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Socio-Economic Drivers of Flood Vulnerability and the Role of Adaptive Capacities in Rural Communities: A Case Study of the Eastern Alamut District, Qazvin Province, Iran

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ABSTRACT

Flooding is one of the major natural hazards affecting the economic and social sustainability of rural communities. Rural household vulnerability is shaped not only by exposure to flood hazards, but also by socio-economic conditions and capacities to cope with, adapt to, and recover from flood events. This study examines the role of socio-economic drivers and adaptive capacities in shaping flood-vulnerability outcomes in rural communities of Rudbar-e Alamut District, Qazvin County, Iran. The research was applied in objective and descriptive-analytical in method. The statistical population included households in 32 flood-prone villages selected through purposive sampling. Data were collected from 336 households using a structured questionnaire and analyzed through structural equation modeling (SEM) in SmartPLS. The results showed that socio-economic drivers, including economic and livelihood conditions, social capital, and risk perception and awareness, had a strong and statistically significant effect on coping, adaptive, and recovery capacities, with a path coefficient of 0.918. These drivers also had a strong direct effect on flood-vulnerability outcomes, with a path coefficient of 0.779, while coping, adaptive, and recovery capacities had a significant effect on vulnerability outcomes, with a path coefficient of 0.222. The R^2 value of 0.843 indicated the strong explanatory power of socio-economic drivers in explaining variations in adaptive capacities. The findings suggest that reducing rural flood vulnerability requires strengthening livelihood capacities, social capital, risk awareness, and household- and community-level recovery mechanisms.

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Introduction

Flooding is one of the most significant natural hazards in the contemporary world. Its simultaneous links with climate change, the expansion of settlements in high-risk areas, land-use change, and weaknesses in risk management systems have turned it into a complex and multidimensional phenomenon (Akhlaghi Pirposhteh et al., 2026; IPCC, 2022; Pörtner et al., 2022). In the hazards literature, flooding is not regarded merely as a hydrological event; rather, it is understood as the outcome of interactions among hazard, exposure, social sensitivity, and communities' adaptive capacity (Birkmann et al., 2022). From this perspective, the severity of flood damage depends not only on the amount of rainfall or river discharge, but also on the social, economic, institutional, spatial, and livelihood characteristics of populations at risk (Cutter et al., 2003; Wisner et al., 2004). Therefore, understanding flood vulnerability requires moving beyond purely physical approaches and examining the mechanisms that make some households and settlements more vulnerable than others to the consequences of flooding (Cutter et al., 2003; Hosseinpour et al., 2026; Wisner et al., 2004).

To explain this issue, the present study understands flood vulnerability through the interplay of three theoretical perspectives: social vulnerability, livelihood capitals and adaptive capacity, and risk perception and protective behaviors. Social vulnerability theory suggests that groups and settlements experience different levels of vulnerability to the same hazard because of differences in resources, assets, access to services, social status, housing quality, and response capacity (Cutter et al., 2003; Wisner et al., 2004). Complementing this perspective, the sustainable livelihoods approach explains that rural households differ in their ability to prevent, cope with, and recover from floods depending on their access to economic, human, social, physical, and institutional capital (Chambers & Conway, 1992; DFID, 1999). Protection Motivation Theory and the Protective Action Decision Model further emphasize that risk awareness, prior experience, perceived hazard severity, assessment of coping ability, and confidence in the effectiveness of protective measures can influence household preparedness and the adoption of risk-reduction behaviors (Rogers, 1975; Lindell & Perry, 2012). Accordingly, the present study considers flood vulnerability a socioeconomic and multilevel phenomenon that, at the household and rural community levels, is influenced by economic and livelihood conditions, social capital, institutional support, risk perception, recovery capacity, and the economic and social consequences of flooding.

Socioeconomic vulnerability refers to the range of conditions that either constrain or strengthen the capacity of households and communities to prevent, cope with, adapt to, and recover from hazardous events (Biswas & Nautiyal, 2023). Within this framework, factors such as income, educational attainment, employment, asset ownership, access to services, social capital, prior flood experience, risk awareness, and institutional trust play a decisive role in shaping different patterns of vulnerability (Rufat et al., 2015; Hosseinpour & Tahmasi, 2025). Low-income households generally have less capacity to reduce losses and rebuild their lives after floods because of limited savings, restricted access to insurance, poor housing quality, and greater dependence on local livelihood resources (Fothergill & Peek, 2004; Davlasheridze & Miao, 2021). Education, risk awareness, and prior flood experience can also influence risk perception, preventive decisions, and the adoption of preparedness measures, thereby explaining some of the behavioral differences among households (Kuhlicke et al., 2011; Tierney, 2025).

This issue is particularly significant in rural communities, where livelihoods, housing, and natural resources are often more directly dependent on the surrounding environment (Rolfe et al., 2020). In many villages, agriculture, livestock farming, horticulture, and

household-based livelihood activities are vulnerable to flooding, and damage to land, livestock, crops, production tools, and access routes can simultaneously disrupt household life, livelihoods, and economic security (Ahmadi et al., 2022). Furthermore, the spatial dispersion of rural settlements, inadequate communication infrastructure, limited emergency services, and distance from decision-making centers reduce the capacity of these communities to respond and recover (Mester et al., 2025). Rural vulnerability to flooding should therefore be understood as a multidimensional phenomenon shaped by the combination of location, social structure, economic conditions, institutional capacity, risk awareness, and households' recovery capacity (Shah et al., 2026; Ghadiri Masoum et al., 2026).

A review of international studies shows that a substantial portion of the recent literature has focused on the multidimensional assessment of flood vulnerability, the analysis of socioeconomic drivers, and the estimation of flood impacts at different scales. For example, by combining population displacement data, remote sensing, and population estimates at the global scale, Mester et al. (2025) demonstrated that human development indicators and the characteristics of rural areas play a more significant role than some macroeconomic variables in explaining differences in flood-induced vulnerability. Using panel data from India, Felix et al. (2025) also showed that flood losses are influenced by a combination of economic, demographic, and environmental factors and that multivariate analysis is essential for identifying the drivers of vulnerability. Similarly, in their study of flood-prone rural communities in Pakistan, Shah et al. (2025) found that rural vulnerability results from the simultaneous influence of social, economic, physical, and institutional components and that disadvantaged households are exposed to greater harm.

Another group of international studies has emphasized the role of social capital, risk perception, household preparedness, and adaptive capacity in reducing flood vulnerability. Savari et al. (2024) showed that social trust, local networks, participation, and social cohesion can strengthen the resilience of rural households to flooding. Savari et al. (2025) and Askari et al. (2025) also demonstrated that risk perception, attitudes, hazard experience, and perceived consequences influence household preparedness and the adoption of protective measures. In a study of rural flood risk in West Africa, Sougué et al. (2024) found that risk perception does not necessarily correspond to the actual level of risk and is influenced more strongly by information, lived experience, and household behaviors. Shah et al. (2024) also examined the health vulnerability of rural households to flooding and showed that access to healthcare services, safe water, sanitation facilities, and proximity to healthcare centers play an important role in determining the severity of vulnerability. Ahmad et al. (2024) further investigated the relationship between climate vulnerability and multidimensional poverty in flood-prone rural areas of Pakistan and found that poverty, deprivation of services, and limited livelihood capacity can intensify rural vulnerability.

Methodologically, international studies have employed a wide range of approaches, including composite indices, remote sensing, panel data, principal component analysis, machine learning, and structural equation modeling (Ha Anh et al., 2018; Mester et al., 2025; Felix et al., 2025; Shah et al., 2025). However, many of these studies have either been conducted at macro or subnational scales or have focused primarily on measuring vulnerability levels, estimating displacement, spatial ranking, and analyzing impacts (Mester et al., 2025; Sarker et al., 2025). Although composite indices are useful for spatial comparisons among settlements, they often fail to reveal how and through which pathways each component affects vulnerability (Wehbe & Baroud, 2024). In contrast,

using partial least squares structural equation modeling in Cambodia and Vietnam, Ha Anh et al. (2018) showed that economic and social dimensions and adaptive capacity interact to influence flood vulnerability and that SEM can be an appropriate tool for analyzing the complex relationships among the drivers of vulnerability. Nevertheless, structural relationships, direct and indirect pathways, and the mediating role of economic and social capacities in explaining the vulnerability of rural households and communities have yet to be sufficiently clarified (Ha Anh et al., 2018; Mester et al., 2025).

In Iran, recent floods have also demonstrated that rural vulnerability is not caused solely by location within hazard-prone areas but is also associated with household resource endowments, livelihood quality, access to support resources, risk awareness, social capital, and the capacity to return to normal conditions (Ahmadi et al., 2022; Savari et al., 2024). Domestic studies can be categorized into several main strands. One group has focused on the economic and livelihood resilience of rural communities, showing that livelihood diversification, household financial capacity, access to support resources, and the ability to restore economic activities after flooding are important determinants of rural economic resilience (Hossein Nia et al., 2023). Another group has emphasized the physical and infrastructural resilience of rural settlements and dwellings, demonstrating that construction quality, building age, material type, number of stories, infrastructure conditions, and access constraints contribute to either reducing or increasing rural resilience to flooding (Mirzaali et al., 2018; Kamali & Ghasemi, 2023). In this context, Bhyarfard et al. (2023), in their study of Zoshk village in Mashhad, found that the village's overall resilience was moderate, while its infrastructural, institutional-organizational, and economic dimensions were in an unfavorable condition.

Another strand of domestic studies has addressed the managerial, environmental, and human challenges associated with flooding in rural settlements. In their study of flood-affected villages in the Central District of Aqqala County, Najafi Kani et al. (2021) found that variations in flood damage among villages depended on factors such as proximity to overflowing rivers, encroachment on river corridors, construction within river boundaries, land slope, village elevation, and inadequate river management. Ramazani et al. (2021) also showed in the Qaleh Chay watershed of Ajab Shir that, alongside environmental factors, human factors play an important role in increasing the vulnerability of rural settlements to flooding. Despite their significance, most of these studies have been descriptive, survey-based, or comparative in nature and have primarily focused on assessing existing conditions, ranking villages, analyzing a specific dimension of vulnerability, or identifying influential factors (Ramazani et al., 2021; Najafi Kani et al., 2021; Kamali & Ghasemi, 2023). Thus, the domestic literature also lacks an integrated empirical model for analyzing the structural relationships among the drivers, capacities, and socioeconomic consequences of flood vulnerability in rural communities.

Given the multi-construct and relational nature of the issue, structural equation modeling can provide an appropriate approach for simultaneously analyzing the relationships between the latent constructs and observable indicators of vulnerability (Kline, 2023). This method allows constructs such as economic-livelihood conditions, social capital, risk perception and awareness, economic recovery capacity, social-collective capacity, and the socioeconomic consequences of vulnerability to be conceptually defined and the relationships among them to be empirically tested (Hair et al., 2022). Another advantage of SEM is that, in addition to measuring direct effects, it

can reveal indirect and mediating effects, thereby providing a more precise understanding of the mechanisms that generate or reduce vulnerability (Cheah et al., 2026). From this perspective, applying structural equation modeling to the study of rural flood vulnerability can establish a link between the theoretical foundations of vulnerability, previous empirical evidence, and the practical requirements of risk-reduction planning (Santoro et al., 2023).

Accordingly, the central problem addressed by the present study is that, although previous research has highlighted the role of socioeconomic, livelihood, institutional, and perceptual factors in flood vulnerability, the structural relationships, pathways of influence, and direct and indirect mechanisms through which these factors operate at the household and rural community levels have yet to be clearly explained (Ha Anh et al., 2018; Mester et al., 2025). Therefore, using structural equation modeling, the present study seeks to identify the key social and economic constructs influencing flood vulnerability at three levels drivers, capacities, and consequences and to test the relationships among them within an empirical model. The ultimate aim of the study is to develop an explanatory model of the socioeconomic drivers of flood vulnerability in rural communities that can provide a basis for prioritizing interventions, targeting support, and strengthening the resilience of rural communities to flooding.

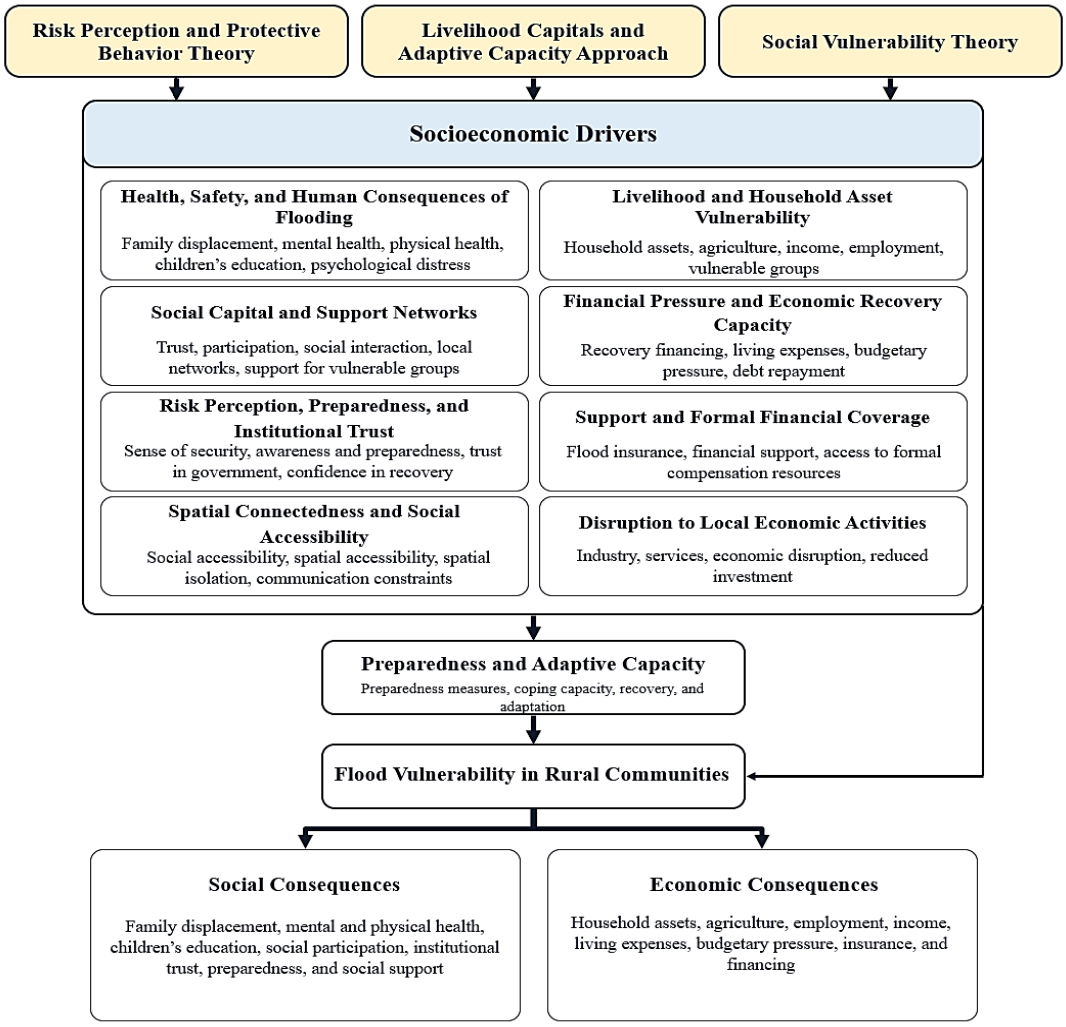


Figure 1. Conceptual research model

Methodology

The present study is applied in purpose and descriptive-analytical in nature and was conducted using a survey approach. The study population consisted of households residing in the villages of Rudbar-e Alamut-e Sharqi District in Qazvin County, a mountainous and predominantly rural area exposed to varying degrees of flood hazard because of the proximity of several settlements to rivers and the history of flooding in the region. Purposive sampling was used to select the study villages based on documented flood occurrence, location within or adjacent to flood-prone areas, evidence of previous socioeconomic and livelihood impacts of flooding, and diversity of socioeconomic conditions. Accordingly, 32 villages were selected to represent different levels of flood exposure and socioeconomic conditions across the study area. The selected villages had a total population of 2,702 residents, and the required sample size was determined as 336 respondents using Cochran's formula.

To operationalize the conceptual framework, an initial pool of indicators was extracted from the theoretical literature and relevant domestic and international studies on flood vulnerability, rural livelihoods, social capital, risk perception, adaptive capacity, and resilience. Following conceptual screening and refinement, the indicators were organized within three main dimensions-drivers, capacities, and consequences. The driver dimension comprised economic–livelihood conditions, social capital, and risk perception and awareness; the capacity dimension included economic recovery capacity and social–collective capacity; and the consequence dimension comprised economic–livelihood, social–health, and demographic and quality-of-life consequences. The constructs, questionnaire items, codes, and their supporting sources are presented in Table 1.

Table 1. Dimensions, constructs, and items measuring drivers, capacities, and consequences of flood vulnerability

Main Dimension	Construct	Item	Code	Source
Drivers	Economic–Livelihood Conditions	My household's income is sufficient to meet its regular living needs.	Drv1	Felix et al., 2025; Shah et al., 2025; Islam et al., 2025; Dey et al., 2024; Ajtai et al., 2023; Chakraborty et al., 2023; Hinojos et al., 2023; Morrison et al., 2021; Rufat et al., 2015, 2019, 2024; Chen et al., 2021; Cutter et al., 2013
		My household has diverse sources of income.	Drv2	
		The employment status of the main household members is relatively stable.	Drv3	
		A substantial share of my household's livelihood depends on activities that are not vulnerable to flooding.	Drv4	
		My household is in a favorable economic condition.	Drv5	
	Social Capital	There is a relatively high level of mutual trust among households in our village.	Drv6	Savari et al., 2024; Shah et al., 2025; Rufat et al., 2015; Cutter et al., 2013; Wisner et al., 2004
		People in our village help one another during difficult times.	Drv7	
		Communication and interaction among households in the village are satisfactory.	Drv8	
		Cooperation among neighbors is common in our village.	Drv9	

		I feel attached to and have a sense of belonging to my community and place of residence.	Drv10	
	Risk Perception and Awareness	I am aware of the likelihood of flooding in my place of residence.	Drv11	Savari et al., 2025; Askari et al., 2025; Yang et al., 2024; Orimoloye, 2023; Lindell & Perry, 2012; Rogers, 1975
		I am aware of the potential consequences of flooding for my household.	Drv12	
		I know the measures required to prepare for flooding.	Drv13	
		I know the safety measures required during a flood.	Drv14	
		I am aware of appropriate evacuation routes and procedures during a flood.	Drv15	
Capacities	Economic Recovery Capacity	My household has access to emergency financial resources in the event of a flood.	Cap1	Ahmad et al., 2024; Felix et al., 2025; Shah et al., 2025; Islam et al., 2025; Chakraborty et al., 2023; Morrison et al., 2021; Rufat et al., 2015
		My household can cover essential living expenses after a flood.	Cap2	
		My household can repay its debts under the financial pressure caused by flooding.	Cap3	
		If necessary, my household can use loans or financial credit to compensate for flood losses.	Cap4	
		My household has adequate insurance coverage in the event of a flood.	Cap5	
		My household can cover the costs of repairing or rebuilding damaged assets.	Cap6	
	Social–Collective Capacity	People in our village cooperate to help one another during crises.	Cap7	Savari et al., 2024; Shah et al., 2025; Yang et al., 2024; Deroliya et al., 2022; Tripathi et al., 2022; Rufat et al., 2015
		In the event of a flood, neighbors take action to help affected households.	Cap8	
		Village households support one another during crises.	Cap9	
		People in the village are prepared to assist older adults, children, and other vulnerable groups.	Cap10	
		Social relationships in our village are maintained during crises.	Cap11	
		People in the village participate in collective flood-response measures.	Cap12	
Consequences	Economic–Livelihood Consequences	Flooding can cause significant damage to my household's assets.	Con1	Felix et al., 2025; Shah et al., 2025; Islam et al., 2025; Dey et al., 2024; Ajtai et al., 2023; Chakraborty et al., 2023;
		Flooding can reduce my household's income or cause it	Con2	

		to fluctuate.		Hinojos et al., 2023; Morrison et al., 2021; Rufat et al., 2015, 2019, 2024
		Flooding can disrupt my household's agricultural activities.	Con3	
		Flooding can disrupt the employment of household members.	Con4	
		Flooding can increase my household's living expenses.	Con5	
		Flooding can place significant financial pressure on my household.	Con6	
		Flooding can disrupt local economic activities and businesses.	Con7	
		Increased flood risk can reduce the willingness of households and local actors to invest.	Con8	
	Social–Health Consequences	Flooding can place significant psychological pressure on household members.	Con9	Savari et al., 2025; Shah et al., 2025; Yang et al., 2024; Orimoloye, 2023; Deroliya et al., 2022; Tripathi et al., 2022; Shah et al., 2020; Aroca-Jimenez et al., 2018
		Experiencing a flood can affect the mental health of household members.	Con10	
		Flooding can threaten the physical health of household members.	Con11	
		Flooding can disrupt the schooling and education of children in the household.	Con12	
		Flooding can reduce the household's sense of security.	Con13	
		Flooding can disrupt the household's social relationships and interactions.	Con14	
	Demographic and Quality-of-Life Consequences	Repeated flooding can increase households' willingness to leave the village.	Con15	Mester et al., 2025; Felix et al., 2025; Shah et al., 2025; Yang et al., 2024; Orimoloye, 2023; Shah et al., 2020; Aroca-Jimenez et al., 2018
		Repeated flooding can increase the risk of households being displaced from the village.	Con16	
		Flooding can reduce the quality of life of rural households.	Con17	
		Continued flood risk can reduce the desirability of living in the village.	Con18	
		Flooding can disrupt the normal continuity of household life.	Con19	
		Continued flood risk can reduce the household's future security.	Con20	

The primary data collection instrument was a structured questionnaire developed from these indicators. To ensure contextual appropriateness and clarity, the preliminary questionnaire was pilot-tested with 10 respondents in two selected villages. Based on the pilot results, repetitive, contextually unsuitable, or conceptually ambiguous items were revised or removed. Content validity was assessed through expert review involving specialists in crisis management, rural geography, regional planning, and

natural hazards. The internal consistency of the instrument was subsequently evaluated using Cronbach's alpha, and items that did not demonstrate sufficient conceptual or statistical consistency with their respective constructs were reconsidered before the final analysis.

Data analysis was conducted in successive stages. The questionnaire data were first coded and screened for missing values and outliers. The measurement model was then evaluated by examining indicator loadings, Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity. Structural equation modeling (SEM) using SmartPLS was subsequently employed to test the hypothesized relationships among the three levels of the conceptual model. Socioeconomic drivers were modeled as antecedent constructs, economic recovery and social–collective capacities represented the intermediate capacity component, and flood-vulnerability consequences constituted the outcome constructs. The structural model was assessed through path coefficients, their statistical significance, explained variance (R^2), and the direct and indirect relationships among the constructs. This analytical framework enabled the study to determine not only which socioeconomic factors are associated with rural flood vulnerability, but also how their effects operate through household and community capacities.

Study Area

The study area is Rudbar-e Alamut-e Sharqi District, located in Qazvin County, Qazvin Province, Iran. Qazvin County covers an area of approximately 5,572 km² and is located between 48°59′ and 50°53′ E longitude and 36°06′ and 36°49′ N latitude (Figure 2). The county comprises five districts, seven cities, and fourteen rural districts. Alamut-e Sharqi District was selected as the primary area for assessing flood vulnerability in this study because of its mountainous characteristics, predominantly rural settlements, and exposure to flood hazards. Climatically, the Moallem Kalayeh synoptic station, located at an elevation of 1,629 m above sea level within Rudbar-e Alamut-e Sharqi District, has recorded an average annual precipitation of 379.8 mm. The maximum and minimum annual precipitation values have been reported as 541.9 and 205.7 mm, respectively. The region's mean annual temperature is 13.7°C, while its average maximum and minimum temperatures are estimated at 18.1°C and 8.3°C, respectively (Statistical Center of Iran, 1401).

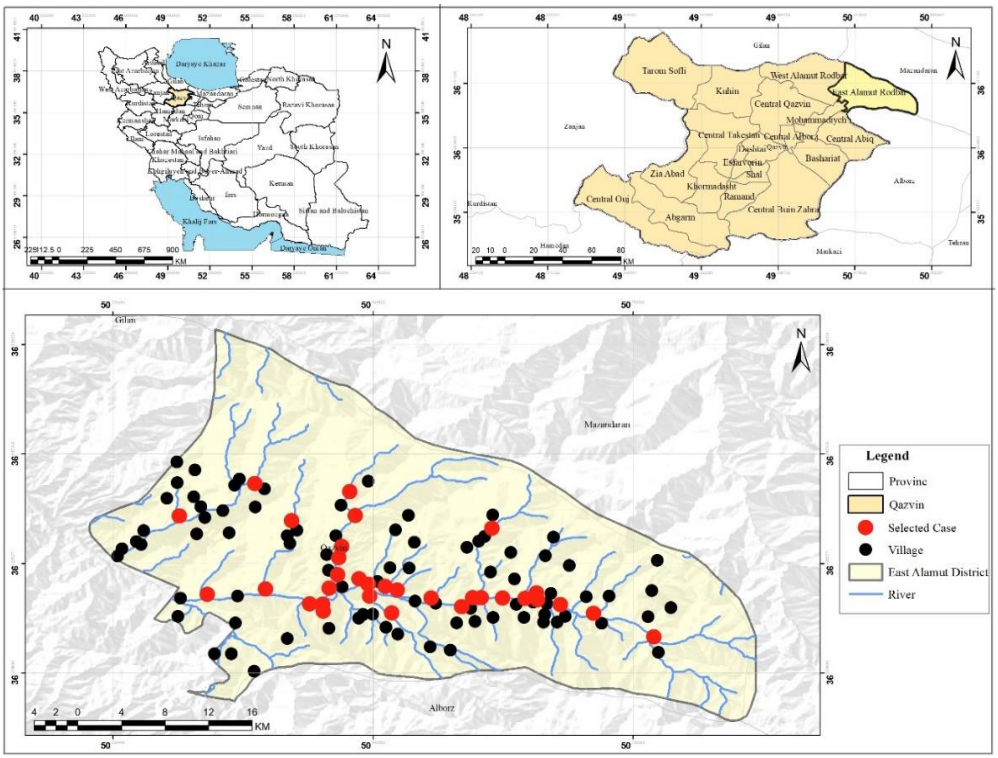


Figure 2. Location of the study area (Source: Authors' own work, 2026)

Results and Discussion

Structural equation modeling (SEM) using SmartPLS was employed to examine the relationships among socio-economic drivers, coping, adaptive, and recovery capacities, and flood-vulnerability outcomes in the rural communities of the Eastern Alamut District. Socio-economic drivers comprised economic and livelihood conditions, social capital, and risk perception and awareness; adaptive and recovery capacities included economic-recovery and social–collective capacities; and flood-vulnerability outcomes encompassed economic, livelihood, social, health, demographic, and quality-of-life consequences. Assessment of the measurement model showed that all 47 observed variables 15 indicators of socio-economic drivers, 12 indicators of adaptive and recovery capacities, and 20 indicators of flood-vulnerability outcomes had factor loadings above 0.40 and were therefore retained in the model. The coefficient of determination (R^2) for flood-vulnerability outcomes was 0.974, indicating that the model explained a substantial proportion of variation in vulnerability outcomes. The R^2 value for coping, adaptive, and recovery capacities was 0.843, showing that socio-economic drivers accounted for a large share of variation in these capacities.

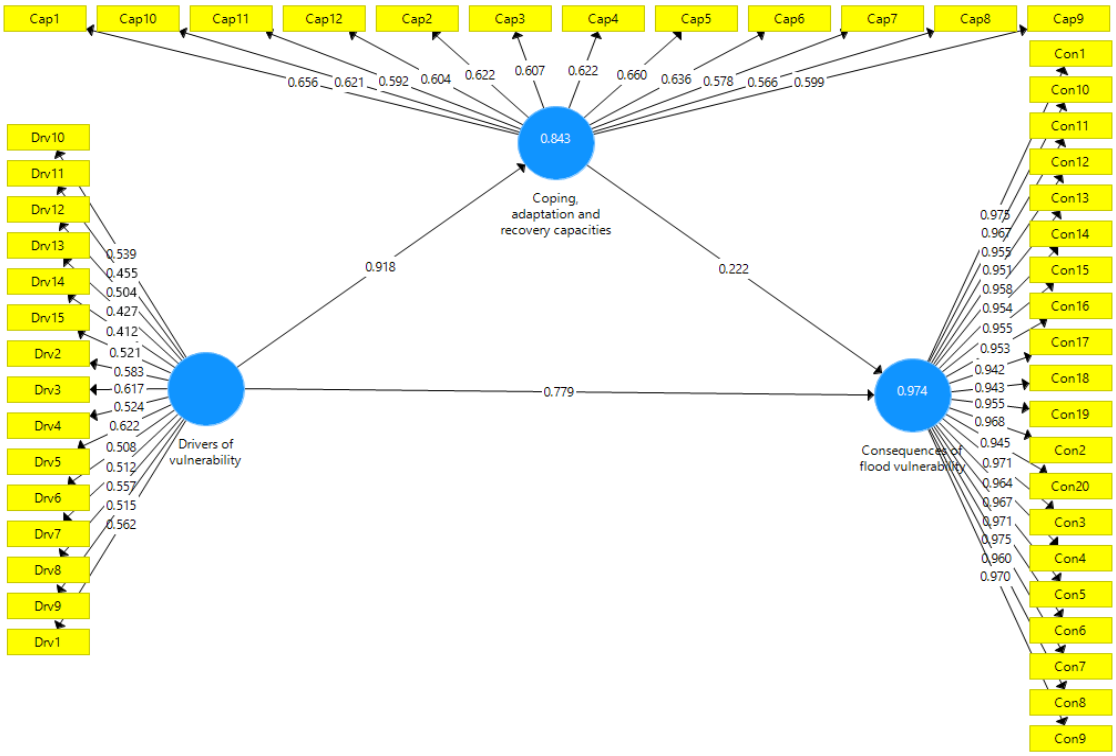


Figure 3. Structural equation model estimating the effects of vulnerability drivers and adaptive capacities on flood-vulnerability outcomes in the rural areas of the Eastern Alamut District

The structural paths further clarify how these components interact. Socio-economic drivers had the strongest relationship with coping, adaptive, and recovery capacities (β = 0.918), indicating that households' economic and livelihood conditions, social capital, and risk perception and awareness are closely associated with their ability to cope with and recover from floods. Socio-economic drivers also had a strong direct relationship with flood-vulnerability outcomes (β = 0.779), while coping, adaptive, and recovery capacities were significantly related to vulnerability outcomes (β = 0.222). These findings support the view that vulnerability cannot be explained solely by the physical characteristics of flooding; rather, it is shaped by households' access to economic, social, informational, and livelihood resources (Cutter et al., 2003; Wisner et al., 2004; Chambers & Conway, 1992). The particularly strong relationship between socio-economic drivers and adaptive capacities is also consistent with Ha Anh et al. (2018), who emphasized the interaction of economic and social factors with adaptive capacity in shaping flood vulnerability.

Table 2. Path coefficients of the independent, mediating, and dependent variables in the model of flood-vulnerability drivers, capacities, and outcomes

Drivers and Capacities	Dependent Variable	Path Coefficient
Socio-economic drivers (independent variable)	Flood-vulnerability outcomes	0.779
Coping, adaptive, and recovery capacities (mediating variable)	Flood-vulnerability outcomes	0.222
Socio-economic drivers (independent variable)	Coping, adaptive, and recovery capacities	0.918

The statistical significance of the estimated relationships was assessed using T-values. All structural paths exceeded the conventional threshold of 1.96 and were statistically significant, with the hypothesized relationships significant at least at the 99%

confidence level. This confirms that the relationships among socio-economic drivers, adaptive and recovery capacities, and flood-vulnerability outcomes are statistically supported within the proposed model. The statistical significance of the estimated relationships was assessed using T-values. All structural paths exceeded the conventional threshold of 1.96 and were statistically significant, with the hypothesized relationships significant at least at the 99% confidence level. This confirms that the relationships among socio-economic drivers, adaptive and recovery capacities, and flood-vulnerability outcomes are statistically supported within the proposed model.

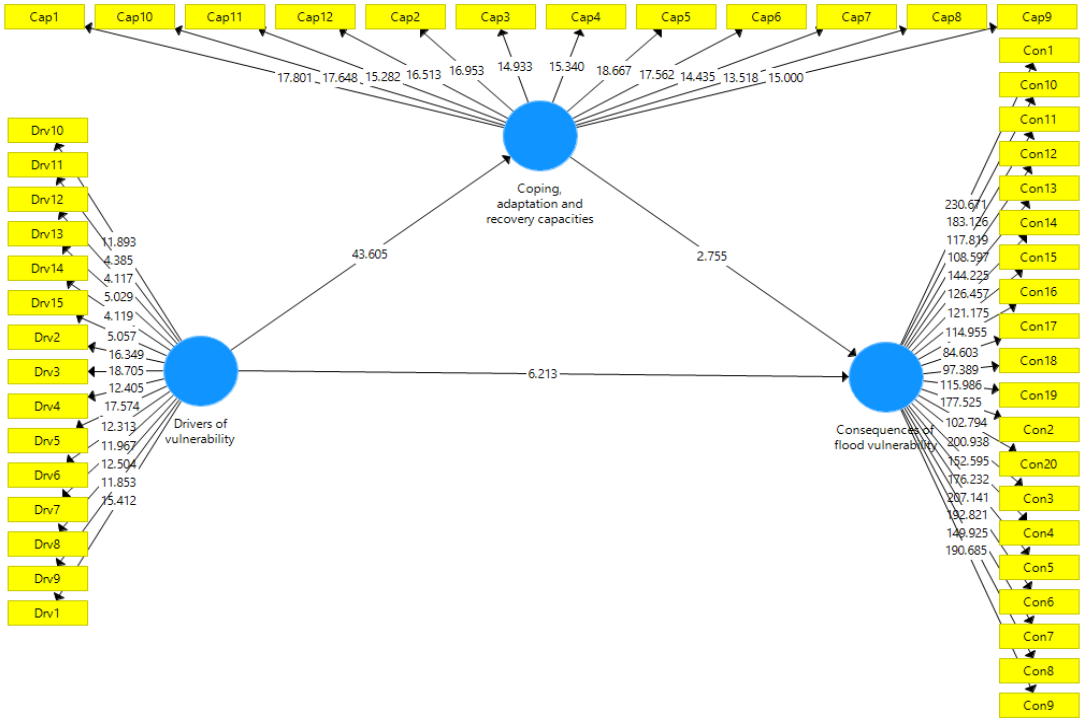


Figure 4. Statistical significance of the effects of vulnerability drivers and adaptive capacities on flood-vulnerability outcomes in the rural areas of the Eastern Alamut District

The substantive meaning of these relationships is particularly important in rural areas, where household livelihoods often depend on agriculture, horticulture, livestock husbandry, and other locally based activities. Floods can simultaneously affect assets, employment, income, and productive activities; consequently, households with limited financial resources, unstable income, and low livelihood diversification have less capacity to meet essential expenses and restore damaged assets and livelihoods. This interpretation is consistent with Ahmadi et al. (2022), Ahmad et al. (2024), and Hossein Nia et al. (2023), who highlighted poverty, livelihood capacity, income diversification, and access to support resources as important determinants of rural flood vulnerability and resilience.

Social capital also constitutes an important component of the socio-economic drivers identified in the model. Mutual trust, reciprocal assistance, neighborhood cooperation, social interaction, and a sense of community belonging can provide households with resources for response and recovery, particularly where access to formal emergency and relief services is limited. This finding is consistent with Savari et al. (2024), who showed that social trust, local networks, participation, and social cohesion strengthen the resilience of rural households to flooding. Social capital can therefore function as an

adaptive resource by facilitating cooperation, information exchange, and mutual support during and after flood events.

Risk perception and awareness form another important component of the model. Knowledge of flood likelihood, possible consequences, preparedness measures, safety actions, and evacuation procedures may influence households' willingness and ability to take protective action. This finding is consistent with the Protective Action Decision Model and related evidence showing that risk perception and evaluation of potential consequences influence preparedness and protective behavior (Lindell & Perry, 2012; Askari et al., 2025; Savari et al., 2025). However, awareness alone may not be sufficient when households lack the financial, social, or institutional resources required to act. The strong relationship between socio-economic drivers and adaptive capacities therefore highlights the interdependence between knowing what to do and having the means to do it.

The reliability and convergent validity of the constructs were subsequently assessed using Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). Cronbach's alpha values ranged from 0.810 to 0.996, CR values from 0.798 to 0.996, and AVE values from 0.626 to 0.922. These values exceeded the recommended thresholds, indicating satisfactory internal consistency and convergent validity of the constructs (Fornell & Larcker, 1981; Hair et al., 2011).

Table 3. Reliability coefficients of the constructs used in the structural equation model

Constructs	Cronbach's Alpha	CR	AVE
Flood-vulnerability outcomes (dependent variable)	0.996	0.996	0.922
Socio-economic drivers (independent variable)	0.879	0.879	0.677
Coping, adaptive, and recovery capacities (mediating variable)	0.81	0.798	0.626

Convergent validity was further evaluated on the basis that CR values should exceed 0.70, CR should be greater than AVE, and AVE should exceed 0.50. These criteria were satisfied for the constructs included in the model (Hair et al., 2021).

Equation (1). Criteria for establishing adequate convergent validity:

$$\text{Convergent Validity} = if \begin{Bmatrix} CR > 0.7 \\ CR > AVE \\ AVE > 0.5 \end{Bmatrix}$$

Discriminant validity was examined using the Fornell–Larcker criterion, under which the square root of each construct's AVE should exceed its correlations with the other constructs (Fornell & Larcker, 1981). The results of this assessment are presented in Table 4.

Table 4. Discriminant validity of the latent constructs in the structural equation model based on the Fornell–Larcker criterion

Constructs	Socio-economic drivers	Coping, adaptive, and recovery capacities	Flood-vulnerability outcomes
Socio-economic drivers	0.823		
Coping, adaptive, and recovery capacities	0.918	0.791	
Flood-vulnerability outcomes	0.475	0.614	0.960

The role of adaptive and recovery capacities is also evident from the substantive structure of the model. Economic recovery capacity, reflected in access to emergency financial resources, the ability to cover essential expenses, access to credit and insurance, and the ability to repair or reconstruct damaged assets, can determine whether flood losses remain temporary or develop into prolonged livelihood problems. This interpretation is consistent with Ahmad et al. (2024), Felix et al. (2025), and Rufat et al. (2015), who emphasized the role of financial and livelihood resources in post-disaster recovery. Similarly, social–collective capacity, expressed through mutual assistance, neighbor support, support for vulnerable groups, preservation of social ties, and participation in collective flood-related actions, represents an endogenous resource within rural communities. This interpretation is consistent with Savari et al. (2024), who highlighted the importance of social networks, trust, participation, and collective support in rural flood resilience.

The predictive relevance of the structural model was assessed using the Stone–Geisser Q^2 criterion. All Q^2 values were positive, ranging from 0.193 to 0.852, indicating predictive relevance for the constructs examined. The Q^2 value for flood-vulnerability outcomes was 0.852, indicating particularly strong predictive relevance for the main outcome construct.

Table 5. Results of the cross-validated redundancy criterion for assessing the quality of the measurement model

Constructs	SSO	SSE	Q^2 (= 1 − SSE/SSO)
Socio-economic drivers	5700	4602.12	0.193
Coping, adaptive, and recovery capacities	4560	3152.82	0.309
Flood-vulnerability outcomes	7600	1124.48	0.852

The overall model was also evaluated using the reported Goodness-of-Fit (GOF) index. Based on the coefficient of determination and mean communality values, the GOF value was calculated as 0.663.

Equation (2). Formula for calculating the Goodness-of-Fit (GOF) index:

$$GOF = \sqrt{\overline{Communality}} \times \sqrt{\overline{\text{R Square}}}$$

Equation (3). Calculation of the Goodness-of-Fit (GOF) index:

$$GOF \rightarrow 0.987 \times 0.672 = 0.663$$

Taken together, the findings indicate that the socio-economic conditions of households and their adaptive and recovery capacities are closely intertwined with the consequences of flooding. The observed outcomes extend beyond direct economic and livelihood losses to include physical and mental health effects, disruption of children's education, reduced perceived security, weakened social interactions, displacement pressures, and deterioration in quality of life (Rezvani et al., 2024). Similar multidimensional consequences have been reported in previous studies examining economic vulnerability, household health risks, displacement, and livelihood disruption (Aroca-Jimenez et al., 2018; Shah et al., 2020; Yang et al., 2024; Mester et al., 2025). The results therefore support understanding rural flood vulnerability as a dynamic process in which pre-existing socio-economic conditions influence households' capacities, while these capacities shape the severity of subsequent economic, social, and demographic outcomes.

One of the main contributions of the present study is that it moves beyond the separate measurement or ranking of vulnerability indicators by examining the structural

relationships among drivers, capacities, and outcomes. Whereas indicator-based and composite-index approaches are useful for identifying relative levels of vulnerability, they do not necessarily reveal the pathways through which underlying conditions translate into flood-related consequences. By applying SEM, the present study demonstrates that socio-economic drivers are associated with vulnerability both directly and through their relationship with adaptive and recovery capacities. Thus, flood vulnerability in the Eastern Alamut District is better understood not as a static condition, but as the outcome of interactions among livelihood conditions, social resources, risk awareness, adaptive capacities, and the consequences experienced by rural households.

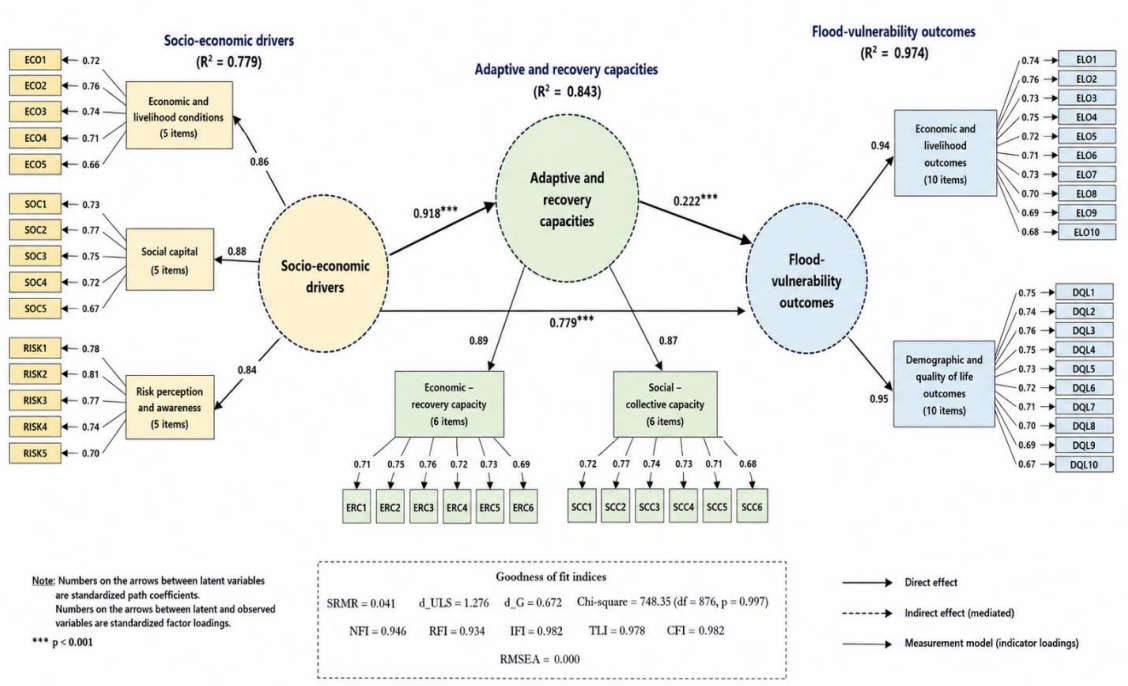


Figure 5. Final Structural Equation Model with Standardized Path Coefficients, Factor Loadings, and Model Fit Indices

Conclusion

The present study aimed to elucidate the role of socio-economic drivers and coping, adaptive, and recovery capacities in shaping the vulnerability of rural communities to floods. The study was conducted in 32 villages in the Rudbar-e Alamut District of Qazvin County. The findings demonstrate that flood vulnerability in these communities is not merely a consequence of exposure to a natural hazard; rather, it is shaped by households' social, economic, livelihood, and perceptual conditions, as well as their capacities to cope with and recover from flood events. Validation of the model further demonstrated that the main constructs of the study exhibited satisfactory reliability and validity, and that the hypothesized relationships within the model were statistically significant at a high level.

The most important finding of the study concerns the determining role of socio-economic drivers in shaping coping, adaptive, and recovery capacities. With a path coefficient of 0.918, this relationship was the strongest relationship in the model, indicating that the capacity of rural households to cope with flood events is largely dependent on their economic and livelihood conditions, social capital, and level of risk perception and awareness. In addition, socio-economic drivers exerted a strong direct

effect on flood-vulnerability outcomes, with a path coefficient of 0.779. Therefore, improving economic and livelihood conditions, strengthening social networks, and enhancing risk awareness and perception can not only generate more favorable socio-economic outcomes but also directly, as well as indirectly through strengthening adaptive capacities, reduce the severity of flood-related impacts.

On the other hand, coping, adaptive, and recovery capacities also have a statistically significant relationship with flood-vulnerability outcomes, with a path coefficient of 0.222. Although the strength of this relationship is lower than that of the other two relationships, its statistical significance indicates that capacities at the household and rural community levels play an important role in shaping the extent to which a natural hazard translates into economic, social, and livelihood impacts. Moreover, the R^2 value of 0.843 for adaptive capacities indicates that a substantial proportion of the variation in these capacities is explained by socio-economic drivers.

Accordingly, the findings support the view that flood vulnerability is not a static condition but a dynamic process shaped by the interaction among households' initial conditions, socio-economic assets, and their capacities to cope with and recover from flood events.

Based on these findings, reducing flood vulnerability in the rural settlements of the Eastern Alamut District requires interventions that directly target socio-economic drivers and adaptive capacities. In this regard, diversifying the income sources of households dependent on agriculture, horticulture, and livestock husbandry; expanding access to credit facilities and emergency financial resources; strengthening insurance coverage for household assets and livelihood activities; and establishing post-flood financial support mechanisms can enhance households' economic recovery capacity. Furthermore, establishing and strengthening local disaster management groups and organizations, educating households about flood warning signs and potential impacts, evacuation routes, and preventive measures, and involving local residents in preparedness and response programs can strengthen community-level social capacity and risk awareness. These interventions should be designed in a place-based manner, taking into account the varying conditions of individual villages across the region, rather than being limited solely to structural flood-control measures.

From a research perspective, future studies should test and compare the proposed model across other flood-prone rural areas and at different spatial scales to determine the extent to which the identified relationships can be generalized. Given the dynamic nature of vulnerability, longitudinal studies and the use of data collected before and after flood events could provide a more precise understanding of changes in household capacities and how socio-economic drivers translate into actual flood outcomes. Furthermore, examining the distinct roles of factors such as local governance, access to emergency and relief services, insurance coverage, previous flood experience, and the intensity and recurrence of flood events could further refine the proposed model. Finally, integrating household survey data with spatial data and observed flood intensity could facilitate the development of a more comprehensive spatial model for identifying vulnerable locations and population groups and prioritizing flood risk reduction interventions.

Overall, the findings of this study indicate that, in the rural communities of the Eastern Alamut District, reducing flood vulnerability depends less on controlling the hazard itself than on addressing the socio-economic factors that produce vulnerability and strengthening the capacities of households and local communities to cope with and recover from flood events. Therefore, an effective approach to flood risk management

should move beyond a sole focus on managing the hazard event toward managing the social and economic conditions underlying vulnerability. Such an approach can simultaneously contribute to reducing flood-related losses, enhancing livelihood and social resilience, and strengthening the sustainability of rural settlements.

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Authors' Contribution
Hossein Hosseinpour had the major role in conceptualization, development of the theoretical framework, methodology design, supervision of the analytical process, interpretation of the results, manuscript preparation, and final formatting of the paper. Bahman Tahmasi contributed to the statistical analysis, inferential analysis, and interpretation of the quantitative findings. Seiyed Mossa Hosseini contributed to methodological guidance, supervision of the research process, interpretation of the findings, critical review, and substantial revision of the manuscript. Alireza Darban Astaneh contributed to supervision, critical review, and refinement of the manuscript. Sara Marefatnia contributed to reviewing, editing, and improving the final version of the manuscript. All authors reviewed and approved the final manuscript.

Conflict of Interest
The authors declare that there is no conflict of interest.

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