frequency, water availability, and pest and disease incidence. The third operationalized climate vulnerability according to the IPCC framework, in which vulnerability is represented by three dimensions: exposure (experience of climate-related hazards), sensitivity (dependence of farming livelihoods on climate-sensitive resources), and adaptive capacity (availability of economic, institutional, human, and social resources that enable adaptation). Each dimension was measured using multiple indicator variables adapted from previous climate vulnerability studies. The fourth section assessed the adoption of on-farm and off-farm adaptation strategies using dichotomous and multiple-response items.

The questionnaire was reviewed by five experts in agricultural extension, climate change, and rural development to establish content validity and was subsequently pre-tested with 30 smallholder farmers outside the study sample. Internal consistency reliability, assessed using Cronbach's alpha, ranged from 0.55 to 0.91. Although a small number of exploratory scales showed relatively modest reliability ($\alpha < 0.60$), these items were retained because they captured conceptually important dimensions of vulnerability identified in previous literature. Accordingly, results associated with these scales are interpreted with appropriate caution. All selected households agreed to participate, resulting in a 100% response rate.

2.3. Data analysis: Estimation of composite vulnerability index

Climate vulnerability was assessed using a composite index based on the IPCC vulnerability framework, which conceptualizes vulnerability as the combined effect of exposure, sensitivity, and adaptive capacity (IPCC, 2021). Exposure captured households' experience of climatic stressors, including rising temperatures, rainfall variability, drought frequency, and water shortages. Sensitivity represented the extent to which agricultural livelihoods were adversely affected by these climatic stresses, measured through indicators related to water dependence, production stability, food security, and reliance on agriculture. Adaptive capacity reflected households' ability to anticipate, cope with, and recover from climate-related impacts and was operationalized through five livelihood capitals: human, natural, financial, physical, and social (Table 1).

Table 1. Study variables.

	Variable	Explanation	Cronbach's alpha
	Environmental impacts	Perceived impacts of climate change on ecosystem services (e.g., reduction in water availability, decline in soil fertility, increased pest outbreaks, loss of biodiversity); 8 ordinal items (1 = very low, 5 = very high)	0.55
	Economic impacts	Perceived impacts on agricultural production and household livelihoods (e.g., crop yield reduction, increased input costs, livestock productivity loss, reduced farm income, price volatility); 7 ordinal items (1–5 scale)	0.65
	Social impacts	Perceived impacts on household and community relations (e.g., water-related conflicts, changes in labor sharing, weakened social networks, migration-related separation); 6 ordinal items (1–5 scale)	0.79
	Psychological impacts	Perceived impacts on mental health and well-being (e.g., anxiety about income instability, uncertainty about farming future, emotional distress linked to crop failure); 4 ordinal items (1–5 scale)	0.91
	Exposure	Degree of direct climatic stress experienced by households (e.g., increased temperature, rainfall variability, drought frequency, water shortages); 5 ordinal items (1–5 scale)	0.68
	Sensitivity	Degree to which livelihoods are affected by climatic stress (e.g., irrigation dependence, crop yield instability, livestock feed vulnerability, income dependence on farming); 7 ordinal items (1–5 scale)	0.66
Adaptive capacity	Natural capital	Availability of natural resources supporting resilience (e.g., access to irrigation water, soil quality, land fertility, pasture availability)	-
	Physical capital	Farm infrastructure and assets (e.g., irrigation infrastructure, machinery availability, storage facilities, access roads)	-
	Financial capital	Economic resources supporting adaptation (e.g., savings, credit access, insurance participation, cash flow stability)	-
	Social capital	Social networks and institutional linkages (e.g., access to extension services, membership in cooperatives, information sharing); 12 ordinal items (1–5 scale)	0.59
	Human capital	Household demographic and educational characteristics (e.g., education level, farming experience, household labor availability)	-
Adaptation strategies	Agronomic management	Crop management adaptations (e.g., crop diversification, changing planting dates, use of drought-resistant varieties, pest control practices, fertilizer adjustments); 8 binary items (0 = not applied, 1 = applied)	0.78
	Soil management	Soil conservation practices (e.g., conservation tillage, residue retention, organic manure application, windbreaks, soil testing, mulching); 8 binary items	0.55
	Water management	Water-related adaptation strategies (e.g., drip irrigation, irrigation scheduling, well deepening, water-saving technologies, irrigation rotation); 11 binary items	0.60
	Livestock management	Livestock adaptation practices (e.g., herd size adjustment, feed supplementation, changing livestock type, fodder storage); 6 binary items	0.91
	Off-farm and livelihood management	Diversification of livelihoods and/or adjustments in farm families' expenditures to adapt to adverse impacts of climate change; 10 ordinal items ranging from 0 (not applied) to 1 (applied) Income diversification and coping strategies (e.g., non-farm employment, seasonal migration, asset sales, savings use, wage labor participation, expenditure reduction); 10 binary items	0.62

Prior to index construction, the conceptual structure of the vulnerability domains was examined using exploratory factor analysis (EFA). Sampling adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) statistic, and the suitability of the correlation matrix was evaluated with Bartlett's test of sphericity. Factor extraction was performed using the principal component method, retaining factors with eigenvalues greater than 1.0. The resulting factor structure was consistent with the three vulnerability domains defined by the IPCC framework. Subsequently, principal component analysis (PCA) was applied to the adaptive-capacity indicators to derive objective indicator weights from factor loadings (Table 2). Exposure and sensitivity indicators were assigned equal weights because they represented predefined conceptual dimensions and comparable measurement scales.

Table 2. Weights of indicators, sub-indicators and concrete indicators.

Indicators	concrete indicators	Weights	Variation explained (%)
	Dependency ratio	0.230	
Human capital	Education of household head	0.382	54.06
	Age of household head	0.388	
	Farm size	0.353	
Physical capital	Agricultural machineries	0.285	48.34
	Irrigation equipment	0.362	
	Crop diversification	0.376	
Natural capital	Cultivation area	0.361	48.75
	Irrigation water access	0.263	
	Income	0.227	
Financial capital	Credit	0.387	56.35
	Insurance	0.386	
	Bridging	0.220	
Social capital	Bonding	0.309	39.44
	Linking	0.471	
	Human capital	0.193	
	Physical capital	0.265	
Adaptive capacity	Natural capital	0.170	35.07
	Financial capital	0.212	
	Social capital	0.160	

To facilitate aggregation, all indicators were normalized to a 0–1 scale using min–max standardization:

$$\text{Index}=\frac{(S_x-S_{min})}{(S_{max}-S_{min})} \quad \text{Eq. (1)}$$

$$\text{Index}=\frac{(S_{max}-S_x)}{(S_{max}-S_{min})} \quad \text{Eq. (2)}$$

where S_x represents the observed value of indicator x for a given household, and S_{min} and S_{max} denote the minimum and maximum values of that indicator across the sample. Equation (1) was applied when indicators were positively related to vulnerability, and Equation (2) when the relationship was negative (e.g., higher income reduces vulnerability).

Following normalization, the three domains were aggregated using the standard IPCC-based formulation:

$$\text{Vulnerability}=\frac{(Exposure+Sensitivity)+(1-Adaptive\ capacity)}{3} \qquad \text{Eq. (3)}$$

The resulting vulnerability index ranges from 0 (least vulnerable) to 1 (most vulnerable).

Before inferential analysis, normality of continuous variables was assessed using the Shapiro–Wilk test together with inspection of histograms and Q–Q plots, while homogeneity of variances was evaluated using Levene's test. Differences between male- and female-headed households were analyzed using independent-samples *t*-tests when parametric assumptions were satisfied and Mann–Whitney *U* tests otherwise. All statistical analyses were performed using IBM SPSS Statistics version 26.

3. Results and discussion

3.1. Perceived climate change impacts

Male- and female-headed households reported broadly similar perceptions of climate change impacts on agricultural production and rural livelihoods (Table 3). Independent-samples *t*-tests indicated no statistically significant gender differences in perceptions of climate change ($p = 0.603$, Cohen's $d == -0.05$), environmental impacts ($p = 0.319$, $d = 0.15$), economic impacts ($p = 0.484$, $d = 0.09$), social impacts ($p = 0.170$, $d = -0.15$), or psychological impacts ($p = 0.624$, $d = -0.06$). The corresponding effect sizes were negligible to very small, indicating limited practical differences between male- and female-headed households.

Table 3. Perceived climate change and impacts.

Climate change impacts	Male farmers		Female farmers		T	Sig.
	Mean	Std. Deviation	Mean	Std. Deviation		
Perception of climate change	13.43	3.75	13.67	3.70	0.520	0.603
Environmental impacts	30.77	3.61	30.21	4.71	-1.00	0.319
Economic impacts	24.68	3.18	24.39	3.54	-0.700	0.484
Social impacts	17.86	4.74	18.56	3.77	1.379	0.170
Psychological impacts	15.03	2.77	15.21	3.18	0.490	0.624

Note: The reported values represent summed scores across multiple Likert-scale items, with higher scores indicating greater perceived impacts.

Across both groups, declining surface and groundwater availability emerged as the most serious climate-related concern. Respondents consistently associated water shortages with reduced precipitation, increasing temperatures, greater evapotranspiration, and long-term groundwater depletion. These perceptions correspond closely with meteorological observations and previous studies identifying water scarcity as the dominant manifestation of climate change in Iran's semi-arid agricultural regions (Keshavarz et al., 2013; Karimi et al., 2018; Saberifar, 2023).

Farmers also perceived increasing pest and disease outbreaks, declining crop productivity, and greater production uncertainty. Similar observations have been reported elsewhere in Iran, where increasing temperatures and rainfall variability have intensified pest pressure and reduced agricultural productivity (Kheyruri et al., 2023; Sabbaghi et al., 2020). Social and psychological impacts—including competition and occasional conflict over water resources, anxiety regarding future farming, uncertainty about household income, and stress associated with repeated droughts—were likewise reported by both groups, highlighting that climate change affects not only agricultural production but also farmers' well-being, consistent with the findings of Keshavarz and Masoomi (2026) and Khalili et al. (2020).

The absence of statistically significant gender differences does not imply that gender is irrelevant to climate vulnerability. Rather, it suggests that male- and female-headed households in Tehran Province experience similar climatic conditions and operate under comparable institutional and socioeconomic constraints. Chronic water scarcity, rising production costs, and limited access to agricultural support services appear to influence both groups in broadly similar ways. This finding supports previous research showing that gendered differences in climate perceptions are highly context-dependent and become less pronounced where farming systems and environmental conditions are largely shared (Thompson-Hall et al., 2016).

3.2. Vulnerability to climate change

3.2.1. Exposure to climate change

No statistically significant gender difference was observed in exposure to climate change (Table 4; $t = -0.462$, $p = 0.644$, Cohen's $d = 0.06$), indicating a negligible practical difference in climatic exposure. Both male- and female-headed households reported comparable experiences of increasing temperatures, rainfall variability, prolonged dry spells, and water shortages. These findings are consistent with long-term climatic observations for Tehran Province (IRIMO, 2021) and indicate that both groups are exposed to similar environmental stressors.

Table 4. Vulnerability of male and female farmers to climate change.

Indicators and sub-indicators	Male farmers		Female farmers		T	Sig.
	Mean	Std. Deviation	Mean	Std. Deviation		
Exposure	0.617	0.207	0.605	0.203	-0.462	0.644
Sensitivity	0.558	0.170	0.508	0.173	-2.318	0.021
Adaptive capacity	0.304	0.085	0.280	0.078	-2.278	0.023
Natural capital	0.441	0.089	0.415	0.081	-1.962	0.050
Physical capital	0.106	0.068	0.103	0.066	-0.220	0.826
Financial capital	0.021	0.064	0.017	0.016	-0.632	0.528
Social capital	0.472	0.138	0.432	0.144	-2.328	0.021
Human capital	0.389	0.161	0.363	0.160	-1.294	0.196
Vulnerability	0.624	0.090	0.611	0.089	-1.116	0.265

Note: Higher scores represent higher levels of the corresponding vulnerability dimension.

This result is expected because exposure primarily reflects biophysical conditions rather than household characteristics. Since respondents reside within the same agro-climatic zones and are exposed to the same climatic hazards, differences in overall exposure would not necessarily be anticipated. Similar findings have been reported in other semi-arid agricultural systems where climatic exposure is largely determined by geographical location rather than gender (Aiswarya et al., 2023; Dargahi Maraghe et al., 2025).

3.2.2. Sensitivity to climate change

Male-headed households exhibited significantly higher sensitivity than female-headed households ($p = 0.021$, Cohen's $d = 0.29$). Although statistically significant, the effect size was small, suggesting that the magnitude of the gender difference was modest. Because exposure did not differ between groups, this result suggests that differences in livelihood characteristics rather than climatic conditions contribute to variation in sensitivity. Sensitivity reflects the extent to which farming households are affected by climatic shocks through their dependence on agricultural production, water resources, and climate-sensitive livelihoods. Previous studies have shown that such differences are influenced by farm structure, production characteristics, and resource dependence rather than gender alone (IPCC, 2021).

Nearly all respondents reported increasing production instability and declining agricultural income, while approximately 94% indicated difficulty maintaining adequate food production under changing climatic conditions. These findings demonstrate that climate change has become a systemic challenge affecting rural livelihoods regardless of gender. Although male-headed households showed slightly higher sensitivity scores, the practical magnitude of this difference was relatively modest. This suggests that both groups remain highly sensitive to climatic variability, reflecting the shared dependence of smallholder livelihoods on increasingly scarce water resources and climate-sensitive agricultural production.

3.2.3. Adaptive capacity and overall vulnerability

Adaptive capacity was significantly higher among male-headed households ($p = 0.023$, Cohen's $d = 0.29$). However, the small effect size indicates that the practical difference between the two groups was limited. Significant differences were observed for natural capital ($p = 0.050$) and social capital ($p = 0.021$), whereas physical, financial, and human capital did not differ significantly. The observed differences suggest that male-headed households possess somewhat stronger access to livelihood resources that facilitate adaptation, particularly institutional networks and natural resource assets. Previous research has similarly demonstrated that stronger social networks, extension services, and access to productive resources enhance adaptive capacity by improving access to information, technologies, and governmental support (Shokati Amghani et al., 2023). Nevertheless, both groups reported limited financial resources and restricted access to modern agricultural technologies, indicating that structural constraints affect adaptive capacity across the entire farming community.

Despite significant differences in sensitivity and adaptive capacity, overall vulnerability did not differ significantly between male- and female-headed households ($p = 0.265$, Cohen's $d = 0.14$). This finding reflects the multidimensional nature of vulnerability as conceptualized by the IPCC framework. Higher sensitivity among male-headed households was balanced by their relatively greater adaptive capacity, whereas the lower sensitivity of female-headed households was offset by comparatively weaker adaptive capacity. Consequently, differences within individual vulnerability components compensated for one another when aggregated into the composite vulnerability index.

These findings demonstrate that evaluating vulnerability solely through a composite index may conceal important differences among its constituent dimensions. Examining exposure, sensitivity, and adaptive capacity separately therefore provides a more comprehensive understanding of climate vulnerability than relying exclusively on aggregate measures.

3.3. Farm families' adaptation strategies

3.3.1. On-farm adaptation strategies

No statistically significant gender differences were observed in the adoption of agronomic (p = 0.983), soil (p = 0.366), water (p = 0.103), or livestock management practices (p = 0.283) (Table 5). These results indicate that adaptation decisions are influenced primarily by common environmental and institutional conditions rather than gender alone.

Crop diversification was the most widely adopted agronomic strategy (Fig. 2), implemented by 78.4% of male-headed households and 74.4% of female-headed households. Approximately 72% of respondents adopted improved agricultural technologies, while around 70% adjusted planting dates in response to changing rainfall patterns. The use of drought-tolerant crop varieties was also common (approximately 65%), reflecting farmers' efforts to reduce production risks associated with increasing climatic variability.

Table 5. Adaptation strategies of male and female farmers.

Adaptation strategies	Male farmers		Female farmers		T	Sig.
	Mean	Std. Deviation	Mean	Std. Deviation		
Agronomic management	5.489	1.845	5.490	1.189	-0.021	0.983
Soil management	4.597	0.871	4.500	0.774	-0.905	0.366
Water management	5.019	1.838	4.634	1.934	-1.637	0.103
Livestock management	2.681	1.282	3.185	1.511	1.078	0.283
Off-farm and livelihood management	8.116	1.942	8.000	1.491	-0.570	0.569

More than 90% of respondents adopted at least one soil conservation practice, including residue retention, conservation tillage, or organic fertilizer application (Fig. 2). This high prevalence is consistent with findings from Iran's drought-affected regions, where soil moisture conservation is a primary coping strategy under declining precipitation (e.g., Savari et al., 2022). By contrast, advanced soil management practices such as soil testing and chemical amendments were adopted by fewer than 2% of households, suggesting that financial constraints and limited extension support continue to restrict technology adoption.

Water management strategies were dominated by relatively low-cost measures (Fig. 2). Canal lining (86%) and improved irrigation conveyance (77%) were the most frequently adopted practices, whereas investment-intensive technologies such as drip irrigation (27%), water reservoirs (34%), and smart irrigation systems (<10%) remained uncommon. These findings are consistent with previous studies (e.g., Ahmadi et al., 2025) demonstrating that financial constraints often represent the principal barrier to adoption of advanced irrigation technologies in Iran.

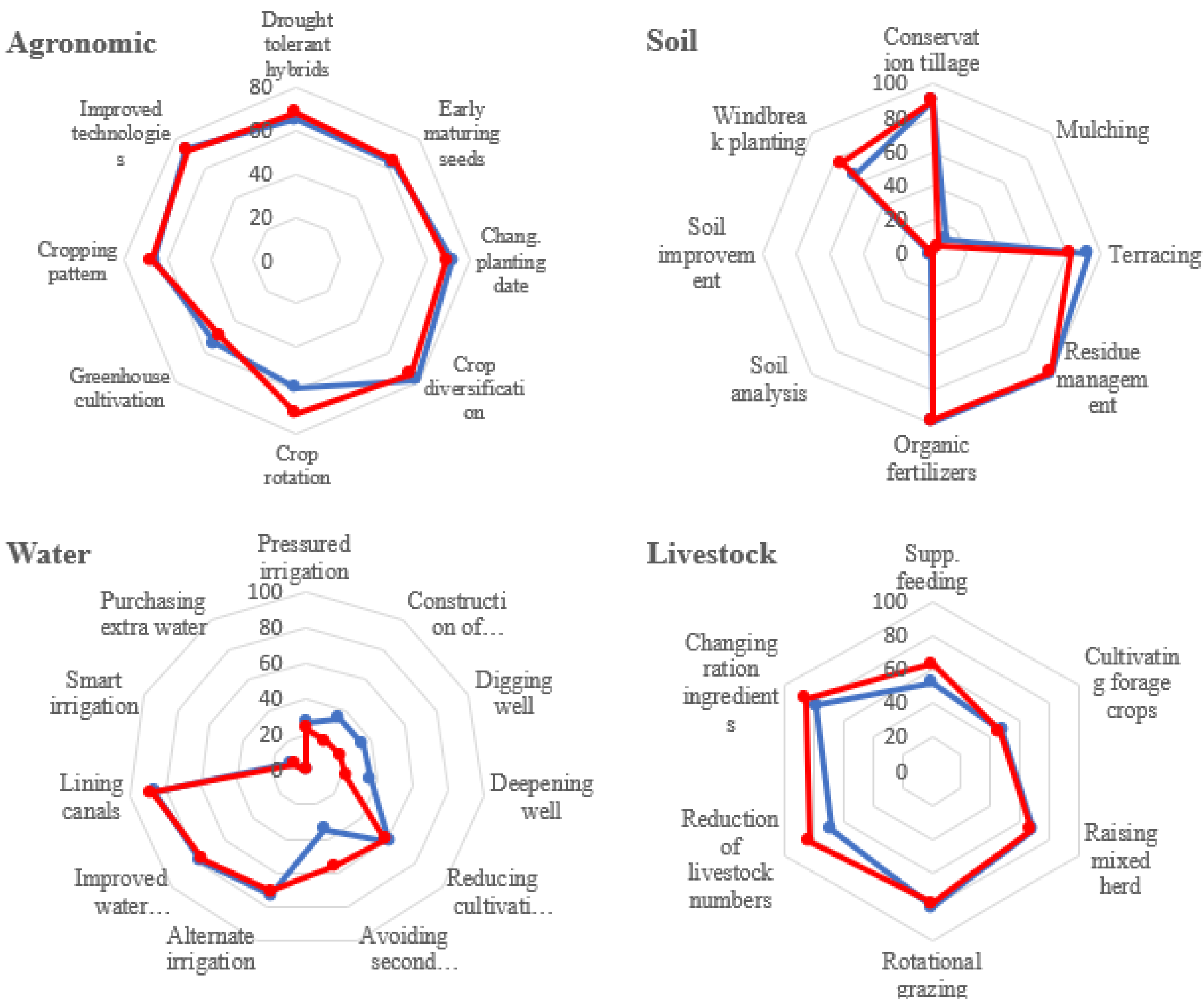

Fig. 2. On-farm adaptation strategies of male (blue) and female (red) farmers.

Livestock keeping was slightly more common among female-headed households (50%) than male-headed households (45%). Feed ration adjustment using crop residues was the most common strategy (~80%), consistent with patterns reported in drought-prone Iranian pastoral and mixed farming systems (Karimi et al., 2018). Herd size reduction was more frequent among female-headed households (83% vs. 69%), which may reflect a stronger emphasis on short-term household food security rather than asset accumulation. Rotational grazing (>80%) and mixed herding strategies (68%) reflect incremental adaptation rather than transformative change, a pattern widely documented in Iran's smallholder livestock systems under prolonged drought conditions (e.g., Karimi et al., 2018).

Overall, the limited gender differences observed in on-farm adaptation suggest that farmers operate under similar production environments and face comparable resource constraints. Consequently, adaptation behavior appears to be shaped more strongly by structural conditions—including water scarcity, limited financial resources, and restricted access to agricultural technologies—than by gender itself.

3.3.2. Off-farm and livelihood adaptation strategies

Off-farm adaptation strategies likewise showed no statistically significant gender differences (Fig. 3; $t = -0.570$, $p = 0.569$). Non-farm employment (91%) was the most common livelihood diversification strategy, followed by farm-product processing (86%) and direct marketing (>80%), highlighting the growing importance of non-agricultural income sources for maintaining household resilience. It is consistent with national trends in Iran where rural households increasingly rely on wage labor and service-sector employment to buffer agricultural income volatility (Dargahi Maraghe et al., 2025).

At the same time, many households reported adopting coping strategies indicative of increasing livelihood stress, including depletion of savings, sale of productive assets, informal borrowing, and reductions in household food consumption. This finding is consistent with Iranian evidence showing that repeated drought cycles have progressively eroded rural household resilience, particularly in peri-urban agricultural zones (Keshavarz et al., 2013). Also, more than 70% reported reducing either food quantity or dietary quality, while approximately 40% engaged in seasonal migration to supplement household income.

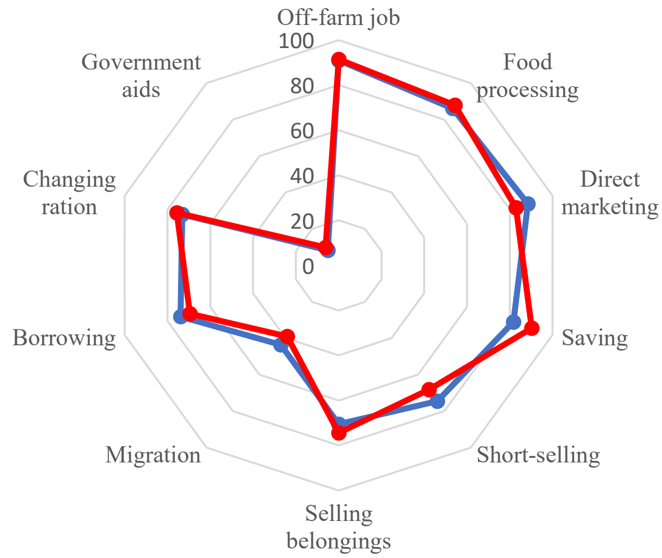

Fig. 3. Off-farm and livelihood adaptation strategies of male (blue) and female (red) farmers.

The absence of statistically significant gender differences should not be interpreted as evidence that gender plays no role in adaptation. Rather, it indicates that the quantitative indicators used in this study captured similar adaptation outcomes among households operating under shared climatic, institutional, and economic conditions. These measures may not fully reflect qualitative differences in decision-making authority, control over productive resources, labor allocation, or intra-household power relations, which have been identified as important dimensions of gendered adaptation in previous studies. Future research employing mixed-method or qualitative approaches would therefore complement the present findings by providing deeper insight into the social processes underlying adaptation decisions.

4. Conclusions

This study examined gender differences in climate change risk perception, vulnerability, and adaptation among smallholder farmers in Tehran Province using the IPCC vulnerability framework. The findings indicate that although male- and female-headed households differed significantly in specific vulnerability components, particularly sensitivity and adaptive capacity, these differences did not translate into significantly different overall vulnerability or adaptation patterns. Rather than supporting generalized assumptions about gendered climate vulnerability, the results underscore that vulnerability is highly context-specific and shaped by the interaction of environmental conditions, livelihood characteristics, and access to resources. These findings highlight the value of applying multidimensional vulnerability assessments to inform context-sensitive and gender-responsive adaptation policies. Nevertheless, the study is limited by its focus on a single province, reliance on cross-sectional self-reported data, and inability to capture qualitative dimensions such as intra-household decision-making and power relations. Accordingly, the findings should be interpreted cautiously beyond the study area, and future research should employ comparative mixed-method approaches across diverse agro-ecological regions to better understand the contextual mechanisms underlying gendered climate vulnerability and adaptation.

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واکاوی ادراک ریسک، آسیب‌پذیری و راهبردهای سازگاری کشاورزان خرده‌مالک با تغییر اقلیم: رویکردی مبتنی بر جنسیت

منیژه درگاهی مراغه، مرضیه کشاورز، و فرید اجلالی

چکیده

تغییر اقلیم به‌طور فزاینده‌ای معیشت کشاورزان خرده‌مالک را از طریق کاهش بهره‌وری کشاورزی و تشدید ناامنی غذایی، به‌ویژه در مناطق خشک و نیمه‌خشک، تهدید می‌کند. اگرچه جنسیت به‌عنوان یکی از ابعاد مهم آسیب‌پذیری در برابر تغییر اقلیم به‌طور گسترده مورد توجه قرار گرفته است، شواهد تجربی درباره چگونگی تأثیر جنسیت بر ادراک ریسک، آسیب‌پذیری و سازگاری کشاورزان در نظام‌های کشاورزی خاورمیانه همچنان محدود است. پژوهش حاضر با هدف بررسی تفاوت‌های جنسیتی در ادراک ریسک ناشی از تغییر اقلیم، آسیب‌پذیری و راهبردهای سازگاری در میان کشاورزان خرده‌مالک استان تهران انجام شد. بدین منظور، یک پیمایش مقطعی بر روی ۳۵۰ خانوار کشاورز مرد-سرپرست و زن-سرپرست، با استفاده از طرح نمونه‌گیری تصادفی طبقه‌بندی‌شده چندمرحله‌ای، اجرا شد. آسیب‌پذیری بر اساس چارچوب ارائه‌شده توسط هیئت بین‌دولتی تغییر اقلیم (IPCC) و در قالب سه مؤلفه مواجهه، حساسیت و ظرفیت سازگاری ارزیابی گردید. برای مقایسه دو گروه جنسیتی، از آزمون t برای نمونه‌های مستقل و شاخص‌های ترکیبی آسیب‌پذیری استفاده شد. یافته‌ها نشان داد که تفاوت معناداری میان زنان و مردان از نظر ادراک پیامدهای تغییر اقلیم یا سطح کلی آسیب‌پذیری وجود ندارد. هر دو گروه، افزایش دما، نوسان بارندگی، خشکسالی و کمبود منابع آب را به‌عنوان مهم‌ترین چالش‌های اقلیمی شناسایی کردند. اگرچه خانوارهای مرد-سرپرست به‌طور معناداری از حساسیت بیشتری برخوردار بودند، اما هم‌زمان ظرفیت سازگاری بالاتری نیز از خود نشان دادند که در نهایت به سطوح مشابهی از آسیب‌پذیری کلی در دو گروه انجامید. همچنین، تفاوت معناداری میان دو گروه از نظر به‌کارگیری راهبردهای اصلی سازگاری در مزرعه و خارج از مزرعه مشاهده نشد. این یافته‌ها نشان می‌دهد که در منطقه مورد مطالعه، آسیب‌پذیری و سازگاری در برابر تغییر اقلیم بیش از آنکه صرفاً متأثر از جنسیت باشد، حاصل برهم‌کنش شرایط محیطی و اجتماعی - اقتصادی است. این پژوهش با ارائه شواهد تجربی از یک بستر نیمه‌خشک که کمتر مورد مطالعه قرار گرفته است، بر اهمیت انجام ارزیابی‌های چندبعدی و متناسب با ویژگی‌های زمینه‌ای از آسیب‌پذیری تأکید می‌کند؛ ارزیابی‌هایی که می‌توانند مبنایی علمی برای تدوین سیاست‌های مبتنی بر شواهد در حوزه سازگاری با تغییر اقلیم فراهم آورند.