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ECOSYSTEM SERVICES AND ENVIRONMENTAL BENEFIT VALUES ON KOMODO ISLAND AND PADAR ISLAND IN KOMODO NATIONAL PARK, INDONESIA

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Abstract

Komodo National Park (KNP) has prioritized eight out of 20 existing ecosystem services. KNP follows the concept of conservation and educational tourism, where visitors can see wildlife and enjoy panoramic views. The negative impact of increasing visitor numbers is the reduction of ecosystem value and benefits. In this article, the expert-based in-depth discussion method is presented, which is complemented by the interpretive structural modelling and system dynamics method. In the weighting phase, the Analytical Hierarchy Process (AHP) and spatial analysis using the Geographic Information System (GIS) and a market valuation of ecosystem service benefits are used. The results of the analysis show that the lost value of ecosystem services will reach USD 727 million, while it will be USD 661 thousand if the number of visitors is limited. This value is considered feasible to achieve restoration while providing economic and sustainable benefits. The programme to increase the number of visitors must be integrated with the management of tourist attractions on other islands in Komodo National Park, Labuan Bajo, and West Manggarai by extending the length of visitors' stay.

Key words: ecotourism, ecosystem services, Komodo National Park, Komodo Island-Padar Island

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1. Introduction

An ecosystem is a complex entity consisting of a dynamic population of plants, animals, and microorganisms together with the abiotic environment such as climate, precipitation, soil, and others that interact to form a functional unit (Anderson-Teixeira et al., 2012; Jørgensen and Müller, 2000). The ecosystem is responsible for carrying out natural processes to provide materials and services needed to directly or indirectly satisfy human needs (De Groot et al., 2010; Yang et al., 2021). There are four functions

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of ecosystem services, namely the provider function, the regulating and/or controlling function, the sociocultural or cultural function, and the primary support function (Jax et al., 2013; KLHK, 2016)

Ecosystems in the tropics can be considered complex because this area has the greatest species richness in the world (Rahman et al., 2017). Information about ecosystem functions can represent the conditions for the carrying capacity of the environment. Carrying capacity can also indicate the quality of a particular ecosystem service. The better or higher the carrying capacity of a site or eco-region, the more it can be said that the ecosystem in that eco-region has a certain quality and can function properly. In general, the functions of provisioning, regulation, and culture are closely related to carrying capacity, while ecosystem regulation is closely related to the ability to adapt to the environment.

Komodo National Park (KNP) is one of the tourist destinations that carry the concept of conservation, as KNP is the only habitat for wild Komodo dragons in the world. Regardless of the conservation concept offered, tourists tend to look for places that are beautiful, unique, and different from the places where they usually live for a while (Sukwika and Kasih, 2020; Yuliawati et al., 2016). The existence of tourism and other human activities in KNP leads to the loss or decline of ecosystem services, such as land cover change. Indeed, land use leads to a significant decline in ecosystem services (Sukwika and Rahmatulloh, 2021; Susilawati et al., 2020).

Consistent with the loss of ecosystem services due to human activities in tourism, the decline in benefits will also continue to fluctuate. A higher number of visitors may lead to greater pressure on resources, which may affect all types of ecosystem services (Zhao et al., 2019). The large number of visitors also has a potential negative impact in the form of changes in kite behavior in the national park area, which may affect the predation process as kites become more docile (Jessop et al, 2018). Therefore, this study discusses ecosystem services using Analytic Hierarchy Process (AHP) and Geographic Information System (GIS), prioritization of ecosystem services using Interpretive Structural Modeling (ISM), and loss of ecosystem services. Based on all these problems, simulations and projections for 30 years from 2015 to 2045 are carried out using system dynamics modeling so that solutions can be found to prevent ecosystem services from drastically declining in Komodo National Park. In addition, the use of system dynamics also serves to see the relationships between variables in a complex way, and the model scenarios can be carried out in the form of measures.

In the Komodo National Park carrying capacity and ecosystem services study report (Firmansyah et al., 2022), ecosystem services were also calculated using a dynamic system to forecast future ecosystem services. The results are used as a reference for decision making in TNK, provincial government and central government and related to carrying capacity. This study is the first to address the calculation of ecosystem services using a dynamic system in TNK.

2. Materials and methods

2.1. Data

The data used in this study are time series data, since time series data are among the data used in analysis under the system dynamics approach. These data were obtained from various agencies, such as the Ministry of Environment and Forestry of the Republic of Indonesia for eco-region data, Komodo National Park Center for visitor data, sentinel imagery for land cover, and primary data collection through willingness to pay (WTP) questionnaires. Further details on the data used can be found in the table below (Table 1).

2.2. Framework

This study describes ecosystem services and benefits based on carrying capacity and resilience pressures in Komodo National Park. The more pressure Komodo National Park experiences, the greater the loss of its ecosystem services.

2.2.1. Identification of ecosystem services

Ecosystem services are the benefits that humans derive from various natural resources and processes that are collectively provided by an ecosystem. Resources and natural processes provided collectively by an ecosystem (MEA, 2005). Ecosystem services are classified into four categories, namely provisioning services, regulating services, cultural services, and supporting services. cultural services, and supporting services. According to the Ministry of Environment and Forestry (KLHK) of the Republic of Indonesia, there are 20 ecosystem services. From these 20 ecosystem services, priority ecosystem services were selected using Interpretive Structural Modeling (ISM) (Table 2).

2.2.2. Calculation of ecosystem service index

The data processing materials and methods used in this study generally include ecosystem service identification from land cover, ecosystem service assessment and weighting based on expert assessments of eco-region and land cover data, spatial analysis and calculation of the ecosystem service index (ESI), and spatial visualization of the ESI. The assessment and weighting of ecosystem services based on land cover and eco-regions was performed using the Analytic Hierarchy Process (AHP) with a pairwise comparison calculation method (Mu and Pereyra-Rojas, 2016). Fig. 2 shows the process of applying the AHP in determining weighting values for eco-regions and land cover using the pairwise comparison method, resulting in ecosystem service value classes that range from very low to very high, applied to spatial data, it will be easier to see the phenomena that occur in the study area (Gumilar and Nandi, 2018).

Table 1. Main data source

Variable	***Data (hectares)***						***Source***
	2015	***2016***	***2017***	***2018***	***2019***	***2020***	
Visitors. Komodo	78.117	107.708	125.067	176.830	221.696	51.720	Komodo National Park Office
Land Cover							
Forest	7.267.64	7.234.74	7.177.33	7.081.15	6.926.93	6.760.19	Sentinel-2 Imagery
Shrubs	5.506.32	5.525.27	5.567.83	5.634.09	5.893.43	6.140.51	
Settlement	8.391.49	8.802.82	9.214.54	9.626.67	9.874.36	1.012.08	
Savanna	2.057	2.059	2.061	2.064	2.054	2.045	
Mangroves	203.68	197.50	191.62	186.04	186.72	187.53	
Organic/Coral Plain	-	-	-	-	-	0.36	The Ministry of Environment and Forestry
Karst Hills	-	-	-	-	-	3.612.79	The Ministry of Environment and Forestry
Structural Hills	-	-	-	-	-	29.787.17	The Ministry of Environment and Forestry

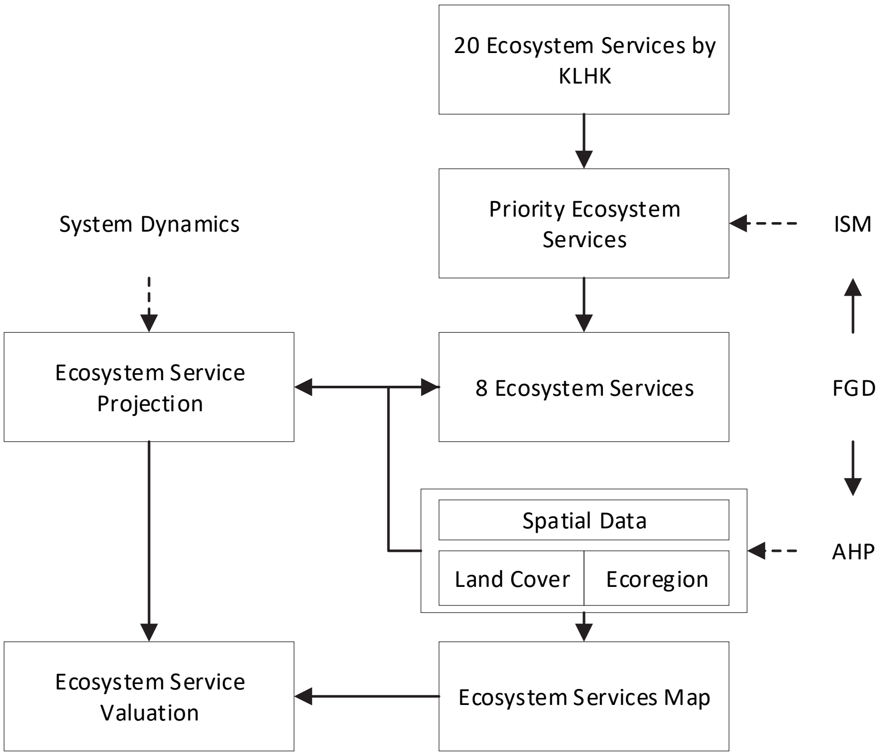


Fig. 1. Stages of data processing

Table 2. Description 20 ecosystem services

Ecosystem Services	***Description***
1.Provisioning	
- Food provider (E1)	Seafood, forest products (plant and animal), agricultural and plantation products for food, livestock products
- Clean water provider (E2)	Water supply from land (including its storage capacity), water supply from surface sources
- Fiber provider (E3)	Forest products, marine products, agricultural and plantation products for materials
- Fuel and fossil fuel providers (E4)	Provision of firewood and fossil fuels
- Genetic resource provider (E5)	Animal, plant and biotechnology breeding (medicinal materials and biochemicals)

2. Regulating	
- Climate regulation (E6)	Regulation of temperature, humidity and rainfall, control of greenhouse gases and carbon
- Flow and flood management (E7)	The hydrological cycle, as well as natural infrastructure for water storage, flood control and water conservancy
- Arrangements for prevention and protection from natural disasters (E8)	Natural infrastructure for prevention and protection from land fires, erosion, abrasion, landslides, storms and tsunamis
- Water purification (E9)	Capacity of water bodies to dilute, decompose and absorb pollutants
- Waste treatment and decomposition (E10)	The capacity of the site to neutralize, decompose and absorb waste and garbage
- Air quality maintenance (E11)	Capacity to regulate air chemistry system
- Natural pollination (E12)	Habitat distribution of natural pollination helper species
- Pest and disease control (E13)	Habitat distribution of pest and disease trigger and control species
3. Culture	
- Shelter and living space (E14)	A space to live and prosper, a "hometown" anchor that has sentimental value
- Recreation and ecotourism (E15)	Landscape features, natural uniqueness, or particular value that is a tourist attraction
- Aesthetics (E16)	Natural beauty that has a selling point
4. Supporting	
- Soil formation and fertility maintenance (E17)	Soil fertility
- Nutrient cycle supporter (E18)	Agricultural production levels
- Primary production support (E19)	Oxygen production, species habitat provision
- Supporting biodiversity (E20)	Supporting the existence and survival of flora and fauna

Source: Ministry of Environment and Forestry Republic of Indonesia (KLHK)

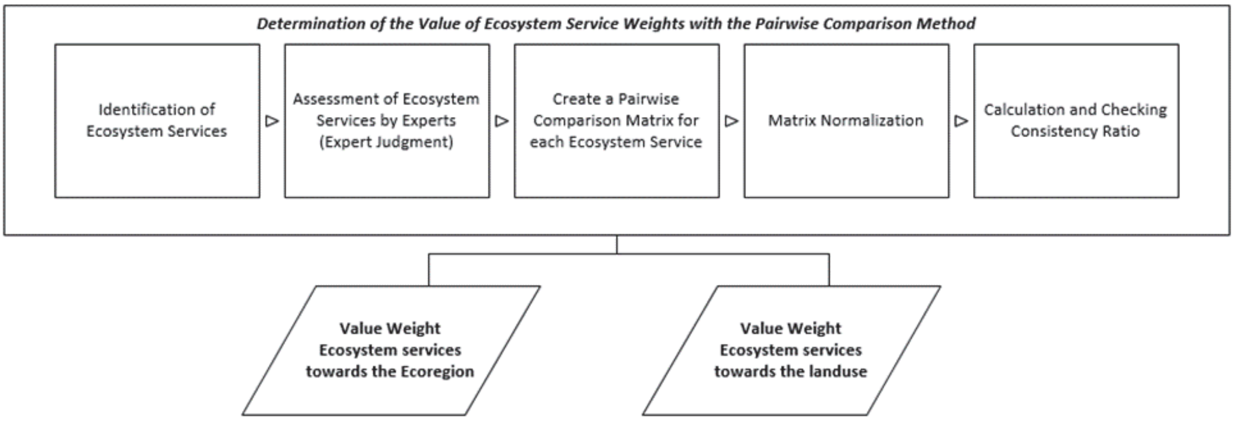


Fig. 2. Determination of the ecosystem services weight

Ecosystem services were assessed by entering the weighting values of each ecosystem service for each type of eco-region and land cover. The results include Tables describing the comparison of the scope of ecosystem services assessment for each land cover class and eco-region type. Experts should complete the list of questions according to theory and their knowledge, observations, and experience with actual conditions. A land-use-based proxy approach was used in mapping ecosystem services by applying the combination of pairwise comparisons from multidisciplinary sciences that enable a comprehensive assessment (Figueroa Alfaro, 2015; Maynard et al., 2010).

To calculate the consistency we used the formula (Eq. 1):

$$CI = \frac{\lambda \max - n}{n-1} \quad (1)$$

λ maxs = maximum feature root
n= matrix size

The value of the consistency ratio (CR) is as follows (Eq. 2):

$$CR = \frac{CI}{random\ value\ consistency\ for\ matrix\ size\ n} \quad (2)$$

To calculate the consistency, the formula is used, if the value CR < is 10%, this shows that the assessment is consistent by completing the questionnaire, then the weight value can be used (Saaty and Vargas, 2012).

2.2.3. Calculation of value and loss of ecosystem services

The calculation of the value of the loss of ecosystem services is done by comparing the lost land cover. The reason is that one of the determinants of ecosystem services is land cover. When land conversion occurs, there will be a decrease in ecosystem services, especially when open land is converted to developed land. This value is calculated using the system dynamics approach with Powersim Studio 10 software.

2.3. Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a concept for multi-criteria decision making. The focus of the AHP concept is the comparison of several criteria with each other (degree of importance). The AHP can be used to determine the comparison of values between variables to determine attribute values per land unit and eco-region. The data obtained from the processed AHP is then entered into spatial data (polygon), which is later overlaid using the Q- GIS software.

2.4. Interpretative Structural Modelling (ISM)

Interpretive structural modeling (ISM) is used to describe abstract problems so that they can be better structured. ISM Analysis using Exsimpro - ISM software can map, prioritize, and structure abstract problems to make them easier to understand.

Based on the ordered variables, the next step is a comparative assessment using VAXO, analysis of ISM output in the form of variable mapping and variable structuring, if the results of the analysis are consistent. ISM is used to determine the priority ecosystem services from 20 existing ecosystem services. This makes the focus of the ecosystem services studied and analyzed clearer.

2.5. System dynamics

System dynamics is used to perform simulations, projections and scenarios. These simulations and projections are very important to identify the state of ecosystem services and the value of ecosystem services in the future, so that appropriate policies can be made to support sustainable development by applying scenarios in the System Dynamics model.

3. Results and discussion

3.1. Results

The calculation of the value of ecosystem services lost is based on the ideal number of tourists, 219,000 visits. A decrease in the value of ecosystem services occurs when the number of visitors exceeds the maximum capacity of 292,000 visitors per year (Firmansyah et al., 2019; Firmansyah et al., 2022), as these conditions have exceeded the carrying capacity and capacity of tourism in TNC. The value is obtained by calculating the tracking length, tracking time, and the number of tourists in a tracking (Table 3). Once the ideal number and maximum number of tourists are known, ecosystem services as a whole can be calculated, both existing conditions and the value of ecosystem services lost using a system dynamics approach, so that current and future values are known.

Table 3. Number of visitors (Firmasyah et al, 2022)

Activities	*Value*	*Unit*
Shortest trek		
Step time average travel time	40	Second
Length of visit	1	Hour
Number of visitors (Standard)	50	People
Number of visitors (Maximum)	100	People
Total visit time	8	Time
Number of visitors/Year (Standard)	146.000	Visitor/Year
Number of visitors/Year (Maximum)	292.000	Visitor/Year
Average number of visitors ideal	219.000	Visitor/Year

The ideal number and maximum number of tourists form the basis for determining the carrying capacity of tourism. When the carrying capacity is exceeded, the value of ecosystem services lost in Komodo National Park increases.

3.1.2. Ecosystem services

The priority of ecosystem services at the study sites was determined through in-depth discussions with experts and KNP office managers who have a better knowledge and understanding of the actual conditions on the ground. In the in-depth discussions, the experts provide an overview of the conditions on the ground and provide values for each parameter of the land and eco-region. The results of the field observations, which are then analyzed using the interpretive structural modeling method (ISM), also provide the reason for the selected sites. The results show that there are 8 priority ecosystem services out of a total of 20 ecosystem services in Fig. 3.

Priority ecosystem services (red colour) include 1) provision of genetic resources (E5); 2) promotion of biodiversity (E20); 3) water supply (E2); 4) climate regulation (E6); 5) primary production (E19); 6) habitat provision (E14); 7) ecotourism and recreation (E15); and 8) aesthetics (E16). The next analysis was to spatially weight the land use and eco-regions of the KNP to obtain a map of ecosystem service classes, as shown in Fig. 4. The dark green color indicates that the ecosystem services are very high, the light green color is an area that belongs to the high ecosystem services, the yellow color indicates that the ecosystem services in this place belong to the middle class, the orange color indicates low ecosystem services, and the red color indicates that the ecosystem services in Komodo National Park are very low, especially in Komodo Island and Padar Island. The priority ecosystem services are explained in more detail below. -6The lost ecosystem services and conservation costs are calculated using the system dynamics approach. System dynamics is a modeling and simulation approach to study and manage systems with feedbacks, such as environmental systems, social systems, economy, and others that are interrelated (Firmansyah et al., 2016). To find out the relationship between the variables in this study, the causal loop diagram (CLD) in Fig. 5 can be used. The relationship between these variables can give an overview of the behavior of the system that adds or subtracts to form a unified overall model.

The Causal Loop Diagram was created using Powersim Studio 10 software. CLD is one of the systems thinking in system dynamics and can give an overview of the interaction between variables with the symbol (+), which means or adds a positive effect, and (-), which means a negative effect or decreases the value of the target variable.

3.1.3. Ecosystem service of genetic resource provider

Padar Island is dominated by areas of low potential, as land use is dominated by savanna, cliffs, and the surrounding sea. In contrast, Komodo Island has areas of very high potential (Fig. 4) of 97.58 ha and areas of medium potential of 6.036.29 ha, so the island has abundant genetic resources in the KNP.

The calculation result of the economic value of Komodo dragons estimates the total economic value (TEV) of the bioprospecting potential of Komodo dragons to be 99.201.82 USD per year. The economic value of ecosystem services of Komodo dragon bioprospecting for anticoagulant drugs is 17.042.72 USD per year, which is about 17.18% of the TEV of Komodo dragon bioprospecting. The economic value of Komodo dragon saliva bioprospecting for MRSA disease control has an economic value of 20,050.25 USD per year or contributes 20.21% to the TEV. In addition, the economic value of Komodo dragon immunity ecosystem services has a value of USD 25.059.84 per year. The value of this benefit, useful for immunoprotection, provides the largest contribution from Komodo dragon bioprospecting, which is 25.26% to the TEV.

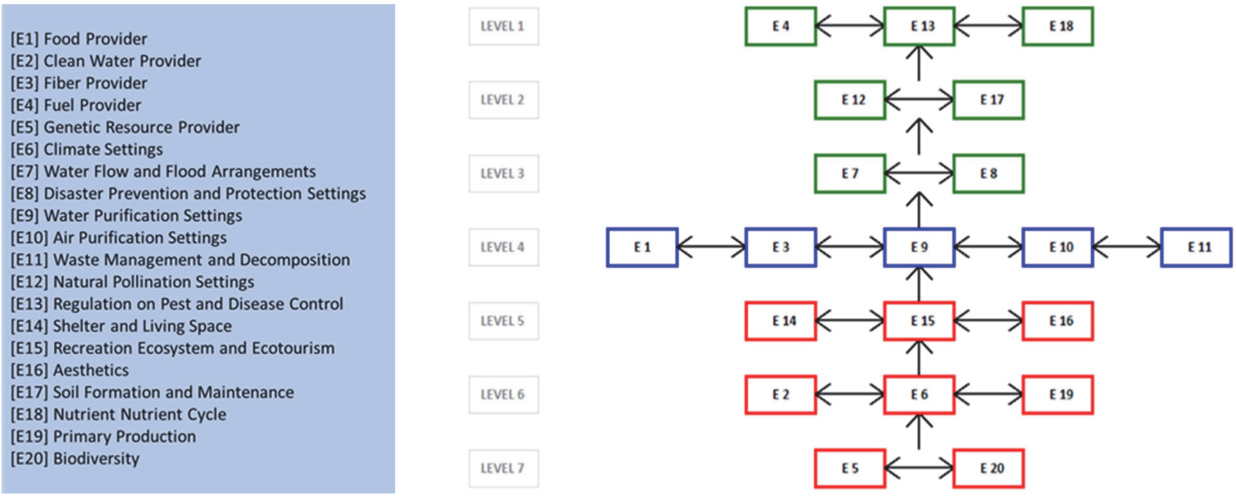


Fig. 3. Variable structure diagram

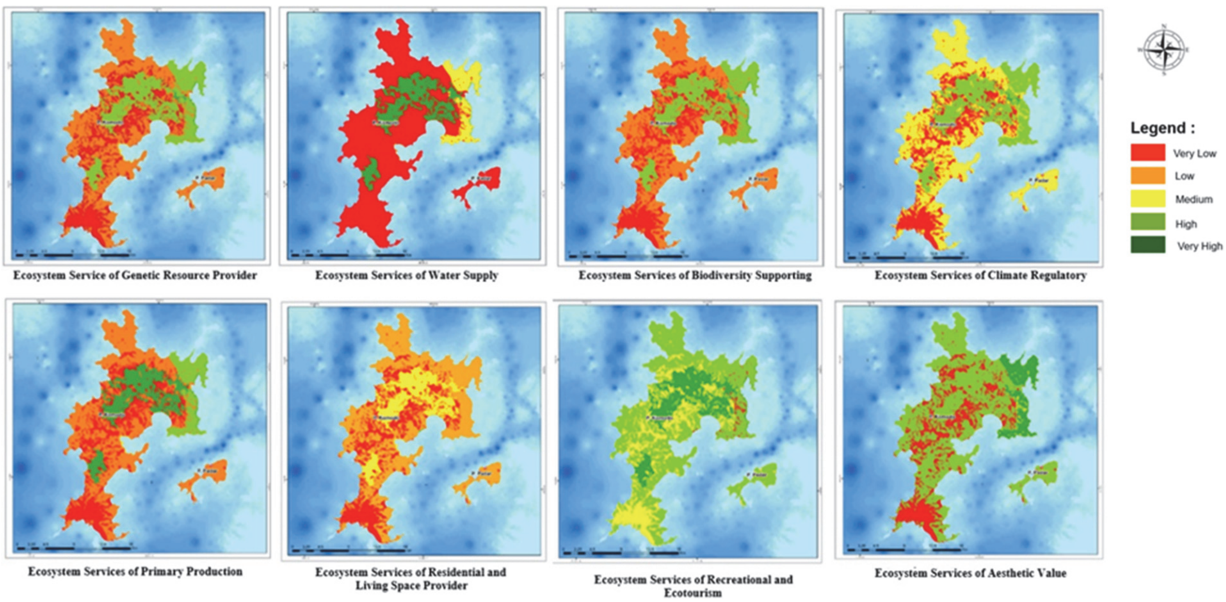


Fig. 4. Map of ecosystem services in Komodo National Park: Komodo and Padar Island

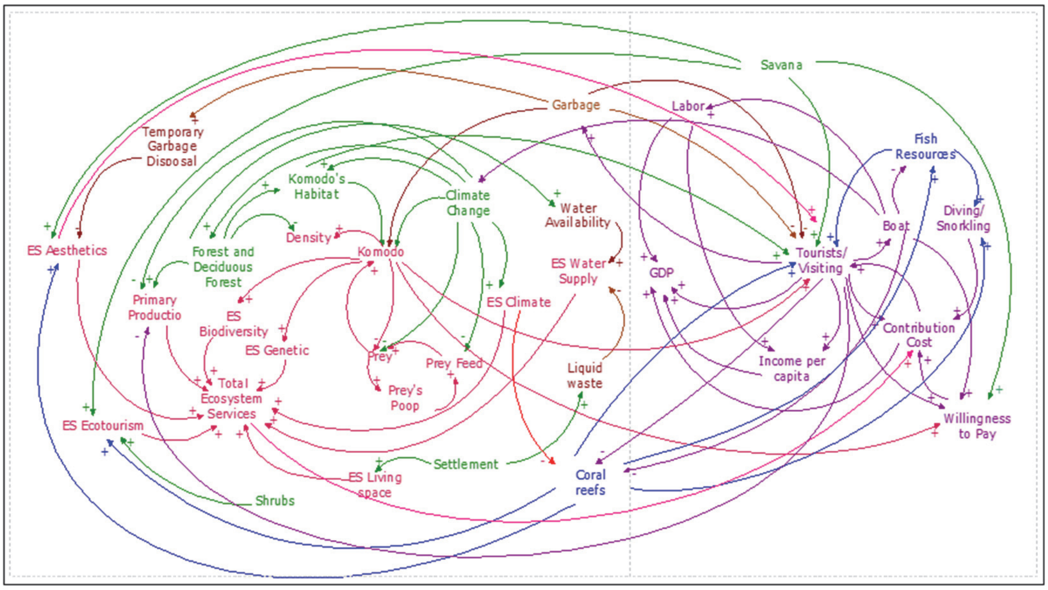


Fig. 5. Causal loop diagram

The economic value of the Komodo dragon population acting as pest controllers for insects and rodents such as rats that damage plantations and crops is estimated at a value of $19.038.82 per year, or 19.19% of the TEV. Finally, the value of ecosystem services resulting from the presence of Komodo dragons in the KNP area and the lives of humans as controllers of animal carcasses or environmental waste is estimated to be approximately $ 18.010.19 per year.

3.1.4. Ecosystem services of biodiversity supporting

Ecosystem services that support biodiversity include the composition, diversity, and structure of animal and plant communities (Lin et al., 2015; Mace et al., 2012). The results of the study show that most areas have low potential (Fig. 5) to support biodiversity. Areas with very high potential (Fig. 4) to support biodiversity are strongly characterized by the presence of vegetation and animals.

The analysis results show that most of the areas are dominated by areas with low potential to support biodiversity, namely 16.436.61 hectares (48.99%). Areas with high potential for biodiversity enhancement are most represented in Komodo Island with 9.026.70 hectares (26.90%). This gives the island a high diversity of vegetation and animals, as well as good landscape conditions in the KNP. Ecosystem services in support of biodiversity are calculated using the spatial land use analysis and eco-region of the KNP area. However, the calculation of ecosystem service loss focuses on terrestrial areas such as open deciduous forests and grasslands, which contribute most to the habitat of Komodo dragons and their prey.

The function of the forest in the KNP is to provide wood products, but also non-timber forest products (NTFPs). The intangible forms of NTFPs consist of nutrient storage, soil protection, and ecosystem protection. The tangible forms of forest products are medicine and food. To determine the economic value of the KNP, a quantitative analysis was conducted. This resource assessment can use the technique of economic valuation to quantitatively determine the use value of a national park (Mahendra et al., 2018). The calculated economic value is the tangible economic value in terms of the use value of NTFPs used by the community. The economic value of NTFPs can also be calculated using the market price approach. Decree of the Minister of Forestry Number: P.35/Menhut- II /2007 Article 1 states that NTFPs are biological forest products, both plant and animal, together with derivatives and cultivated products, excluding wood derived from forests. The potential economic value of ecosystem services around the KNP consists of medicines and food products. The economic value of tangible products used in the KNP is $3.186.718.82 per year. Herbal medicines contribute the most to the economic value with USD 2.124.479.21 or 66.67%. The economic value of ecosystem service for spices and fruits is USD 1.062.239.61 per year or 33.33%.

The result also provides information on the TEV of the intangible ecosystem services in the KNP. There, the TEV of intangible NTFP reaches 20.837.825.77 USD per year. The highest economic value comes from the protective ecosystem function, which contributes to increasing soil fertility, and is 14.351.969.48 USD per year. In second place is the soil protective function, which serves to protect the ecosystem chain and has a value of about 3.667.779.24 USD per year. Finally, minimizing erosion and wear functions by providing nutrient cycling storage has an annual economic value of $2.818.077.05 USD per year. The role of forest resources can continue to provide benefits in their protected functional corridor, then it is equitably distributed throughout the community. Several efforts that can be undertaken require a management model based on both the ecological function of the protected area and the potential of natural resources within the area, the form of economic use by the community, and the role of the manager (Hastari and Yulianti, 2018; Sukwika et al., 2016; Sukwika et al., 2022).

3.1.5. Ecosystem services of water supply

The results of the spatial analysis by mapping ecosystem services for clean water supply on the islands of Komodo and Padar show that most areas have very low potential (Fig. 4). One area with very high potential is located on Komodo Island. The forest areas with their diverse vegetation play an important role as a storage medium for rainwater falling on an area.

On Komodo Island, there are predominantly forested areas, so this island provides sufficient but limited clean water. The denser the vegetation in a forested area, the better it can shop water. Unlike Padar Island, there is no dense vegetation cover on this island, so the potential for providing clean water on this island is considered very low.

The area with a very high potential for water supply is located on Komodo Island, so the island has a good function for providing clean water in the Komodo National Park area. The analysis results show that most of the areas are dominated by very low and very high potential water supply, with a total area of 24.090.58 hectares (71.80%) and 6.011.29 hectares (17.92%), respectively.

Clean water supply is an ecosystem service, which emphasises the importance of clean water (Liu et al., 2013). Therefore, this study uses the basic data to evaluate the economic value of water intake potential. In 2013, the value determined is USD 1.086.965.84 per year, with the downward trend continuing and the TEV will be USD 890.708.45 per year in 2045.

3.1.6. Ecosystem services of climate regulatory

The analysis results show that most of the areas are dominated by medium and high potential areas (Fig. 4), with climate regulations affecting 16.489.64 hectares (49.15%) and 9.149.50 hectares (27.27%), respectively. The distribution area of the high potential is located in Komodo Island, so the island has a good climate regulation function. The value of the ecosystem services climate regulation benefit is climate stability with a value of 1.259.530.74 USD. This value is calculated based on a forest area of 6,707 hectares, and the value of carbon absorption is 3.64 USD. This carbon absorption will have an impact on local climate change in the KNP, especially on Padar Island and Komodo Island. The valuation of climate regulating ecosystem services is based on land use changes from forest to non-forest. Forest loss due to land conversion is calculated and used as the basis for determining the value of climate regulating ecosystem services. In 2013, the determined value is USD 1.374.897.03 per year, this value continues to decrease until in 2045 the value reaches USD 1.126.652.16 per year.

3.1.7. Ecosystem services of primary production

Areas with very high potential (Fig. 4) for primary production ecosystem services are strongly influenced by the presence of terrestrial and aquatic vegetation. Forested areas with their diverse vegetation play an important role as a medium for oxygen production and as a habitat for species. On Komodo Island, forest cover is widespread, making it an area for oxygen production and providing good habitat for species with very high potential primary production in the KNP. The denser the vegetation in a forested area, the better it produces oxygen and provides habitat for species. The distribution of areas with very high potential for primary production ecosystem services is about 6.133.87 hectares (18.28%) in Komodo Island, so the island fulfils the function of oxygen production and providing good habitat for species in the KNP.

Primary production ecosystem services include carbon sequestration or absorption and storage. Carbon absorption and storage on Komodo and Padar islands is calculated based on forest area and other vegetation. The map of land use changes on Komodo and Padar islands from 2013 to 2021 and projections of forest area in 2045 show a decrease in forest area. This condition is caused by the effects of land clearing, land conversion, and forest fires on vegetation loss and/or destruction, litter loss, and reduced soil quality. All of these causes affect the process of carbon sequestration and also affect the value of ecosystem services, especially primary production ecosystem services. Oxygen calculations were performed for forest, savanna, and coral reef areas (Table 4). This area is the location of the use zone for tourist activities. In general, coral reefs contribute the most to oxygen levels. Coral reefs have the greatest oxygen potential compared to forests and savannas. About 80% of the world's oxygen is derived from aquatic environments such as plankton and coral reefs. The availability of oxygen on Padar and Komodo islands is one of the most important factors in promoting tourism. Based on the analysis results in early 2013, the valuation of ecosystem services of primary production was 13.991.02.975.44 USD per year, in 2045 the value is only 1.146.487.596.89 USD per year.

This decline is due to a decrease in vegetation due to natural deforestation or human activities, as well as climate change causing an increase in sea surface temperature.

Table 4. Oxygen production

Land use	***Area***	***Oxygen quantity***	***Units***	***Total***	***Unit***
Forest	5999.49	4555	kg/hectares /year	27.327.676.95	kg/year
Savanna	18042.14	540	kg/hectares /year	9.742.755.60	kg/year
Coral reefs	55888.93	11607.457	kg/hectares /year	648.728.351.75	kg/year

Looking at some general climate changes, the decline of oxygen in the oceans is the most serious impact of human activities on the Earth's environment. In the last 50 years, areas of minimal oxygen in the ocean have increased fourfold, and estuaries, bays, and coastal areas of low oxygen have increased tenfold (GO2NE, 2016).

3.1.8. Ecosystem services of residential and living space provider

According to the Decree of the General Directorate for the Conservation of Ecosystem Natural Resources (KSDAE) No: SK.212/KSDAE/SET.3/KSA.0/11/2020 dated November 6, 2020 on the Zoning Map of Komodo National Park, the administrative area of KNP is divided into seven zones. The habitat and shelter needs of the indigenous population are regulated in a special zone for the settlement of indigenous people. The zone is defined on the basis of special regulations issued by the KNP and local governments. The area is in the form of villages scattered throughout the KNP area, which is designated as a special zone for the settlement of indigenous people on an area of 26.87 hectares. The entire Padar Island area is an uninhabited area, which means that it is one of the areas with low and very low potential for housing and habitat. The results of the analysis show that the cultural ecosystem services of housing and habitat in Komodo Island and Padar Island are dominated by low and very low potential areas (Fig. 4), covering 19.760.48 hectares (58.89%) and 7.653.75 hectares (22.81%), respectively. The area with high potential for residential and habitat ecosystem services covers 26.87 hectares (0.08%). This falls under the KNP zoning regulations with a special zoning function that regulates the maximum area for residential zoning on Komodo Island at 26.87 hectares.

The KNP area has many potential values, not only from ecosystem services provided by nature, but also from non-natural sources such as housing and habitat. Estimating the economic value of the land for indigenous peoples to use as housing yields a value of approximately $ 671.189.66. If the areas within the KNP that have both covered and shaded spaces, including services to protected areas and the number of houses are also estimated, the result is a use value of approximately $189.031.04 per year. This valuation approach uses a market rate for the staging or resting area, which is $0.33 per visit. A similar economic value can also be applied to the gathering places as part of the public facilities value. Based on the results of the estimated economic value, the value is $287.652.71. The estimated value of the object of the identity of the owner of the land results from the payment of a land tax of about 29.807.98 USD. This value, analogous to the cost of a land registry, is estimated at about 51.56 USD. The economic value, which is only felt by people, should not exceed the actual cost of maintenance. Therefore, population growth is controlled, especially in Komodo Village. Due to the large number of people in the area, there will be conflicts over land use for agriculture, water use, shelter, and food, especially for buffalo and deer, and marine tuna (Adil and Triwijoyo, 2017; Ahmad et al., 2021).

3.1.9. Ecosystem services of recreational and ecotourism

The results of the analysis show that most of the areas are dominated by areas with high and very high (Fig. 4) potential for ecosystem services in recreation and ecotourism, namely 193.22.85 hectares (57.59%) and 6134.08 hectares (18.28%). The areas with high potential are located in Komodo Island. The value of benefits is derived from ecosystem services for recreation and ecotourism, including conservation of nature, preservation of culture, educational facilities, socialization facilities, stress relief, and financial benefits. The variables considered in determining this value are the number of visits and the conservation costs incurred by visitors (Ahmad, 2009; Bhat and Sofi, 2021; Platania and Rizzo, 2018; Ramdas and Mohamed, 2014; Reynisdottir et al., 2008; Sukwika and Kasih, 2020; Sukwika and Rahmatulloh, 2021; Zhao et al., 2022).

In this study, the ecosystem services of recreation and ecotourism are discussed, such as conservation of nature, preservation of culture, educational facilities, socialization facilities, stress relief, and financial benefits. Some of these variables are calculated based on the total number of visitors. Once the values are determined, they are summed to obtain the total value of ecosystem services for recreation and ecotourism. Recreation and ecotourism ecosystem services are calculated based on the number of visitors, specifically the entrance fees collected from visitors. In 2021, the value of this ecosystem service was $1.454.246.58, but there was a significant increase so that the value in 2045 would be $11.471.258.92.

3.1.10. Ecosystem services of aesthetic value

The spatial analysis results of mapping aesthetic ecosystem services on Komodo Island and Padar Island, predominantly aesthetic ecosystem services have a high and very high potential (Fig.4) of aesthetic ecosystem services. Areas with a very high potential for aesthetic ecosystem services are found on Komodo Island. The recapitulation results of the aesthetic ecosystem services area on Komodo Island and Padar Island show that most of the area is dominated by areas with high and very high potential with an area respectively of 22.123.57 ha (65.94%) and 3.333.51 ha (9.94%). The benefits value of aesthetic ecosystem services analyzed is to enhance the beauty and appreciation the nature. The value for enhancing beauty is based on the activity of taking videography and photography, including the time needed to take the videos or photos. Meanwhile, the analysis for the appreciation of nature is based on the price of photo services and the number of visits. The valuation of aesthetic ecosystem services takes the tourist's baseline since the valuation process is related to the beautiful quality and it involves the visitors' judgment. It can be seen in the graph that there is a value increase that will be directly proportional to the visitors. In 2013 the valuation value is USD 214.651.76 and in 2045 the valuation will be USD 161.235.251.30.

3.1.11. The value of ecosystem services

Tourism has a positive impact on social and economic aspects (Sukwika and Kasih, 2020; Sukwika and Rahmatulloh, 2021). Nonetheless, tourism also harms the ecosystem services function if this tourism activity has exceeded the carrying capacity of the region (Bhat and Sofi, 2021; Ramdas and Mohamed, 2014; Zhao et al., 2022). The calculation of the ecosystem services analysis shows that the benefits value total amount of the 8 ecosystem services generated from the KNP area is USD 1.524.474.127.74 which is described in detail in Table 5. This aquatic economic value comes from coastal, mangrove, seagrass, and coral reef areas. In total, the aquatic economic value is 188.501.511.16 USD, with the coral reef sector being the largest contributor with a value of 172.408.555.30 USD or 91.46% of the four sectors analyzed. The benefits of coral reefs are that coral reefs are home to various fish species and other marine biota and are one of the leading tourist attractions (diving and snorkeling) in the KNP area. Other aspects such as beaches, mangroves, and seagrass beds contribute 8.54% or the equivalent of $16.092.955.87 when these three aspects are combined. One source of funds for the conservation of the national park is to make the national park area productive and to maintain it. The loss of value of ecosystem services is due to a decline in ecosystem services (Sukwika and Kasih, 2020). The reason for the decline in ecosystem services is due to the high interest of visitors in popular tourist attractions. Therefore, it is necessary to know the trend of the missing value at this time and in the future. The dynamic results of the simulation system are shown in Fig. 6. It is known that the loss of ecosystem services is increasing, while the value of socioeconomic benefits shows a slight movement. Based on these conditions, efforts to control the loss of conservation value and restore the current environmental conditions are important. One form of this is that the management of national parks must consider the carrying capacity and absorptive capacity of their ecosystem services.

The system dynamics analysis generates several simulations and projections related to the loss of ecosystem services and the value of socioeconomic benefits, as shown in Fig. 6. Visitor restrictions can be applied when the loss of ecosystem services is close to the line of socioeconomic value added so that equilibrium is reached. The loss of value in ecosystem services will affect the cost of environmental restoration, which is quite high (Benayas and Bullock, 2013). The simulation results show that the total loss of ecosystem services in 2045 will be $737.037.407.92 if there is no visitation policy. The system dynamics simulation shows the results of the WTP (Willingness to Pay) analysis, as well as the analysis of the respondents' characteristics, which show the value that should be imposed on visitors due to the lost ecosystem services caused by tourism activities in the KNP (Fig. 7).

Based on various analyses conducted and considering future pressures to sustain the KNP, a value for ideal visitor ecosystem services is recommended to range from $194.60 to $389.20. This value represents the average cost simulated using system dynamics. This value takes into account the stress and loss of ecosystem services from past activities.

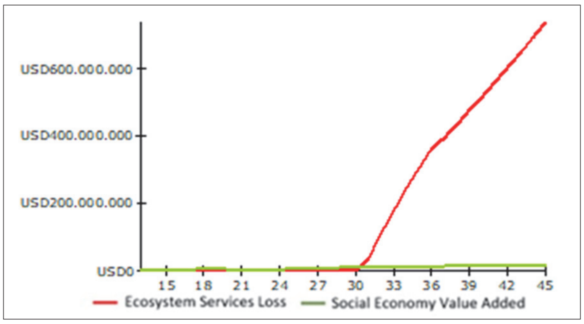


Fig. 6. Ecosystem services loss and the value of socio-economic benefits

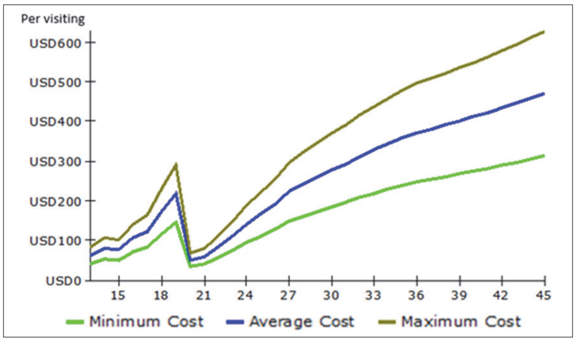


Fig. 7. Willingness to pay for ecosystem services loss

The limitation of visitors and the loss of environmental services should lead the local government to integrate various tourist attractions to increase the length of stay of visitors, thus increasing the direct benefits and the value of ecosystem services in a balanced way. Considering the direct benefits and value of ecosystem services is part of the sustainable tourism management that must be implemented to achieve a balance between conservation and the economic sector. Well-designed tourism will contribute significantly to sustainable development (Budiasa and Ambarawati, 2014).

3.1.12. Real value of visit contribution

KNP is an area used as a leading natural tourist attraction and is one of the priority tourism destinations in East Nusa Tenggara Province.

Table 5. Terrestrial and aquatic ecosystem values

Ecosystem services	***Value (USD)***
Ecosystem services of residential and living space provider	1.177.681.39
Ecosystem services of aesthetic value	204.402.84
ecosystem services of recreational and ecotourism	1.454.246.58
ecosystem service of genetic resource provider	94.497.75
Ecosystem services of biodiversity supporting	237.582.324.64
Ecosystem services of primary production	1.281.705.583.54
Ecosystem services of water supply	995.860.27
Ecosystem services of climate regulatory	1.259.530.74
Total	1.524.474.127.75

As a leading regional and national tourist attraction, it is obviously necessary to consider the value of visitor contribution so that management can develop the tourism sector in a sustainable, environmentally friendly, with good service and a high level of safety. The real value of the contribution to the KNP is derived from the current total value added to the KNP in the form of entrance tickets (non-tax revenues) combined with the additional costs resulting from the willingness to pay (WTP) and ecosystem service loss calculation results.

Figure 8 is the result of a survey of 120 people, taking into account the different social, economic and educational status of the respondents. The results of the questionnaire on the willingness to collect additional entrance fees for conservation showed that the community would like to increase the entrance fees for KNP and sustainable management from $6.61 to $165.27. The most important reason for respondents is the Komodo factor as a creature that needs to be protected and is the only ancient animal in Indonesia today.

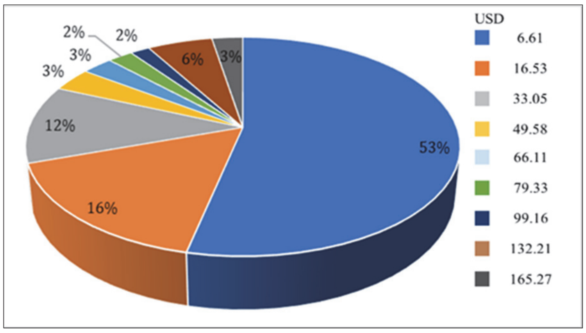


Fig 8. Willingness to additional entrance fee for conservation

Conservation and sustainability considerations are mostly cited as reasons why people are willing to add value to the entry as a form of support for the management and protection of fauna and flora in the area (Ahmad, 2009; Bhat and Sofi, 2021; Platania and Rizzo, 2018; Yang et al., 2022). The data analysis shows the final result obtained from the added value of 30.05 USD; the value is obtained from the weighting analysis and the calculations considering all the data/questionnaires entered. The calculation of the current entry value based on PNBP and Government Regulation No. 12 of 2014 is USD 29.75, so the total value of the current WTP is USD 59.79. However, this value does not take into account the loss of ecosystem services ranging from USD 194.60 to USD 389.20.

3.2. Discussion

Ecosystem services and the value of ecosystem services have declined in TNC due to unrestricted tourism activities, as economic factors are prioritised over social factors. However, the assumptions underlying economic valuation may not be appropriate when applied to ecosystem services (David and Mette, 2010). Every ecosystem service has added socioeconomic value. If a human activity is not curtailed, there is an imbalance between the two variables: The socioeconomic value added will remain, but the loss of ecosystem services will be higher (Fig. 6).

The potential loss of ecosystem services must be anticipated through efforts to restore ecosystem services so that ecosystems damaged by human activities can be restored (Wahyudin et al., 2022) and environmental conditions maintained. WTP can provide an overview of visitors' willingness to contribute to the protection of Komodo National Park. WTP is one of the indicators of visitor involvement in environmental concern and participation in conservation (Kamri, 2013). This is consistent with the conditions in Komodo National Park: visitors are willing to pay more for entrance tickets to support conservation in Komodo National Park.

4. Conclusions

For ecosystem services, 8 priority ecosystem services were selected from 20 ecosystems studied in depth. The analysis of the 8 ecosystem services was conducted by weighting the expert assessments and analyzed using ISM to obtain 8 ecosystem services that can be mapped and their extent. For the mapping of ecosystem services, expert assessment is performed using AHP so that the value per parameter of land cover and eco-region can be determined. Each ecosystem service represents a value for environmental benefits.

When the pressure on ecosystem services in KNP increases, the value of the services also decreases. However, for the existing condition, the decline in benefits is still under control because the KNP has not exceeded the carrying capacity and capacity of its environment and has a total benefit value of $1.524.474.127.74. The value of ecosystem services lost if no restrictions are imposed reaches $727 million per year in 2045, whereas the value lost if restrictions are imposed is about $661.000 per year and still able to repair and restore while maintaining the value of economic and sustainable benefits.

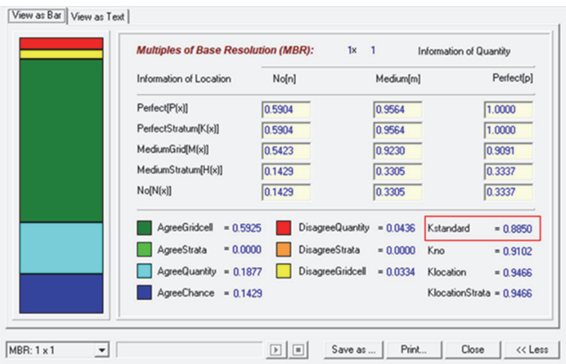
Given the decline in ecosystem services, conservation is needed to restore environmental conditions to maintain them with a loss of ecosystem services of $194.60 to $389.20 per tourist visit. This value will be used for general conservation in Komodo National Park, especially for the survival of the Komodo dragon.

Appendix

The validation test in this study uses the AME (Absolute Means Error) and AVE (Absolute Variance Error) validation tests to find out the data variation and also the difference in values between data from simulations and primary data. The following are the results of the validation that has been carried out in this study, tourists, Komodo dragons and also land become the object of validation for this study. For more details, please see the table below.

AME and AVE Validation Table

	AME 1	*AME 2*	*AVE*
Savana	2.74	2.69	6.66
Forest	5.07	4.68	7.16
Scrub	9.51	9.85	8.79
Settlement	2.12	2.32	4.51
Mangrove	1.35	1.30	8.36
Komodo	9.89	10.00	2.65
Visitors	2.62	0.65	1.89



Kappa spatial dynamics validation image

Based on the results of the validation that has been carried out, for AME validation all variables tested show an error value of less than 10%, which means that this model is very close to the real world value or close to the primary data entered. As with AME, for AVE all variables the error value is below 10%, which means that the data variation entered is valid. Meanwhile, for dynamic spatial validation, the value is 0.8850 or 88.5%, which means that the error from dynamic spatial is only 11.5%, still far from the minimum standard of 15%. Thus, for the use of spatial projections, it can be said that the validation value is qualified for further use.

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