# ISLAND COMMUNITY AWARENESS OF ECOSYSTEM SERVICES IN THE WORLD BIOSPHERE RESERVE, CU LAO CHAM, VIETNAM

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**Abstract.** Like many places around the world, the livelihoods of island communities in the Cu Lao Cham World Biosphere Reserve depend directly on ecosystem services. Understanding how people perceive these services can benefit natural resource planning and management. In this study, we used both qualitative and quantitative research methods to examine ecosystem services on Cu Lao Cham Island, Vietnam. We conducted 105 household interviews, 3 group discussions, and 6 in-depth interviews on the island from March to May 2022. We assessed a list of 26 ecosystem services from the Millennium Ecosystem Assessment Framework using principal component analysis (PCA) and a general linear model. The findings showed that 21 ecosystem services were evaluated by the residents. Services that were especially valued included environmental education, fresh water supply, and recreation. PCA analysis revealed that all ecosystem services are interrelated, with agriculture and livestock being the services that most significantly impact others. This research has highlighted people's perceptions of ecosystem services and their interactions. It provides valuable information for management agencies to consider when planning policies related to nature conservation and sustainable development)
**Keywords:** *ES, PCA, perception, Cu Lao Cham*

## Introduction

Ecosystem services (ES) are the various benefits that people derive from nature. They illustrate humanity's dependence on natural resources (Kadykalo, 2021) and help to link natural and human systems (Costanza et al., 2014; Vihervaara et al., 2010). The relationships between local people and natural forests are diverse (Soe and Yeo-chang, 2019). This connection forms the basis for developing policies and strategies that benefit all parties, influencing decision-making in the trade-off between conservation and social benefits to improve people's livelihoods (Lhoest et al., 2019; Truax and Gagnon, 2019).

There are many studies on ecosystem services around the world (Aneseyee et al., 2019; De Groot et al., 2010). In particular, ecosystem service valuation has advanced over the last two decades (Aneseyee et al., 2019; Gashaw et al., 2018). Numerous studies have explored how different ecosystem services are valued by communities. For instance, research has found that local communities often place high value on provisioning services like clean water and food (Feld et al., 2009). Cultural services, such as recreational and spiritual values, are also recognized for their significant impact


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on well-being (Chan et al., 2012). For forest ecosystems, research focuses on measures, policies, decision-making processes and issues related to forest resource developments (Hailemariam et al., 2016). However, general approaches and specific assessments of ecosystem services often do not take into account local people's understanding and perceptions of conservation in their areas (Fagerholm et al., 2012). Consequently, the social values and benefits of ecosystem services have not yet been fully demonstrated (Schmidt et al., 2016; Smith and Sullivan, 2014). Inversely, realization of the perceptions, understanding, and values of local communities is vital for accurate conservation of natural resources.

Local community awareness of ecosystem services (ES) is not uniform. It can be influenced by geographical and cultural contexts, lifestyles, ethical beliefs, and other values related to resources (Casado-arzuaga et al., 2013). Currently, social aspects in ES assessment are being considered more thoroughly (Acharya and Cockfield, 2019; Lhoest et al., 2019). To manage ecosystems sustainably, it is essential to integrate social considerations and qualitative assessments of how ecosystem services benefit local people (Muhamad et al., 2013; Braat and De Groot, 2012; MEA, 2005). Therefore, understanding local community awareness of ES is crucial, as it helps in the effective conservation of forest ecosystems (Schmid, 2014). People need to understand the ecosystems from which they benefit, the mechanisms for sharing these benefits, and to participate in developing appropriate conservation policies.

Although scientific research into the perception and utility of ecosystem services (ES) among local people is important, research on people's awareness of ES in Cu Lao Cham is still lacking. The forests in Cu Lao Cham play a crucial role in conservation and provide a variety of goods and services, including timber, food, firewood, livestock grazing, and other ecological benefits (Liping et al., 2018; Roces-díaz et al., 2018). The lives of people living along the forest edge also significantly impact the forest. Thus, understanding the relationship between humans and the environment requires scientific research into the ES that people obtain, the trade-offs involved, and the existing services (Mengist et al., 2019; Mengist and Soromessa, 2019).

Therefore, the objectives of the study are: (i) to understand the current status of ecosystem services in the region; (ii) to learn about the important ecosystem services for households; and (iii) to gather people's views on sustainable management and protection solutions for ecosystem services. By combining household interviews with quantitative surveys, this study provides both broad patterns and in-depth insights into how local people perceive and value ecosystem services.

## Materials and methods

### *Study area*

This study was conducted in three villages: Bai Huong, Bai Lang, and Bai Ong within Tan Hiep Commune, which is located in the buffer zone of the Cu Lao Cham Biosphere Reserve (CLC BR) (*Fig. 1*). The local population primarily earns a living through fishing, tourism, and the collection, processing, and sale of medicinal plants. The entire commune has 611 households with a total of 1833 people.

Cu Lao Cham is a marine protected area consisting of an archipelago with eight islands, the largest of which is Cu Lao Cham itself, covering an area of 1317 ha. The biodiversity of the Cu Lao Cham archipelago is exceptionally rich. Research has identified 947 species of organisms living in the waters around the islands, including:


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178 species of marine fish on the coral reefs, belonging to 80 genera and 32 families; 122 species of seaweeds; 215 species of phytoplankton; 87 species of zooplankton; 134 species of corals, belonging to 40 genera; 144 species of mollusks; 25 species of crustaceans; 21 species of echinoderms; and 21 species of worms. The islands' biodiversity is also evident in their mountainous areas, which feature tropical rainforest ecosystems significantly influenced by monsoons. Coral reefs, with hard corals accounting for 17.3-24.9% and soft corals 13.5-20.7%, are representative of tropical seas and are particularly notable in the Cu Lao Cham region.

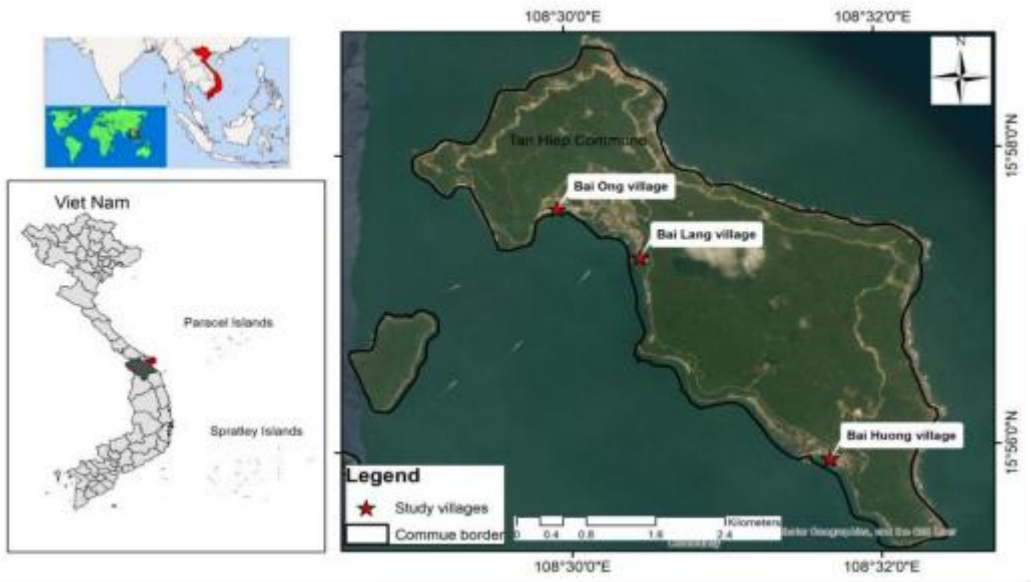


***Figure 1.*** *Map of the study site*

Cu Lao Cham in Vietnam is one of the few islands maintaining a relatively large vegetation cover of about 60-70%. The largest area is covered by tropical broad-leaved evergreen forest, which is predominantly found at elevations between 50 and 500 m. This forest is home to many valuable timber trees and other resources such as rattans, medicinal plants, and construction materials. Cu Lao Cham is also strategically located at an estuary, serving as a storm shelter and stopping point for international merchant ships. This port played a role in the development of the ancient city of Hoi An, which has been recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a World Cultural Heritage site, with over 1360 historical and religious relics and landmarks. The island is home to 2900 residents, with many engaged in fishing and bird nest harvesting, while a smaller number grow rice and vegetables, engage in small trade, and provide tourism services.

### *Research methods*

To fully understand the multifaceted nature of community perceptions and their implications, a mixed-methods approach is essential. This research utilizes both qualitative and quantitative methods to provide a comprehensive analysis of the subject. Quantitative methods offer statistical rigor and generalizability, enabling us to quantify patterns and test hypotheses on a larger scale. In contrast, qualitative methods provide


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depth and context, revealing the underlying reasons behind these patterns and offering a richer, more nuanced understanding of individual and collective experiences.

Combining these approaches allows us to capture both the breadth and depth of the research topic. Quantitative data will identify trends and provide a broad overview, while qualitative insights will explore the contextual and subjective aspects of community perceptions. This integrative approach ensures a more complete picture, enhancing the validity and applicability of the findings. By synthesizing the strengths of both methodologies, this research aims to deliver a well-rounded analysis that is both statistically significant and contextually meaningful.

### *Determine ecosystem services (ES)*

Ecosystem services (ES) are the conditions and processes of natural ecosystems that maintain and satisfy human requirements. They support the production of ecosystem goods and encompass around 25 functions of ES, categorized into provisioning, regulating, and cultural services according to the Millennium Ecosystem Assessment Framework (MEA, 2005). However, this research focuses on approximately 19 functions of ES specific to Cu Lao Cham Island.

### *Select sample size*

This study employs a non-random sampling method, chosen based on the research team's experience and understanding in implementing Knowledge, Attitude, and Practices (KAP) surveys, which provide both quantitative and qualitative information through predefined questions formatted in standardized questionnaires.

The survey subjects were selected using a combination of quota sampling and convenience sampling. The criteria for selecting households included: (1) being of working age, (2) engaging in activities related to forest use, exploitation, and protection management, (3) gender, (4) having occupations or livelihoods related to forest resource use, and (5) representing both well-off and poor households. This approach is similar to stratified random sampling.

The sample size formula $n = N / 1 + N \times e^2$ was used to determine the total number of respondents, where n is the sample size, N is the population size, and e is the level of precision (Morse, 2000). Based on this formula, a total sample size of 105 respondents was determined to provide ± 9% accuracy from a total population of 611 households, achieving a 95% statistical accuracy.

### *Data collection*

Before conducting interviews with households, the research team held a working session with the Marine Protected Area Management Board and local authorities at the commune level to gain an overview of the socio-economic conditions of people living around the natural reserve. Based on this overview, the research team selected three villages on Cu Lao Cham Island: Bai Ong, Bai Lang and Bai Huong as research locations.

A semi-structured questionnaire was used to interview 105 households on Cu Lao Cham. The list of households in each village was obtained from the village heads. To calculate the distance coefficient k, we used the formula: k = N/n (N is the number of individuals in the population (N = 611), n is the sample size (n = 105)). The first household was selected randomly, and subsequent households were selected by adding k to the previous number. The $105^{th}$ research object has the serial number (105-1)k.


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Household interviews provided a direct and detailed understanding of how local people perceive and utilize ecosystem services. These interviews revealed insights into the values, benefits, and dependencies associated with their surrounding environment. This approach ensured that the data reflected local knowledge and experiences, which might not be captured through broader surveys.

Data were collected through face-to-face interviews and group discussions using the questionnaires. The study objectives and information security issues were explained to all respondents. The respondents were primarily engaged in agriculture and tourism services. They rated the importance of ecosystem services using a Likert scale from 0 to 5, where 0 = ”Don’t know,” 1 = ”Very little important,” 2 = ”Little important,” 3 = ”Moderately important,” 4 = ”Highly important,” and 5 = ”Very highly important,” based on their significance for local livelihoods.

The questionnaire was reviewed by experts in ecology, environmental science, and social science to ensure it covered all relevant aspects of ecosystem services and was appropriate for the target population. It was tested with 10 households and revised based on feedback before full implementation. Exploratory Factor Analysis (EFA) was conducted to identify underlying dimensions or constructs measured by the questionnaire items, confirming that items grouped together as expected. Internal consistency was assessed using Cronbach’s alpha, with a value above 0.7 generally considered acceptable. The results of the pilot test and feedback were analyzed to make necessary revisions to the questionnaire, such as clarifying questions or modifying the scale.

In addition, three focus group discussions (FGDs) were conducted in the three villages. Participants for the focus groups were selected based on specific criteria to ensure relevance and representativeness, including age, gender, socioeconomic status, and other relevant factors. Each FGD included representatives from the village head, the farmers’ association, the women’s association, the youth union, and the veterans’ association. Each group consisted of 8–10 people and lasted around 30 min.

The structure of the focus group discussions was designed to facilitate a comprehensive exploration of the topic while encouraging open and in-depth conversation. Each session began with a brief introduction explaining the purpose of the discussion, the importance of the participants’ insights, and the confidentiality of their responses. Initial questions were designed to ease participants into the conversation and build comfort.

A series of open-ended questions guided the main part of the discussion, crafted to elicit detailed responses about participants’ perceptions, experiences, and attitudes related to ecosystem services. Moderators used probing questions to delve deeper into specific points of interest or clarify ambiguous responses. The discussion concluded with a summary of key points and an opportunity for participants to add any final thoughts or comments. Each FGD involved two researchers: one was responsible for moderation, and the other took notes on A0 paper. The moderator maintained a neutral stance, avoiding any influence on the participants’ responses. Their role was to facilitate the discussion, ensure that all voices were heard, and keep the conversation focused on the topic. Moderators actively encouraged participation from all group members, managing dynamics to ensure that dominant voices did not overshadow quieter participants. Techniques included asking direct questions to quieter members and creating an environment where everyone felt comfortable sharing their views. Moderators were skilled in managing group dynamics, addressing any conflicts or disagreements respectfully, and ensuring that discussions remained constructive and relevant.


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Discussions were audio-recorded with participants' consent to ensure accurate capture of the conversation. Detailed notes were also taken to document key points, non-verbal cues, and group interactions. The discussions explored important natural resources for local livelihoods, factors affecting ecosystem services, and the main changes over the past few decades.

### *In-depth interviews with key leaders*

During March to May 2022, in-depth interviews were conducted with representatives from the Cu Lao Cham Biosphere Reserve Management Board, the Tourism Information Center, village heads from Bai Ong, Bai Lang, Bai Huong, and members of the Tan Hiep Commune People's Committee. Key questions in these interviews focused on the current state of ecosystem service use. All six staff members, serving as key informants, were consulted to enhance our understanding of forest and marine ecosystem services in the Biosphere Reserve.

### *Analyze data*

The data collected from survey were analyzed using SPSS (Statistical Package for Social Science, version 20) (IBM, 2011) and the "corr, FactoMineR, ggcorrplot, ggplot2, factoextra" packages in R 4.4.0 (Hue et al., 2018; Rosseel, 2012). To determine which ecosystem services affect others in the lives of people on Cu Lao Cham Island, Principal Component Analysis (PCA) was employed after identifying the ecosystem services from interview participants. PCA is a powerful tool for dimensionality reduction, particularly useful in ecology for identifying key ecosystem services and their interrelationships.

Ecosystem services datasets often involve many variables that can be challenging to interpret individually. PCA reduces these variables into a smaller set of principal components that capture the most significant variance in the data. This simplification aids in understanding and visualizing core patterns and relationships without losing critical information. PCA helps identify which variables contribute most to the variance in the data, revealing the most influential or critical ecosystem services or factors. Additionally, PCA uncovers hidden interrelationships between different ecosystem services, with principal components often representing underlying patterns that combine multiple original variables. It provides a means to visualize complex, high-dimensional data effectively. Dimensional data were reduced to a lower-dimensional space (usually two or three dimensions) using Principal Component Analysis (PCA). This visualization aids in understanding the distribution and clustering of different ecosystem services and their relationships. Before applying PCA, the data were checked for missing values and outliers, and it was ensured that all variables were measured on a similar scale or were comparable. Scatter plots and correlation matrices were used to assess the presence of linear relationships. For non-linear relationships, transformations or alternative methods were applied.

The Kaiser–Meyer–Olkin (K–M–O) measure and the Bartlett's Test of Sphericity were conducted to evaluate the suitability of the data for factor analysis. The K–M–O value needs to be above 0.5 for the data to be considered suitable for PCA; otherwise, the data are not applicable (Parinet et al., 2004). The Bartlett's Test of Sphericity assesses whether the correlation matrix is an identity matrix and whether the data is suitable for factor analysis (Antonio Cano-Orellana, 2015). The values from these tests


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indicate whether the variables are appropriate for inclusion in PCA (Regmi and Johnson, 2019).

## Results

### *Socio-economic characteristics of survey respondents*

Of the 105 interviewees, 75.5% were female and 24.5% were male. The age group of 36-60 years accounted for the highest proportion, 68.6%. The youngest respondent was 19 years old, while the oldest was 89 years old. Most respondents had only completed primary school (83.8%) and had basic literacy skills. The majority of the interviewees had been born and raised in the area for more than 30 years (88.6%). Descriptive details for the interview participants are provided in *Table 1*.

***Table 1.*** *Characteristics of survey respondents*

| Social-economic situation | Categories | Frequency (n) | Proportion (%) |
|---|---|---|---|
| Gender | Male | 25 | 24.5 |
| | Female | 80 | 75.5 |
| Age | <20 | 1 | 1 |
| | 21-35 | 10 | 9.5 |
| | 36-60 | 72 | 68.6 |
| | >60 | 22 | 21 |
| Education | Lower secondary | 22 | 20.95 |
| | Upper secondary | 71 | 67.62 |
| | University/college | 6 | 5.71 |
| | Illiterate | 12 | 11.43 |
| Years of stay in the commune | Under 10 | 2 | 1.9 |
| | 10-20 | 2 | 3.8 |
| | 21-30 | 15 | 13.2 |
| | Above 30 | 88 | 83 |
| Income | Well-off | 25 | 23.8 |
| | Medium | 75 | 71.4 |
| | Poor/Near poor | 5 | 4.8 |
| Main livelihood | Fishing | 36 | 34 |
| | Services | 38 | 35.8 |
| | Homestay | 20 | 18.9 |
| | Governmental sector | 11 | 11.3 |

In Cu Lao Cham, the population primarily consists of Kinh people. Most of the interviewed households are engaged in fishing and tourism-related livelihoods.

### *Ecosystem services considered important by the community*

Ecosystem services were recognized and described by community members as important (*Table 2*). These services are categorized according to the Millennium Ecosystem Assessment (MEA) and The Economics of Ecosystems and Biodiversity (TEEB) frameworks.


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***Table 2.*** *Importance of ecosystem service*

| Ecosytem category | Identified ES | Indicators of ES | Perceived importance (mean) | Std. deviation |
|---|---|---|---|---|
| Providing services | Agriculture | Rice, vegetables, fruit trees | 3.42 | 0.949 |
| | Animal husbandry | Pigs, cows, goats, chickens | 1.09 | 1.510 |
| | Collecting forest products for daily use | Firewood, mushrooms, forest fruits, medicinal plants, stream fish, small animals, honey, stone crabs (*Gecarcoidea lalandii*) | 2.15 | 1.680 |
| | None timber forest product (for selling) | Honey, medicinal plants, and sycamore bark make hammocks | 1.25 | 1.938 |
| | Fresh water | Drinking water and agricultural irrigation water | 4.15 | 0.886 |
| | Energy | Hydropower, solar power | 0 | 0 |
| | Timber | Wood for houses and boats building | 0 | 0 |
| | Sand | Building a house using sea sand; the sand is placed on the roof to prevent it from being blown off during strong storms | 2.25 | 1.604 |
| Regulating services | Pollination | Pollinate plants | 0 | 0 |
| | Air regulation | Filters air through trees, vegetation, seas, and lakes | 3.66 | 0.898 |
| | Climate regulation | Cooling, absorbing CO2, controlling rainfall through forests, vegetation, seas, lakes | 3.96 | 0.831 |
| | Water purification | Water quality, clear or cloudy, especially during the rainy season | 3.53 | .639 |
| | Erosion regulation and protect land | Reduce the speed of flood water flowing from the forest to people's houses, reducing soil erosion | 3.26 | .738 |
| | Disease regulation | Reduce diseases in humans and pets | .23 | .933 |
| Cultural services | Recreation and tourism | Ecotourism (see coral reefs, scuba diving, go on a basket boat at sea, squid fishing at night with indigenous people) | 3.38 | 2.021 |
| | Entertainment | Beautiful scenery, forests, beaches, rocks | 4.13 | .482 |
| | Aesthetic value | Paintings, literature, photos about Cu Lao Cham | .30 | .952 |
| | Environmental education | Environmental education activities on Cu Lao Cham, guests are not allowed to bring plastic waste to the island | 4.2 | .409 |
| | Indigenous knowledge | Experience in exploiting bird's nest, knowledge of seafood fishing, knowledge of stone crab exploitation | 1.45 | 1.957 |
| | Cultural identity | Basket boat swimming, Cau Ngu festival, death anniversary of the bird's nest craft | 3.53 | 1.137 |
| | Spiritual value | Pagoda, temple | 3.57 | 0.694 |


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Provisioning, regulating, and cultural services were universally recognized as important, including clean air, flood regulation, and spiritual significance. Nature has endowed Cu Lao Cham with both forest and marine ecosystems. The community has a strong interest in the sea, which includes coral reefs, tidal flats, seagrass beds, and beaches. This marine ecosystem is a principal source of income for the residents, who catch seafood for their own consumption and for sale to tourists.

The people of Cu Lao Cham are highly conscious of environmental hygiene and are the first island in Vietnam to officially reject plastic waste. Freshwater is also a significant concern for the community. In the special-use forest, residents primarily collect medicinal plants for daily use and for sale to tourists. Stone crab is a particularly valuable species in the forest. To prevent resource depletion, the government has established groups to educate and promote sustainable harvesting practices. All harvested crabs must be labeled as ecological products and bear anti-counterfeit stamps from the Ministry of Public Security before they can be sold. The benefits perceived by respondents include both tangible and intangible aspects.

The value of ecosystem services (ES) indicates that 10 out of 21 services are rated above average in importance. Specifically, some services have average scores greater than 4 (high importance), including environmental education ($\bar{x}$ = 4.2), fresh water ($\bar{x}$ = 4.15), and entertainment ($\bar{x}$ = 4.13), These services are considered the most important. The lowest-rated ES services are energy ($\bar{x}$ = 0), timber ($\bar{x}$ = 0), and pollination ($\bar{x}$ = 0). *Figure 2* displays the ranking results according to the Likert scale assigned importance values and the number of respondents (n = 105).

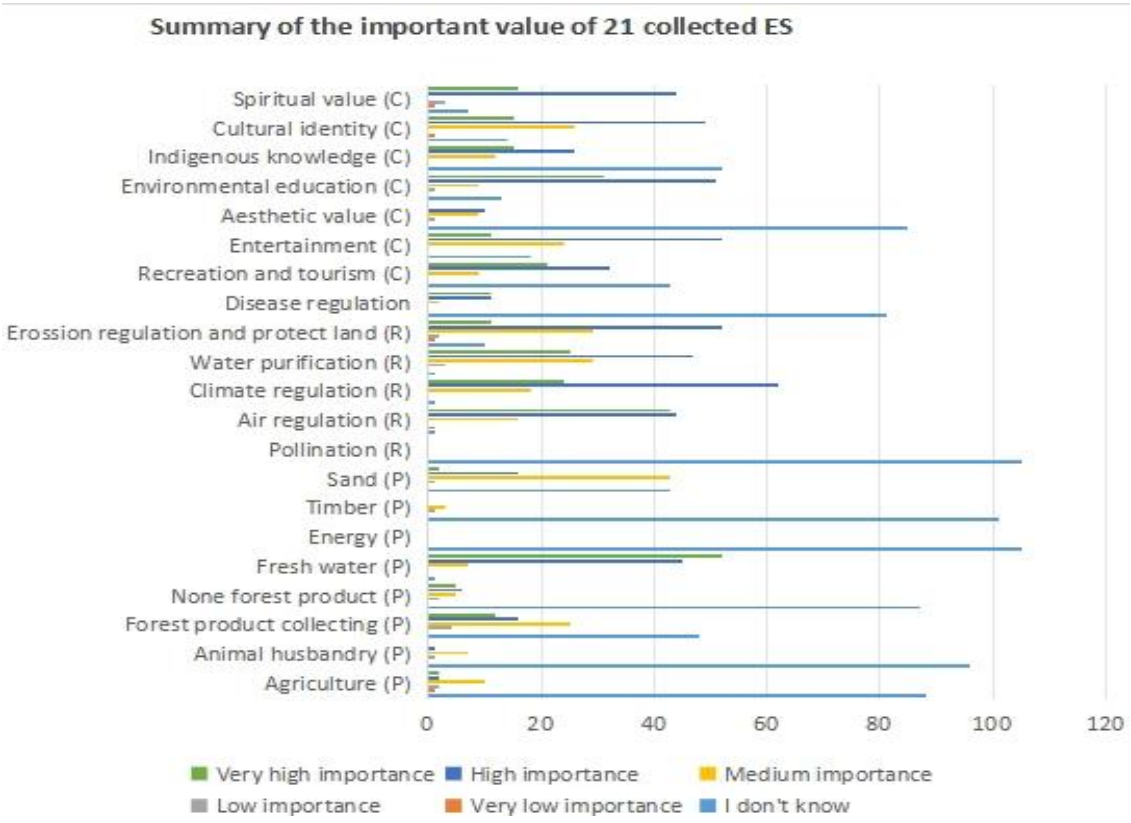


***Figure 2.*** *Summary of the importance of 21 selected ecosystem services for residents. P = provisioning service, R = regulating service, C = cultural service, S = supporting service; 105 household interviews*


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For household interviews, participants were asked to select the four most important ecosystem services for their family, with the following results (*Fig. 3*). Freshwater on the island is a major concern for residents. In the past, people obtained water from streams in the forest. Since 1976, after the establishment of a defense forest, the water source changed, and wells were drilled. Currently, 90% of residents use well water, which is often turbid and salty. Focus group discussions attribute the salinity to environmental changes, reduced groundwater levels, and seawater intrusion due to excessive well drilling. There is a current need to preserve the forest. Some households use water provided by the local government from the commune's island reservoir.

For Cu Lao Cham, both the marine and forest ecosystems are crucial. The forest ecosystem is valued for its water and air sources, erosion control, and the provision of medicinal plants, wild vegetables, and stone crabs. The marine ecosystem is important for providing food and supporting tourism. The most frequently chosen ecosystem services are: Freshwater (21%), Air Regulation (12%), Environmental Education (10%), Water Purification (9%), Climate Regulation (8%), Forest Product Collection (7%), and Spiritual Value (6%).

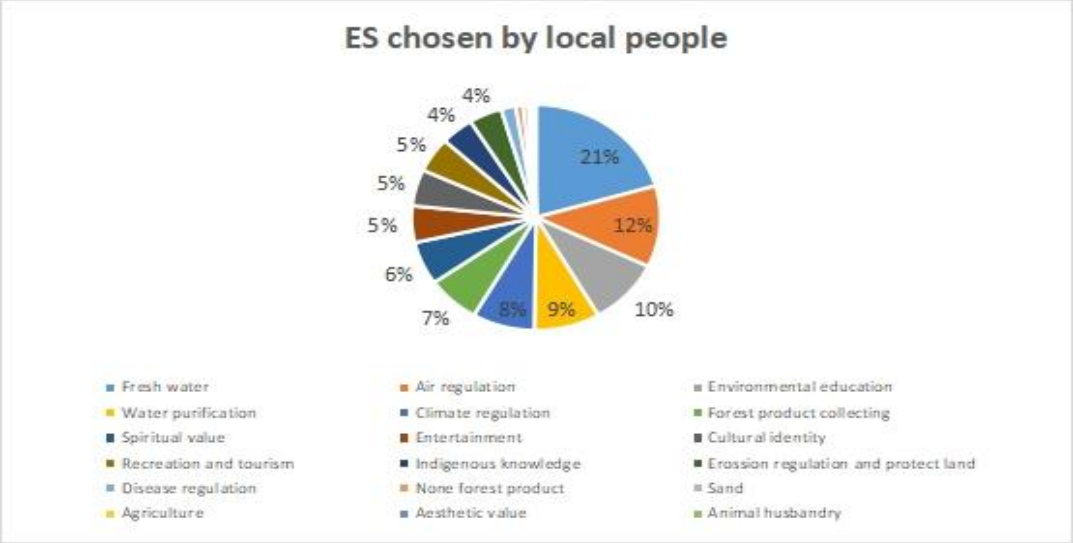


***Figure 3.*** *Number of people selecting important ecosystem services for their families*

### *Relationships among ecosystem services (ES)*

Relationships among ES are demonstrated through PCA (Principal Component Analysis). The validity of the latent variables was tested using components with Varimax rotation. In the initial test run, 2 out of 21 ecosystem services were eliminated (energy and pollination services), while 19 ecosystem services were retained, representing a combination of initial elements and described appropriately (*Fig. 4*). The two variables are positively correlated (with values closer to +1) or negatively correlated (with values closer to -1). The importance of ES is presented in *Table 3.*

From the analysis, we found that all 19 principal components were generated, corresponding to the number of variables in the data. Each component clarifies the total percentage of variance in the data. In the cumulative section, the variance explained by the first component is relatively low, at only 26.3%. However, the cumulative proportion of Variance explained by Components 1, 2, 3, and 4 accounts for nearly 68%


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of the total variance. This indicates that the first four principal components can accurately represent the data. To determine whether these first four components are truly meaningful, we examined how they relate to each column using the principal components (*Table 4*).

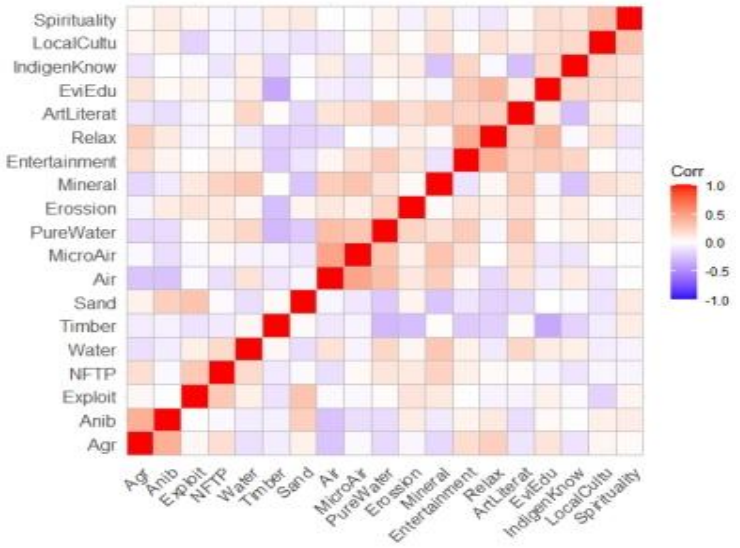


***Figure 4.*** *Description of ES*

***Table 3.*** *The importance of components*

Importance of components:

| | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Comp.9 | Comp.10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Standard deviation | 0.5840906 | 0.4884661 | 0.3783635 | 0.3719653 | 0.30503491 | 0.27418239 | 0.24025257 | 0.2267582 | 0.19592991 | 0.18686894 |
| Proportion of Variance | 0.2631635 | 0.1840492 | 0.1104291 | 0.1067259 | 0.07177352 | 0.05798882 | 0.04452473 | 0.0396635 | 0.02961193 | 0.02693639 |
| Cumulative Proportion | 0.2631635 | 0.4472127 | 0.5576418 | 0.6643677 | 0.73614126 | 0.79413008 | 0.83865481 | 0.8783183 | 0.90793023 | 0.93486662 |

| | Comp.11 | Comp.12 | Comp.13 | Comp.14 | Comp.15 | Comp.16 | Comp.17 | Comp.18 | Comp.19 |
|---|---|---|---|---|---|---|---|---|---|
| Standard deviation | 0.13725963 | 0.13138909 | 0.11841082 | 0.100466893 | 0.095955606 | 0.079125617 | 0.073878331 | 0.057391000 | 0 |
| Proportion of Variance | 0.01453285 | 0.01331631 | 0.01081553 | 0.007785941 | 0.007102412 | 0.004829469 | 0.004210167 | 0.002540696 | 0 |
| Cumulative Proportion | 0.94939947 | 0.96271578 | 0.97353131 | 0.981317255 | 0.988419667 | 0.993249136 | 0.997459304 | 1.000000000 | 1 |

***Table 4.*** *Loading matrix of the first four principal components*

| | Comp.1 | Comp.2 | Comp.3 | Comp.4 |
|---|---|---|---|---|
| Agr | 0.33673370 | 1.304428e-01 | 0.287926181 | 0.0436430690 |
| Anib | 0.35663166 | 1.481164e-02 | 0.088625619 | 0.0036311614 |
| Exploit | 0.05511380 | -1.319875e-01 | 0.153406689 | -0.4643602974 |
| NFTP | -0.03319130 | -2.629794e-02 | 0.387979717 | -0.2149020909 |
| Water | -0.21883501 | -3.238548e-02 | 0.068405363 | -0.0760562055 |
| Timber | 0.02959160 | -4.343757e-01 | 0.071078560 | 0.3481132193 |
| Sand | 0.27696222 | -2.514380e-01 | -0.092217115 | -0.3227050656 |
| Air | -0.40021265 | -4.681750e-02 | -0.234555851 | -0.1476574706 |
| MicroAir | -0.33156613 | -8.324382e-05 | 0.024904792 | 0.0040213908 |
| Purewater | -0.35769928 | 1.989635e-01 | -0.094281335 | -0.1454946804 |
| Erossion | -0.07834084 | 1.535992e-01 | 0.007505612 | -0.3349160666 |
| Mineral | -0.33293027 | -1.048606e-01 | 0.218211748 | 0.1804251835 |
| Entertainment | -0.01153762 | 4.327022e-01 | 0.052825108 | -0.0884261185 |
| Relax | 0.09914413 | 4.489139e-01 | 0.268086152 | 0.1761846571 |
| ArtLiterat | -0.27301056 | 1.484554e-01 | 0.247356728 | 0.1964108259 |
| EviEdu | 0.12443676 | 3.963505e-01 | -0.089157314 | -0.0001545308 |
| IndigenKnow | 0.07950521 | 1.836754e-01 | -0.559578461 | -0.1468801061 |
| LocalCultu | 0.04091370 | 1.605218e-01 | -0.235930665 | 0.4054703009 |
| Spirituality | 0.08246659 | -8.912113e-02 | -0.303581842 | 0.2324559831 |


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The loading matrix shows that the first two principal components have high positive values for Agriculture and Livestock, but relatively negative values for Air, Climate, and Fresh Water. This suggests that households focused on farming and livestock may pay less attention to air quality, climate, and water filtration. Regarding the third principal component, it shows highly negative values for Indigenous Knowledge and Spiritual Values. This implies that the importance of ecosystem service values may vary depending on the respondent's profession.

The previous analysis of the loading matrix provides a good understanding of each of the first four principal components and their characteristics in the data.

### *Contributing each variable*

The goal of the observation is to determine how much each ES is represented in a given component. The quality of representation is called $Cos^2$ (the squared cosine), which is computed for each ES. A low value indicates that the ES is not well represented by that component, whereas a high value signifies a good representation of the ES (see *Fig. 5*). The code for calculating the squared cosine value of each ES with respect to the first two principal components has been provided. The top five ES requirements—air, pure water, relaxation, timber, and entertainment—have the highest $Cos^2$ values, thus contributing the most to PC1, PC2, PC3, and PC4.

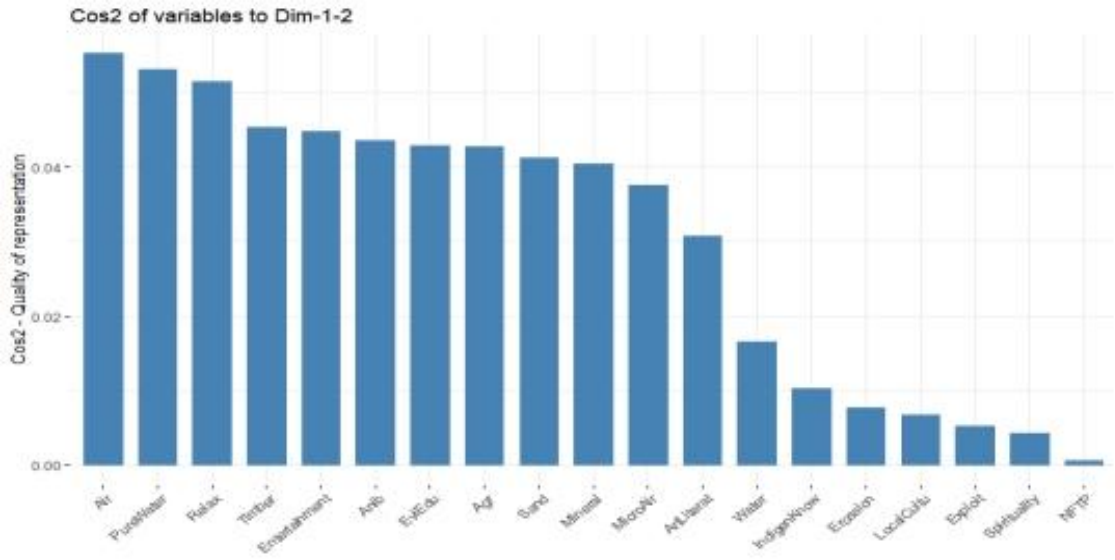


***Figure 5.*** *Contribution of each ecosystem service*

Three principal aspects can be examined in the previous plot:

1. Correlation of ES Variables: All the ecosystem services (ES) are positively correlated with each other. For example, agriculture and livestock show a positive correlation. Notably, the highest values in the loading matrix correspond to the first principal component. Therefore, the greater the distance between an ES and the origin, the better that ES is represented in the biplot. Similarly, agriculture and livestock have the highest magnitudes in ES and are thus well represented compared to other ES. Conversely, ES that are negatively correlated are shown on opposite sides of the biplot's origin.


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2. Visualization of Principal Components: The biplot is used to visualize the importance of each principal component and to determine how many principal components to retain. The diagram below illustrates the eigenvalues in a descending curve from highest to lowest. The first four components, which account for almost 68% of the total information in the data, can be considered the most significant.

3. Biplot Visualization of ES Similarities and Differences: The biplot can be used to visualize the similarities and differences between ES and the impact of each attribute on each principal component. Attributes with similar Cos² scores are represented with similar colors in the biplot (see *Fig. 6*):

- High Cos² attributes are colored in green: Pure Water, MiroAir, Relaxtion.
- Medium Cos² attributes are colored in yellow: Entertainment, Timber, Environmental Education, Agriculture, Animal Husbandry, Sand, Mineral, Water, Art and Literature.
- Low Cos² attributes are colored in black: Exploit, Spirituality, Indigenous Knowledge, Local Culture, Erosion, Non-Timber Forest Products (NTFP).

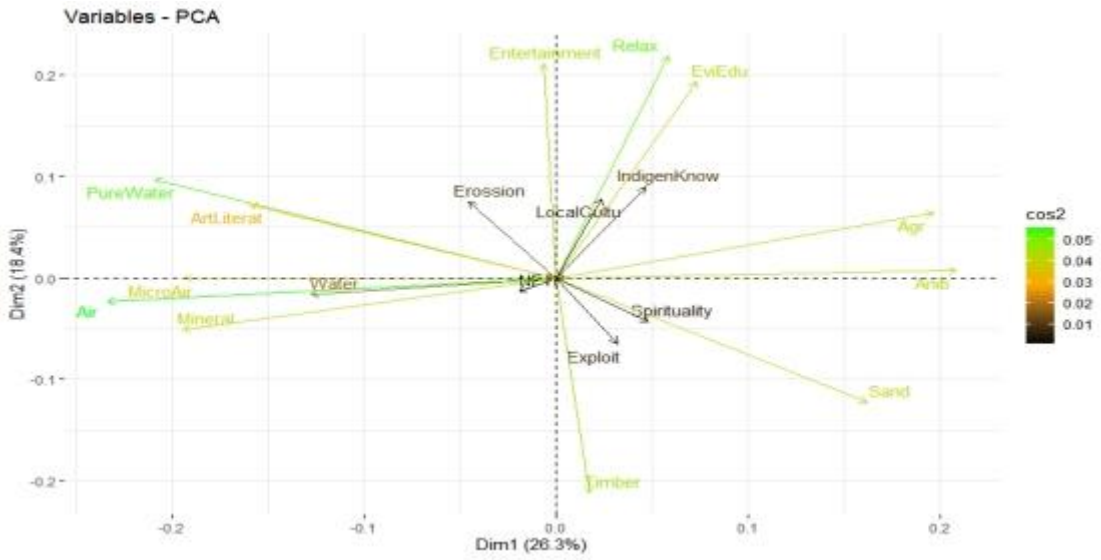


***Figure 6.*** *Combination of biplot and cos2 score*

## Discussion

### *Which ecosystem services are prioritized by the community?*

The distinction in the perception and value of ecosystem services (ES) was examined in local communities. Similar to many other regions globally, people here view the sea and forests as highly beneficial for health, providing both direct and indirect income to their families, and contributing to social welfare. However, compared to other studies (Ouko et al., 2018; Casado-arzuaga et al., 2013), the current research reveals a lower perceived value of ES by local individuals. The research indicates that ES priorities vary among local people, confirming that contextual and socioeconomic factors influence their ES preferences (Mengist and Soromessa, 2019; Paudyal et al., 2018).

Interestingly, key respondents valued freshwater ES, a perspective that agrees with findings from other areas (Wondimagegn, 2022; Dorji et al., 2019). Clean water is seen as essential for daily activities. Without it, people face challenges such as high costs for


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water transported by cargo ships from the mainland, making them acutely aware of water-related issues. Climate and air quality are also significant concerns. The clear perceptions regarding these ES may be influenced by training from non-governmental organizations (NGOs) and government agencies. These findings are consistent with those from the Democratic Republic of the Congo (Cuni-sanchez et al., 2019).

We recommend training local people to raise awareness about the lower-value ES, as these services are indirectly linked to well-being and may not be easily understood in local communities (Kadykalo, 2021). Similar to residents in buffer zones of many National Parks and Protected Areas, people on Cu Lao Cham Island are highly aware of the value of ES, especially provisioning, conservation services, and cultural aspects. This result aligns with the findings of Lhoest et al. (2019) and Dorji et al. (2019). However, unlike in other studies (Zhang et al., 2019; Ouko et al., 2018; Mensah et al., 2017) where regulation services were preferred, this community shows different prioritization patterns.

### *The influence of environmental and social factors on the perceived value of ecosystem services (ES)*

Although local people assign different ratings to the role of ES, rural communities in developing countries are significantly affected and dependent on natural resources. This includes their reliance on agriculture, forest products, and other ES, both directly and indirectly (Adhikari et al., 2018). In this study, people placed emphasis on entertainment services, tourism, environmental education, and the provision of fresh water. Specifically, over the past 10 years, there has been a 70% decrease in seafood availability, leading to fewer people engaging in fishing. Consequently, they have shifted to tourism services; some households operate homestays, while others work as motorbike taxi drivers (through a motorbike taxi association), tour guides, scuba diving instructors, or boat operators taking tourists to squid fishing areas.

Preferences also vary between households living near the sea and those near forests. According to group discussions, people living near forests prioritize ES provision more than those living near the sea. This is because forest-dwellers still harvest non-timber forest products like medicinal plants for sale and personal use. They also engage in activities such as stone crab fishing and tourism, particularly near spiritual attractions like Hai Lang Pagoda. Conversely, those living near the sea have mostly transitioned from fishing to tourism services over the past decade. Households near the mountains are concerned about heavy rainfall and potential landslides, while those near the sea worry about high tides. Therefore, perceptions of ES value differ based on proximity to forests or the sea, reflecting variations in socio-demographic and environmental factors. These findings are consistent with research conducted in South Africa, where distance from forests influenced perceptions (Mensah et al., 2017).

The varying importance of ES among local communities aligns with other studies that identify socio-demographic factors and the living environment as predictors of differences in awareness and prioritization of ES (Muhamad et al., 2013). The research shows that community livelihoods are a statistically significant predictor of how ES are valued. People with different livelihoods perceive the importance of ES in diverse ways.

### *Perceptions of anthropogenic pressures and threats to ecosystem services (ES)*

Forests are home to many vital terrestrial ecosystems, but they have been transformed for other land uses due to human demands for social development (Curtis,


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2018; Rasmussen et al., 2017). Most respondents recognized that natural forest cover has increased due to effective forest preservation and protection policies. However, non-timber forest products, especially medicinal plants and forest vegetables, have significantly declined. Many people harvest these products for personal use and to sell to tourists and restaurants.

The decline in the quality and quantity of ES is attributed to human-induced factors, such as population growth and the increasing number of annual tourists to the island. According to local residents, during the summer, around 40,000 tourists visit the island, leading to a shortage of fresh water for some households and motels. Additionally, the scarcity of agricultural land and fresh water has worsened since 1976, when the government constructed national defense roads through the forest, disrupting the water supply to farmers' fields. This has resulted in more abandoned fields and a decline in farming activities. Furthermore, people on the island are unable to grow crops or fruit trees due to frequent disturbances by monkeys.

### *Practical significance in forest management*

The research results have significant implications for enhancing the benefits that local people and communities derive from managing natural forests. Comprehending the crucial factors that affect local community perceptions of ecosystem services (ES) can inform better planning and management strategies. These results can also guide the development of awareness training programs needed to support conservation efforts and improve human welfare. Additionally, the research provides valuable insights for local and central forest managers and policymakers to effectively conserve forest ecosystems.

Local knowledge (García-nieto et al., 2014; Fagerholm et al., 2012) and local context (Hartter et al., 2014) are crucial in ES assessments, as residents may prioritize the ES provided by their natural forests. However, conflicts have arisen between local communities and wildlife organizations due to agricultural destruction and property damage caused by wildlife. On Cu Lao Cham Island, the destruction of crops and fruit trees by monkeys has led residents to shift their focus to seafaring, tourism, and services. Despite these challenges, forest management and protection on the island are effective, with protection groups conducting regular patrols funded by forest environmental services. The local population is educated on environmental protection and benefits significantly from the forest through activities such as collecting wild vegetables, medicinal plants, and catching stone crabs.

Raising awareness among local people about the less valuable ES could foster conservation by creating a balanced relationship between natural resources and local communities, leading to mutually beneficial outcomes. Such awareness is likely to influence community actions positively. It is anticipated that the insights from this comprehensive research will provide valuable insights for policymakers and forest managers in shaping effective forest management strategies.

### *Limitations and future research*

This study has several potential limitations. The first limitation is the use of a simplified scenario with brief explanations of ecosystem services (ES) provided to respondents. This approach may lead to rankings of ES that are influenced by the respondents' feelings and mood at the time. Although the people on the island are very friendly, they tend to be shy during interviews, making it challenging to access their true thoughts.


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The second limitation is the imbalance in gender representation among respondents. This study primarily includes female respondents (75.5%), despite men being direct beneficiaries of ES. Men often serve as the family breadwinners, heads of households, decision-makers, and are more actively involved in ES than women.

Future studies should address these limitations by ensuring a more balanced gender representation and adequately measuring the involvement of male respondents. This approach will help avoid potential underestimation of the value and role of ES.

## Conclusion and recommendations

There is growing evidence that ecosystem services (ES) are not only beneficial for people in mountainous areas, wetlands, and coastal regions but are also particularly valuable for those living on islands. Residents can benefit from both forest and marine ecosystems. Natural forests and seas provide significant ES that contribute to the economic and social development of communities. Local people favor the cultural and practical benefits provided by the mountains, forests, and seas in their daily lives. The variation in ES can be attributed to differences in forest cover and available natural products. Additionally, forests and seas offer crucial benefits to populations facing food insecurity, providing non-timber forest products such as wild vegetables, medicinal plants, and high-value mountain crabs.

The development of tourism has created new livelihoods and reduced pressure on natural resources. However, the increasing number of tourists has led to a surge in demand for local specialties, including mountain crabs and vegetables. This increased demand places additional pressure on forest resources. To address this, initiatives such as ecological labeling of mountain crab products and price adjustments have been implemented to manage consumption. Further research is needed to quantify mountain crab populations and develop effective strategies for the conservation and sustainable use of this valuable species.

Natural forests are also impacted by social factors and construction projects related to military strategies and the development of high-end resort tourism. These factors can affect the preservation and sustainability of forest ecosystems.

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**Conflict of interests.** The authors declare that there is no conflict of interests related to this paper.

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