

## Sustainability of community-based mangrove ecotourism in Bali, Indonesia

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### CHRONICLE

### ABSTRACT

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Bali is a world tourist destination that is famous for having various types of interesting maritime tourism, including mangrove areas which are typical of equatorial regions. The purpose of this study is to develop a model that can predict the sustainability of ecotourism in the mangrove area in Bali based on the approach of empowering local potential and empowering the community. Data analysis was carried out using Bayesian Network analysis, where input was based on the results of the FGD. The results show high probability of realizing the sustainability of ecotourism, where the most influential variables are community participation and local product developers or mangrove-based products. In addition, the condition of the mangrove forest also needs attention, considering that the sustainability of mangrove ecotourism is very sensitive to changes in the condition of the mangrove forest. The three main variables have reflected the combination of the three elements of sustainability, namely people-social (community participation), planet-environment (mangrove forest condition), and profit-economic (developing of mangrove-based products). Mangrove ecotourism development in Bali should be focused on increasing community participation and the development of mangrove-based products.

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## 1. Introduction

Indonesia is a country with a tropical climate and is located along the equator (Febriandika & Rahayu, 2021). These geographical conditions make Indonesia the home for the growth of various types of tropical plants, one of which is mangroves. Mangroves are a unique and distinctive form of forest ecosystem, found in coastal intertidal zones, beaches and small islands and are a potential natural resource (Mahmuda et al., 2023). Bali Province is a popular tourist destination in the world (Budhi et al., 2022). Bali also has the potential for mangrove forests in several areas and has been developed as a tourist area. Mangrove forests in Bali Province cover an area of around 2143.97 hectares (3067.71 Ha) spread across several places. First, it is located in the West Bali National Park (TNBB) which is also a tourist destination, research and scientific development (Rani et al., 2019). TNBB is located in Buleleng Regency and Jembrana Regency. Second, it is located in Tanjung Benoa and Serangan Island which are known as the Ngurah Rai Grand Forest Park (TAHURA), which is administratively located in Badung Regency and Denpasar City. The location of the second mangrove forest is very strategic because it is located in the Bali business and tourism growth area and is also a tourist spot because of its beautiful panorama. Third, it is located in Nusa Lembongan (Nusa Penida Islands, Klungkung Regency) which has become a hits and popular recreation spot with natural charm as the main attraction (Husnayaen et al., 2023).

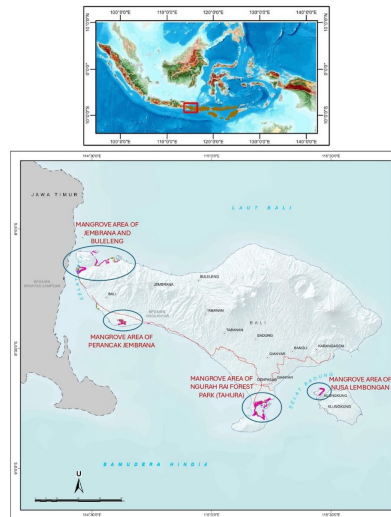
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Source: Ministry of Environment and Forestry (2021)

**Fig. 1.** Map of Mangrove Distribution in Bali

The development of mangrove areas as tourism areas, in addition to providing positive impacts, can also be a threat if it causes deforestation of mangrove forests. According to Goldberg et al. (2020), global deforestation of mangrove forests between 2000 and 2016 was 3,363 km<sup>2</sup> (2.1%) and an estimated 62% was caused by land conversion, mostly from aquaculture and conversion to agriculture and urban development (Friess et al., 2019).



(a) Bali National Park

Source: sobathiking.com



(b) Perancak Sanctuary

Source: detik.com



(c) TAHURA

Source: menpan.go.id



(d) Nusa Lembongan

Source: epaper.mediaindonesia.com

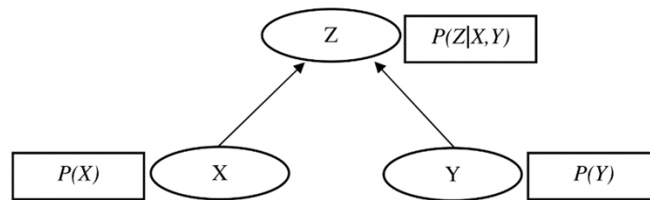
**Fig. 2.** Mangrove Area Tourism in Bali

Mangrove forest management cannot be separated from the role of local communities, as an effort to maintain sustainability and regulation so that mangroves can have an impact on community welfare (Turisno et al., 2018). The purpose of this study is to develop a model that can predict the sustainability of ecotourism in mangrove areas in Bali based on the approach of empowering local potential and empowering communities. Community empowerment in tourism in Bali in particular and Indonesia in general, is carried out through tourist villages and tourism awareness groups consisting of local communities.

## 2. Material and method

### 2.1 Belief Bayesian Network

Belief Bayesian Network (BBN) is a probability network that presents causal relationships, and in this study, it is used to examine the sustainability of mangrove ecotourism in Bali, especially in the Kedonganan Village area. The BBN analysis technique was chosen to make it easier to describe the problem. In addition, through BBN analysis, it can also build a more flexible model because it can add variables and simulate variables. The basic structure in BBN consists of as illustrated in Fig. 3.



**Fig. 3.** Simple Structure for BBN Analysis Techniques (Suasih et al., 2024)

The image shows the relationship between variables or called Directed Acyclic Graph (DAG). There are arrows from variable X and variable Y, so the two variables are called "parents variables", while variable Z is called "child variable".

The probability distribution in a BN with n nodes ( $X_1, \dots, X_n$ ) can be written as (Chakraborty et al., 2016):

$$P(X_1, \dots, X_n) = \prod_{i=1}^n P(X_i | P_a(X_i))$$

where  $P_a(X_i)$  is the set of the probability distributions corresponding to the parents of node  $X_i$ . For Figure 2, the above equation can be formulated as (Chakraborty et al., 2016):

$$P(Z) = P(Z|X, Y) * P(X) * P(Y)$$

### 2.2 Framework

The development of the conceptual framework of the research is the basis for the preparation of BBN modeling. Where the preparation begins with the identification of variables and will then be arranged in a framework. The focus of stakeholders is related to mangroves in the TAHURA Ngurah Rai area, especially Kedonganan Village. This mangrove area is very vulnerable to deforestation because it is located in the city center. Based on the results of the literature review and FGD involving stakeholders who are directly and indirectly involved, the variables identified in this study are completely presented in Table 1.

**Table 1**  
Identification of Research Variables

Variable Nodes	Description	Node States
Sustainable ecotourism	The concept of sustainable tourism aims to preserve nature and culture, as well as improve community welfare, where this research is based on mangroves.	high; moderate; low
Tourism village	Village areas are developed into tourist destinations, involving local communities in their management.	very active; active; not active
Tourism support facilities	The existence of tourism amenities support, namely facilities owned by a tourist destination area that are provided for tourists.	developed; moderate; not well developed
Traditional art performance	Traditional dance performances that are characteristic of the local area.	organized; moderate; not well organized
Local products	Processed mangrove products developed according to local potential.	developed; moderate; not well developed
Community participation	Community Involvement in decision-making, problem-solving, and development processes.	high; moderate; low
Mangrove conditions	Condition of mangrove plants at the research location, where mangroves are tropical plants in coastal areas.	good condition; moderately destroyed; heavily destroyed

So based on the results of the identification of these factors/variables, a framework can be prepared as shown in Fig. 4.



Fig. 4. DAG of BN Structure of Sustainable Ecotourism in Bali

After the BN structure is reconstructed clearly, the stakeholders involved in the FGD then determine the probabilities of each relationship. The next analysis is carried out with GeNIe Academic (Version 5) to be used to provide a picture of the results of the BN analysis according to the structure (Fig. 4).

### 3. Results and Discussion

#### 3.1 Strength analysis in the Framework of Sustainable Ecotourism

Based on the results of the BBN analysis based on the results of the FGD, the results of the child node probabilities were obtained as in Fig. 4.

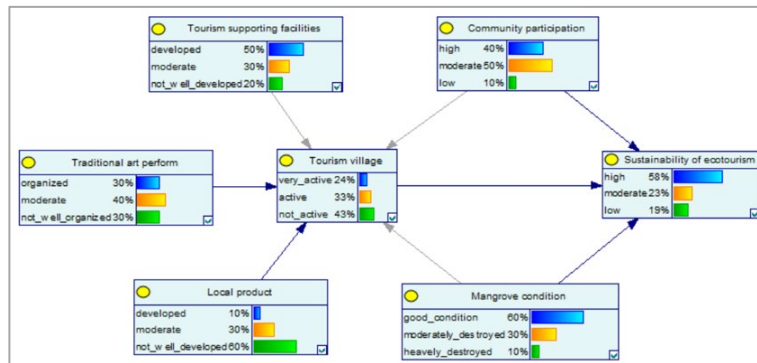


Fig. 5. Structure of BN of Sustainable Ecotourism with Prior Probabilities

Fig. 5 shows the results of the analysis that in existing conditions the probability of ecotourism sustainability is 58%, while tourist villages tend to be inactive. The next BBN analysis also presents the strength or influence which is the potential for a causal relationship between variables. The width of the arc represents the strength of each connection between parent and child nodes (Ali et al., 2024).

**Table 2**  
Score of Strength Between Parent and Child Nodes in the BN Structure

Parents	Child	Average	Maximum
Community participation	Tourism village	0	0
Community participation	Sustainability of ecotourism	0.126	0.2
Local products	Tourism village	0.390	0.6
Mangrove conditions	Tourism village	0	0
Mangrove conditions	Sustainability of ecotourism	0.336	0.556
Tourism support facilities	Tourism village	0	0
Tourism village	Sustainability of ecotourism	0.264	0.264
Traditional art performance	Tourism village	0.083	0.173



Based on Table 2, it can be observed that the impact of community participation on the sustainability of ecotourism is the largest with an average score of 0.39 and a maximum of 0.6. This is followed by the impact of local products (average score of 0.39) and mangrove conditions (average score of 0.336) on the sustainability of ecotourism.

### 3.2 Analysis of the role of community participation and local product development

As previously explained, the advantage of BBN analysis is that it can simulate variables/nodes. This study attempts to test the probability of sustainable ecotourism by optimizing community participation and developing local products (mangrove-based products). The analysis is carried out by setting the two nodes with a probability value of 100% in ideal conditions or using them as "evidence". Figure 6 presents the results of the analysis by optimizing community participation and local products simultaneously, while Figures 7 and Figure 8 present the results of the analysis partially.

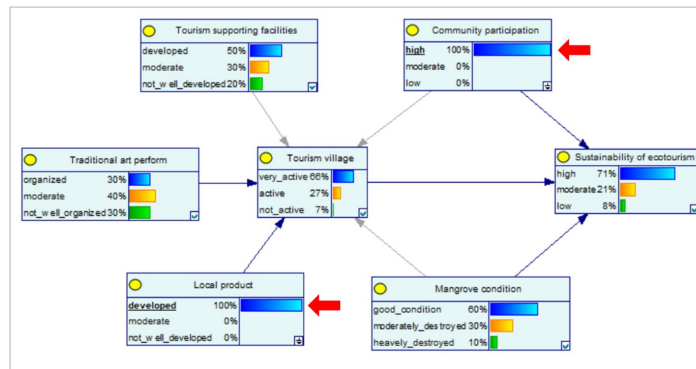


Fig. 6. BN Structure with Community Participation and Local Product as Evidence

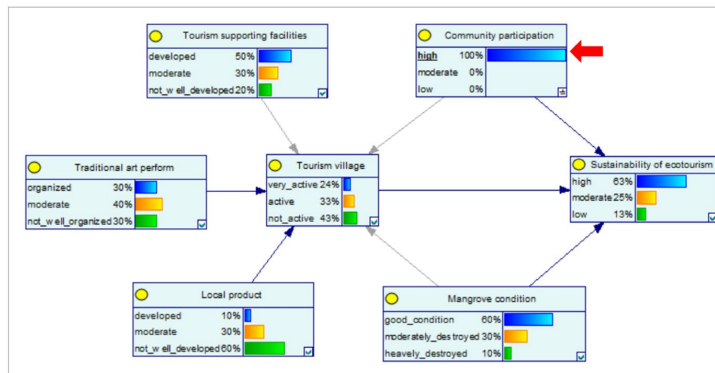


Fig. 7. BN Structure with Community Participation as Evidence

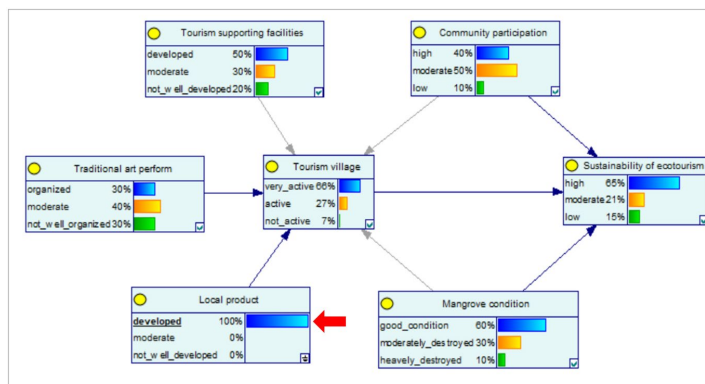
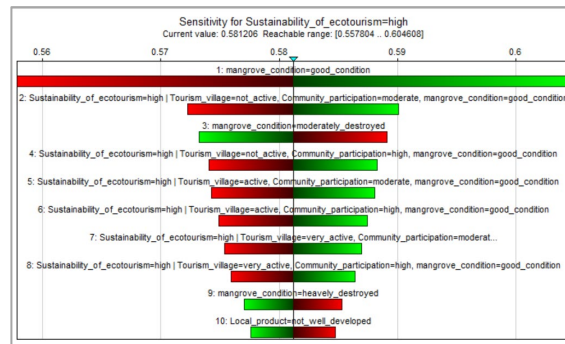


Fig. 8. BN Structure with Local Product as Evidence

Fig. 6, Fig. 7, and Fig. 8 show that there is an increase in the probability of sustainability of ecotourism if community participation and local products are optimized. The best results are shown if both are optimized simultaneously, where the high probability of sustainability of ecotourism increases from 58% to 71%. When analyzed partially, the development of local products or mangrove-based products produces a higher probability of sustainability of ecotourism value when compared to community participation.

### 3.3 Sensitivity analysis

Another advantage of BBN analysis is the ability to present sensitivity analysis of targeted nodes in response to changes in node evidence (Wang et al., 2023). So it is expected to know which nodes or variables, if they change, will have a significant impact on the target probability. Sensitivity analysis in BBN is presented as a tornado diagram, where the tornado diagram in this study is presented in Figure 9. The target variable or node is the sustainability of ecotourism.



**Fig. 9.** Tornado Diagram for Sensitivity Analysis of Sustainability of Ecotourism as Target

The horizontal axis of the tornado diagram shows the absolute change in posterior probability of sustainable ecotourism in Bali mangrove tourism, where the length of the bars is the impact of specific nodes on the target variable. The red bar indicates a negative influence while the green bar indicates a positive influence. Based on the Figure 9, it is known that the condition of the mangrove has the most impact on the sustainability of ecotourism (Sahputra et al., 2022), where the better the condition of the mangrove, the better the sustainability of ecotourism (indicated by the color green). The variable sustainable ecotourism is also very sensitive to tourism village and community participation, where if the community's participation is higher, it will have a positive impact on the sustainability of ecotourism (Rosid et al., 2024), as well as the activities of the tourism village (indicated by the color green).

### 3.4 Discussion

According to the results of the BBN analysis, namely strength analysis, probability, and sensitivity analysis, it can be said that there are three main variables that will greatly determine the sustainability of mangrove ecotourism. The first is community participation which represents the active involvement of the community in ecotourism, tourist villages, and maintaining the condition of mangrove forests. Next is the development of mangrove-based products, where mangroves can actually be processed into various products, such as food products, body care, and natural dyes (Nuraeni & Kusuma, 2023; Sofyana & Refli, 2023).

These three key factors represent the three main elements of sustainability, namely people (social), profit (economic), planet (environment) as shown in Fig. 10.



**Fig. 10.** Three Components of Sustainability in the Analysis of Sustainability of Mangrove Ecotourism

#### 4. Conclusions

The use of the Bayesian network has been able to show the probability of the impact of key variables on the sustainability of ecotourism. The results of the analysis with existing conditions show a high probability of realizing the sustainability of ecotourism, where the most influential variables are community participation and local product developers or mangrove-based products. If these two factors are optimized, it will increase the chances of realizing the sustainability of ecotourism. In addition, the condition of the mangrove forest also needs attention, considering that the sustainability of mangrove ecotourism is very sensitive to changes in the condition of the mangrove forest. The three main variables have reflected the combination of the three elements of sustainability, namely people-social (community participation), planet-environment (mangrove condition), and profit-economic (developing of mangrove-based products). So that in the future the direction of mangrove ecotourism development in Bali is focused on increasing community participation and the development of mangrove-based products while maintaining the condition of the mangrove forest.

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