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Research Paper

Adaptive strategies and community engagement for sustainable conservation and tourism in Komodo National Park, Indonesia

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ABSTRACT

The sustainability of Komodo protection efforts is closely linked to tourism development. To achieve this, it is important to have a deep understanding of local community behaviors and adaptation strategies. This study focuses on the complex relationships between sociodemographic factors, attitudes towards forest conservation, participation in adaptive management programs, and willingness of local communities in the Komodo district to engage in sustainable tourism practices. Using structural equation modeling (SEM), we analyze the connections that either support or hinder the conservation of Komodo habitats while promoting responsible tourism growth. The results show that sociodemographic characteristics have a significant impact on conservation attitudes, leading to increased participation in adaptive programs that are crucial for sustainable tourism. Additionally, the willingness to adapt is a key factor that influences the level of community involvement in sustainable tourism initiatives. This study emphasizes the importance of developing behavioral and adaptive forest protection programs that cater to both Komodo conservation and the sustainable growth of tourism. Policy recommendations focus on community-centered conservation strategies, education on sustainable practices, and the implementation of adaptive management to ensure the long-term viability of Komodo habitats. Overall, this research provides a nuanced understanding of conservation behavior in regions with rich biodiversity. It highlights the pivotal role of community engagement and adaptive strategies in achieving sustainable tourism and conservation goals.

1. Introduction

Komodo National Park, established in 1980 and declared a UNESCO World Heritage Site in 1991, is internationally renowned for its stunning marine biodiversity and being the natural habitat of the iconic Komodo dragon (*Varanus komodoensis*) (Asriyani & Verheijen, 2020; Barnard, 2012; Forth, 2010). Located in the Lesser Sunda Islands of Indonesia, the park spans approximately 1,817 km^2 of land and sea, including three major islands: Komodo, Rinca, and Padar (Imansyah et al., 2009). It attracts tourists

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from around the world who are drawn to its vibrant coral reefs, diverse marine life, and beautiful beaches (Germanov et al., 2022; Zulpikar & Handayani, 2021), making it a premier destination for activities such as diving and snorkeling. The terrestrial portion of the park is equally captivating, offering visitors the chance to observe the Komodo dragons in their natural habitat, alongside other unique fauna and flora (Asriyani & Verheijen, 2020; Susanti et al., 2022). However, the park has faced significant challenges in marine conservation, particularly due to illegal fishing practices that have threatened its delicate ecosystems (Germanov et al., 2022; Hidyarko et al., 2021). Historical overfishing and destructive methods such as dynamite fishing have caused extensive damage to coral reefs and depleted fish populations, complicating conservation efforts (De Alessi, 2014; Dirhamsyah, 2012; Djohani, 1998). Despite these ongoing illegal fishing activities (Germanov et al., 2022; International Union for Conservation of Nature, 2020), the enforcement of fishing bans since 1996 (Pet & Yeager, 2000) and monitoring by tourism operators have provided some protection for manta rays. Climate change further complicates the situation, with rising sea temperatures and ocean acidification causing coral bleaching and disrupting the marine ecosystem, adding more stress to the park's biodiversity (Ann et al., 2022; Malanson & Alftine, 2023; Zhang et al., 2022). Despite the challenges, ongoing conservation initiatives and the implementation of stricter regulations have played a critical role in mitigating the impacts and promoting sustainable management of terrestrial and marine resources in Komodo National Park. One such regulation is the Governor of East Nusa Tenggara Regulation Number 85 of 2022 on the Conservation of Biological Natural Resources and Their Ecosystems in Komodo National Park.

Tourism in Komodo National Park is largely driven by its exceptional marine attractions. Although fishing is officially banned in key areas of the park, including the use of gillnets, long-lines, and blast fishing (Pet & Yeager, 2000), enforcement remains a challenge, and illegal fishing persists (International Union for Conservation of Nature, 2020). These illegal activities are a serious threat to the park's manta rays and highlight the need for stronger enforcement (Germanov et al., 2022). The park is a top destination for diving and snorkeling, attracting visitors eager to explore its vibrant coral reefs and diverse marine life. The chance to see Komodo dragons and enjoy the scenic beaches further enhances its appeal (Asriyani & Verheijen, 2020). However, the growing number of tourists also brings environmental challenges. Marine debris, especially plastic waste from tourism, is a major issue, damaging coral reefs and endangering marine species (Bahar, 2023; Cordova et al., 2021).

The intricate relationship between human livelihoods, environmental conservation, and the burgeoning field of sustainable tourism forms the crux of this study, particularly within the unique ecosystem of the Komodo National Park. Komodo National Park has rich biodiversity and is the habitat of the iconic Komodo dragons (Hidyarko et al., 2021; Pramatana et al., 2023; Reuleaux et al., 2020), which has rapidly emerged as a global tourist destination. The influx of tourists has significantly altered the local economy and community dynamics (Islami et al., 2021), underscoring the imperative for sustainable tourism practices that safeguard ecological integrity while promoting the local community's well-being (Baloch et al., 2023). This study situates itself at the intersection of these critical issues, aiming to unravel how sociodemographic factors influence conservation attitudes and behaviors among the local populace. With the Komodo National Park serving as a living laboratory, the research delves into how the local community's engagement with their natural environment and the tourism economy shapes their approach to forest conservation. It is posited that sustainable tourism, in this context, transcends mere choice, becoming an essential strategy for maintaining the delicate balance between human activity and the preservation of natural resources (Saarinen, 2021).

Historically, research in environmental conservation has emphasized the importance of community involvement (Buta et al., 2014; Gurung & Thapa, 2023; Nguyen et al., 2021; Nguyen & Jones, 2022; Tokuoka et al., 2024; Xu et al., 2022). However, many studies have focused on single variables, such as economic incentives or educational programs, without considering how sociodemographic factors affect conservation attitudes and behaviors. This narrow focus has created a significant knowledge gap: there is a lack of comprehensive understanding of how different sociodemographic characteristics, such as age, income, education level, and marital status, influence local communities' engagement with conservation and sustainable tourism practices. Additionally, there is a specific lack of understanding of how these sociodemographic factors impact conservation attitudes and participation in adaptive management programs in the context of a major tourism destination like Komodo National Park. Using structural equation modeling (SEM), we examine the complex relationships between these factors, providing a detailed analysis of how they influence conservation behaviors. This methodology allows us to explore both direct and indirect effects, offering a nuanced understanding of the interactions at play (Jou et al., 2024; Purnomo et al., 2021; Savari & Khaleghi, 2023; Trépanier et al., 2015). By addressing these gaps, our research contributes to the broader literature on community engagement and sustainable tourism in biodiversity-rich regions.

Our study situates its findings within the wider context of previous studies (Buta et al., 2014; Gurung & Thapa, 2023; Nguyen et al., 2021; Nguyen & Jones, 2022; Tokuoka et al., 2024; Xu et al., 2022), conducting a comparative analysis that enhances the understanding of engagement in conservation within the unique cultural and social setting of Komodo. We explore the potential synergy between positive attitudes towards conservation and sustainable tourism development, suggesting that focused efforts in these areas may result in stronger outcomes for forest conservation (Kuvan & Akan, 2012; Pham et al., 2021). The research is based on the belief that cultivating a willingness to adapt among members of the community can drive significant advancements in conservation efforts. This adaptability, motivated by an awareness of and support for sustainable tourism, plays a crucial role in securing long-term conservation successes. The study also argues that interventions must be tailored to align with the sociocultural intricacies of Komodo National Park, ensuring that they resonate with and are embraced by the local community. By providing a comprehensive analysis of these factors through SEM, our study fills existing gaps in research and offers valuable insights that can guide future strategies for forest conservation, guaranteeing their sustainability, cultural sensitivity, and effective mobilization at the community level.

2. Material and methods

2.1. Study location

Situated in the Lesser Sunda Islands of Indonesia, Komodo National Park encompasses a vast area of land and marine environment (See Figure 1). The park's primary goal is to preserve the unique biodiversity found within its boundaries and protect the Komodo dragons, a species found nowhere else on Earth. However, the history of the park goes back much further than its official establishment in 1980. Evidence suggests that early human settlements existed in the region, and interactions with the Komodo dragons can be traced back centuries. It was not until the early 20th century that the existence of these impressive reptiles became widely known to the rest of the world. Recognizing the importance of preserving the Komodo dragons and its habitat, Komodo National Park was officially established in 1980 (Singleton & Sulaiman, 2002), covering the main islands of Komodo, Rinca, and Padar, along with numerous smaller islands. This marked a crucial milestone in the conservation of the Komodo dragons and the unique flora and fauna within the park's boundaries. In 1991, Komodo National Park was designated as a UNESCO World Heritage Site, further emphasizing its global significance (Hawkins, 2013). The park's extraordinary terrestrial and marine ecosystems, including coral reefs, seagrass beds, and mangrove forests, earned it this prestigious recognition, attracting increased attention and resources for preservation efforts. Despite its protected status, Komodo National Park faces various threats that put its fragile ecosystems at risk, such as illegal poaching, unsustainable fishing practices, habitat degradation, and climate change. The rise in tourism has also raised concerns about its environmental impact and the well-being of the Komodo dragons (Rahman et al., 2025; Sofiyah et al., 2025; Suryawan, Sianipar, & Lee, 2025).

Tourism to Komodo National Park has seen significant growth over the years. The number of visitors increased from 44,492 in 2010 to a peak of 300,488 in 2023 (Suadnyana & Ardin, 2024). This rise was temporarily interrupted by the COVID-19 pandemic, with a notable decrease in tourist numbers in 2020 and 2021. However, tourism has rebounded strongly, with 2023 seeing the highest number of visitors to date. The park attracts both domestic and international tourists, with the top five countries of origin in 2023 being Indonesia, United States, China, Germany, and France (Suadnyana & Ardin, 2024). The park's tourism infrastructure includes various services such as guided tours, diving expeditions, and accommodations, catering to the needs of a diverse visitor base.

The local community surrounding Komodo National Park primarily engages in fishing, agriculture, and tourism-related activities. The community's demographics include a mix of different age groups, with many families relying on the park's resources for their livelihoods. In 2022, the population of Labuan Bajo, a key town in the region, was 6973, with a population density of 506 people per square kilometer (Kementerian Dalam Negeri, 2021). The community in Labuan Bajo is mainly composed of the Manggarai ethnic group, who speak the Manggarai language alongside the national language, Indonesian (Ampur et al., 2023). The Manggarai people are primarily involved in farming, cultivating crops such as rice, cassava, corn, fruits, and vegetables, as well as raising livestock such as buffalo, cattle, horses, pigs, dogs, and chickens. The area is also home to the Bajo ethnic group, known for their fishing skills.

To address the threats facing Komodo National Park, several conservation initiatives have been implemented. These include enhanced monitoring, anti-poaching measures, sustainable fishing practices, habitat restoration projects, and community engagement. Collaboration between local authorities, NGOs, and international organizations plays a crucial role in ongoing conservation efforts. Recognizing the potential of ecotourism, Komodo National Park has embraced sustainable practices in tourism. This includes enforcing strict visitor guidelines and actively involving local communities in ecotourism activities. Such efforts provide opportunities for economic development while ensuring the protection of the park's natural and cultural heritage.

This research was conducted in the Komodo district, which is located in the Manggarai Barat Regency of Indonesia's East Nusa Tenggara Province. The district includes sections of Flores Island, Komodo and Rinca Islands, and several smaller islets. The study mainly focuses on Labuan Bajo, an important hub for tourists visiting Komodo National Park, as well as the more traditional Komodo Village. Labuan Bajo serves as the main entry point to the park, providing vital services and infrastructure to support tourism that revolves around the region's unique biological and cultural assets (Dwipayanti et al., 2022; Putri & Aras, 2021), such as the renowned Komodo dragons.

2.2. Survey execution

Our study focused on understanding community perspectives on conservation in the Komodo district of Indonesia. These perspectives are crucial for maintaining the ecological balance of the region. The survey was conducted over a period of six months, from January to June 2023, in various locations within the Komodo district, including both urban areas and the islands. We interviewed a total of 520 individuals, ensuring a comprehensive sample that represented a diverse range of sociodemographic backgrounds. This sample size exceeds the minimum requirement of 400, calculated using Slovin's formula with a 5% margin of error, making the results statistically significant.

To ensure the robustness of our research design, we employed a stratified random sampling method. This approach allowed us to select participants from different sociodemographic strata, avoiding biases and ensuring that the sample could accurately represent the demographic composition of the community. The interview process began with a thorough training program for all interviewers. The training aimed to familiarize interviewers with the survey's objectives and procedures, including mock interviews and detailed guidelines on how to ask questions without leading participants' responses. This training ensured that interviewers could conduct the survey professionally and consistently across participants. Participants were selected using a stratified random

sampling method, dividing the population into subgroups based on settlement type (urban areas versus islands), educational background, economic dependence on tourism, gender, and marital status. Random samples were then drawn from each subgroup to ensure adequate representation. This method helped avoid sample biases and ensured the representativeness of the sample. To further avoid biases, the selection process within each subgroup was entirely random. Interviewers were rotated among different regions and subgroups to prevent any biases related to interviewers. Additionally, interviews were conducted at various times of the day and week to capture a wide range of participants and ensure representation of different demographics.

The survey aims to explore how sociodemographic backgrounds influence individuals' views on environmental advocacy and forest conservation. It specifically examines the relationship between factors like age, income, marital status, and attitudes towards preserving forest habitats, including interactions with Komodo dragons and the growth of forest-conservation-minded tourism. Out of the 520 participants, 51.35% lived in urban areas while 48.65% were from the islands. In terms of education, 51.54% had completed secondary school, 46.92% held a bachelor's degree, and 1.54% had a master's or doctorate degree. Regarding reliance on tourism for their livelihood, 54.23% of respondents were not dependent on tourism, while 45.77% were. The gender distribution showed that 41.92% of participants were male and 58.08% were female. In terms of marital status, 42.31% were single, and 57.69% were married.

To ensure ethical standards, we obtained approval from the relevant institutional review board before conducting the study. All participants were fully informed about the research purpose, guaranteed anonymity and confidentiality, and were provided with informed consent prior to participating in the interviews. This ethical oversight was essential in conducting the study responsibly and respecting the rights and well-being.

Table 1 displays a series of statements that measure the community's active engagement in forest conservation. Respondents' answers, collected on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), indicate the degree of community involvement in various conservation and sustainable tourism practices. These practices include participation in beach and forest conservation, support for community-led initiatives, and advocacy for sustainable tourism development. The survey also seeks to understand the community's adaptability to forest management programs. The final question in the table directly addresses individuals' willingness to adjust their practices in support of overarching forest management objectives. By analyzing the data presented in Table 1, we aim to identify patterns and preferences that can inform targeted conservation strategies, ensuring they align with the community's socioeconomic realities and conservation values. This approach aims to foster effective forest management efforts that benefit both the community and their natural environment.

Table 1
Survey measures for evaluating community engagement in sustainable tourism in the Komodo district.

Variable	Indicator	Code	Information
Sociodemographic	Wage level	Binary	Earning above the minimum wage
	Education	Binary	Attained education level beyond high school
	Marital status	Binary	Currently married
	Age	Binary	Older than 39 years
Forest conservation attitude	Komodo and forest interaction	5-Likert scale	I frequently engage with Komodo dragons and their forest habitats
	Forest tourism Expansion	5-Likert scale	I support the widespread development of tourism that includes and respects forest areas
	Forest conservation engagement	5-Likert scale	I consistently involve myself in conservation activities aimed at forest preservation
	Beach and forest conservation	5-Likert scale	Participating in beach cleanups and forest conservation efforts is routine for me
	Environmental advocacy for forests	5-Likert scale	I am actively involved in an organization focused on the environmental protection of forests
Forest adaptive programs participation	Sustainable forest advocacy	5-Likert scale	I advocate for sustainable practices to preserve forest beauty, attract visitors, and ensure the forest's future sustainability
	Operational flexibility in forest conservation	5-Likert scale	I possess the ability to swiftly and effectively adapt conservation operations in response to environmental changes or weather conditions in forest areas
	Community-led forest initiatives	5-Likert scale	I support and participate in local community organizations that address challenges affecting our forests' livelihoods and well-being
	Forest rights and accountability	5-Likert scale	I collaborate with others to protect forest community rights and interests, holding forest developers and government agencies accountable
Sustainable tourist programs participation	Advocacy for sustainable tourism	5-Likert scale	I believe in promoting sustainable tourism to protect natural beauty
	Sustainable infrastructure development	5-Likert scale	I support the development of sustainable infrastructure for tourism
	Backing community-based organizations	5-Likert scale	I endorse community-based organizations involved in sustainable efforts
	Championing sustainable tourism initiatives	5-Likert scale	I am in favor of initiatives that advance sustainable tourism practices
	Acquiring skills for sustainable tourism	5-Likert scale	I am committed to learning marketing and business skills relevant to sustainable tourism
Willingness to adapt		Binary	Are you willing to adapt your practices to participate in forest management programs aimed at conservation and sustainable tourism?

2.3. Hypothesis development

The visual representation in Fig. 2 provides an outline of the proposed hypotheses that aim to understand the complex interplay between sociodemographic factors, attitudes, and participation in adaptive forest management programs and sustainable forest-related tourist activities. This hypothesized model seeks to analyze the various aspects of community engagement in conservation efforts within forested areas, particularly in regions where tourism and conservation are interconnected.

Hypothesis 1 (H_1) suggests that sociodemographic variables such as marital status, income level, and age have a significant influence on individual attitudes towards forest conservation and sustainable tourism. Hypothesis 2 (H_2) proposes that these attitudes are crucial factors to consider when it comes to participating in adaptive forest management programs. Hypothesis 3 (H_3) extends this reasoning by suggesting that participation in adaptive programs also influences support for sustainable forest-related tourism initiatives. Additionally, hypotheses Hypothesis 4 (H_4)–Hypothesis 7 (H_7) explore the potential impact of sociodemographic factors and individual attitudes on a person's willingness to adapt to sustainable forest management and tourism programs. Hypothesis 4 (H_4) and Hypothesis 5 (H_5) propose that sociodemographic factors and attitudes directly affect this

Fig. 1. Study location (Suryawan et al., 2024).

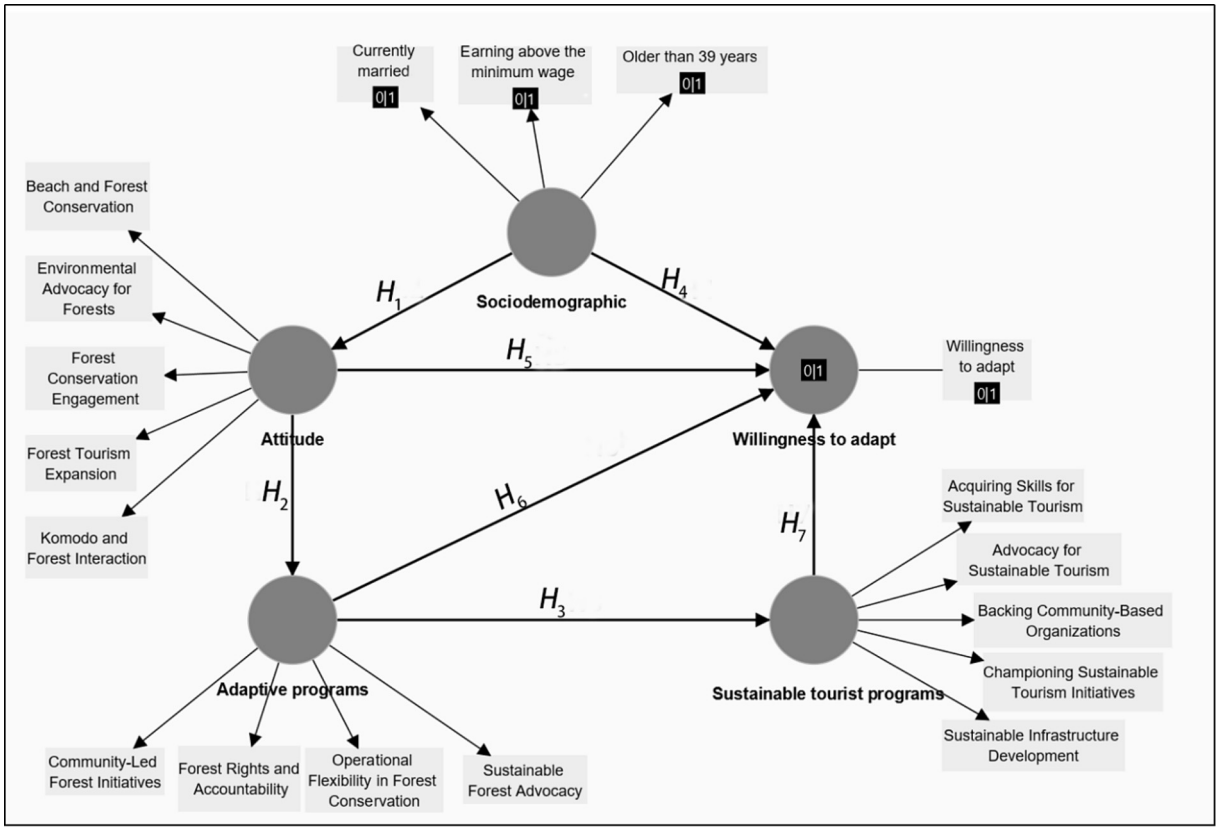

Fig. 2. Hypothesis development.

willingness to adapt, while Hypothesis 6 (H_6) and Hypothesis 7 (H_7) examine how this willingness may mediate the relationships between attitudes, adaptive programs, and participation in sustainable tourist programs.

These propositions serve as the foundation for our SEM approach, which aims to uncover the intricacies of community participation in the conservation of forested areas, particularly in cases where the interdependence of conservation and tourism is prominent. At the core of this model are seven hypotheses that bridge the gaps between personal characteristics, conservation attitudes, adaptive actions, and sustainable tourism:

- H_1: Sociodemographic factors, such as being married, earning above minimum wage, and being older than 39 years, significantly influence individuals' attitudes towards forest conservation, environmental advocacy, and interactions with Komodo dragons within the forest context.
- H_2: A positive attitude towards beach and forest conservation, environmental advocacy for forests, engagement in forest conservation, and expansion of forest tourism significantly affect participation in adaptive programs related to forest management.
- H_3: Engagement in adaptive programs, which include community-led forest initiatives, promoting forest rights and accountability, and operational flexibility in forest conservation, has a significant impact on individuals' willingness to support sustainable tourism programs associated with forest management.
- H_4: Sociodemographic factors directly impact individuals' willingness to adapt to changes within the context of sustainable tourism and forest conservation.
- H_5: There is a direct relationship between individuals' attitudes towards forest-related issues and their willingness to adapt to sustainable tourism practices. However, it is assumed that this relationship has a negative influence, implying that a higher willingness to adapt may decrease participation in sustainable tourism programs.
- H_6: Willingness to adapt acts as a mediating factor between individuals' attitudes towards forest-related issues and their participation in sustainable tourism programs. This suggests that greater adaptability could be associated with reduced support for sustainable tourism programs, including acquiring skills for sustainable tourism, advocating for sustainable tourism, and supporting the development of sustainable infrastructure.
- H_7: The participation in sustainable tourism programs is negatively influenced by individuals' willingness to adapt. This indicates that an increased readiness to adapt may correlate with a decrease in support for sustainable tourism programs, including acquiring skills for sustainable tourism, advocating for sustainable tourism, and supporting the development of sustainable infrastructure.

2.4. Data analysis

In this study, we utilized SEM with the SmartPLS 4 software to meticulously process our data. Our analysis began with a confirmatory factor analysis (CFA) within the measurement model to validate how well the survey items represented the intended constructs. This step involved correlating the scores of individual survey items with the scores of their associated constructs to check for convergent validity. Typically, loading factors of 0.60 or higher are considered standard (Psomas et al., 2011; Setyawati et al., 2022; Van Der Stede, 2001), but our study accepted loading factors from 0.50 to include a broader range of data (Awang et al., 2015; Wan Afthanorhan, 2013). To ensure the consistency of our constructs, we employed Cronbach's alpha with a minimum threshold of 0.50 alongside composite reliability measures (Bujang et al., 2018; Chrispin et al., 1997; Leelapattana et al., 2011; Spittaels et al., 2010), reinforcing the strength and reliability of our research model.

Following our preliminary analysis, we proceeded to scrutinize the appropriateness of our constructed model by examining specific model fit indices, namely the normed fit index (NFI) and the standardized root mean square residual (SRMR), using the partial least squares (PLS) algorithm framework. These metrics are crucial for assessing the degree to which our theoretical model aligns with the gathered data, ensuring that our conceptual propositions are accurately reflected in our empirical observations. The NFI, a comparative fit index, evaluates the model's fit relative to a baseline model that typically assumes no relationships between variables, serving as a measure of improvement. Values approaching 1 indicate a superior fit (Glenn Richey & Autry, 2009; Kominis & Emmanuel, 2007), suggesting that our model effectively elucidates the data more accurately than the baseline. On the other hand, the SRMR quantifies the average discrepancy between the observed correlations in the data and those predicted by the model. It calculates the square root of the difference between the residuals of the observed correlations and the model's predicted correlations, where these residuals are standardized across the dataset. SRMR values close to zero imply minimal discrepancy (Cho et al., 2020; Moshagen & Auerswald, 2018), indicating a close match between the model's predictions and the observed data. These indices provide a robust measure of our model's validity, reflecting its ability to capture the complex realities underlying our study.

The final step of our analysis involved hypothesis testing, where we determined the significance of our model's pathways by examining the *p*-values and *t*-statistics obtained through the bootstrap procedure. Results indicating *p*-values below 0.05 and *t*-statistics above 1.96 indicated statistical significance (Fahmi et al., 2022; Riady & Kusumawati, 2023), validating our hypotheses. This comprehensive approach using SEM allowed us to effectively analyze and interpret the intricate relationships within our data, focusing on the community's role in forest management and sustainable tourism practices.

3. Results

Table 2 presents the goodness-of-fit indices obtained from the SEM analysis, comparing the saturated and estimated models. The SRMR measures the difference between the observed correlation and the correlation predicted by the model. Lower SRMR values indicate a better fit. The discrepancy functions d_ULS and d_G, along with the Chi-square statistic, provide information on the overall fit of the model. Smaller values indicate a better fit. The NFI is a comparative fit index, with values closer to 1, indicating a better-fitting model. Both models show similar fit indices, suggesting that the estimated model aligns well with the observed data.

Table 3 displays the reliability and validity statistics for the constructs used in our SEM analysis. Cronbach's alpha value for each construct measures internal consistency, indicating how closely related the set of items are as a group. The composite reliability values, both rho_a and rho_c, estimate the internal consistency of the construct, accounting for the variability of factor loadings across items. The average variance extracted (AVE) measures the level of variance captured by the construct compared to the amount of variance due to measurement error. The values presented in Table 3 confirm the adequacy of the constructs for SEM analysis.

Fig. 3 presents a comprehensive structural model that illustrates the complex effects of sociodemographic factors on individuals' attitudes and subsequent involvement in programs aimed at managing and conserving forested environments. The model outlines the various pathways through which demographic characteristics, such as marital status, income level, and age, can significantly influence an individual's perspective and engagement with forest conservation efforts.

At the core of the model lies the concept of “attitude,” which encompasses an individual's views on beach and forest conservation, their participation in forest conservation activities, and their interactions with iconic Komodo dragons within forest environments. This central attitude is shaped by foundational sociodemographic factors, highlighting the crucial role of personal and economic circumstances in shaping one's inclination towards environmental stewardship. In addition to influencing attitude, the model suggests that these sociodemographic variables also directly impact an individual's “willingness to adapt.” This willingness represents the readiness of community members to integrate and support sustainable practices in forest management and to adjust their behaviors in accordance with the evolving demands of environmental conservation.

Table 2
Goodness-of-fit indices for SEM analysis.

Parameters	Saturated model	Estimated model
SRMR	0.068	0.071
d_ULS	0.782	0.863
d_G	0.216	0.220
Chi-square	650.773	662.743
NFI	0.821	0.818

Table 3
Reliability and validity measures for SEM constructs.

Variable	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Adaptive programs	0.769	0.795	0.854	0.599
Attitude	0.831	0.834	0.881	0.598
Sociodemographic	0.527	0.563	0.760	0.520
Sustainable tourist programs	0.888	0.889	0.918	0.692

Situated in the lower part of the model are “adaptive programs,” which symbolize community-led initiatives, the protection of forest rights and accountability, and flexible operational practices within forest conservation efforts. These adaptive programs are depicted as having a significant influence on individuals' attitudes, indicating that a community's collective outlook can profoundly affect the practical implementation of conservation strategies. Adjacent to this is the realm of “sustainable tourism programs,” which is closely linked to adaptive programs and emphasizes the community's support for initiatives that promote tourism sustainability while preserving the natural integrity of the forest. The model suggests that a community's involvement in sustainable tourism is not solely driven by direct motivation but also reflects its adaptability and responsiveness to conservation needs. Interconnecting these elements is the crucial role of willingness to adapt, which serves as a crucial point that potentially mediates the impact of one's attitude on their active participation in sustainable tourism programs. The model proposes that a higher degree of willingness to adapt may not always correspond to increased participation in sustainable tourism initiatives. Instead, it could indicate a nuanced relationship where adaptability shapes the nature and extent of engagement in such programs.

Table 4 clarifies the factor loadings associated with SEM construct indicators, which are crucial for understanding the connections between sustainable tourism and forest conservation efforts. These loadings quantitatively measure how well each indicator represents its corresponding latent construct in the SEM framework. The “original sample” and “sample mean” show the factor loadings calculated from the collected data, indicating the strength of the relationship between indicators and their constructs. A high loading suggests a strong connection, indicating that the indicator is a good measure of the construct.

Significant factor loadings, such as those for “acquiring skills for sustainable tourism,” demonstrate strong associations with the overarching construct of “sustainable tourist programs.” This relationship highlights the importance of educational efforts in equipping individuals with the necessary knowledge and skills to engage in and promote sustainable tourism practices. Similarly,

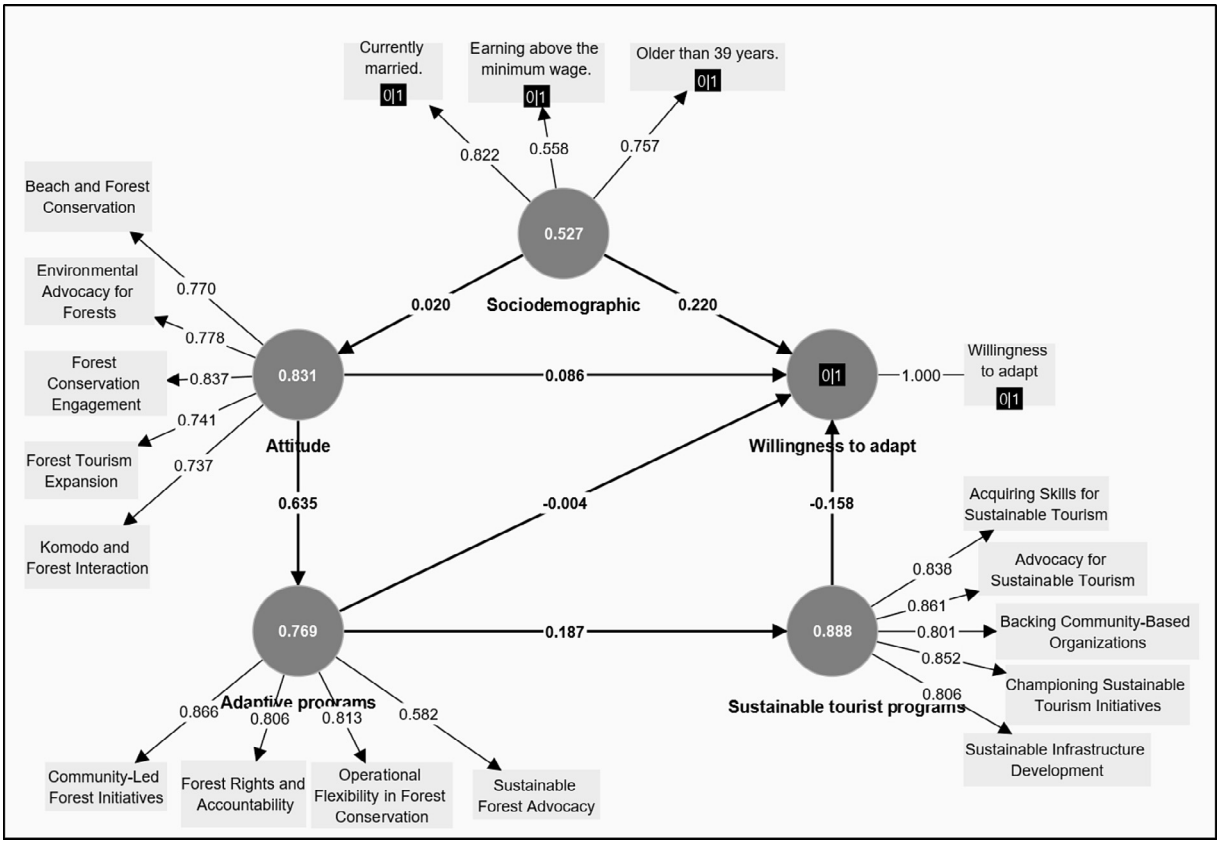

Fig. 3. Structural model of sociodemographic impact on attitudes and participation in forest management programs.

Table 4
Factor loadings for SEM construct indicators.

Path	Original sample	Sample mean	Standard deviation	*t*-statistics	*p*-values
Acquiring skills for sustainable tourism ← sustainable tourist programs	0.838	0.838	0.012	69.437	<0.001
Advocacy for sustainable tourism ← sustainable tourist programs	0.861	0.861	0.010	88.358	<0.001
Backing community-based organizations ← sustainable tourist programs	0.801	0.800	0.013	60.363	<0.001
Beach and forest conservation ← attitude	0.770	0.770	0.023	34.065	<0.001
Championing sustainable tourism initiatives ← sustainable tourist programs	0.852	0.853	0.011	78.816	<0.001
Community-led forest initiatives ← adaptive programs	0.866	0.866	0.014	64.108	<0.001
Currently married ← sociodemographic	0.822	0.823	0.017	47.847	<0.001
Earning above the minimum wage ← sociodemographic	0.558	0.553	0.060	9.276	<0.001
Environmental advocacy for forests ← attitude	0.778	0.778	0.022	35.887	<0.001
Forest conservation engagement ← attitude	0.837	0.837	0.014	58.372	<0.001
Forest rights and accountability ← adaptive programs	0.806	0.805	0.029	27.917	<0.001
Forest tourism expansion ← attitude	0.741	0.739	0.026	28.738	<0.001
Komodo and forest interaction ← attitude	0.737	0.736	0.027	27.642	<0.001
Older than 39 years ← sociodemographic	0.757	0.757	0.028	26.607	<0.001
Operational flexibility in forest conservation ← adaptive programs	0.813	0.813	0.020	39.910	<0.001
Sustainable forest advocacy ← adaptive programs	0.582	0.579	0.051	11.523	<0.001
Sustainable infrastructure development ← sustainable tourist programs	0.806	0.806	0.014	57.343	<0.001
Willingness to adapt ← willingness to adapt	1.000	1.000	0.000	N/A	N/A

the pronounced loadings for "community-led forest initiatives" emphasize the vital role of community involvement in the success of adaptive conservation programs. These initiatives rely on local expertise and commitment, which are crucial for effectively managing and preserving forest ecosystems. The *t*-statistics and *p*-values support the loadings by providing statistical evidence of the significance of these relationships. A *t*-statistic exceeding the critical value and a *p*-value below the significance threshold of 0.05 indicate a statistically significant relationship, strengthening the empirical basis of the SEM constructs.

Table 5 presents a comprehensive statistical evaluation of the relationships explored in the SEM analysis. It focuses on the significance of the paths between different variables, specifically the path coefficients that indicate the strength and direction of the relationships within the model. The *t*-statistics and *p*-values are used to determine the significance of these relationships. Upon examining the path coefficients, it becomes clear that certain paths within the model are particularly noteworthy due to their statistical significance. For example, the negative coefficient for the relationship between "adaptive programs" and "willingness to adapt" is particularly intriguing. It suggests that greater involvement in adaptive programs may paradoxically result in a reduced willingness to adapt. Conversely, a positive and statistically significant relationship between "attitude" and "sustainable tourist programs" indicates that having a positive attitude towards forest conservation is likely to enhance support for sustainable tourism initiatives.

Table 5
Path coefficients, indirect, and total effects in SEM.

Path	Original sample	Sample mean	Standard deviation	*t*-statistics	*p*-values
Path coefficients					
Adaptive programs → willingness to adapt	−0.015	−0.015	0.005	3.049	0.002
Attitude → sustainable tourist programs	0.119	0.119	0.025	4.684	<0.001
Attitude → willingness to adapt	−0.030	−0.030	0.019	1.628	0.104
Sociodemographic → adaptive programs	0.026	0.026	0.057	0.451	0.652
Sociodemographic → sustainable tourist programs	0.005	0.005	0.011	0.439	0.660
Sociodemographic → willingness to adapt	0.002	0.002	0.005	0.397	0.691
indirect effects					
Adaptive programs → willingness to adapt	−0.015	−0.015	0.005	3.049	0.002
Attitude → sustainable tourist programs	0.119	0.119	0.025	4.684	<0.001
Attitude → willingness to adapt	−0.030	−0.030	0.019	1.628	0.104
Sociodemographic → adaptive programs	0.026	0.026	0.057	0.451	0.652
Sociodemographic → sustainable tourist programs	0.005	0.005	0.011	0.439	0.660
Sociodemographic → willingness to adapt	0.002	0.002	0.005	0.397	0.691
total effects					
Adaptive programs → sustainable tourist programs	0.187	0.187	0.038	4.951	<0.001
Adaptive programs → willingness to adapt	−0.047	−0.047	0.029	1.647	0.100
Attitude → adaptive programs	0.635	0.634	0.033	19.176	<0.001
Attitude → sustainable tourist programs	0.119	0.119	0.025	4.684	<0.001
Attitude → willingness to adapt	0.045	0.044	0.021	2.109	0.035
Sociodemographic → adaptive programs	0.026	0.026	0.057	0.451	0.652
Sociodemographic → attitude	0.041	0.041	0.090	0.452	0.651
Sociodemographic → sustainable tourist programs	0.005	0.005	0.011	0.439	0.660
Sociodemographic → willingness to adapt	0.211	0.210	0.042	4.965	<0.001
Sustainable tourist programs → willingness to adapt	−0.081	−0.082	0.021	3.879	<0.001

However, certain expected relationships do not hold statistical weight in this model. This is evidenced by the non-significant *p*-values for paths such as "attitude → willingness to adapt" and "sociodemographic → adaptive programs." This implies that while there may be an assumed relationship between these variables, the evidence does not support a strong or consistent connection across the sample studied. Significant indirect effects within the model are limited, suggesting a lesser degree of mediation between constructs than expected. This is exemplified by paths like "adaptive programs → willingness to adapt," which, despite their significance, are not as influential as direct relationships. The total effects, which consider both direct and indirect impacts, reveal the overall influence of certain variables within the SEM framework. In this regard, the prominence of "attitude → adaptive programs" suggests that community attitudes play a crucial role in determining engagement in adaptive programs, more so than demographic factors alone.

4. Discussion

The results of our SEM analysis provide insightful findings on the complex relationship between sociodemographic factors, attitudes, adaptive programs, and willingness to adapt in the context of sustainable tourism and forest management. The following discussions compare our findings with previous studies to position them within the broader scope of environmental and tourism research. Our SEM analysis shows that sociodemographic factors such as marital status, income, and age have varying degrees of influence on attitudes towards forest management and sustainable tourism. Interestingly, these factors do not significantly predict individuals' willingness to adapt. This aligns with findings from the literature, where demographic variables often influence environmental attitudes but do not necessarily translate into behavioral intentions or adaptive actions (Demski et al., 2017; Milfont & Duckitt, 2010; Spence et al., 2011; Suryawan & Lee, 2025; Yang, Lee, & Suryawan, 2025). In the case of the Komodo district, it is plausible that while the local community recognizes the importance of forest conservation and sustainable tourism, this acknowledgment does not directly compel them to adapt to related programs.

Regarding attitudes, our findings indicate that a positive stance towards forest management is crucial for encouraging participation in adaptive programs. This is consistent with studies that emphasize the role of environmental attitudes in promoting conservation behavior (Barata et al., 2017; Janmaimool & Khajohnmanee, 2019). The significance of this relationship underscores the importance of fostering positive attitudes to enhance community engagement in adaptive forest management practices (Fernandez-Gimenez et al., 2008). While statistically significant, the path from adaptive programs to willingness to adapt is negative. This could be interpreted in several ways. It may reflect a saturation point, where those heavily involved in adaptive programs feel they have already adapted sufficiently and thus exhibit less willingness to change further. This observation is consistent with studies that have reported diminishing returns in behavior change when individuals repeatedly engage in specific practices (Ren et al., 2022). It indicates a complex interplay between program involvement and the perception of the need for further adaptation. On the other hand, the strong positive effect of attitudes on participation in sustainable tourist programs underscores the pivotal role that individual perceptions play in supporting sustainable initiatives. This finding implies that nurturing positive attitudes towards conservation and sustainable practices among residents can directly contribute to the success of such programs in forest-rich regions (Ihemezie et al., 2021). Considering the total effects, we see a comprehensive picture of the interrelationships at play. Some variables exert more influence than others, with attitudes standing out as a critical predictor of participation in adaptive programs and sustainable tourism initiatives.

Contrastingly, the non-significant *p*-values for specific paths suggest areas where our study diverges from previous research. For example, unlike the findings that suggest a direct link between sociodemographic factors and conservation behaviors (Nguyen & Jones, 2022; Takahashi et al., 2018), our study does not find such a relationship statistically significant. Furthermore, the lack of significant mediation effects, as expected, highlights the potential need for more targeted interventions. This is particularly relevant for adaptive programs, where additional factors not captured in the study may influence the relationship between attitudes and willingness to adapt. This gap allows future research to explore other variables that could influence this mediation effect (He et al., 2019; Sabbir & Taufique, 2022), arguing for including broader contextual and psychological factors in environmental behavior models.

In response to the pressing need for forest protection in areas like the Komodo habitat, where conservation efforts must be balanced with the growth of tourism, a nuanced approach is essential. A key strategy involves the engagement and education of local communities, providing them with knowledge and resources to understand their critical role in protecting their environment. Residents can become proactive guardians of their natural heritage by implementing programs focusing on the ecological and economic advantages of maintaining biodiversity. To ensure the success of these endeavors, capacity building is crucial. Training local forest managers and community leaders in cutting-edge conservation techniques will equip them with the skills to respond to environmental challenges effectively. Coupled with this training, economic incentives could be offered to those actively engaged in habitat protection, reinforcing the link between conservation activities and tangible benefits. Finally, empowering local communities through community-based monitoring systems could transform residents into critical stakeholders in the conservation process. This would allow for real-time monitoring of habitat conditions and foster a sense of ownership and responsibility among community members. Together, these integrated policy recommendations, underpinned by a collaborative and inclusive framework, can significantly contribute to protecting the Komodo habitat while supporting the sustainable growth of tourism.

Our analysis reveals a clear connection between tourism, income, and the motivation of local communities to engage in conservation efforts (Fig. 4). It emphasizes how the economic benefits derived from tourism can drive behaviors that prioritize conservation. Komodo National Park has experienced significant growth in tourism, with visitor numbers increasing from 44,492 in 2010 to 300,488 in 2023, resulting in substantial economic benefits for local communities (Suadnyana & Ardin, 2024). These

benefits include expanded employment opportunities in tourism-related activities such as guiding, hospitality, and transportation services, leading to improved local incomes and livelihoods. As tourism has flourished, the financial gains have heightened local awareness of the economic importance of preserving the park's natural resources. Research has shown that financial incentives from tourism can effectively increase local support for conservation initiatives (Marchant, 2021; Rampheri & Dube, 2021; Shang et al., 2023), indicating that economic incentives play a significant role in motivating conservation behavior.

In Komodo, individuals who directly benefit from tourism are more likely to engage in conservation activities such as beach clean-ups, forest restoration projects, and community-led environmental programs. For instance, tour guides and hotel staff, who depend on the continuous flow of tourists (Buzova et al., 2023; Fu et al., 2021), recognize that their income is directly tied to the health of the local ecosystem (Suryawan et al., 2024). This realization compels them to actively participate in efforts to maintain and protect the environment. The economic benefits from tourism not only provide a tangible incentive for conservation but also foster a sense of responsibility and stewardship among local residents. As they witness the positive impact of tourism on their economic well-being, they become more invested in ensuring the sustainability of the natural resources that attract visitors. This dynamic creates a virtuous cycle where economic gains from tourism reinforce conservation efforts, which, in turn, helps sustain tourism. Similar findings have been observed in other regions where economic benefits from tourism have prompted local communities to adopt more sustainable and conservation-oriented practices (Li et al., 2019; Nepal et al., 2022; Silva & Khatiwada, 2014). Thus, the economic benefits derived from tourism in Komodo National Park serve as a crucial driving force behind conservation-oriented behaviors, demonstrating that aligning financial incentives with environmental sustainability can effectively engage local communities in conservation efforts.

Integrating local communities into park operations is vital for the effective management and protection of both terrestrial and marine parks in Indonesia (Table 6). Strategies for fostering conservation efforts should include economic incentives such as creating sustainable tourism jobs, sharing tourism revenue, and providing financial rewards for community-led conservation initiatives. Participatory approaches, where locals are involved in decision-making processes, are crucial for ensuring that conservation strategies align with the community's needs and values (Armitage et al., 2020; Nguyen et al., 2022). Training programs for local residents in advanced conservation techniques and sustainable tourism practices can enhance their capacity and empower them to take an active role in protecting their environment. Establishing community-based monitoring systems can foster a sense of ownership and responsibility (Muhamad Khair et al., 2020), allowing locals to track the health of their ecosystems and respond quickly to threats. Addressing the challenges of managing and protecting parks in Indonesia requires a collaborative effort that combines traditional knowledge with modern conservation practices, ensuring the long-term sustainability of these critical natural areas. By integrating local communities into park operations, we can establish a sustainable model that benefits both the environment and the people who depend on it.

4.1. Implication for management

These findings have important policy implications, highlighting the need to focus on enhancing community involvement and education, providing economic incentives for active participation in conservation activities, and ensuring that conservation and tourism policies are flexible and adaptable. Practitioners can implement specific action-oriented recommendations, such as offering training programs for local forest managers and community leaders in advanced conservation techniques, developing

Table 6
Recommendation area for for the effective management and protection of both terrestrial and marine parks.

Recommendation area	Specific recommendations
Community engagement	Involve local communities in decision-making processes to ensure conservation strategies align with local values and priorities
	Establish regular community meetings and forums for open dialogue and feedback on park management and conservation efforts
	Develop educational programs and workshops to raise awareness about the ecological and economic benefits of conservation
	Create community-based monitoring systems to empower locals to track ecosystem health and respond to threats
Tourism-related income opportunities	Create job opportunities in sustainable tourism, such as eco-guides, hospitality staff, and conservation project workers
	Ensure that a portion of tourism revenue is reinvested into the local economy and community development projects
	Develop local handicrafts and products for tourists to support small businesses and increase income
	Offer training programs in sustainable tourism practices and advanced conservation techniques to enhance local capacity and employability
Adaptive management programs	Implement flexible and adaptive conservation programs that can be adjusted based on ongoing feedback and changing environmental conditions
	Provide financial incentives for community-led conservation initiatives, such as habitat restoration projects and anti-poaching patrols
	Integrate traditional knowledge with modern conservation practices to create culturally appropriate and effective management strategies
	Foster collaboration between local authorities, NGOs, and international organizations to support comprehensive and inclusive conservation efforts

educational campaigns to raise awareness about the ecological and economic benefits of conservation, and establishing community-based monitoring systems to empower residents and foster a sense of ownership and responsibility. Additionally, creating job opportunities related to sustainable tourism and reinvesting a portion of tourism revenue back into the local economy can strengthen the connection between tourism and environmental stewardship. Our study provides valuable insights for enhancing the effectiveness of adaptive forest management programs and sustainable tourism initiatives, laying the groundwork for future research into these dynamics and contributing to a broader understanding of how to effectively engage communities in conservation efforts.

Community engagement is crucial for the implementation of sustainable tourism practices in protected areas like Komodo National Park. Involving local residents in the planning and management of tourism fosters a sense of ownership and responsibility towards their natural environment. It is essential to integrate the community into decision-making processes to ensure that tourism development aligns with local values and priorities. Effective community engagement can lead to more sustainable and culturally appropriate tourism practices, enhancing the conservation of the park while providing economic benefits to the local population. By empowering local communities and involving them in the stewardship of their natural resources, sustainable tourism can be a powerful tool for both conservation and economic development in Komodo National Park.

5. Conclusions

In the Komodo district, where majestic Komodo dragons roam and tourists flock to witness this natural spectacle, our study provides critical insights into the delicate balance of habitat conservation and sustainable tourism growth. Using SEM, we explored the intricate relationships between local community traits, attitudes towards environmental conservation, participation in adaptive management programs, and willingness to engage in sustainable tourism activities. Our findings highlight the profound impact of sociodemographic factors such as age, marital status, and income on conservation attitudes, significantly shaping how individuals in the Komodo district interact with their environment and respond to conservation efforts. Positive attitudes towards preserving forests and beaches encourage active participation in adaptive programs, which are essential for balancing tourism with conservation. The community's willingness to adapt emerged as a crucial element, influencing both their participation in sustainable practices and the connection between sociodemographic factors and engagement in sustainable tourism programs. Although we identified the key sociodemographic factors influencing conservation attitudes, our study did not find significant direct links between these factors and the willingness to adapt, indicating a need for further research to explore other potential influences on adaptive behavior. These findings have significant policy implications, suggesting that policies should focus on enhancing community involvement and education, providing economic incentives for active participation in conservation activities, and ensuring that conservation and tourism policies are flexible and adaptive. Training local forest managers and community leaders in advanced conservation techniques and empowering local communities through community-based monitoring systems can also foster a sense of ownership and responsibility. Our study provides valuable insights for enhancing the effectiveness of adaptive forest management programs and sustainable tourism initiatives, setting a foundation for future studies to further investigate these dynamics and contributing to a broader understanding of how to effectively engage communities in conservation efforts.

Ethical statement

Ethical approval for this study was obtained from the Department of Natural Resources and Environmental Studies, National Dong Hwa University (NDHU), and through a local government research permit, as confirmed by approval number 503.707/IDPMPTSP/096/XI/2023. Additional permissions were secured from relevant authorities in the Komodo Subdistrict, ensuring full compliance with both local and international ethical standards for field research involving human participants.

Prior to participation, all community respondents were fully informed about the purpose, scope, intended data use, and their rights as participants. Written informed consent was obtained from each participant, confirming that their involvement was entirely voluntary and free of coercion. At the beginning of each survey and questionnaire, participants were presented with an ethical statement outlining confidentiality, anonymity, and their right to withdraw from the study at any point without consequence.

CRediT authorship contribution statement

Imelda Masni Juniaty Sianipar: Resources, Methodology, Funding acquisition, Data curation, Project administration, Investigation, Formal analysis, Conceptualization. **Chun-Hung Lee:** Validation, Supervision. **Doo-Chul Kim:** Supervision, Writing – review & editing. **I. Wayan Koko Suryawan:** Writing – original draft, Supervision, Funding acquisition, Data curation, Writing – review & editing, Visualization, Methodology, Formal analysis, Conceptualization.

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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