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Pathways of household adaptiveness to climate risk: A survey in a semi-arid region of Indonesia

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ABSTRACT

Communities in semi-arid regions, including farmers and livestock holders, are more likely to suffer from environmental stresses due to climate change volatility. Therefore, understanding the diverse pathways to community resilience and adaptability is imperative. This study explores the pathways of household adaptiveness to climate risks on Sumba Island, a semi-arid region in Eastern Indonesia characterised by smallholder livestock farming and frequent climate-induced disasters. It investigates the strategies employed by rural households to cope with climate-related events and defines household adaptability as the capacity to prepare for and respond to shocks through actions such as accumulating savings and diversifying livelihood portfolios in anticipation of climate crises. The research hypothesises that prior disaster experience, place attachment, social capital, participation, and social protection are key predictors of household adaptiveness. Using structural equation modelling analysis conducted with SmartPLS software, the study analyses data collected from a survey of 300 households across ten villages located in coastal, inland, and suburban areas of East Sumba. Findings suggest that prior disaster experience and social protection are stronger predictors than other variables, serving as direct pathways to household adaptiveness to climate change risks. The study implies that effective adaptive social protection policies can foster community engagement and enhance household adaptability and resilience in disaster-prone regions.

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1. Introduction

The global risks of climate change include an increased frequency and intensity of extreme weather events, rising sea levels, and changes in rainfall patterns, leading to floods, droughts, and reduced agricultural yields [1]. The IPCC Assessment Report (WGII) highlighted the fact that climate change will likely alter semi-arid ecosystem services, which will have the greatest impact on communities that depend directly on natural resources for their livelihoods, water and food systems. Dryland communities in remote areas, where persistent structural barriers such as inadequate social protection, healthcare, sanitation, infrastructure, and functioning markets exist, are highly likely to have limited adaptive capacity, thereby exacerbating their existing vulnerabilities [80]. Unfortunately, there is a notable absence of documented adaptation cases from semi-arid regions from Southeast Asian regions as seen from recent IPCC Report [80].

Southeast Asia contains pockets of semi-arid regions, including the drylands of Eastern Indonesia and Timor-Leste. One example is Sumba Island in Eastern Indonesia—a semi-arid region increasingly affected by climate change. This is evident in the rising frequency and severity of floods and droughts, which significantly reduce food crop productivity [2,3]. Known for its unique culture and traditions, Sumba has a dryland climate and depends largely on a smallholder, livestock-based economy. Its high exposure to natural hazards—including droughts, floods, and cyclones—makes it one of Indonesia's most disaster-prone regions.

In general, Sumba Island experiences an erratic rainfall pattern. Rainfall typically occurs between January and April, while the dry season extends over the following eight months, resulting in a semi-arid climate. With the exception of certain areas in West and Central Sumba that receive higher rainfall, the island generally experiences low rainfall intensity. Consequently, the eastern and northern regions of Sumba exhibit a more arid climate, characterised by undulating grasslands and savanna landscapes. For example, some parts of East Sumba recorded fewer than 45 rainy days and received less than 700 mm of total rainfall during that period. In contrast, the Tabundung sub-district often experiences higher rainfall compared to other areas [4].

As more than half of the land area is savannah, characterised by a single rainy season lasting several months, agricultural options are predominantly limited to cassava and maize. In contrast, in the more humid central and western regions of the island, farmers utilize buffaloes for rice cultivation, alongside the widespread rearing of pigs as livestock [5–7]. Polyculture, including agroforestry, is commonly practised in upland areas, primarily to mitigate the risk of crop failure in this predominantly semi-arid region and to diversify income sources. While monoculture rice farming is prevalent in the lowlands when water resources are sufficient, rainfed rice farming becomes dominant when water availability poses a significant constraint [8].

In the socio-cultural context of Sumba, the Marapu belief system serves as the foundation of Sumba's traditional sociocultural framework, functioning as the basis for its social, political, and cultural structures as reflected from its social hierarchy. Social stratification in Sumba is a system profoundly influenced by customary and traditions, with a division of social classes comprising Maramba (nobility) who hold power and resources, Kabihu (freemen) who represent the majority as independent individuals, and Ata (servants) the lowest caste, expected to serve the nobility without autonomy. Such a social structure not only influences social relationships but also determines access to resources such as land, which remains a pillar of Sumba's economy [6,8–10].

Such a social stratification creates unequal access to resources, particularly land, leaving some families dependent on their masters. Although the Maramba class enjoys socioeconomic advantages, such as land, labour, and networks, they face greater risks, especially when climate change disrupts their assets and livelihoods. Vel [6] emphasises that the hierarchical social structure in Sumbanese society, embedded within the "Uma" kinship system, has shaped adaptation patterns to change. This is evident in implementing various adaptation strategies, including land management practices, economic diversification, labour migration, and the utilization of social networks as survival mechanisms.

Challenges such as droughts, floods, landslides, cyclones, forest fires, and agricultural pests further highlight the Maramba's vulnerability to resource instability. Consequently, while their role as political and economic leaders sustains their social status, it also increases their exposure to environmental and systemic risks, thereby exacerbating inequalities within Sumbanese society [11].

From a socio-economic perspective, results of a national survey [12] indicates that in 2023, Central Sumba emerged as one of the districts with the highest proportion of impoverished individuals in Sumba Island, with 31.78 % of its inhabitants falling under the poverty line. This was followed by East Sumba (28.08 %), Southwest Sumba (27.48 %), and West Sumba (27.17 %). Overall, the economic well-being in the Sumba Island area remained relatively poor, with the poverty rate far exceeding the East Nusa Tenggara provincial average of 19.96 % in 2023. Economically speaking the island-wide statistics do not indicate relative wealth differences between members of the population in Sumba [13]. The majority of Sumba residents residing in rural areas engage in animal breeding (horses, cattle, pigs, and poultry), farming, fishing, and weaving. While urban inhabitants predominantly work as office employees or operate small businesses [14].

Furthermore, in Sumba, the wealth of an individual has historically been linked to their ownership of animals [13]. Livestock, known as banda la marada or possessions in the field, are classified as banda luri or living goods and life (mobile) property [15]. The greater the number of banda luri (livestock) one possesses, the higher their social standing. Livestock also serves as an economic resource that can be sold during times of adversity. Unfortunately, most economically disadvantaged members of the community do not have any animals in their possession.

The continuous occurrence of extreme weather events, attributed to climate change, can lead to the deterioration of natural ecosystems and the occurrence of disasters in the Island [16]. Such disasters triggered by extreme weather changes encompass five primary hazards: heat waves, floods caused by heavy rainfall, droughts during extended dry periods, forest fires, and tropical cyclone hazards [17].

We observed that the Cyclone Seroja 2021 destroyed irrigated and rainfed agriculture at the lowland areas. As a result, most

farmers were forced to have a break from rice production during 2021–2023. In addition, in the last 20 years, Sumba Island have suffered from recurrent pest attacks from locust at island-wide scale. Some of these events can be attributed to the local consequences of global climate change. To sustain their livelihoods and provide for their families, households in the Sumba community must adapt as a survival strategy to mitigate the impacts of climate change and extreme weather events. Therefore, it is imperative to investigate the adaptation strategies of Sumba community households to climate change and the influencing factors.

We investigated how households adapt to climate change proxied by the recent extreme climate events in particular East Sumba district. This study was primarily interested in understanding how social protection and/or social security shapes household adaptiveness within the context of climate change and in the strong socio-cultural environment. This article presents some of the key findings from a survey of 300 households in East Sumba district from October 2023 (Thirty months after the Cyclone Seroja in April 2021 in the middle of COVID-19 pandemic) till December 2023.

2. Literature review and model development

The authors purposefully explore the literature on household adaptiveness within the context of adaptive social protection, anticipating climate change risks and the need for resilience building. In fact, adaptive social protection is a relatively new public policy idea, marking a significant shift from traditional social protection and security programs that focused mainly on poverty reduction.

A foundational 20th-century concept is the sustainable livelihoods framework, which explains household adaptiveness through livelihood diversification systems [79], recognising climate risk, collective and individual social capital (Abunyewah et al. [21], and the roles of risk perception and self-efficacy (Budhathoki et al. [20]). Savari et al. [19] examined the impact of social capital—including networks, solidarity, trust, awareness, participation, and collective action—on strengthening rural household resilience to floods. Fitrinitia and Matsuyuki [18] explored how social protection shapes coping strategies for climate-related disasters, mediated by livelihood capitals (financial, social, human, and physical) among smallholder farmers in Indonesia. Coping strategies refer to household responses to absorb, adapt, and transform in response to severe flooding.

In brief, we identify four clusters of variables that helped us establish a baseline of household adaptiveness in Sumba Island: climate risk perception, social capital, social participation, social protection and security.

2.1. Predictor of climate risk perception

Risk perception refers to the process of understanding and interpreting signals from various sources about events, and forming a judgment about the likelihood and severity of current or future losses caused by these [22–24]. Factors determining risk perception include informational factors, personal factors (age, gender, education level, profession, personal knowledge, personal experience in dealing with disasters, and religiosity) as well as contextual factors (e.g. economic conditions, family status, residential area, and community size) [23]. Socio-demographic factors such as gender, age, and education play important roles in risk perception. Some research suggested that women, in particular, are more often concerned about disaster risk than men, which may be attributed to the intensity of socialization and gender roles in the community. Furthermore, the higher the education corresponds to a better understanding of disaster risk [25,26].

Natural hazard-induced disasters generally disrupt lives and can cause significant economic and non-economic losses including deaths. Individuals impacted by a disaster are profoundly affected, and the experience becomes ingrained within them. Personal encounters during a disaster offer authentic insights and influence an individual's risk perception [22,27].

Diakakis et al. [28] show a positive relationship between a person's experience of natural hazards and their risk perceptions of climate change. This suggests that individuals who have directly experienced a disaster event are more likely to be sensitive to climate change and its impacts. Sambrook et al. [29] argue that a crucial factor that can enhance climate change risk perception is an individual's personal experience of extreme climate events and/or localized weather anomalies, such as fluctuations in daily temperatures that deviate from normal seasonal patterns.

Place attachment describes how a person stays and survives in a particular place despite the risks of climate change. The concept of place attachment refers to the emotions and affect that connect a person to a place. Hummon [30] describes it as an individual's cognitive or emotional connection to a specific environment. More comprehensively, place attachment can be defined as the overall feelings, bonds, behavioural intentions, and thoughts that a person develops over time about the place where they live [31].

Understanding a person's reasons for staying in a disaster-prone area and their attachment to the place shapes their perception of risk and enhances their ability to connect within the community [32]. Some studies suggest that higher levels of social capital can encourage mitigation actions against climate change and impact risk perception [33,34].

Based on the above understanding, the following hypothesis can be formulated.

H1. Gender affects climate risk perception

H2. Age affects climate risk perception

H3. Education level affects climate risk perception

H4. Prior disaster Experience affects climate risk perception

H5. Place attachments affect climate risk perception

H6. Social capital affects climate risk perception

2.2. Predictor of social capital

Social capital is a concept that encompasses the social norms and relationships existing among individuals, groups, and communities [21]. These connections facilitate collective action and the utilization of relationships to access financial, emotional, physical, and other resources to fulfil survival needs and achieve mutual benefits. It is commonly defined as social norms and mutual trust [19,35]. Social capital can develop in relationships that extend beyond group boundaries, connecting individuals, communities, and organizations with diverse power dynamics within society [36]. Individuals or communities with strong ties to their local environment often foster a sense of community, establish neighbourly connections, and provide mutual support, which are fundamental elements of social capital behaviour in society [35,37]. Therefore, the following hypothesis can be proposed.

H7. Place attachments affect social capital

2.3. Predictor of social participation

Social participation enables individuals to engage and establish networks that are valuable for sharing information and fostering trust among community members [38]. Participation in society entails individuals addressing and solving their problems to enhance their socio-economic development [39]. Social participation enhances and strengthens the social cohesion of the community, helping maintain unity during challenging situations. This factor drives the progress and sustainable development of humans through the perspective of human intervention [40]. Individuals with a positive perception of climate are more likely to engage in activities related to climate [41]. Increased risk perception leads to a higher tendency to seek information regarding climate change, enabling individuals to plan and mitigate occurrences in their daily lives [42]. There is a correlation between risk perception and household social participation in addressing climate change.

Experiences related to disaster management can foster community engagement and social involvement concerning disaster-related matters [43]. For instance, communities engage with one another and provide mutual assistance as a means of survival before the arrival of formal aid. Moreover, individuals can overcome the impact of disaster experiences through active social engagement. Individuals who have encountered severe weather events in the past tend to hold strong convictions about climate change and exhibit heightened concerns regarding future risks, in contrast to individuals without such experiences who perceive future risks as minimal or non-existent [44].

The connection to a place is intricately linked to a feeling of belonging to a community. Individuals with strong social connections to their community often resist moving elsewhere to preserve their livelihood and are hesitant to depart from the social group in which they were previously engaged, and to adjust to a new community [45].

In addition to the factors of previous disaster experience and place attachment that influence increased social participation in social activities, socio-demographic factors also play a role in determining the extent of engagement in social activities. Lee et al. [46] found that individuals with higher levels of education and younger age tend to be more involved in climate change and disaster mitigation campaign activities. Therefore, the following hypothesis was formulated (Fig. 1).

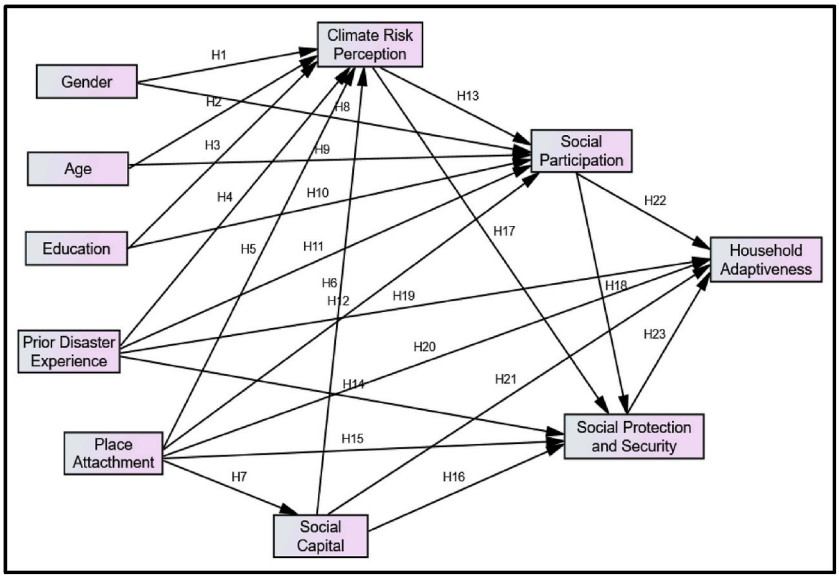

Fig. 1. Household adaptation model in the context of sumba.

H8. Gender affects social participation

H9. Age affects social participation

H10. Education level affects social participation

H11. Prior disaster experience affects social participation

H12. Place attachments affect social participation

H13. Climate risk perception affects social participation

2.4. Predictor of social protection and security

The intersection of climate change disasters and human system often resulted in intricate socioeconomic consequences for communities, particularly affecting impoverished and susceptible populations. Consequently, the implementation of social protection policies is imperative to assist affected individuals in ensuring their resilience and recovery. Social protection policies play a crucial role in mitigating the socioeconomic repercussions of climate change, particularly in terms of managing poverty and income risks [47].

Social protection encompasses various forms of assistance, such as cash transfers or material support, provided to disadvantaged individuals to shield them from livelihood risks, enhance the social standing and rights of marginalized communities, and ultimately extend the advantages of economic development while diminishing the economic and social vulnerabilities of the impoverished, vulnerable, and marginalized populations [48].

In the context of climate change, social protection mechanisms are seen as a key form of assistance for communities. They can help protect basic needs in times of crisis and provide new sources of income that expand the response options of community households themselves [49]. Social protection not only focuses on strengthening economic, human, and social capital to stimulate economic growth, but it can also address issues of social justice and marginalization [50]. Thus, social protection is recognized as one of the ways and strategies to reduce vulnerability in the face of disaster risks and increase adaptive capacity for climate change adaptation [51].

Formal social protection is characterised as the provision of resources to individuals and families by governmental entities, aimed at assisting them in sustaining their income during challenging times or enhancing their quality of life [47]. Adaptive social protection combines the three strategies: social protection, disaster risk reduction, and climate change adaptation. The integration of these strategies creates significant opportunities to enable impoverished and marginalized populations to articulate their perspectives, assert their entitlements to protection, and influence social protection mechanisms [52].

H14. Prior disaster Experience affects social protection and security

H15. Place attachment affects social protection and security

H16. Social capital affects social protection and security

H17. Climate risk perception affect social protection and security

H18. Social participation affects social protection and security

2.5. Predictor of household adaptiveness

Adaptation is primarily concerned with the fundamental traits that facilitate the survival and procreation of individuals within their environment [53]. It emphasises society's capacity to address climate-related risks by mitigating the impacts of actual loss levels [41]. Moreover, climate change adaptation entails various modifications, including behavioural, social, and economic adjustments at both individual and community scales, with the goal of minimizing risks in reaction to or in anticipation of climate change [54].

Adaptation refers to the processes or modifications individuals undertake to mitigate the negative effects of climate change on their health and overall welfare, as well as to take advantage of the opportunities presented by their climate conditions [55]. Adaptation is acknowledged as one of the four essential components, along with mitigation, technological cooperation, and financing, in addressing climate change [56].

The selection of adaptation strategies by households is influenced not only by climatic and geographical factors but also by various household social and economic attributes, agricultural features or infrastructure, social, institutional, and governance elements, and ultimately by the community's perceptions [57]. Household adaptability is also considered integral to resilience, which is defined as the capacity of a system to withstand and adjust to changes and disruptions while preserving the same relationships among populations or variables within the system [58].

One of the motivations for incorporating resilience perspectives into climate change adaptation efforts is the shift away from a predict-and-prevent strategy towards a resilience-oriented approach that can effectively address both anticipated and unforeseen climate-related risks [59].

Social capital serves as a crucial factor influencing the ability to adapt to climate change, given its historical role in mitigating risks at the individual, household, and community levels. The significance of social capital is exemplified through the implementation of effective practices in social capital-driven post-disaster recovery, which forms a vital aspect of adaptive capacity [60]. Additionally, Kumari et al. [61] contend that social capital offers insights into the essential social characteristics that foster societal and personal advancement in addressing climate change. Community-owned social networks, facilitated by social capital, enhance their adaptive

capacity to confront the challenges posed by climate change and withstand various pressures.

Several studies have indicated that perceptions of climate change serve as more accurate indicators of household intentions to adapt to climate change than socio-demographic factors [62,63]. Individuals' perceptions of the risks associated with climate change play a significant role in shaping their behaviours, particularly in terms of their preparedness to confront risks and their attitudes toward adaptation [44]. Individuals engaged in fostering social participation exhibit positive attributes, such as emotional maturity, confidence, and perseverance, which motivate them to actively seek out initiatives that enhance their surroundings and contribute to their psychosocial well-being [64]. Genuine and wholehearted participation can only be achieved when individuals possess a comprehensive understanding of the risks posed by climate change and are regarded and involved as equal collaborators in the planning of adaptation and mitigation strategies by relevant stakeholders [65]. Participation is recognized as a significant factor influencing households' readiness to adjust to climate change [66].

Prior disasters experience is a significant factor to consider when assessing resilience, as it can demonstrate a community's ability to adapt to past events [67]. Individuals who have encountered disasters before are also more inclined to take part in activities that entail personal adjustments and efforts to mitigate the impact of climate change-related disasters [44]. Therefore, the following hypothesis can be formulated (Fig. 1).

H19. Prior disaster Experience affects household adaptiveness

H20. Place attachments affect household adaptiveness

H21. Social capital affects household adaptiveness

H22. Social participation affects household adaptiveness

H23. Social protection and security affects household adaptiveness

Based on the literature review related to the factors influencing household adaptability as a form of resilience to climate change, as described above, the following research model was developed.

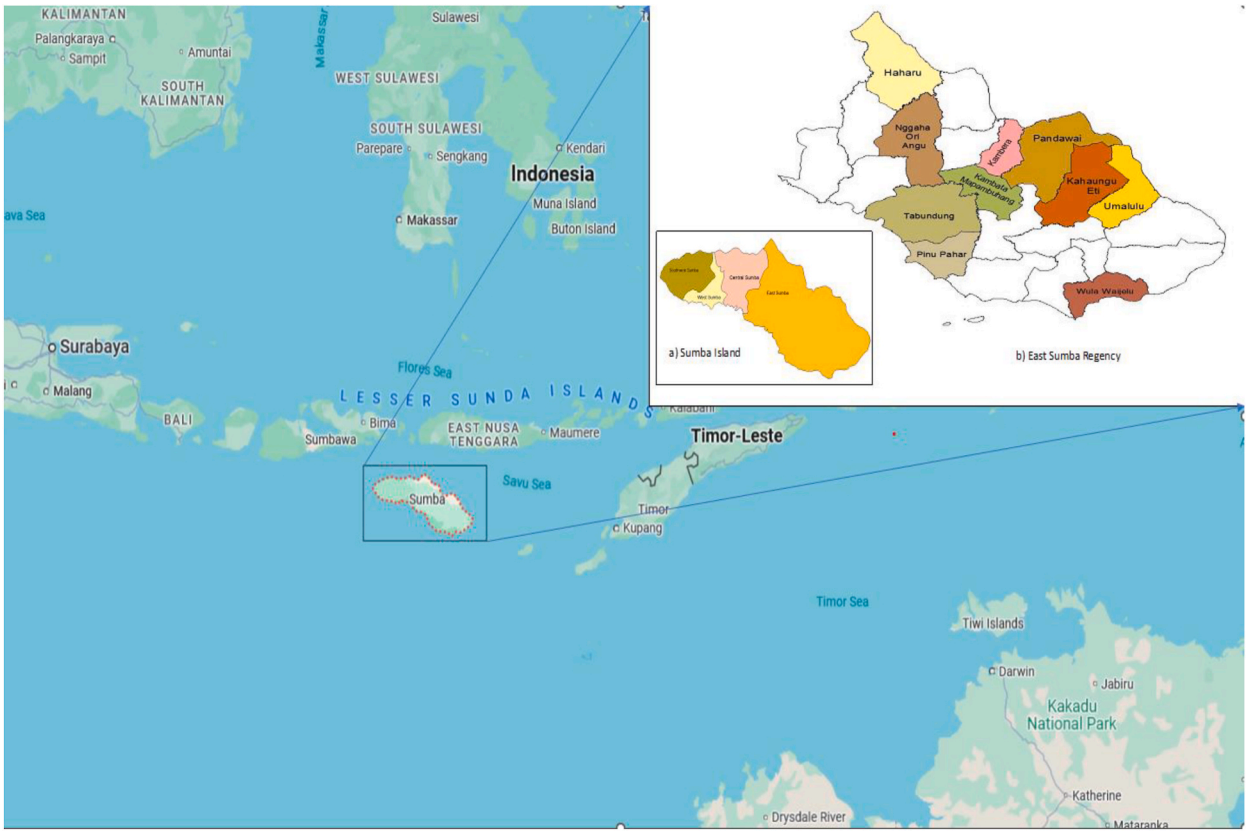

Fig. 2. Study area.

3. Research method

3.1. Sampling strategies and study area

Sumba Island (Fig. 2) is bounded by the Sumba Strait to the north, the Savu Sea to the east, and the Indian Ocean to the south and

Table 1
Latent variable measurement.

Constructs	Code	Indicator/Description	Data type/Scale
Prior disaster experience	Pde1	Concern about climate change	[1] not vary influential [2], not influential [3], neutral [4], influential [5], very influential
	Pde2	Intensity of climate change impact on daily life	[1] not very impactful [2], not impactful [3], neutral [4], impactful [5], very impactful
	Pde3	Number of types of climate change impact	[1] none [2], 1 type of disaster [3], 2 types of disaster [4], 3 types of disaster [5], > 3 types of disaster
Place Attachment	Pa1	local authority, either village government or district government are well functioned	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Pa2	my village is always prepared to disaster	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Pa3	I am telling other people that i am proud of my residential area	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Pa4	I am confidence about local authority decision making process	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Pa5	People in my village know their role in emergency situation	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Pa6	I have sense of belonging to my village	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Pa7	local authority shows great leadership in disaster management	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
Social Capital	Sc1	there are mutual support and care in my residential area	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Sc2	relationship between various groups in my village are in a good term	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
	Sc3	I can rely on my neighbour support during crisis situation	[1] Strongly disagree [2], disagree [3], somewhat agree [4], agree [5], strongly agree
Climate Risk Perception	Crp1	temperature 10 year ago compared to now	[1] getting colder [2], colder [3], ordinary [4], hotter [5], getting hotter
	Crp2	rain intensity 10 year ago compared to now	[1] getting lower [2], lower [3], moderate [4], higher [5], getting higher
	Crp3	flooding intensity 10 year ago compared to now	[1] getting rarer [2], rarer [3], ordinary [4], more often [5], getting more often
	Crp 4	wind intensity 10 year ago compared to now	[1] getting weaker [2], weaker [3], ordinary [4], faster [5], getting faster
	Crp5	sea level raise 10 year ago compared to now	[1] getting lower [2], lower [3], moderate [4], higher [5], getting higher
	Crp 6	locust pest intensity 10 year ago compared to now	[1] getting rarer [2], rarer [3], ordinary [4], more often [5], getting more often
	Crp7	rat's pest intensity 10 year ago compared to now	[1] getting rarer [2], rarer [3], ordinary [4], more often [5], getting more often
	Crp8	drought intensity 10 year ago compared to now	[1] getting rarer [2], rarer [3], ordinary [4], more often [5], getting more often
Social participation	Spc 1	Meeting with government official	[1] Never [2], seldom [3], often [4], very often
	Spc2	Meeting frequency with government official	[1] Never [2], seldom [3], often [4], very often
	Spc3	Number of planning activities involved	[1] none [2], 1 activity [3], 2 activities [4], >2 activities
	Spc 4	Actively involved in planning activities	[1] None [2], non actively involve [3], actively involve [4], very actively involve
Social protection and security	Sps1	Number of social protection program	[1] none [2], 1 type program [3], 2 types of program [4], 3 types of program [5], >3 types of program
	Sps 2	Frequency aid from community/family	[1] rarely [2], seldom [3], 2 occasionally [4], often [5], very often
	Sps 3	Amount of aid received	[1] not very much [2], note many [3], quate allot [4], lots [5], huge
	Sps4	How helpful the aid	[1] not very much [2], note many [3], quate allot [4], lots [5], huge
	Sps5	Number of Loan place	[1] none [2], 1 loan place [3], 2 loan places [4], 3 loan places [5], >3 loan places
Household adaptiveness	Ha1	Livestock variation	[1] none [2], less varied [3], quite varied [4], varied [5], very varied
	Ha2	Emergency fund	[1] not ready [2], not well ready [3], quite ready [4], ready [5], very ready
	Ha3	Survival method	[1] 1 method [2], 2–3 methods [3], 4–5 methods [4], 6–7 methods [5], >7 methods

west. It can typically be accessed by flight from Bali Island (to the west) or Timor Island (to the east). Covering an area of approximately 10,914 km^2, Sumba Island has a relatively sparse population of over 835,390 people [12]. Unlike most islands in East Nusa Tenggara, which are part of the non-volcanic Sunda-Banda arc at the front of the Lesser Sunda Islands volcanic arc, Sumba Island is geologically older, and its tectonic origins have been a topic of some debate [68]. Over the past decade, East Nusa Tenggara (NTT) has experienced a total of 576 disaster events, with typhoons being the most prevalent, followed by floods, landslides, and droughts. The province has a risk index value of 139,23 (medium risk) based on the 2022 Indonesian Disaster Risk Index (IRBI). Specifically, all regencies in the Sumba Island region have a moderate risk index, with the highest value recorded in East Sumba at 139,14 [69].

According to the Sumba Island climate condition, this study involved household respondents from 10 sub-districts and villages in East Sumba Regency. The selection of sub-districts and villages was determined based on the level of disaster impact experienced, considering the representation of coastal, inland, and suburban areas. Tarimbang village in Tabundung sub-district, Lumbu Menggit village in Wula Waijelu sub-district, and Wunga village in Haharu sub-district are coastal villages. Kotak Kawau village in Kahaungu Eti sub-district, Marada Mundi village in Kambata Mapangbuhang sub-district, Mau Bokul village in Pandawai sub-district, Tana Tuku village in Nggaha Ori Angu sub-district, and Wangga Mbewa village in Pinu Pahar sub-district represent inland areas. Meanwhile, Mauliru village in the Kambera sub-district and Watu Hadang village in the Umalulu sub-district represent the suburban areas.

The study utilized 300 household respondents selected through purposive sampling techniques during October–December 2023. The data analysis technique utilizes structural equation modelling with the assistance of Smart PLS software. The use of Smart PLS was chosen because it is easier and more flexible for conducting data analysis, especially with a relatively small sample size. It is also quite tolerant of model specification errors and can handle data that does not meet the assumption of normality.

Referring to the model developed, there are two categorical scale variables: gender and education level, and one ratio scale variable: age. Meanwhile, other variables, such as place attachment, social capital, climate change risk perception, trust in government, social participation, and household adaptiveness, are interval-scale.

3.2. Survey instruments

To ensure that the survey instrument is a questionnaire that is directly administered to respondents, we verify that the variable measurement indicators align with the theory. Instead of utilizing instruments from previous researchers, we ensure that each question asked aligns theoretically with the developed variables. To assess whether the questions for each measurement indicator align with content validity and face validity, we piloted the questionnaire with 30 household respondents who shared similar characteristics with the target respondents. Based on the test results, we refined the scoring and questions for each indicator to enhance respondent comprehension. Subsequently, the revised questionnaires were inputted into the Kobotoolbox application, which enumerators utilize to collect data directly from respondents. The number of respondents from each targeted village was determined proportionally based on the population size. The selection of households to serve as respondents was conducted by considering the condition of the house, the gender proportion of household heads, and the proportion of households with members who have disabilities.

3.3. Measures

This study utilizes seven latent variables, operationally defined as follows: First, prior disaster experience refers to the direct experience of disasters retained in the memory of individuals or communities, which forms a key mechanism for understanding and adapting to disaster conditions. Second, place attachment is the comprehensive emotions, connections, behavioural intentions, and cognitive evaluations an individual develops over time concerning their residence, expressed through their affective, cognitive, and behavioural processes. Third, social capital refers to the norms and social relationships among individuals, groups, and communities that facilitate collective actions by leveraging these relationships to access financial, emotional, physical, and other resources for survival and mutual benefit, often understood as social norms and reciprocal trust. Fourth, risk perception refers to the process of understanding and interpreting signals from various sources about events and forming a judgment regarding the likelihood and severity of current or future losses caused by these. Fifth, social participation refers to the level of individual engagement in building networks to share valuable information and enhance mutual trust within the community. Sixth, social protection and security are essential support mechanisms for safeguarding vulnerable groups against disasters and climate change, ensuring the fulfilment of basic needs, and expanding household response options. And seventh, household adaptiveness refers to a household's ability to adjust behaviourally, socially, and economically to minimize risks and anticipate the impacts of climate change and disasters.

Latent measurement in the model is established using multiple indicators that have undergone testing for content validity and face validity (Table 1). The majority of these indicators are presented in the questionnaire with interval scale options. However, indicator Pde3 for the Prior Disaster Experience variable, indicator Spc3 for the Social Participation variable, indicators Sps1 and Sps5 for the Social Protection and Security variable, and indicator Ha3 for the Household Adaptiveness variable were derived from open-ended questions. Subsequently, during the data coding process, intervals were assigned to each respondent's answer.

3.4. SEM software for statistical analysis

The data collected underwent analysis through Structural Equation Modelling (SEM) utilizing a Variance-Based approach (VB-SEM). This method was selected due to the confirmatory nature of the research, which emphasises theory development, particularly concerning household adaptiveness within the Sumba context. The Partial Least Square (PLS-SEM) application was employed to assess the constructed model. The decision to utilize PLS-SEM was predicated on the belief that it offers a more practical analytical method for

testing the model and is better equipped to accommodate novel relationships in models that lack theoretical grounding.

To ensure the compliance of the tested model with the essential goodness-of-fit criteria that are statistically accepted, an initial analysis is conducted on the model using the calculated Partial Least Squares (PLS) Algorithm for the initial model (Results are provided in Appendix 1 & Appendix 2). An outer loading of 0.5 is considered significant, as at this threshold, the indicator plays a crucial role in the formation of the latent construct [70,71]. It is noted in Appendix 2 that there are 12 (outer) indicators with loading values below 0.5 that need to be eliminated, namely indicators Crp1, Crp2, Crp3, Crp5, Crp7, Crp8, Pa2, Sc3, Spc2, Sps1, Sps4, and Ha2. Following the removal of these indicators, a second round of the PLS Algorithm calculation was performed (results are detailed in Appendix 3 & Appendix 4). In the subsequent analysis, two indicators, Pde1 and Pde2, were identified with loading values below 0.5 and were consequently excluded. Subsequently, the third PLS Algorithm calculation was conducted after removing Pde1 & Pde2, with results presented in Appendix 4 & Appendix 5. In the third iteration, no indicators of latent variables exhibited loading values below 0.5, indicating that the model is suitable for further testing. The evaluation of construct reliability and validity, based on Cronbach Alpha, rho-A, Composite Reliability (CR), and Average Variance Extracted (AVE), is outlined in the subsequent table.

Based on the results of the construct reliability and validity test presented in Table 2, it is evident that the Cronbach Alpha value for the Climate Risk Perception variable and the Household Adaptiveness variable is relatively low, falling below the recommended Cronbach Alpha value of 0.6. Nevertheless, the CR and AVE values of the Household Adaptiveness variable exceed 0.5, as [70] suggested, thus justifying the retention of this variable for subsequent analysis.

The subsequent step in statistical analysis within the Partial Least Squares Structural Equation Modelling (PLS-SEM) framework involves evaluating the model fit through the examination of various index criteria, such as the Standardized Root Mean Square (SRMS), Normal Fit Index (NFI), and Geodesic Discrepancy (d_G) values. The SRMR serves as a fit measure that quantifies the variance between the observed covariance matrix and the one predicted by the model. SRMR values below 0.08 are indicative of a satisfactory model fit. The NFI is a fit measure that assesses the agreement between the hypothesized and base models. A higher NFI value closer to 1 signifies a better model fit. Typically, an NFI value exceeding 0.9 is considered to meet the model fit criteria. Additionally, the d_G value represents a measure of discrepancy based on the geodesic distance between the observed covariance matrix and the predicted matrix. A lower d_G value suggests a better fit [70,71]. The outcomes of the model fit assessment are displayed in the subsequent table.

The test results presented in Table 3 reveal that while the NFI value falls below the required threshold for model fit, the SRMR value and d_G value align with the optimal criteria. Therefore, the constructed model can be deemed acceptable in meeting the model fit standards.

4. Result and discussion

4.1. Demographic characteristics description

The main demographic characteristics presented in the results of this study include gender, age, education level, number of family members, household income, and household expenses. The description of the demographic characteristics of household respondents, as presented in Table 4, shows that the majority (70 %) of the respondents were male. As many as 25.7 % of respondents were aged 41–50 years. Meanwhile, when viewed from the perspective of education, the majority (51 %) of respondents did not graduate from primary school. Most (61 %) households have a family size of between 1 and 4 people, while around 2.3 % of households have more than 8 family members. Economic conditions based on monthly expenditure showed that 87.7 % of respondent households had expenditures of less than Rp 2,000,000 (USD 125), and 94.3 % of households had incomes of less than Rp 2,000,000 per month.

4.2. Model and hypothesis testing

The inner model serves as a structural framework employed to forecast the causal connections among latent variables that are directly inferred from the theory's substance (see Fig. 1). The validation of the inner model is conducted through bootstrap and blind procedures in Smart PLS. The outcomes of the structural model equation testing are presented in Fig. 3 and Table 5.

The outcomes of the structural equation modelling tests, as illustrated in the figure and table above, reveal that among the 23 hypotheses postulated, 12 hypotheses lack empirical support, while 11 hypotheses are empirically supported. The findings of the

Table 2
Construct reliability and validity.

Constructs	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Age	1.000	1.000	1.000	1.000
Climate Risk Perception	0.341	0.343	0.752	0.602
Education	1.000	1.000	1.000	1.000
Gender	1.000	1.000	1.000	1.000
Household Adaptiveness	0.283	0.338	0.721	0.574
Place Attachments	0.860	0.882	0.896	0.591
Prior Disaster Experience	1.000	1.000	1.000	1.000
Social Capital	0.611	0.616	0.837	0.719
Social Protection and Security	0.901	0.924	0.938	0.834
Social Participation	0.708	0.766	0.840	0.643

Table 3
Model fit index.

Fit Index Criteria	Saturated Model	Estimated Model
SRMR	0.077	0.081
d_ULS	1.509	1.657
d_G	0.465	0.486
Chi-Square	887.509	918.273
NFI	0.637	0.624

Table 4
Demographic characteristics.

Demographic Characteristics	Percent
Gender	
Male	70
Female	30
Age Categories	
18-30 yo	4
31-40 yo	13.3
41-50 yo	25.7
51-60 yo	19.3
61-70 yo	19.3
>70 yo	18.3
Education	
Not completed in Primary School	51
Primary School	32.3
Junior High School	4.7
Senior High School	11
Higher Education	1
Number of family members	
1-4 person	61
5-8 person	36.7
>8 person	2.3
Household Income	
< Rp 2,000,000	94.3
Rp 2,000,000–4,000,000	5.3
Rp 4,000,000–6.000.000	0.3
Household Expenses	
< Rp 2,000,000	87.7
Rp 2,000,000–4,000,000	11.3
Rp 4,000,000–6,000,000	1

Note. 1 USD is Rp. 16,000.

analysis suggest that demographic variables, such as age, do not serve as predictors for climate change risk perception and social participation. However, gender and education level emerge as significant predictors for both climate change risk perception and social participation. Additionally, place attachments are identified as predictors for climate change risk perception, social capital, and social participation. Moreover, climate change risk perception is found to be a predictor for social participation and social protection and security. Similarly, social capital is a predictor of social protection and security. However, the data suggests that social participation does not exert a significant impact on household adaptiveness. Conversely, social protection and security are shown to significantly influence household adaptiveness; thus, serving as predictors for household adaptiveness.

4.3. Risk perception

Findings suggest that gender (H1) matters as male perceive less climate risk than women; while education (H3, $\beta = 0.101$, p 0,041) has greater association with risk perception; and place attachment (H5, $\beta = -0.439$, $p < 0.001$) is associated with lower risk perception. Such a finding is consistent with the literature [25,26]. Unfortunately, it was surprising to see that age, prior-disaster experience and social capital do not show significant impact on climate risk perception as suggested by literature [23].

While the findings aligned with the existing literature the data offers new insights. Unfortunately, the data suggests counter intuitive findings as prior disaster experience does not have significant influence on perception but household adaptiveness. Previous studies from Germany and Indonesia suggested that prior disaster experience is a good predictor of risk perception (e.g. 73,74) because past disaster events serve as a repertoire for memory that can shape perception about future risk [75,76].

4.4. Social capital

Place attachment has strong positive effect on social capital (H7, $\beta = 0.456$, $p < 0.001$). This suggest that individuals more attached

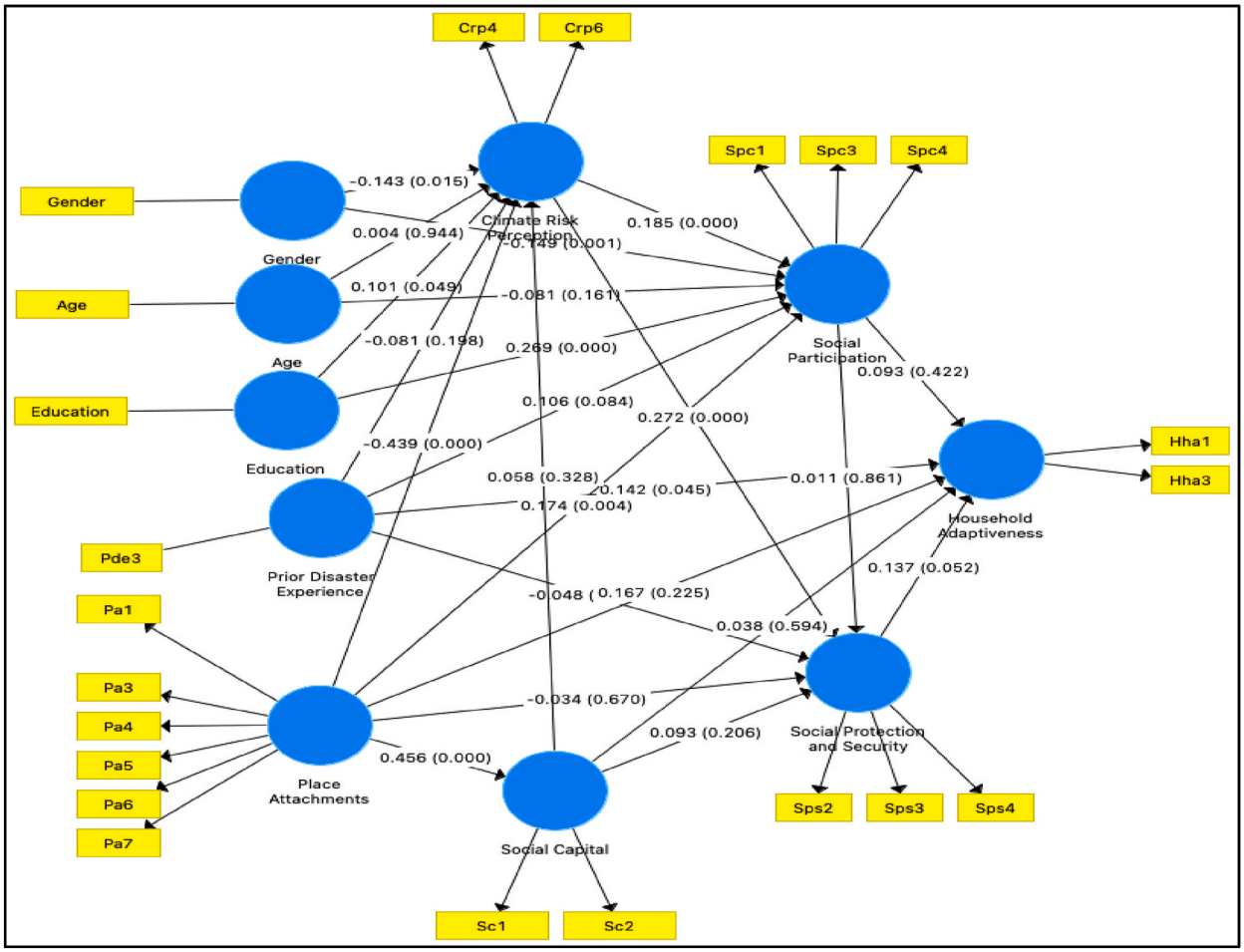

Fig. 3. Full model testing.

to their place have higher social connections. While the rest of the test do not serve as a predictor to social capital.

4.5. Social participation

The data suggests that gender, education, place attachment and risk perception are better predictors for participation. While prior disaster experience does not lead to participation. This data does not suggest that those who experience disasters tend to be left behind.

Gender (H8 Gender - > Social Participation) is a good predictor for social participation ($\beta = -0.149$, $p = 0.002$*), as males participate more in social and public affairs than females. Education (H10) has significant positive effect ($\beta = 0.269$, $p < 0.001$*) on participation as people get more educated, they are more likely to either participate or invited to participate in community affairs. Data also suggest that Place Attachment (H12) affects participation ($\beta = 0.174$, $p = 0.002$*). It suggests that the more an individual is attached to a place, the more they are willing to participate in community affairs. Interestingly the data also suggests that those who perceiving higher climate risk are more likely to participate in social affairs (H13, $\beta = 0.185$, $p < 0.001$). While the data also suggest that age do not affect participation.

4.6. Social protection and security

The findings suggest that climate risk perception (H17) is a good predictor of the likelihood of a household to receive or access social protection or social security ($\beta = 0.272$, $p < 0.001$*). While, the data suggest that Prior Disaster Experience, Place Attachment, Social Capital, Social Participation (H14, H15, H16, H18) do not significantly affect access to social protection services.

4.7. Pathways to household adaptiveness

Households with prior experience to disasters are likely to be more adaptive as the data suggests (H19, $\beta = 0.142$, $p = 0.036$*). In

Table 5
Model testing results (total effect).

Hypothesis	Path	Path Coefficient β	T Statistics	P Values
H1	Gender - > Climate Risk Perception	−0.143	2.557	0.011**
H2	Age - > Climate Risk Perception	0.004	0.069	0.945
H3	Education - > Climate Risk Perception	0.101	2.044	0.041**
H4	Prior Disaster Experience - > Climate Risk Perception	−0.081	1.234	0.218
H5	Place Attachments - > Climate Risk Perception	−0.439	7.932	0.000**
H6	Social Capital - > Climate Risk Perception	0.058	0.996	0.320
H7	Place Attachments - > Social Capital	0.456	8.258	0.000**
H8	Gender - > Social Participation	−0.149	3.179	0.002**
H9	Age - > Social Participation	−0.081	1.551	0.122
H10	Education - > Social Participation	0.269	4.379	0.000**
H11	Prior Disaster Experience - > Social Participation	0.106	1.727	0.085*
H12	Place Attachments - > Social Participation	0.174	3.069	0.002**
H13	Climate Risk Perception - > Social Participation	0.185	3.850	0.000**
H14	Prior Disaster Experience - > Social Protection and Security	−0.048	0.780	0.436
H15	Place Attachments - > Social Protection and Security	−0.034	0.415	0.678
H16	Social Capital - > Social Protection and Security	0.093	1.240	0.216
H17	Climate Risk Perception - > Social Protection and Security	0.272	4.130	0.000**
H18	Social Participation - > Social Protection and Security	0.011	0.174	0.862
H19	Prior Disaster Experience - > Household Adaptiveness	0.142	2.103	0.036**
H20	Place Attachments - > Household Adaptiveness	0.167	1.171	0.242
H21	Social Capital - > Household Adaptiveness	0.038	0.565	0.572
H22	Social Participation - > Household Adaptiveness	0.093	0.905	0.366
H23	Social Protection and Security - > Household Adaptiveness	0.137	1.994	0.047**

(*p-value <0,10, **p-value <0,05).

addition, better access to social protection or social security services enhances household adaptiveness (H23β = 0.137, p = 0.047*). While, contrary to other studies (for example, 21, 31, 32), the data suggest that place attachment, social capital and social participation (H20-H22) do not directly contribute to household adaptation.

The findings clearly suggest that social protection and security and prior disaster experience are stronger predictors of household adaptiveness. This aligns with existing literature from India and elsewhere [49–51]. However, it does not suggest that place attachment, gender, education, place attachment and climate risk perception are entirely not relevant to household adaptiveness. Fig. 4 exhibits four distinct pathways toward household adaptiveness influenced by gender, education, place attachment, and prior disaster experience. In pathways (a) to (c), climate risk perception acts as a mediator linking sociodemographic (gender and education) or psychosocial variables (place attachment and risk perception) to social protection and ultimately household adaptiveness. These findings align suggests that gender, education, and place attachment significantly shaped climate risk perception. Social protection and security further mediated these effects.

In contrast, pathway (d) shows a direct effect of prior disaster experience on household adaptiveness, emphasizing experiential learning's role in shaping adaptive behaviours independently of perceived risk or institutional factors. This finding might be counter intuitive because participants were recruited from semi-arid rural settings of Sumba Island where recurrent disasters often occur and some of the large-scale events such as Cyclone Seroja leading to local dam failures as well as widespread plagues [77] and COVID-19 collectively affect the communities. Furthermore, during COVID-19, the Government of Indonesia had implemented strong social protection [78].

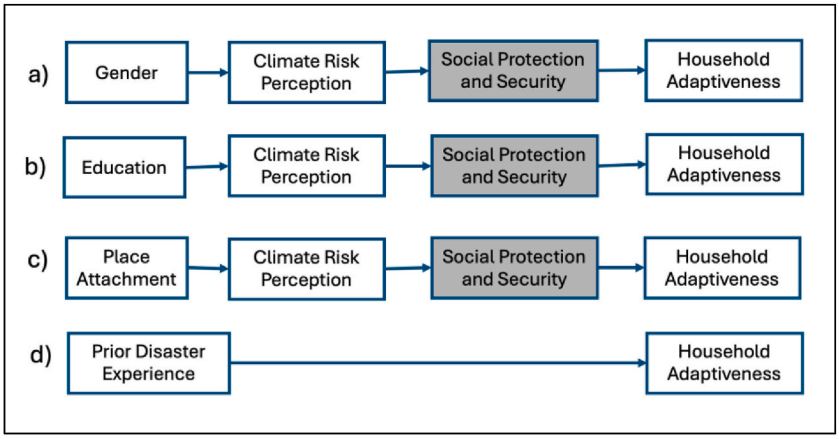

Fig. 4. Alternative paths for strengthening household adaptiveness.

Nevertheless, the finding echoed the existing studies that show adaptation can be enhanced by effectives social protection in various rural context [47] in drought and flood prone regions of 'developing countries' [72]. Social protection measures that anticipate climate change are urgently needed in Sumba, where poverty persists and forms of slavery remain prevalent in both rural and urban settings.

5. Conclusions and recommendation

This study investigates the determinants that influence household adaptiveness. Conventional wisdom suggests that prior disaster experience, place attachment, social capital, social participation, and social protection and security are strong predictors of household adaptiveness. However, the findings suggests prior disaster experience and social protection and security have a direct impact, while the other variables do not show a statistically significant effect. Nonetheless, factors such as gender, education, place attachment, social capital, and climate risk perception warrant further attention, as they contribute indirectly to enhancing household adaptiveness.

Social protection and security serve as the primary factor in enhancing household adaptiveness and also as a mediator for other variables. This suggests further understanding on how a household access different types of social protection (e.g. formal protection such as or social security programs or informal such as sources for household access to social transfers or loans), can strengthen their adaptive capabilities. The results of this study confirm the findings of previous research indicating that social protection directly impacts the coping strategies of smallholder farming households in Indonesia when dealing with climate change-related disasters [18]. However. Further examination of the mediating role of social protection in enhancing household adaptiveness suggests an alternative pathway worth exploring.

6. Limitation

Dryland islands in Eastern Indonesia frequently experience severe droughts, cyclones, and floods. This study focuses on villages recently affected by Cyclone Seroja, prolonged drought, and pest outbreaks in East Sumba District, the largest district on Sumba Island, though these findings do not necessarily represent Sumba or Eastern Indonesia as a whole. Future research should examine how variations in agroecological systems influence household adaptive capacity. We did not fully apply the Sustainable Livelihoods Framework in designing the survey instruments, as our focus was primarily on understanding the use of social protection during recent climate-related hazards and the COVID-19 pandemic in the most vulnerable communities.

CRediT authorship contribution statement

Maklon Felipus Killa: Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jonatan Lassa:** Writing – review & editing, Writing – original draft, Supervision, Resources, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Elsa Christin Saragih:** Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Saut Sagala:** Supervision, Resources, Project administration, Funding acquisition. **Debby Paramitasari:** Resources, Project administration, Investigation. **Victoria Fanggidae:** Writing – review & editing, Resources, Investigation, Conceptualization. **Ayu Krishna Yuliawati:** Writing – review & editing, Investigation, Conceptualization. **Hestin Kezia Octalina Klaas:** Writing – review & editing, Investigation, Conceptualization. **John Petrus Talan:** Writing – review & editing, Investigation, Conceptualization. **Dominiggus Elcid Li:** Writing – review & editing, Resources, Investigation. **Kerstin Zander:** Writing – review & editing, Validation. **Matthew Abunyewah:** Writing – review & editing, Validation. **Michael Odei Erdiaw-Kwasie:** Writing – review & editing, Validation.

Informed consent statement

Not applicable.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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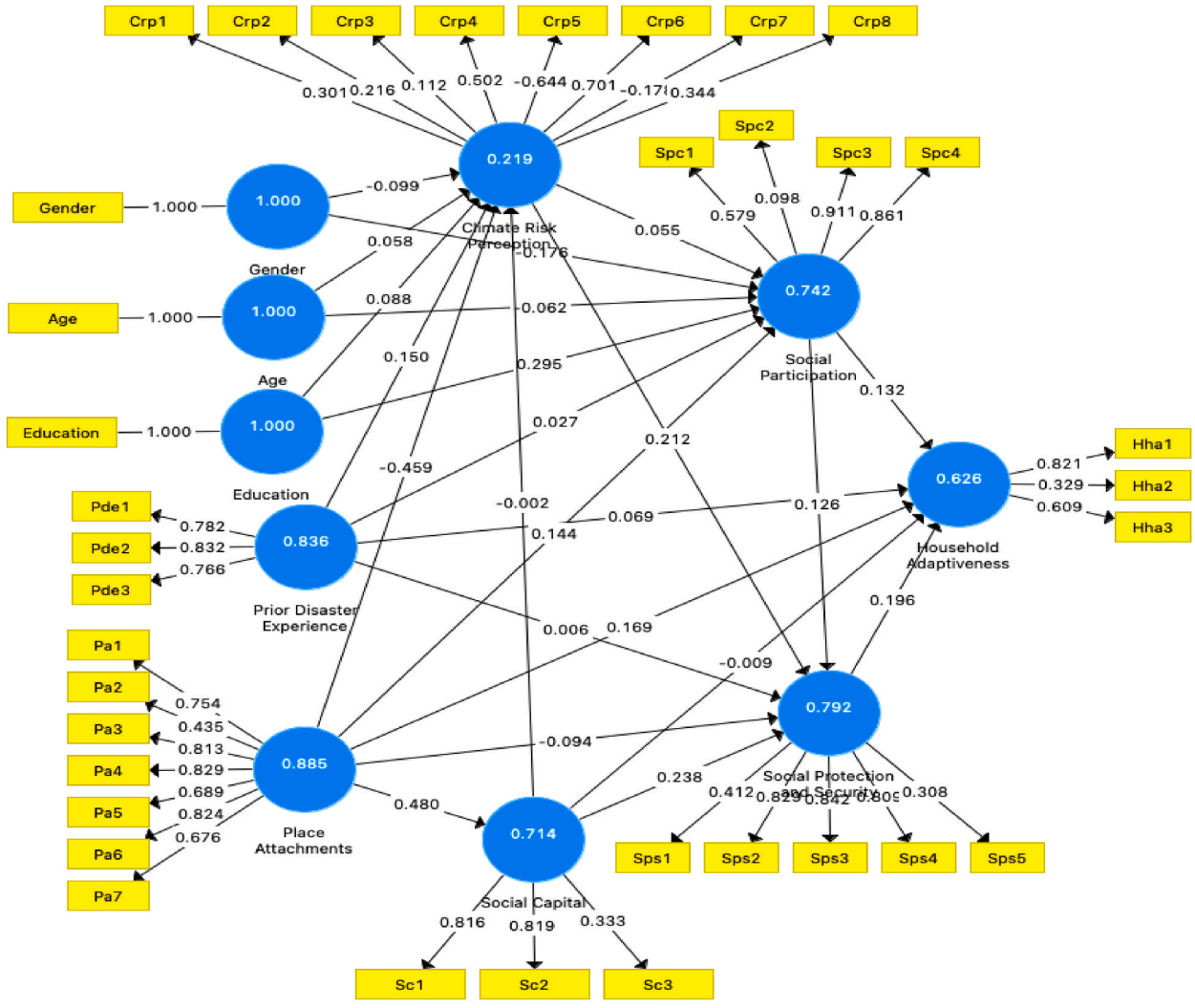
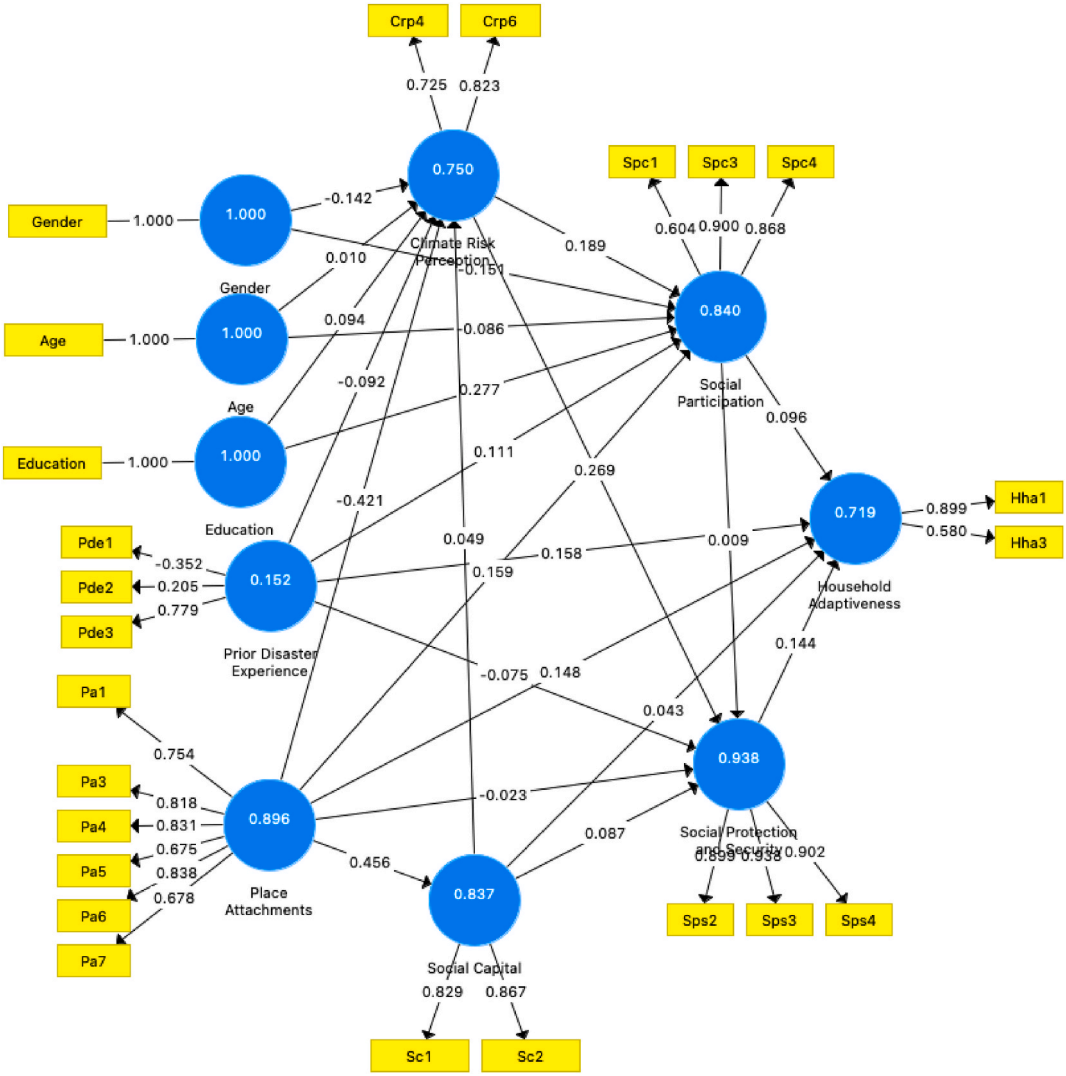
Appendix 1. PLS Algorithm for Developed Model (full indicators)



Appendix 2. Outer Loading for Initial Model (full indicators)

	Age	Climate Risk Perception	Education	Gender	Household Adaptiveness	Place Attachments	Prior Disaster Experience	Social Capital	Social Protection and Security	Social Participation
Age	1.000									
Crp1		0.301								
Crp2		0.216								
Crp3		0.112								
Crp4		0.502								
Crp5		-0.644								
Crp6		0.701								
Crp7		-0.178								
Crp8		0.344								
Education			1.000							
Gender				1.000						
Hha1					0.821					
Hha2					0.329					
Hha3					0.609					
Pa1						0.754				
Pa2						0.435				
Pa3						0.813				
Pa4						0.829				
Pa5						0.689				
Pa6						0.824				
Pa7						0.676				
Pde1							0.782			
Pde2							0.832			
Pde3							0.766			
Sc1								0.816		
Sc2								0.819		
Sc3								0.333		
Spc1										0.579
Spc2										0.098
Spc3										0.911
Spc4										0.861
Sps1									0.412	
Sps2									0.829	
Sps3									0.842	
Sps4									0.809	
Sps5									0.308	

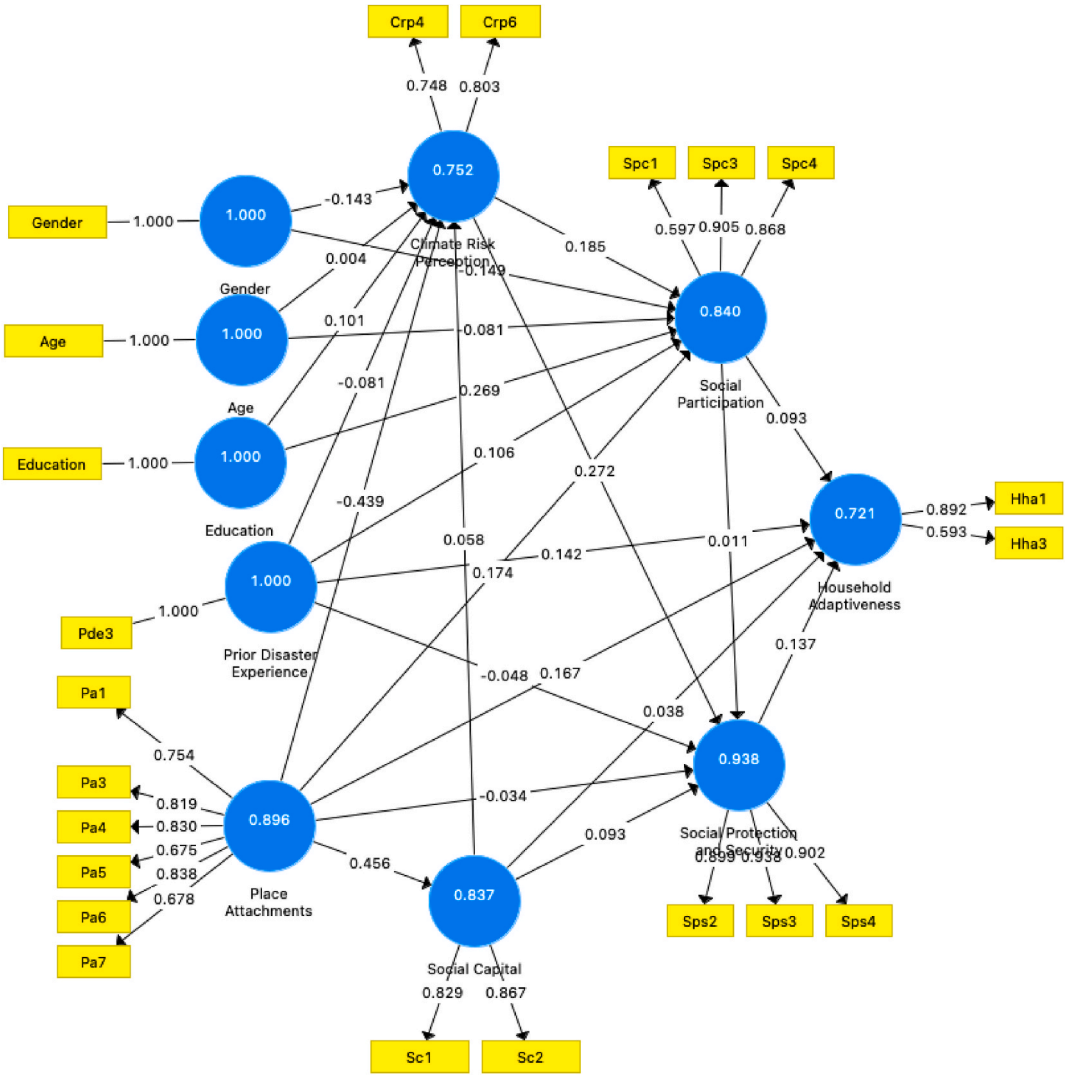
Appendix 3. PLS Algorithm for Developed Model (12 indicators deleted/item reduction) (second running)



Appendix 4. Outer Loading for Initial Model (12 indicators deleted/item reduction) (second running)

	Age	Climate Risk Perception	Education	Gender	Household Adaptiveness	Place Attachments	Prior Disaster Experience	Social Capital	Social Protection and Security	Social Participation
Age	1.000									
Crp4		0.725								
Crp6		0.823								
Education			1.000							
Gender				1.000						
Hha1					0.899					
Hha3					0.580					
Pa1						0.754				
Pa3						0.818				
Pa4						0.831				
Pa5						0.675				
Pa6						0.838				
Pa7						0.678				
Pde1							-0.352			
Pde2							0.205			
Pde3							0.779			
Sc1								0.829		
Sc2								0.867		
Spc1										0.604
Spc3										0.900
Spc4										0.868
Sps2									0.899	
Sps3									0.938	
Sps4									0.902	

Appendix 5. PLS Algorithm for Developed Model (2 indicators deleted/item reduction) (third running)



Appendix 6. Outer Loading for Initial Model (2 indicators deleted/item reduction) (third running)

	Age	Climate Risk Perception	Education	Gender	Household Adaptiveness	Place Attachment	Prior Disaster Experience	Social Capital	Social Protection and Security	Social Participation
Age	1.000									
Crp4		0.748								
Crp6		0.803								
Education			1.000							
Gender				1.000						
Hha1					0.892					
Hha3					0.593					
Pa1						0.754				
Pa3						0.819				
Pa4						0.830				
Pa5						0.675				
Pa6						0.838				
Pa7						0.678				
Pde3							1.000			
Sc1								0.829		
Sc2								0.867		
Spc1										0.597
Spc3										0.905
Spc4										0.868
Sps2									0.899	
Sps3									0.938	
Sps4									0.902	

Data availability

Data will be made available on request.

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