frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 22 July 2024
DOI 10.3389/fenvs.2024.1434708

OPEN ACCESS

EDITED BY
Prashant Sharma,
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, India

REVIEWED BY
Kamlesh Verma,
Central Soil Salinity Research Institute (ICAR), India
Pankaj Thakur,
Chaudhary Charan Singh National Institute of Agricultural Marketing, India
Priyanka Lal,
Lovely Professional University, India

*CORRESPONDENCE
Mohammad Reza Pakravan-Charvadeh,
pakravan.m@lu.ac.ir

RECEIVED 20 May 2024
ACCEPTED 09 July 2024
PUBLISHED 22 July 2024

CITATION
Kalantari R, Pakravan-Charvadeh MR and Rahimian M (2024), Multi-level factors influencing climate migration willingness among small-scale farmers.
Front. Environ. Sci. 12:1434708.
doi: 10.3389/fenvs.2024.1434708

Multi-level factors influencing climate migration willingness among small-scale farmers

Razieh Kalantari, Mohammad Reza Pakravan-Charvadeh* and Mehdi Rahimian

[1]Department of Agricultural Economics and Rural Development, Lorestan University, Khorramabad, Lorestan, Iran, [2]Faculty of Agriculture, Lorestan University, Khorramabad, Iran

Introduction: Climate change is a pressing global challenge impacting agriculture and rural communities. This study investigates the willingness to migrate against climate change among small-scale farmers and explores the associated socioeconomic and sociodemographic factors.

Method: A sample of 296 small-scale farmers was randomly selected, and data were collected through face-to-face interviews. A logistic regression model was used to assess the association of multi-level factors with willingness to climate migration.

Results: The results showed that different dimensions of adaptation strategies are inversely associated with willingness to migrate in response to climate change. In contrast, human capital was directly associated with the desire to migrate. Also, improving financial capital was indirectly associated with farmers' willingness to migrate to the rural area. The study also found that education level plays a key role in increasing the probability of being willing to relocate in response to climate change. Specifically, a 1-year increase in education level was associated with a 4.2% increase in the likelihood of being willing to migrate.

Discussion: Therefore, providing financial support for sustainable farming practices to alleviate the economic challenges faced by small-scale farmers, and implementing targeted capacity-building programs to enhance farmers' adaptive capacity and promote sustainable agricultural development can be suggested. Furthermore, improving farmers' specialized knowledge regarding the various consequences of climate migration, in conjunction with their general education, can help control and manage their migration.

KEYWORDS

climate change, climate migration, socioeconomic, sociodemographic, willingness

Abbreviations: Coeff, Coefficient; F, F-Statistics; Fa, Familiarity; Fig, Figure; Gov, Government; HH, Household's Head; M^2, Square meter; Me, Membership; NGO, Non-governmental organization; Nu, Number; Pa, Participant; Pe, Personal; Prob, Probability; Re, Receiving; VIF, Variance Inflation Factor; Z, Z-Statistics.

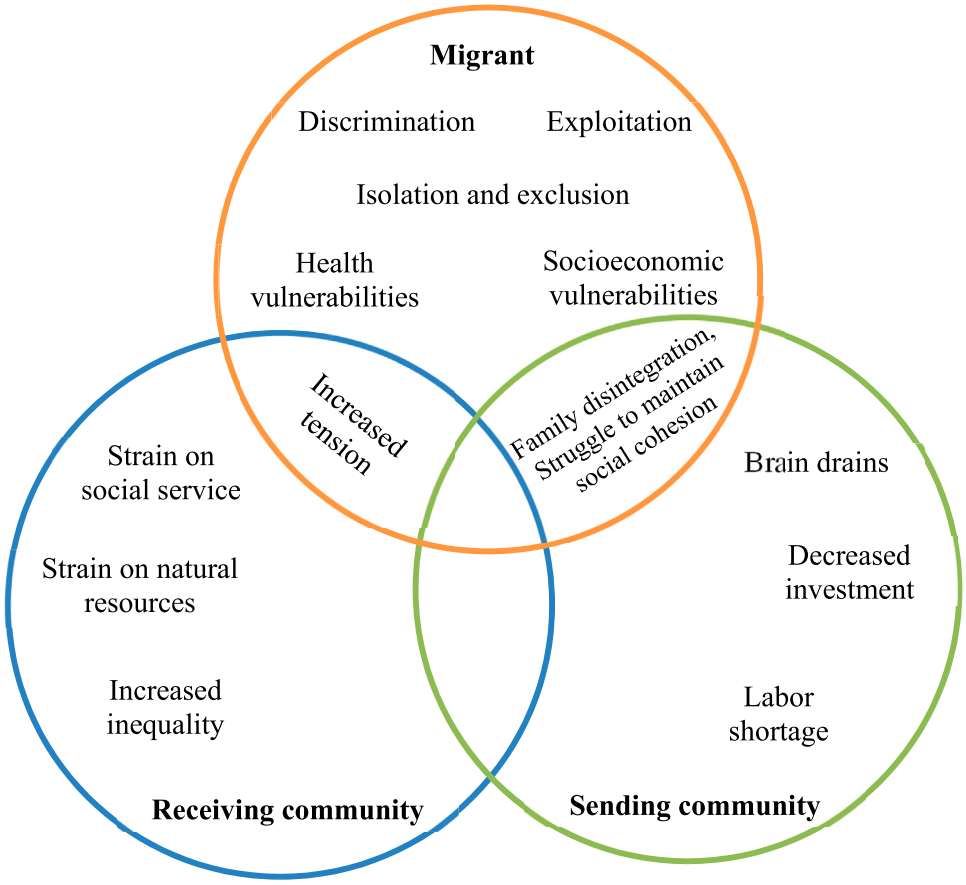

FIGURE 1
Various challenges of migration as an adaptation strategy against climate change (adapted from (McInerney et al., 2022)).

Introduction

Climate change is recognized as one of our most pressing global challenges, with far-reaching implications for various aspects of human life, including agriculture and rural communities (Shivanna, 2022; Feigin et al., 2023). The impacts of climate change are already being felt globally (Abbass et al., 2022), with consequences for ecosystems, economies, human health, and human societies (Loucks, 2021; Malhi et al., 2020; Nyang'au et al., 2021). These effects include rising sea levels, more frequent and severe weather events (such as hurricanes, droughts, and heatwaves), shifts in precipitation patterns, altered growing seasons, and changes in the distribution of plant and animal species (Bell et al., 2018; Bolan et al., 2024).

As climate change impacts become increasingly evident (Balsari et al., 2020), the phenomenon of climate migration has gained attention as a potential adaptation strategy for vulnerable populations (McLeman and Hunter, 2010). Climate migration, or climate-induced migration, refers to the movement of people from one location to another, either within their countries or across international borders, due to the impacts of climate change (McInerney et al., 2022). This form of migration is driven by the need to seek more favorable living conditions, economic opportunities, and greater resilience in the face of climate-related challenges (Balsari et al., 2020). Climate migration can take various forms, including both voluntary and forced movements (Balsari et al., 2020; McInerney et al., 2022). Voluntary migration occurs when individuals or communities choose to relocate in response to changing environmental conditions, such as decreasing agricultural productivity or increased vulnerability to natural disasters. On the other hand, forced migration involves the displacement of individuals or communities due to severe environmental degradation, loss of livelihoods, or the inability to sustain a viable living in their current location (Brown, 2007). Considering both forms of climate migration, it is important to acknowledge that despite certain benefits, this decision can result in several adverse consequences for migrants, the receiving community, and the sending community (Figure 1).

In the receiving communities, an influx of climate migrants may strain local resources, services, and infrastructure, leading to tensions with the existing population and potential conflicts over access to land, water, and other natural resources (Brown et al., 2007). This can adversely affect the social cohesion and economic development of the receiving areas. For the sending communities, the outmigration of farmers can result in a loss of agricultural labor, disrupting local food production and food security (Hosseini et al., 2017; Pakravan-Charvadeh and Flora, 2022). It may also lead to the abandonment of farmland, which can accelerate environmental degradation and the loss of traditional farming knowledge and practices (Morton, 2007; Nyang'au et al., 2021). This can have cascading effects on the local economy and the overall resilience of the community to climate change impacts.

In a country with diverse climates and a significant agricultural sector, understanding the willingness to climate migration among small-scale farmers is crucial for effective policy planning and

sustainable development. This study aims to examine the willingness to climate migration among small-scale farmers, taking into account the associated socioeconomic and sociodemographic factors. Climate change has the potential to significantly impact agricultural productivity, water availability, food security, and overall livelihoods (Kalele et al., 2021; Habib-ur-Rahman et al., 2022). Small-scale farmers, who often rely heavily on rainfed agriculture and have limited resources, are particularly vulnerable to the adverse effects of climate change (Morton, 2007; Nyang'au et al., 2021). Exploring their willingness to migrate in the face of changing climatic conditions can provide valuable insights into rural communities' adaptive capacity and resilience.

The decision to migrate is complex and influenced by various factors, including socioeconomic and sociodemographic characteristics (Parrish et al., 2020; Bye et al., 2023). While climate migration has been studied more broadly, there is a specific need to understand the factors shaping the willingness to migrate among vulnerable small-scale farming communities that are heavily impacted by climate change. Understanding these factors is essential for designing targeted interventions and policies that support farmers in making informed decisions about their future. By considering socioeconomic and sociodemographic factors, this study aims to uncover the underlying dynamics that shape farmers' willingness to migrate in response to climate change.

The findings of this study will contribute to the existing literature on climate migration and provide valuable insights for policymakers, researchers, and development practitioners. By identifying the factors that influence the willingness to migrate against climate change among small-scale farmers, policymakers can design appropriate strategies and interventions to enhance the adaptive capacity of rural communities, promote sustainable livelihoods, and ensure the preservation of agricultural productivity in the face of a changing climate. Through this research, we aim to contribute to the broader understanding of climate migration dynamics and support evidence-based decision-making for sustainable development in the agricultural sector. Understanding the multifaceted challenges of climate-induced migration is particularly crucial in the study region, which is heavily dependent on small-scale agriculture for both income and food production. The livelihoods and food security of these farmers are acutely vulnerable to the impacts of climate change, making migration a potential adaptation strategy. However, the consequences of migration, whether for the migrants themselves, the receiving communities, or the sending communities, can have far-reaching implications for the overall resilience and sustainability of the regional agricultural sector. Regarding the above-mentioned details, we will follow two main objectives below:

- Identify the key determinants of climate migration willingness at different levels (individual, livelihood, vulnerability, and adaptation).
- Examine the interconnections and pathways between these multi-level factors and their influence on the farmers' migration decisions.

Material and method

Conceptual framework

To achieve the overarching objective of the study, we utilized a constructed conceptual framework based on previous studies as shown in Figure 2 (Rashidi et al., 2024b; 2024a). Taking into account the diverse impacts of climate change on individuals' health, we categorized the supportive explanatory factors into four levels: the individual level (socioeconomic and sociodemographic factors), the livelihood level (natural, social, human, physical, and financial capitals), vulnerability level (economic, geographic, and behavioral factors), and the adaptation level (knowledge, consultation, availability, and accessibility factors) (Pakravan-Charvadeh et al., 2020b; Pakravan-Charvadeh et al., 2021a). Each of these levels operates under the influence of various climate change effects. To determine the impact of climate change on farmers' willingness to migrate, it is necessary to consider all these factors within a comprehensive model and explore their interconnectedness.

The conceptual framework suggests that these multi-level factors, operating under the influence of climate change effects, collectively shape the willingness of small-scale farmers to migrate. By considering this comprehensive set of factors, the study aims to uncover the underlying dynamics and interrelationships that drive the farmers' migration decisions in response to climate change. The application of this conceptual framework allows us to identify the key determinants of climate migration willingness, examine the interconnections and pathways between these multi-level factors and their influence on the farmers' migration decisions, provide a holistic understanding of the complex decision-making process involved in climate-induced migration among small-scale farmers, and inform the development of targeted interventions and policies that can enhance the adaptive capacity of farmers and support sustainable livelihoods in the face of climate change.

Study setting

Our research was conducted in Khorramabad, the largest city in Lorestan province, Iran (Figure 3). With a population of 373,416 people, according to the 2019 census by the Iran Statistics Center, Khorramabad is situated at an altitude of 1147.8 m above sea level, located at coordinates 33.48 north and 48.35 east within the Zagros mountains. The selection of Khorramabad as our study location was driven by the significant impact of climate change in the area.

Climate change has manifested through various factors, including increased dust presence, rising temperatures, a shift in precipitation patterns from snow and rain, and an uneven distribution of rainfall (Rashidi et al., 2024b). These changes have exacerbated drought conditions and resulted in substantial losses for local farmers. In response to the challenges posed by climate change, farmers in Khorramabad have implemented various adaptation strategies, with a particular emphasis on soil and water management (Rashidi et al., 2024a). They have recognized the importance of addressing these issues to mitigate the effects of climate change and sustain agricultural practices in the face of mounting environmental pressures. Furthermore, some farmers have expressed a willingness to migrate as an alternative to confronting the consequences of climate change. The combination of these adaptation strategies and migration decisions reflects the proactive measures taken by farmers to navigate the impacts of climate change and promote long-term agricultural resilience in Khorramabad.

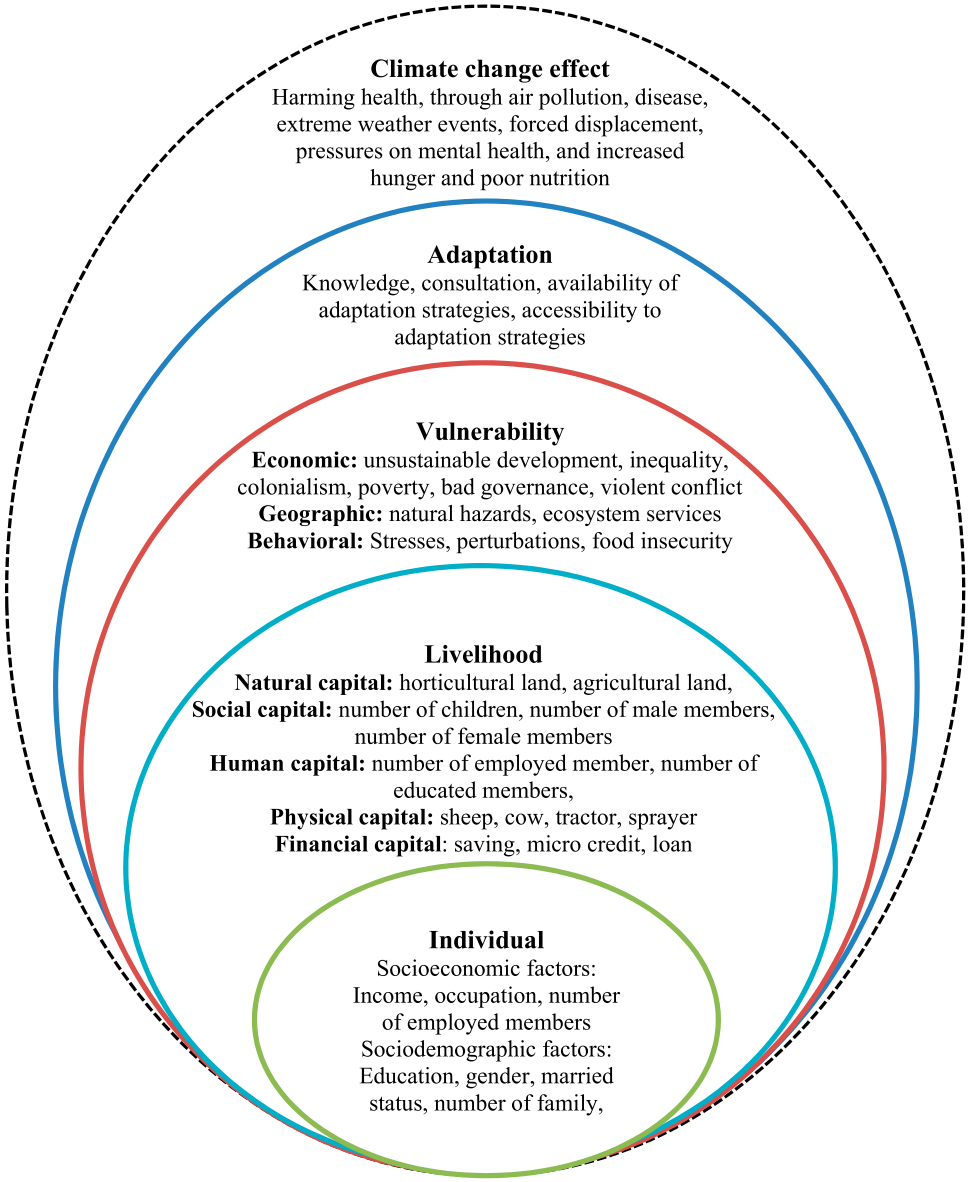

FIGURE 2
Conceptual framework for climate migration (Rashidi et al., 2024a; Rashidi et al., 2024b).

Study population and sampling method

Regarding the objective of the study, the small-scale farmers who are residing in rural Khorramabad city were invited to participate in the data collection process. Cochran's method (finite populations, $\alpha = 0.05$, and Z = 1.96) was applied to determine the sample size. Since the exact proportion of small-scale farmers willing to migrate (p) was not known beforehand, the researchers used a conservative estimate of $p = 0.5$, as recommended when the true proportion is unknown (Sadat et al., 2023; Saif-Nijat et al., 2023). This maximizes the sample size required to achieve the desired level of precision, and finally, 296 small-scale farmers were selected randomly to fill out the constituted questionnaire. This process involved two consecutive stages, including choosing six villages within the study location and selecting randomly sampled farmers from these selected villages. Unit numbers of farmer households were set as the basis of the random sampling process. The heads of these farmer households were then face-to-face interviewed to collect the necessary information.

Data collection instrument

To address the research questions of the current study, a questionnaire consisting of three sections was utilized. The first part consists of information on the use of different adaptation strategies against climate change. Different dimensions of using these operations, including knowledge, usage, availability, accessibility, and consultation were asked. In the second part, the socioeconomic and sociodemographic characteristics of the

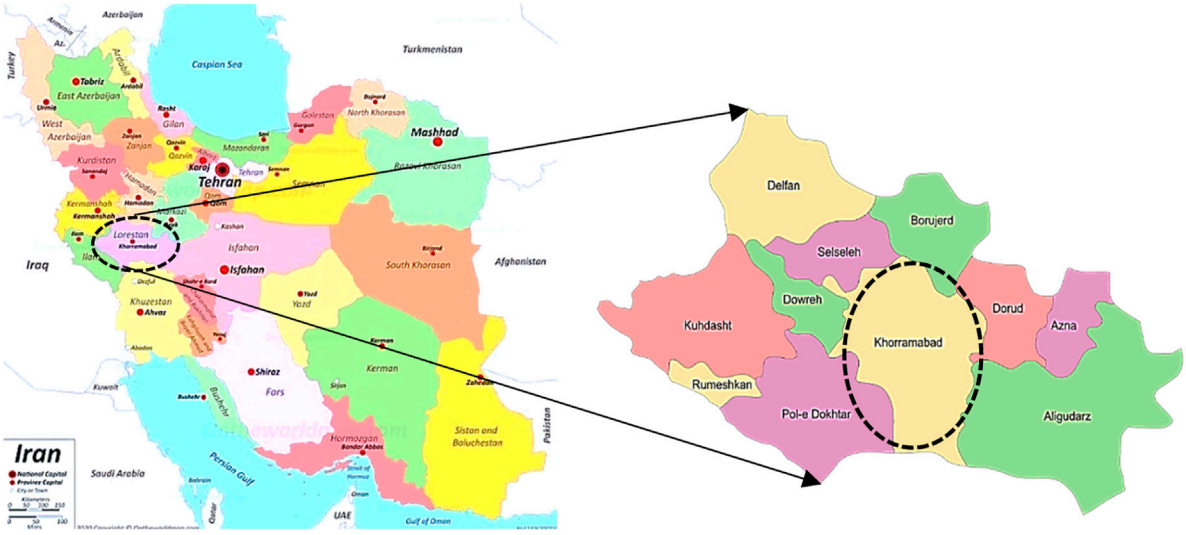

FIGURE 3
The map of the study location (Khorramabad city in Lorestan province).

interviewed farmers were asked. Then, we asked some questions to assess the status of the farmers' vulnerability to climate change.

Data collection process

We recruited five students who specialized in various fields, including agricultural economics, agricultural promotion and education, and rural development, to join the data collection team. Before administering the questionnaire, two training sessions were held for data collectors to teach them effective communication techniques and establish rapport with the respondents in the rural areas. Furthermore, we conducted a pre-test sampling in the study location using 30 questionnaires to verify the accuracy and reliability of our data collection methods (Ghanbari Movahed et al., 2022). The researchers made necessary adjustments to the questionnaire's wording, structure, and flow based on the pre-test participants' feedback and observations (Thakur, 2022). The pre-test and pilot study helped ensure that the final data collection instruments and methods were well-suited to the local context and capable of eliciting the required information from the target respondents. During the actual data collection, the research team implemented several quality assurance measures, such as comprehensive training and debriefing of the interviewers to ensure consistent data collection procedures; random spot-checks and supervision of the interviewers in the field; immediate review and verification of completed questionnaires for completeness and consistency; and double data entry and cross-checking to minimize transcription errors. These steps helped maintain the integrity and reliability of the data collected from the small-scale farmers.

Study variables

In our study, we categorized the independent factors into various groups, encompassing sociodemographic factors, socioeconomic factors, adaptation dimensions, human capital, financial capital, physical capital, natural capital, and social capital. Natural capital refers to the planet's stocks of water, land, air, and renewable and non-renewable resources (such as plant and animal species, forests, and minerals). Social capital refers to a set of shared values or resources that allows individuals to work together in a group to effectively achieve a common purpose. Human capital Refers to assets like education, training, intelligence, skills, health, and other things employers value such as loyalty and punctuality. Also, physical capital refers to the human-created tangible assets or inputs that are used to support the production of goods and services. Finally, financial capital refers to money, credit, and other forms of funding that build wealth for people and businesses. These groups provided a comprehensive framework to capture the diverse factors that might influence the outcome of interest. Within these groups, we had a mix of continuous and dichotomous factors. To provide a clear overview of all the dependent and independent factors included in our analysis, we have presented them in Table 1. This table serves as a visual reference, detailing the factors within each group and their respective categorization as continuous or dichotomous variables.

Statistical analysis

To conduct the descriptive analysis, we calculated key statistical measures for the continuous socio-economic and socio-demographic factors, including the maximum, minimum, mean, and standard deviation. For the categorical determinants, we examined the frequency, percentage, and mode. Subsequently, we divided the small-scale farmers into two distinct groups based on their willingness or unwillingness to migrate due to climate change. To identify the factors associated with this decision, we employed a logistic regression model. Logistic regression is an appropriate statistical technique when the outcome variable is binary or dichotomous, as is the case with the farmers' migration

TABLE 1 Description of socioeconomic and sociodemographic factors in the estimated model.

Variables	Description	Scale
Willingness	Willingness to climate migration	Yes = 1, No = 0
Knowledge	Adequate knowledge to adopt the adaptation strategies	Very poor = 0, poor = 1, acceptable = 3, good = 4, very good = 4
Consulting	Having the needed consulting about adaptation strategies	
Availability	Available tools for adopting the adaptation strategies	
Accessibility	Access to the tools for adopting the adaptation strategies	
HH-Sex	Sex of heads of households	Male = 1, Female = 0
HH-Married	Married status of heads of households	Married = 1, No-married = 0
HH-Occupation	Occupation status of heads of households	Employed = 1, Unemployed = 0
HH-Income	Income of heads of households	US dollars
HH-Education	Education level of heads of households	Literate = 1, Illiterate = 0
HH-Higher education	Higher education of heads of households	Yes = 1, No = 0
HS-Educate	Education level of heads' spouses	Literate = 1, Illiterate = 0
HS-Higher education	Higher education of heads' spouses	Yes = 1, No = 0
Nu-family	Number of family members	Number
Nu-female	Number of female members	Number
Nu-male	Number of male members	Number
HS-Age	Age of heads' spouses	Year
Nu-Higher education	Members with higher education	Number
HH-Age	Age of heads of households	Year
Nu-Children18	Children over 18 years old	Number
Nu-Children6	Children under 6 years old	Number
Nu-employed	Number of employed members	Number
Nu-unemployed	Number of unemployed members	Number
Non-agriculture	Non-agricultural occupation	Agriculture = 1, non-agriculture = 0
Home-owner	Homeownership status	Personal = 1, Rental = 0
Home-area	Home area	M^2
Nu-rooms	The number of rooms	Number
Age-Building	Age of the building	Year
Access-gas	Access to urban gas	Yes = 1, No = 0
Distance	Distance from the city center	Kilometer
Horticultural-land	Horticultural land area	Hectares
Agricultural-land	Agricultural land area	Hectares
Nu-sheep	Number of sheep	Number
Nu-cows	Number of cows	Number
Nu-chickens	Number of local chickens	Number
Pe-tractor	Having a personal tractor	Yes = 1, No = 0
Pe-sprayer	Having a personal sprayer	Yes = 1, No = 0
Pe-saving	Having a personal saving	Yes = 1, No = 0

(Continued on following page)

TABLE 1 (*Continued*) Description of socioeconomic and sociodemographic factors in the estimated model.

Variables	Description	Scale
Pa-Nutrition	Participating in nutrient courses	Yes = 1, No = 0
Re-loan	Receiving a loan	Yes = 1, No = 0
Me-micro credit	Membership in micro-credit fund	Yes = 1, No = 0
Fa-social media	Familiarity with social media	Yes = 1, No = 0
Me-NGOs	Membership in NGOs	Yes = 1, No = 0
Gov-support	Under governmental supports	Yes = 1, No = 0
Nu-Subsidy	The number of subsidized members	Number
Constant	Constant	Constant

TABLE 2 The percent of adaptation dimensions among farmers in the study location.

Adaptation dimension	Very poor	poor	Acceptable	good	Very good
Knowledge	55	21	12	8	1
Availability	64	21	9	4	2
Accessibility	63	21	9	5	2
Consultation	62	19	9	7	3

intentions (willingness to migrate or not). This method allows the researchers to model the probability of a farmer's decision to migrate as a function of various explanatory variables while accounting for the non-linear relationship between the dependent variable and the predictors. A significance level of 0.05 was used for all factors. In the final model, only two outcomes are used: either willing ($y = 1$) or not willing to migrate against climate change ($y = 0$) as Eq. 1 (Munshi et al., 2014):

$$Log\left(\frac{P_i}{1-P_i}\right) = b_0 + b_i x_i \quad (1)$$

Where P_i, as the dependent factor, is the probability of willingness to migrate. It allows us to assess the extent to which the independent factors influence the likelihood of belonging to one of the two groups. By utilizing logistic regression, we can uncover and quantify the significance of the independent factors considering the farmers' migration intentions in response to climate change (Rashidi et al., 2024a). To estimate the quantitative model, STATA 18 software was used.

Results

Descriptive analysis

The results of the descriptive analysis in Table 2 showed that about 55% of the responders have a very low level of knowledge about adaptation strategies. Additionally, 64% of farmers declared a very low level of availability of adaptation equipment, while 63% and 62% of the participating farmers had a very low level of accessibility and consultation regarding adaptation strategies.

Regarding Table 3, of the total sample, 58% of small-scale farmers are willing to migrate in response to climate change, while 42% of the farmers are unwilling to migrate. The analysis also revealed that 95% of the farmers were male, with 93% of them being married. Furthermore, about 82% of these farmers had a second job, 70% were literate, and 36% had a high level of education. The average size of the farmers' households was four individuals, with the average age of the household heads being 49 years and the average age of the spouses being 44 years.

In terms of housing, approximately 80% of the farmers had a personal home, with an average area of 121 square meters. The average age of the buildings was 14 years, and 95% of these buildings had gas connections. The average distance of the participating farmers from the city center was 9 km. The participating farmers were found to possess a minimum of 4 ha of arable land, 4 sheep, 1 beef, and 2 chickens as part of their property. In terms of financial resources, approximately 28% of the responders reported having personal savings, while 46% of the participating farmers received loans from national banks. Only 27% of the responders were members of a rural micro-credit fund, while 47% of the participating farmers indicated familiarity with social media platforms. Lastly, 84% of the responders reported receiving governmental subsidies.

Regression analysis

Table 4 summarizes the results of the statistical tests performed on the estimated logistic regression model. The results suggest that there are no statistical issues present, such as heteroscedasticity, multicollinearity, or problems with the functional form of the model. This suggests that the model's assumptions are met.

10.3389/fenvs.2024.1434708

TABLE 3 Descriptive demographic and socio-economic characteristics of farmers in study location.

Variable	Statistical outputs for continuous factors			
	Min	Max	Mean	SD
I. Continuous				
(a). Age of head of household (year)	24	95	49.3	15.32
(b). Age of spouses (year)	22	88	44.7	15.73
(c). Household/family size	1	11	4.1	1.92
(d). Size of home (m2)	50	700	161	101.5
(e). Age of building	1	35	14.5	10.45
(f). Distance from city center (km)	2	160	9.1	4.40
II. Categorical	Statistical outputs for categorical factors			
	Category	Frequency	Percentage	Mode
(a). Willingness to migration	1–2			
1. Yes		172	58	☑
2. No		124	42	
(b). Gender of head	1–2			
1. Male		281	95	☑
2. Female		15	5	
(c). Married status	1–2			
1. Married		275	93	☑
2. Single		21	7	
(d). Head education status	1–5			
1. Illiterate		88	29.7	☑
2. Rudimentary		52	17.6	
3. Under diploma		49	16.6	
4. Master		75	25.3	
5. Doctorate		32	10.8	
(e). Mother's education status	1–5			
1. Illiterate		113	38.2	☑
2. Rudimentary		65	22.0	
3. Under diploma		46	15.5	
4. Master		57	19.2	
5. Doctorate		15	5.1	
(f). Home status	1–2			
1. Owner		237	80.1	☑
2. Rental		59	19.9	
(g). Personal saving	1–2			
1. Yes		85	28.7	
2- No		211	71.3	☑
(h). Borrowing or loan	1–2			
1. Yes		138	46.6	
2- No		158	53.4	☑
(i). Membership in microcredit funds	1–2			
1. Yes		80	27.0	
2- No		216	73.0	☑
(j). Familiarity with social media	1–2			
1. Yes		141	47.6	
2- No		155	52.4	☑
(k). Under the support of institutions and NGOs	1–2			
1. Yes		84	28.4	
2- No		212	71.6	☑
(l). Receive government subsidies	1–2			
1. Yes		249	84.1	☑
2. No		47	15.9	

TABLE 4 Statistical test for the estimated logit regression model.

Test		Statistics		Prob
Heteroskedasticity	Breusch-Pagan/Cook-Weisberg	Chi2	2.80	0.09
Multicollinearity	Varian Inflation Factor	—	1.79	-
Functional form	Ramsey	F	9.71	0.001
All $\beta's = 0$	likelihood ratio chi-square test	Chi2	201.67	0.001

Furthermore, the results reveal that the null hypothesis of a zero coefficient is rejected, indicating that the coefficients of the independent variables have a significant impact on the outcome. Therefore, it is important to consider and interpret all the coefficients when analyzing the results of the logistic regression model.

As shown in Table 5, the logistic regression analysis found significant indirect relationships between the adaptation dimensions and individuals' willingness to migrate due to climate change. This suggests that enhancing farmers' adaptive capacity through sustainable farming practices can reduce their desire to migrate in response to climate change. Knowing using various adaptation strategies, accessing adequate consultation related to adaptation strategies, the availability of adaptation strategies, and the ability to access different adaptation strategies were found to be significantly and inversely associated with the willingness to migrate. This suggests that individuals who possess greater knowledge and resources in terms of adaptation are less likely to express a willingness to migrate as a response to climate change.

Additionally, the analysis also identified that households headed by males and married individuals are more likely to consider climate migration compared to other households. These demographic factors appear to play a role in shaping the inclination toward migration in the face of climate change.

Surprisingly, our findings did not reveal a significant association between households' income and the willingness to migrate due to climate change. This suggests that income alone may not be a determining factor in influencing individuals' decisions regarding climate migration in the study location. However, it was observed that having a second job was associated with an increased probability of being willing to migrate in response to climate change. These unexpected results highlight the complex nature of factors influencing the willingness to migrate.

In the context of human capital, our analysis indicated that education plays a crucial role in shaping the willingness to migrate as a response to climate change. Specifically, our findings suggest that increasing the level of education is associated with a higher probability of individuals being inclined toward climate migration.

Regarding the financial capital of small-scale farmers, receiving a loan from private or governmental banks was found to have a significant and indirect association with the willingness to migrate. Also, receiving government financial support was found to be significantly and indirectly associated with the willingness to migrate.

Taking into account physical capital as a livelihood dimension, while home ownership was significantly and indirectly associated with the willingness to migrate, a larger home increases the probability of the willingness to migrate in response to climate change. Homeownership could provide individuals with a sense of security and flexibility, helping them to adapt their situation to cope with climate change. Also, individuals with larger homes may have more resources and capacity to stay in their current location, as they may have accumulated more physical assets and financial means.

Finally, distance from the city center and membership in rural non-governmental organizations as social capitals had a negative and significant association with willingness to migrate in response to climate change.

Discussion

The study conducted on the willingness to climate migration among small-scale farmers in Iran provides valuable insights into the adaptive capacity and resilience of rural communities in the face of climate change. The findings shed light on the factors associated with farmers' decisions to migrate, which can inform policymakers and researchers in designing effective interventions and policies for sustainable development in the agricultural sector. The conceptual framework utilized in the study provides a comprehensive model to understand the impact of climate change on farmers' willingness to migrate. By categorizing factors into individual, livelihood, vulnerability, and adaptation levels, the study recognizes the interconnectedness of these factors and their influence on migration decisions. This approach allows for a more holistic understanding of climate migration dynamics and provides a basis for developing effective strategies to enhance the adaptive capacity of rural communities.

The results suggested that farmers who have greater knowledge about adaptation strategies, better access to these strategies, adequate availability of necessary equipment, and sufficient consultation about these strategies are less likely to consider migration as a response to climate change. Improving farm-level use of multiple climate change adaptation strategies is essential for improving household food security, particularly against a backdrop of a high risk of climatic shocks (Teklewold et al., 2019). Enhancing knowledge about adaptation strategies is crucial because it empowers farmers with information on how to mitigate the negative impacts of climate change (Abbasi and Nawaz, 2020; Diallo et al., 2020). In such a situation, they can make informed decisions and take proactive measures to protect their livelihoods (Abbasi and Nawaz, 2020; Thakur, 2022). This knowledge equips them with the skills and confidence to implement appropriate adaptation measures (Mustafa et al., 2023), which can reduce their vulnerability to climate change (Aryal et al., 2021) and, in turn, decrease their willingness to migrate. Furthermore, when farmers have access to a variety of adaptation options that are suitable for their specific contexts, they are more likely to adopt measures that can help them adapt to changing climatic conditions (Ali and Erenstein, 2017). This finding emphasizes the importance of supporting farmers by providing them with a diverse range of adaptation options tailored to their local conditions (Rashidi-Chegini et al., 2021). In addition to availability, farmers require access to tools, technologies, financial resources, and support systems to effectively implement and sustain adaptation measures (Grigorieva et al., 2023). Providing financial and technical support to small-scale farmers to implement effective adaptation strategies can

10.3389/fenvs.2024.1434708

TABLE 5 The results of the estimated model of willingness to climate migration.

Levels	Variables	Coeff	Z	P>|z|	[95% Conf. Interval]		VIF
					Lower	Upper	
Adaptation strategies	Knowledge	−1.47	−6.04	0.001	−1.94	−0.99	1.73
	Consulting	−0.93	−4.96	0.001	−1.30	−0.56	2.00
	Availability	−1.88	−14.70	0.001	−2.14	−1.63	2.24
	Accessibility	−0.60	−65.65	0.001	−0.62	−0.58	3.09
SDE	HH-Sex	1.50	4.40	0.001	0.83	2.17	1.69
	HH-Married	1.04	3.23	0.001	0.41	1.68	1.62
	HS-Age	−0.02	−0.90	0.366	−0.05	0.02	2.51
	HH-Age	0.01	1.37	0.170	−0.004	0.02	2.51
SEC	HH-Occupation	0.47	10.79	0.001	0.38	0.56	1.22
	HH-Income	$-1.67*10^{-7}$	−1.73	0.084	$-3.56*10^{-7}$	$2.24*10^{-8}$	1.24
Human capital	HH-Education	0.34	6.77	0.001	0.24	0.44	2.45
	HH-Higher education	0.58	4.46	0.001	0.32	0.83	2.01
	HS-Educate	0.39	17.00	0.001	0.34	0.44	2.69
	HS-Higher education	0.60	59.42	0.001	0.58	0.62	1.94
	Nu-family	0.28	1.58	0.114	−0.07	0.64	2.37
	Nu-female	−0.01	−0.34	0.737	−0.09	0.06	1.51
	Nu-male	0.04	1.34	0.181	−0.02	0.11	1.33
	Nu-Children18	−0.45	−1.30	0.193	−1.14	0.23	3.57
	Nu-Children6	−0.21	−0.61	0.542	−0.92	0.48	1.50
	Nu-employed	−0.001	−0.001	0.997	−0.64	0.64	1.65
	Nu-unemployed	0.45	18.19	0.001	0.40	0.50	1.65
	Nu-Higher education	0.36	3.15	0.002	0.13	0.58	2.31
Financial capital	Pe-saving	−0.01	−0.02	0.984	−1.06	1.04	1.60
	Re-loan	−1.11	−4.63	0.001	−1.58	−0.64	1.54
	Gov-support	−1.01	−3.57	0.001	−0.45	−1.56	1.76
	Nu-Subsidy	0.05	1.78	0.075	−0.005	0.10	2.63
Physical capital	Home-owner	−0.25	−3.06	0.002	−0.42	−0.09	1.36
	Home-area	0.002	7.88	0.001	0.001	0.003	1.53
	Nu-rooms	0.003	0.01	0.988	−0.39	0.40	1.43
	Age-Building	−0.02	−0.59	0.554	−0.08	0.04	1.21
	Access-gas	0.01	0.01	0.994	−3.74	3.76	1.54
	Pe-tractor	0.07	0.80	0.424	−0.10	0.24	1.30
	Pe-sprayer	−0.82	−1.87	0.062	−1.68	0.04	1.60
Natural capital	Horticultural-land	0.12	4.02	0.001	0.06	0.19	1.31
	Agricultural-land	0.05	0.79	0.428	−0.07	0.17	1.49
	Nu-sheep	−0.002	−0.55	0.582	−0.01	0.006	1.45
	Nu-cows	−0.007	−0.35	0.723	−0.05	0.03	1.62
	Nu-chickens	−0.06	−1.75	0.080	−0.14	0.008	1.57

(Continued on following page)

TABLE 5 (*Continued*) The results of the estimated model of willingness to climate migration.

Levels	Variables	Coeff	Z	P>|z|	[95% Conf. Interval]		VIF
					Lower	Upper	
Social capital	Distance	0.12	2.04	0.001	0.10	0.14	1.45
	Pa-Nutrition	0.44	1.28	0.201	−0.23	1.11	1.54
	Me-micro credit	−0.002	−0.03	0.979	−0.15	0.15	1.47
	Fa-social media	−0.43	−0.87	0.384	−1.42	0.54	1.52
	Me-NGOs	−0.33	−12.87	0.001	−0.38	0.28	1.57
Constant		−8.73	−16.27	0.001	−9.79	−7.68	

help them cope with the impacts of climate change and reduce their motivation to migrate. When small-scale farmers have the means to access and utilize these resources, they can effectively implement adaptation strategies, improve their resilience, and reduce their inclination to migrate in the face of climate change. Furthermore, adequate consultation and guidance provide farmers with a support system and enable them to navigate the complexities of climate change and adaptation. This access to consultation and guidance can contribute to reducing the likelihood of migration as farmers feel more confident and empowered to face the challenges of climate change within their current locations. The finding that different dimensions of adaptation strategies are inversely associated with the willingness to migrate aligns with previous studies that have highlighted the role of adaptation in reducing the need for climate-induced migration (Obokata et al., 2014; Berhanu and Beyene, 2015). This suggests that when small-scale farmers can effectively adapt to climate change through sustainable farming practices, they are less likely to consider migration as an option.

The results showed that, in the context of human capital, individuals with higher levels of education are more likely to consider migration as a viable adaptation strategy in the face of climate challenges. Education equips individuals with knowledge, critical thinking skills, and a broader understanding of the potential impacts of climate change (Reimers, 2020; Newsome et al., 2023), leading to greater recognition of the need for proactive measures such as migration. The significance of education in influencing the willingness to migrate highlights the importance of investing in the education of climate change adaptation behavior to more educated and literate people and promoting educational opportunities (Kumar et al., 2023), particularly in areas vulnerable to climate change. Improving farmers' specialized knowledge about the consequences of climate migration, along with their general education, can help them make informed decisions about whether to migrate or not. Enhancing educational attainment can empower individuals to adapt effectively to changing environmental conditions (Grabow et al., 2023). It is worth noting that the relationship between education and willingness to migrate may be influenced by various contextual factors and individual circumstances.

The findings of the study highlighted that financial capital, specifically in the form of loans from private or governmental banks and government financial support, has a significant and indirect association with migration inclination. The association between financial support and willingness to migrate can be understood within the context of farmers' financial resources and constraints (Ruben et al., 2019). Access to loans provided farmers with additional financial capital that can be utilized to invest in climate change adaptation measures, improve agricultural practices, and enhance resilience (Ruben et al., 2019; Lipper et al., 2021). Farmers who receive loans may have greater financial flexibility and resources to implement adaptive strategies (Sahraei et al., 2022), reducing their vulnerability to climate change impacts and subsequently decreasing their inclination to migrate (Rashidi et al., 2024a). Furthermore, loans can contribute to the development of income-generating activities, diversification of livelihoods, and the creation of alternative sources of income (Ayana et al., 2022). This financial stability and diversification may reduce farmers' reliance on agriculture as the sole income source (Rashidi-Chegini et al., 2021), making migration less necessary as a coping strategy. Also, government support in the form of subsidies, grants, or financial aid can provide farmers with additional resources to invest in climate change adaptation measures and improve their resilience. This financial assistance can contribute to the development of sustainable agricultural practices, the adoption of new technologies (Piñeiro et al., 2020), and the implementation of measures to mitigate climate-related risks. Government financial support also reflects the commitment of policymakers to address the challenges faced by farmers (Eriksen et al., 2021) in the context of climate change. It signifies a recognition of the importance of supporting farmers and rural communities in adapting to changing environmental conditions. The provision of financial assistance can alleviate financial burdens, enhance farmers' capacity to invest in adaptation strategies and reduce their inclination to migrate as a response to climate change (Rashidi et al., 2024a). The indirect association between improving financial capital and farmers' willingness to migrate to rural areas aligns with previous research that has highlighted the importance of financial resources in supporting adaptation and livelihood strategies (Adger et al., 2002; Neil Adger et al., 2005; Jain et al., 2015).

The results indicated that while home ownership has a significant and indirect association with migration inclination, a larger home is associated with a higher probability of being willing to migrate. The association between homeownership and migration inclination can be understood within the context of assets and investments (Pakravan-Charvadeh, et al., 2021b; Sadat et al., 2023). Homeownership represents a form of physical capital and

is often considered a valuable asset (Pakravan-Charvadeh, et al., 2021b; Rashidi-Chegini et al., 2021). Individuals who own their homes may have a sense of security, stability, and attachment to their property (Pakravan-Charvadeh et al., 2020a; Sahraei et al., 2022). Homeownership can also provide a sense of belonging and identity within a community (Rolfe et al., 2020). These factors may contribute to a reduced inclination to migrate, as individuals with a sense of ownership and attachment may be less likely to leave their homes in response to climate change. On the other hand, a larger home is associated with a higher probability of being willing to migrate. This finding may be attributed to several factors. Firstly, a larger home often implies higher maintenance and upkeep costs, which can be financially burdensome for individuals, especially in the context of climate change impacts (Rashidi et al., 2024a). Individuals with larger homes may perceive a greater risk of damage or higher adaptation costs (Pakravan-Charvadeh et al., 2022) associated with climate-related events, leading to an increased willingness to migrate as a means to mitigate these risks. Additionally, a larger home may imply a higher level of investment in the property and attachment to a specific location (Zavisca and Gerber, 2016). This attachment can make individuals more sensitive to the potential risks and vulnerabilities associated with climate change. They may perceive their larger homes as more vulnerable to climate-related hazards and may be more inclined to seek safer or more resilient locations through migration.

The direct association between distance from the city center and migration inclination suggests that individuals residing farther away from urban areas are more likely to express a willingness to migrate in response to climate change. This finding can be understood in terms of economic opportunities and access to resources. Urban areas often offer a broader range of employment opportunities, social services, and amenities (Zarifa et al., 2019). People living further away from cities may have better prospects for economic livelihoods and access to adaptive resources in urban areas (Satterthwaite et al., 2010), making migration a more appealing option as a means to improve their circumstances in the face of climate change-related challenges. Conversely, individuals who are members of rural non-governmental organizations are less likely to express a willingness to migrate in response to climate change. Membership in rural NGOs can provide individuals with access to social networks, support systems, and capacity-building initiatives (Nikkhah and Redzuan, 2010). These factors can enhance individuals' adaptive capacity and resilience, reducing their inclination to migrate as they perceive greater opportunities for implementing climate change adaptation measures within their communities (Rashidi et al., 2024a).

Limitations

The study relies on self-reported data from farmers regarding their willingness to migrate. Self-reporting can introduce biases, such as social desirability bias or recall bias, which may affect the accuracy and reliability of the responses. Also, the study may not capture the full range of contextual factors that influence farmers' willingness to migrate. Factors such as cultural norms, local governance, and historical context can significantly impact migration decisions but might not be fully accounted for in the study. Also, climate change impacts and migration decisions are influenced by future projections and uncertainties. The study's findings may not fully capture the complexity and unpredictability of future climate scenarios and their implications for small-scale farmers' migration decisions. Finally, the findings of the study may be specific to the context of Iran and may not be directly applicable to other regions or countries with different socioeconomic, cultural, and environmental conditions.

Conclusion

In conclusion, addressing the challenges of climate migration among small-scale farmers in Iran requires a comprehensive set of policy measures. First and foremost, policies should prioritize strengthening social safety nets to mitigate the adverse consequences of migration for both sending and receiving communities. This can be achieved through the provision of financial assistance, access to healthcare services, and the establishment of social support networks. Furthermore, promoting sustainable agricultural practices and providing support to small-scale farmers is crucial for enhancing their resilience to climate change impacts.

Climate change is a global challenge that requires regional cooperation and coordination. Policies should prioritize regional collaboration to address shared climate change impacts and develop joint adaptation strategies. This can involve sharing best practices, exchanging knowledge and expertise, and pooling resources to enhance the adaptive capacity of rural communities across borders.

Future research could explore the influence of institutional and policy-level factors, such as government support programs, land tenure policies, and climate adaptation initiatives, on farmers' willingness to migrate. Also, future research could focus on examining the long-term socioeconomic, environmental, and community-level impacts of climate-induced migration, both for the sending and receiving communities. Finally, expanding the research to other agricultural regions, both within Iran and in other countries, would provide a more comprehensive understanding of the factors influencing climate migration willingness across diverse contexts.

Policy recommendations

The results showed that improving financial capital was indirectly associated with farmers' willingness to migrate. Policies that provide financial assistance and incentives for small-scale farmers to adopt sustainable agricultural practices can help alleviate their economic challenges and reduce the need to migrate. Also, the findings suggest that improving farmers' specialized knowledge about the consequences of climate migration, in conjunction with their general education, can help control and manage their migration decisions. Policies should focus on education and awareness-raising campaigns to equip farmers with a better understanding of the implications of climate migration. Developing and implementing targeted capacity-building programs to enhance farmers' adaptive capacity and promote sustainable agricultural development could be an effective policy approach.

Policy interventions should focus on facilitating the adoption of climate-smart agricultural techniques, promoting efficient water management, and ensuring access to necessary resources and inputs. Additionally, policies should emphasize the dissemination of accurate and up-to-date information on climate change and its implications for farmers. Awareness campaigns, capacity-building programs, and knowledge-sharing platforms can empower farmers to make informed decisions regarding their farming practices and adaptation strategies. To reduce the vulnerability of small-scale farmers, policies should encourage diversification of livelihoods beyond agriculture. This can be accomplished by promoting alternative income-generating activities, providing training and resources for entrepreneurship, and facilitating access to credit and markets for non-agricultural enterprises.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RK: Data curation, Formal Analysis, Resources, Writing–original draft, MP-C: Investigation, Methodology, Supervision, Writing–review and editing, MR: Conceptualization, Formal Analysis, Validation, Visualization, Writing–review and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abbasi, Z. A. K., and Nawaz, A. (2020). Impact of climate change awareness on climate change adaptions and climate change adaptation issues. *Pak. J. Agric. Res.* 36 (3), 422–691. doi:10.17582/journal.pjar/2020/33.3.619.636

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., and Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environ. Sci. Pollut. Res.* 29 (28), 42539–42559. doi:10.1007/s11356-022-19718-6

Adger, W. N., Kelly, P. M., Winkels, A., Huy, L. Q., and Locke, C. (2002). Migration, remittances, livelihood trajectories, and social resilience. *AMBIO A J. Hum. Environ.* 31 (4), 358–366. doi:10.1579/0044-7447-31.4.358

Ali, A., and Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Clim. Risk Manag.* 16, 183–194. doi:10.1016/j.crm.2016.12.001

Aryal, J. P., Sapkota, T. B., Rahut, D. B., Marenya, P., and Stirling, C. M. (2021). Climate risks and adaptation strategies of farmers in East Africa and South Asia. *Sci. Rep.* 11 (1), 10489. doi:10.1038/s41598-021-89391-1

Ayana, G. F., Megento, T. L., and Kussa, F. G. (2022). The extent of livelihood diversification on the determinants of livelihood diversification in Assosa Wereda, Western Ethiopia. *GeoJournal* 87 (4), 2525–2549. doi:10.1007/s10708-021-10379-5

Balsari, S., Dresser, C., and Leaning, J. (2020). Climate change, migration, and civil strife. *Curr. Environ. Health Rep.* 7 (4), 404–414. doi:10.1007/s40572-020-00291-4

Bell, J. E., Brown, C. L., Conlon, K., Herring, S., Kunkel, K. E., Lawrimore, J., et al. (2018). Changes in extreme events and the potential impacts on human health. *J. Air & Waste Manag. Assoc.* 68 (4), 265–287. doi:10.1080/10962247.2017.1401017

Berhanu, W., and Beyene, F. (2015). Climate variability and household adaptation strategies in southern Ethiopia. *Sustainability* 7 (6), 6353–6375. doi:10.3390/su7066353

Bolan, S., Padhye, L. P., Jasemizad, T., Govarthanan, M., Karmegam, N., Wijesekara, H., et al. (2024). Impacts of climate change on the fate of contaminants through extreme weather events. *Sci. Total Environ.* 909, 168388. doi:10.1016/j.scitotenv.2023.168388

Brown, O. (2007). *Climate change and forced migration: observations, projections and implications*. New York, NY: Human Development Report Office.

Brown, O., Hammill, A., and Mcleman, R. (2007). Climate change as the 'new' security threat: implications for Africa. *Int. Aff.* 83 (6), 1141–1154. doi:10.1111/j.1468-2346.2007.00678.x

Bye, H. H., Yu, H., Portice, J. S., and Ogunbode, C. A. (2023). Interactions between migrant race and social status in predicting acceptance of climate migrants in Norway. *Clim. Change* 176 (4), 46. doi:10.1007/s10584-023-03523-2

Diallo, A., Donkor, E., and Owusu, V. (2020). Climate change adaptation strategies, productivity and sustainable food security in southern Mali. *Clim. Change* 159 (3), 309–327. doi:10.1007/s10584-020-02684-8

Eriksen, S., Schipper, E. L. F., Scoville-Simonds, M., Vincent, K., Adam, H. N., Brooks, N., et al. (2021). Adaptation interventions and their effect on vulnerability in developing countries: help, hindrance or irrelevance? *World Dev.* 141, 105383. doi:10.1016/j.worlddev.2020.105383

Feigin, S. V., Wiebers, D. O., Lueddeke, G., Morand, S., Lee, K., Knight, A., et al. (2023). Proposed solutions to anthropogenic climate change: a systematic literature review and a new way forward. *Heliyon* 9 (10), e20544. doi:10.1016/j.heliyon.2023.e20544

Ghanbari Movahed, R., Maleki Fard, F., Gholamrezai, S., and Pakravan-Charvadeh, M. R. (2022). The impact of COVID-19 pandemic on food security and food diversity of Iranian rural households. *Front. Public Health* 10, 862043. doi:10.3389/fpubh.2022.862043

Grabow, M. L., Stull, V. J., Hahn, M. B., and Limaye, V. S. (2023). A blueprint for strengthening climate and health literacy through professional adaptability. *Front. Public Health* 11, 1112944. doi:10.3389/fpubh.2023.1112944

Grigorieva, E., Livenets, A., and Stelmakh, E. (2023). Adaptation of agriculture to climate change: a scoping review. *Climate* 11 (10), 202. doi:10.3390/cli11100202

Habib-ur-Rahman, M., Ahmad, A., Raza, A., Hasnain, M. U., Alharby, H. F., Alzahrani, Y. M., et al. (2022). Impact of climate change on agricultural production; issues, challenges, and opportunities in Asia. *Front. Plant Sci.* 13, 925548. doi:10.3389/fpls.2022.925548

Hosseini, S. S., Pakravan-Charvadeh, M. R., Salami, H., and Flora, C. (2017). The impact of the targeted subsidies policy on household food security in urban areas in Iran. *Cities* 63, 110–117. doi:10.1016/J.CITIES.2017.01.003

Jain, M., Naeem, S., Orlove, B., Modi, V., and DeFries, R. S. (2015). Understanding the causes and consequences of differential decision-making in adaptation research:

adapting to a delayed monsoon onset in Gujarat, India. *Glob. Environ. Change* 31, 98–109. doi:10.1016/j.gloenvcha.2014.12.008

Kalele, D. N., Ogara, W. O., Oludhe, C., and Onono, J. O. (2021). Climate change impacts and relevance of smallholder farmers' response in arid and semi-arid lands in Kenya. *Sci. Afr.* 12, e00814. doi:10.1016/j.sciaf.2021.e00814

Kumar, P., Sahani, J., Rawat, N., Debele, S., Tiwari, A., Mendes Emygdio, A. P., et al. (2023). Using empirical science education in schools to improve climate change literacy. *Renew. Sustain. Energy Rev.* 178, 113232. doi:10.1016/j.rser.2023.113232

Lipper, L., Cavatassi, R., Symons, R., Gordes, A., and Page, O. (2021). Financing adaptation for resilient livelihoods under food system transformation: the role of multilateral development banks. *Food Secur.* 13 (6), 1525–1540. doi:10.1007/s12571-021-01210-7

Loucks, D. P. (2021). "Impacts of climate change on economies, ecosystems, energy, environments, and human equity: a systems perspective," in *The impacts of climate change* (Amsterdam, Netherlands: Elsevier), 19–50. doi:10.1016/B978-0-12-822373-4.00016-1

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., et al. (2020). Climate change and ecosystems: threats, opportunities and solutions. *Philosophical Trans. R. Soc. B Biol. Sci.* 375 (1794), 20190104. doi:10.1098/rstb.2019.0104

McInerney, E., Saxon, J., and Ashley, L. (2022). *Migration as a climate adaptation strategy: challenges & opportunities for USAID programs*. Washington, DC: USAID.

McLeman, R. A., and Hunter, L. M. (2010). Migration in the context of vulnerability and adaptation to climate change: insights from analogues. *Wiley Interdiscip. Rev. Clim.* 1 (3), 450–461. doi:10.1002/wcc.51

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proc. Natl. Acad. Sci.* 104 (50), 19680–19685. doi:10.1073/pnas.0701855104

Munshi, T., Zuidgeest, M., Brussel, M., and van Maarseveen, M. (2014). Logistic regression and cellular automata-based modelling of retail, commercial and residential development in the city of Ahmedabad, India. *Cities* 39, 68–86. doi:10.1016/j.cities.2014.02.007

Mustafa, G., Alotaibi, B. A., and Nayak, R. K. (2023). Linking climate change awareness, climate change perceptions and subsequent adaptation options among farmers. *Agronomy* 13 (3), 758. doi:10.3390/agronomy13030758

Neil Adger, W., Arnell, N. W., and Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Glob. Environ. Change* 15 (2), 77–86. doi:10.1016/j.gloenvcha.2004.12.005

Newsome, D., Newsome, K. B., and Miller, S. A. (2023). Teaching, learning, and climate change: anticipated impacts and mitigation strategies for educators. *Behav. Soc. Issues* 32 (2), 494–516. doi:10.1007/s42822-023-00129-2

Nikkhah, H. A., and Redzuan, M. B. (2010). The role of NGOs in promoting empowerment for sustainable community development. *J. Hum. Ecol.* 30 (2), 85–92. doi:10.1080/09709274.2010.11906276

Nyang'au, J. O., Mohamed, J. H., Mango, N., Makate, C., and Wangeci, A. N. (2021). Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya. *Heliyon* 7 (4), e06789. doi:10.1016/j.heliyon.2021.e06789

Obokata, R., Veronis, L., and McLeman, R. (2014). Empirical research on international environmental migration: a systematic review. *Popul. Environ.* 36, 111–135. doi:10.1007/s11111-014-0210-7

Pakravan-Charvadeh, M. R., and Flora, C. (2022). Sustainable food consumption pattern with emphasis on socioeconomic factors to reduce food waste. *Int. J. Environ. Sci. Technol.* 2022, 9929–9944. doi:10.1007/S13762-022-04186-9

Pakravan-Charvadeh, M. R., Flora, C., and Khan, H. A. (2022). Simulating potential associated socio-economic determinants with sustainable food security (a macro-micro spatial quantitative model). *Front. Public Health* 10 (July), 923705. doi:10.3389/fpubh.2022.923705

Pakravan-Charvadeh, M. R., Khan, H. A., and Flora, C. (2020a). Spatial analysis of food security in Iran: associated factors and governmental support policies. *J. Public Health Pol.* 41, 351–374. doi:10.1057/s41271-020-00221-6

Pakravan-Charvadeh, M. R., Mohammadi-Nasrabadi, F., Gholamrezai, S., Vatanparast, H., Flora, C., and Nabavi-Pelesaraei, A. (2020b). The short-term effects of COVID-19 outbreak on dietary diversity and food security status of Iranian households (A case study in Tehran province). *J. Clean. Prod.* 281, 124537. doi:10.1016/j.jclepro.2020.124537

Pakravan-Charvadeh, M. R., Savari, M., Khan, H. A., Gholamrezai, S., and Flora, C. (2021a). Determinants of household vulnerability to food insecurity during COVID-19 lockdown in a mid-term period in Iran. *Public Health Nutr.* 1, 1619–1628. doi:10.1017/S1368980021000318

Pakravan-Charvadeh, M. R., Vatanparast, H., Khakpour, M., and Flora, C. (2021b). Food insecurity status of Afghan refugees is linked to socioeconomic and resettlement status, gender disparities and children's health outcomes in Iran. *Child Indic. Res.* 14 (5), 1979–2000. doi:10.1007/s12187-021-09827-y

Parrish, R., Colbourn, T., Lauriola, P., Leonardi, G., Hajat, S., and Zeka, A. (2020). A critical analysis of the drivers of human migration patterns in the presence of climate change: a new conceptual model. *Int. J. Environ. Res. Public Health* 17 (17), 6036. doi:10.3390/ijerph17176036

Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., et al. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nat. Sustain.* 3 (10), 809–820. doi:10.1038/s41893-020-00617-y

Rashidi, T., Pakravan-Charvadeh, M. R., Gholamrezai, S., and Rahimian, M. (2024a). Efficiency of small-scale farmer's conservative behavior on their food security status in Iran. *Reg. Environ. Change* 24 (1), 23. doi:10.1007/s10113-023-02180-6

Rashidi, T., Pakravan-Charvadeh, M. R., Gholamrezai, S., and Rahimian, M. (2024b). Unveiling the nexus of climate change, adaptation strategies, and food security: insights from small-scale farmers in zagros mountains in Iran. *Environ. Res.* 252 (Pt 1), 118691. doi:10.1016/j.envres.2024.118691

Rashidi-Chegini, K., Pakravan-Charvadeh, M. R., Rahimian, M., and Gholamrezaie, S. (2021). Is there a linkage between household welfare and income inequality, and food security to achieve sustainable development goals? *J. Clean. Prod.* 326, 129390. doi:10.1016/j.jclepro.2021.129390

Reimers, F. M. (2020). *The role of universities building an ecosystem of climate change education*. Cham, Switzerland: Springer, 1–44. doi:10.1007/978-3-030-57927-2_1

Rolfe, S., Garnham, L., Godwin, J., Anderson, I., Seaman, P., and Donaldson, C. (2020). Housing as a social determinant of health and wellbeing: developing an empirically-informed realist theoretical framework. *BMC Public Heal.* 20 (1), 1138. doi:10.1186/s12889-020-09224-0

Ruben, R., Wattel, C., and van Asseldonk, M. (2019). "Rural finance to support climate change adaptation: experiences, lessons and policy perspectives," in *The climate-smart agriculture papers* (Berlin, Germany, Springer International Publishing), 301–313. doi:10.1007/978-3-319-92798-5_26

Sadat, S. A. A., Pakravan-Charvadeh, M. R., Gholamrezai, S., Rahimian, M., Lane, G., Béland, D., et al. (2023). Factors associated with Afghan household food security pre- and post-Taliban regime. *J. Public Health Policy* 44, 551–565. doi:10.1057/s41271-023-00439-0

Sahraei, S., Pakravan-Charvadeh, M. R., Gholamrezai, S., and Rahimian, M. (2022). Assessing the association of sustainable agriculture with rural household food security (considering ecological, economic, and social aspects). *Front. Nutr.* 9, 899427. doi:10.3389/FNUT.2022.899427

Saif-Nijat, J., Pakravan-Charvadeh, M. R., Gholamrezai, S., Rahimian, M., Lane, G., Béland, D., et al. (2023). The association of the quality of life with Afghan households' food insecurity before and after the recent political change in Afghanistan: a comparative analysis. *BMC Public Heal.* 23 (1), 2066–2114. doi:10.1186/s12889-023-16967-z

Satterthwaite, D., McGranahan, G., and Tacoli, C. (2010). Urbanization and its implications for food and farming. *Philosophical Trans. R. Soc. B Biol. Sci.* 365 (1554), 2809–2820. doi:10.1098/rstb.2010.0136

Shivanna, K. R. (2022). Climate change and its impact on biodiversity and human welfare. *Proc. Indian Natl. Sci. Acad.* 88 (2), 160–171. doi:10.1007/s43538-022-00073-6

Teklewold, H., Mekonnen, A., and Kohlin, G. (2019). Climate change adaptation: a study of multiple climate-smart practices in the Nile Basin of Ethiopia. *Clim. Dev.* 11 (2), 180–192. doi:10.1080/17565529.2018.1442801

Thakur, P. (2022). Determinants of farmers' adoption behaviour towards farm business management practices for vegetable farming in mid-hills of Himachal Pradesh, India. *Econ. Aff.* 67 (2), 117–122. doi:10.46852/0424-2513.2.2022.19

Zarifa, D., Seward, B., and Milian, R. P. (2019). Location, location, location: examining the rural-urban skills gap in Canada. *J. Rural Stud.* 72, 252–263. doi:10.1016/j.jrurstud.2019.10.032

Zavisca, J. R., and Gerber, T. P. (2016). The socioeconomic, demographic, and political effects of housing in comparative perspective. *Annu. Rev. Sociol.* 42 (1), 347–367. doi:10.1146/annurev-soc-081715-074333