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Applying the model for nature policy to estimate biodiversity values in Tram Chim National park, Dong Thap province

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Abstract: *The Model for Nature Policy was proposed for use in the environmental impact assessment of biodiversity and the effectiveness evaluation of the Dutch government's biodiversity conservation policies. Biodiversity in biomes and habitats was quantitatively measured using biodiversity points. This study employed expert interviews to identify the major biomes in Tram Chim National Park. Subsequently, the Model for Nature Policy and the analytic hierarchy process were applied to measure the ecological quality of the biomes, weighting, biodiversity points, and biodiversity values for the biomes. The results of this study showed that (i) there were 6 major biomes in the park, ranked by decreasing importance: Eleocharis dulcis, Oryza rufipogon, Melaleuca cajuputy, Nelumbo nucifera, Ischaemum rugosum, and Panicum repens; (ii) the ecological quality of Melaleuca cajuputy was 91%, while Nelumbo nucifera, Ischaemum rugosum, and Panicum repens each had about 75%, and Oryza rufipogon and Eleocharis dulcis had around 40%; (iii) the estimated biodiversity values of TCNP in 2024 were 4,35 billion Vietnamese dong per year (0,6 million Vietnamese dong per ha); and (iv) a map was developed to represent the biodiversity values of the park. Our findings may support the decision-making process in the management of biodiversity in TCNP. These contributions are achieved through four approaches: identifying ecological damages caused by environmental incidents; analyzing trade-offs between actions and inactions; assessing the cost-effectiveness of conservation or ecological restoration projects; and proposing plans for resource utilization or land-use transformation.*
Keywords: *Tram Chim National Park, Biodiversity, Valuation, Model for Nature Policy.*

1. Introduction

The statistician and management expert Deming once made a famous statement, implying that: "The most important things are those that cannot be measured." If something cannot be measured, it cannot be managed. In ecosystems, biodiversity is a crucial factor for ensuring the sustainable provision of ecosystem services over the long term and maintaining their resilience (Isbell et al., 2017). Current approaches to valuing biodiversity primarily use stated preference methods, such as Contingent Valuation or Choice Modeling. These methods measure the willingness to pay of the public or service users to value biodiversity through scenarios of improved conditions. However, these methods have some limitations, including: (i) only estimating the value of biodiversity for the entire ecosystem without detailed spatial breakdown; (ii) being highly dependent on the respondents' psychology and the clarity of the hypothetical scenarios; (iii) being difficult to apply when assessing losses from development projects that impact ecosystem quality and integrity. For example, a road construction project connecting two cities that cuts through a forest may benefit transportation but reduce the value of biodiversity. The use value of the forest for various economic purposes may increase due to shorter travel times for visitors. However, the non-use values of biodiversity, such as existence value and bequest value, could be significantly affected due to forest fragmentation and increased pollution from traffic and tourists. These factors are difficult to quantify using only stated preference methods.

Since 2005, the Model for Nature Policy (MNP) has been taught at Wageningen University, Netherlands. By 2017, the authors published version 4.0 of this model. The primary objective of MNP 4.0 is to quantify the impact of management policies on biodiversity at various scales by analyzing the correlation between environmental conditions (habitat types, nitrogen cycle, groundwater levels, etc.) and the conditions necessary to ensure the long-term viability of communities. Since 2005, many scientists have applied this model to quantify biodiversity values in different areas. In 2009, Sijtsma and colleagues utilized the MNP to propose the Biodiversity Points Method (BPM) (Sijtsma et al., 2009). BPM is an innovative and practical approach to measuring the impact of development projects on the non-use value of biodiversity (Klooster et al., 2018). This method does not rely on consumer or public preferences and

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information but is standardized based on expert opinions from ecologists. This paper integrates the Biodiversity Points Method (BPM) and Analytic Hierarchy Process (AHP) to quantify the biodiversity value of Tram Chim National Park.

2. Study site

Tram Chim National Park (TCNP) covers an area of 7,313 ha (coordinates 10°42’49” N latitude, 105°30’12” E longitude) and is one of the last remnants of the wetland ecosystem of the Plain of Reeds, located in the Mekong Delta, Vietnam (Ramsar, 2012). It is the first wetland national park in Vietnam, the fourth Ramsar site in the country, and the 2,000th Ramsar site in the world (Ni et al., 2006). The landscape of TCNP mainly depends on the region’s hydrological regime and soil characteristics (Shepherd, 2008). Although TCNP is situated in a large lowland area, its micro-topography is not uniform, resulting in significant differences in vegetation composition and structure across wetland areas within the park (Triet, 2005). These variations contribute to the rich biodiversity and ecological functions of TCNP, providing a wide range of ecosystem goods and services (Nguyen et al., 2020; Triet, 2005). TCNP is divided into five management zones (A1−A5), each surrounded by a system of canals and dikes with a total length of approximately 50 km (Minh et al., 2014; Ni et al., 2006). The buffer zone of TCNP lies within the administrative boundaries of five communes and one town (Phu Tho, Phu Hiep, Phu Thanh B, Phu Duc, and Tan Cong Sinh) (**Figure 1**).

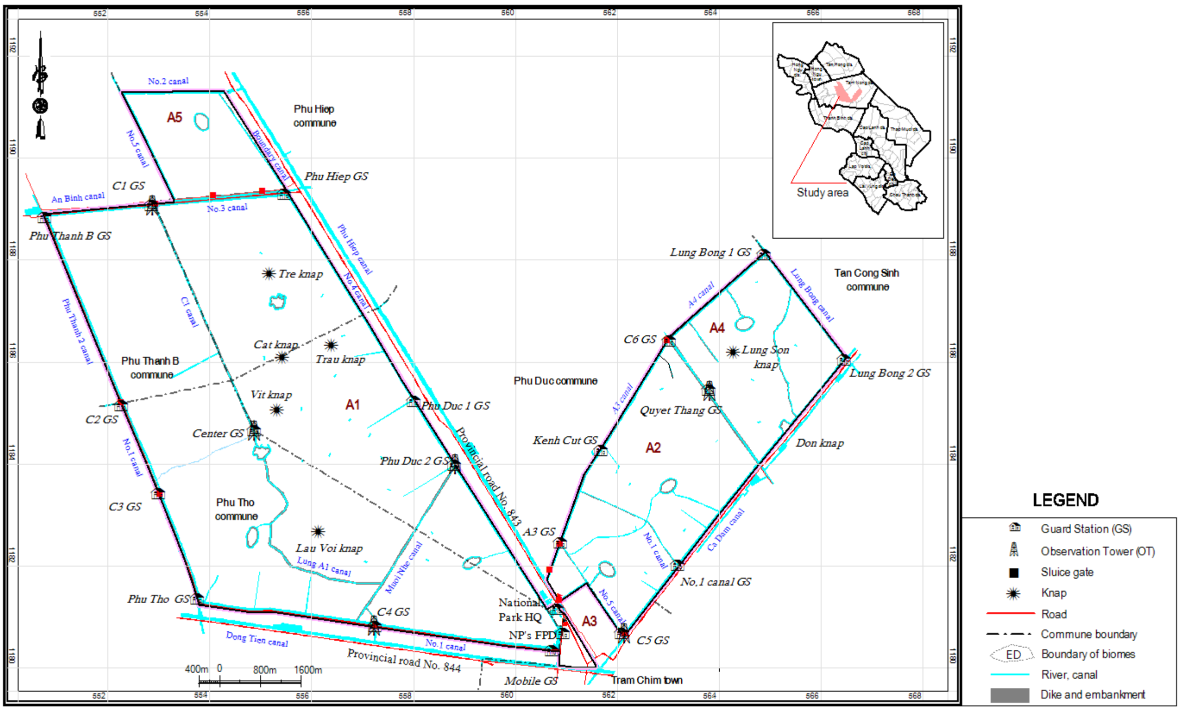

Fig. 1. Map of the study area(adapted from TCNP, 2023)

3. Methodology

The study was divided into four stages, including: (i) data collection and calculation of variables Ai, Qi, and wi; (ii) applying the BPM method to calculate biodiversity points for major biomes; (iii) valuation; and (iv) compiling outcome maps (**Figure 2**).

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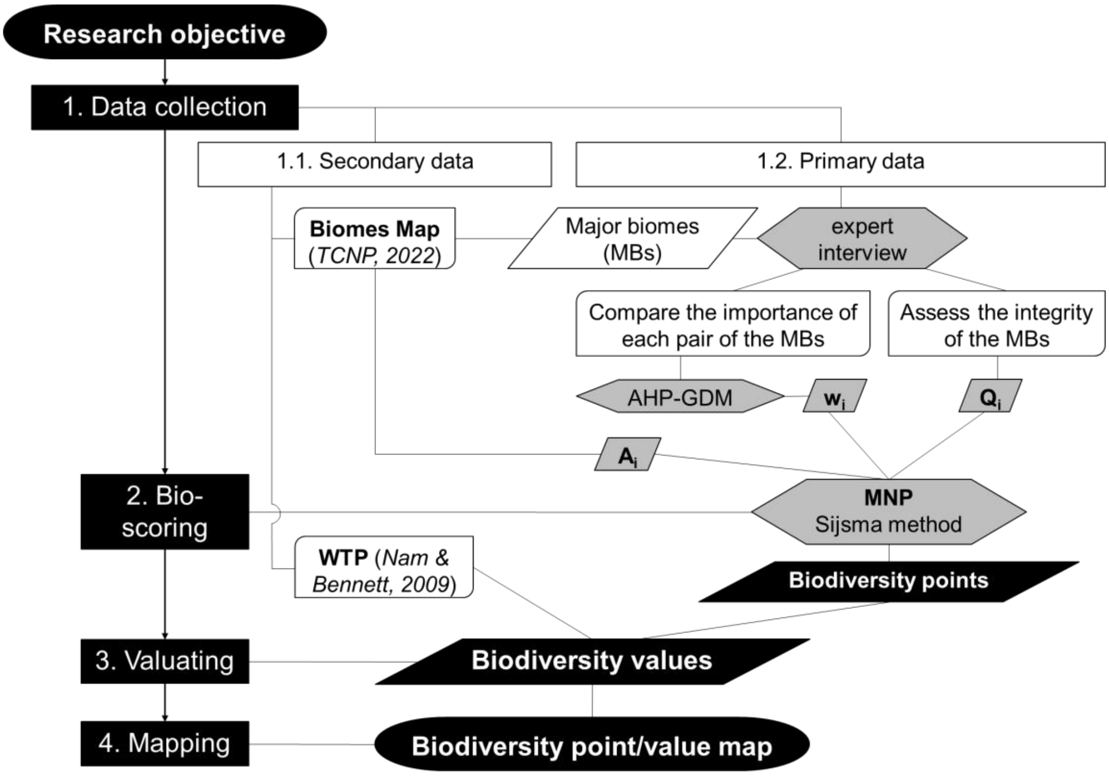

Fig. 2. Research flowchart

3.1. Expert Survey Method

The number of experts selected was based on the guidelines of Crouch and colleagues (Crouch & McKenzie, 2006). According to these guidelines, the number of experts required for an in-depth interview on a specific topic is less than 20 (sample size < 20), depending on the purpose and content of the interview. The aim of the expert survey in this study was to determine the weighting for the biomes using the Analytic Hierarchy Process combined with group decision-making techniques (AHP-GDM). According to the requirements of this method, the maximum number of experts per group is 12 (Moreno-Jiménez et al., 2002). Based on these criteria, the study selected 12 experts for the interviews.

The survey questionnaire was divided into three sections with a total of 14 questions: (i) personal information, current job position, expertise, and years of research experience at Tram Chim National Park (6 questions); (ii) assessment of the importance of biomes at Tram Chim National Park (6 questions); and (iii) evaluation of the integrity of biomes (2 questions).

3.2. Analytic Hierarchy Process-Group Decision Making (AHP-GDM)

According to Saaty (1980), the consistency of pairwise comparison matrices (PCMs) refers to the cardinal transitivity among judgments. For a pairwise comparison matrix A = (aij), i,j = 1,...,n, A is considered consistent if ∀i,j,k aij·ajk = aik. Aguarón and Moreno-Jiménez (2003) introduced the precise consistency consensus matrix (PCCM), which serves as a decision-making tool for handling AHP-Group Decision Making (AHP-GDM). The PCCM employs the Row Geometric Mean (RGM) to derive local priorities and the Geometric Consistency Index (GCI):

$$\mathbf{GCI} = \frac{2}{(n-1)(n-2)} \sum_{1 \le i < j \le n} \log^2 e_{ij} \text{ with } e_{ij} = a_{ij} \cdot \frac{w_j}{w_i} \quad (1)$$

where $w = (w_j)$, *j=1, ..., n is the priority vector.*

3.3. Biodiversity Point Method (BPM)

This method was proposed by Sijtsma and colleagues (Sijtsma et al., 2020), based on the Model for Nature Policy (MNP) (Pouwels et al., 2017) to determine the biodiversity point (BDS). In 2021, Frits Bos and colleagues refined Sijtsma's method into an empirical formula (Bos & Ruijs, 2021). The BDS is an innovative and practical approach for measuring the impact on the non-use value of biodiversity (Bos & Ruijs, 2021):

$$\text{Biodiversity point (PoB)} = \sum_{i=1}^{n} A_i \times Q_i \times w_i \quad (2)$$

where:

A_i = *Area of natural or semi-natural affected biomes;*

Q_i = *Quality of biomes (0-100%); Q_i thể hiện mức độ toàn vẹn của các biome tại thời điểm đánh giá so với biome nguyên thủy và được đánh giá bởi các chuyên gia thông qua phiếu khảo sát.*

w_i = *Weight of biomes*.

3.4. Method for Valuing Biodiversity Functions

The biodiversity value is determined based on the results from BPM using formula (3) below. The willingness to pay (WTP) of the community for biodiversity conservation options is typically determined using stated preference methods such as the Contingent Valuation Method (CVM) or Choice Modeling (CM).

Biodiversity value (VoB) = PoB x WTP (3)

In this paper, the authors use an estimated WTP for the entire national park ranging from 2,54 to 3,15 million USD (Nam & Bennett, 2009). These WTPs were updated based on the price levels in 2024 using the reference site of AREPPIM (https://stats.areppim.com/). Accordingly, 1,0 USD in 2009 is equivalent to 1,45 USD in 2024.

3.5. Mapping Method

The base data layers were standardized from the 2022 habitat map (TCNP 2023). The classification scale and color schemes of the thematic data layers (biodiversity points, biodiversity values) were edited in compliance with the regulations set forth in Circular No. 17/2011/TT-BTNMT on technical procedures for creating environmental maps and the handbook for constructing maps for forest environmental service payments, issued with Decision No. 392/2018/QĐ-TCLN-KHTC.

4. Results

4.1. Vegetation Community Data

The authors standardized the spatial distribution data of the communities using the 2006 vegetation cover map, the 2022 community map, and field survey results from 2024 to compile the 2024 major biomes map as shown in **Figure 3**.

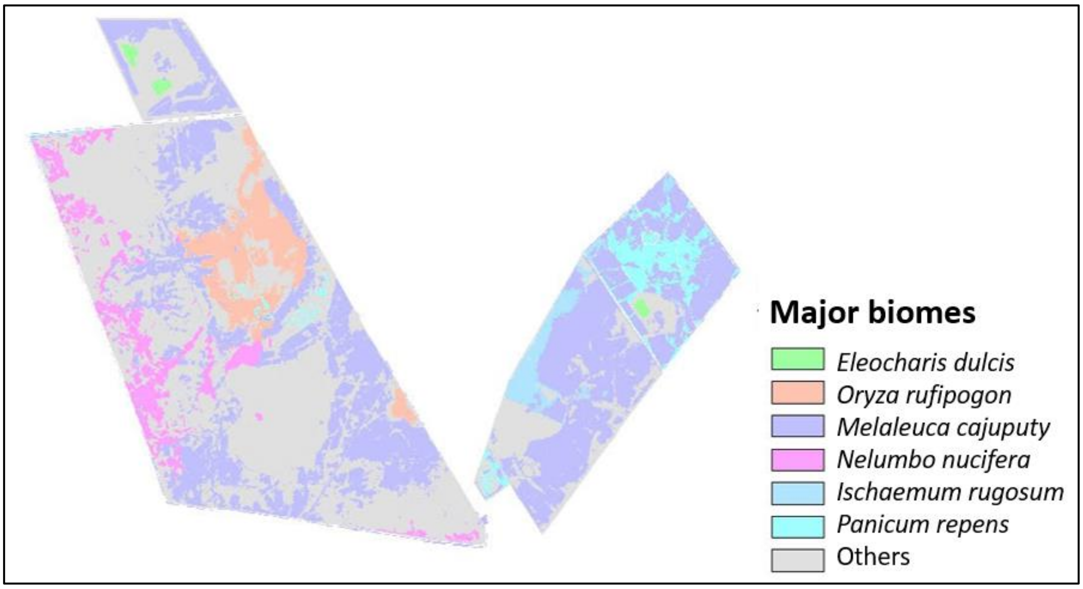

Fig. 3. Major biomes layer of Tram Chim National Park (TCNP, 2023)

4.2. Expert Interview Results

4.2.1. Weights of major biomes

The survey results classified the six major biomes into three groups based on importance (high, medium, low). The *Eleocharis dulcis* (BM_4) and *Oryza rufipogon* (BM_2) biomes were rated as highly important by 11 out of 12 experts. The *Panicum repens* (BM_6), *Ischaemum rugosum* (BM_5), and *Melaleuca cajuputy* (BM_1) biomes were rated as less important by at least two experts.

To quantify the importance of the biomes, the authors applied the Analytic Hierarchy Process (AHP) with Group Decision-Making (GDM) techniques, resulting in a set of weights (**wi**) as shown in column 4 of **Table 1**. All weights had a consistency ratio (RC%) < 10%, proving their reliability for further calculations.

Tab. 1. Results of the calculated weights for the biomes

No	Code	Biome name	w_i	RC(%)
1	BM_4	*Eleocharis dulcis*	0,421	5,545
2	BM_2	*Oryza rufipogon*	0,197	6,021
3	BM_1	*Melaleuca cajuputy*	0,159	8,090
4	BM_3	*Nelumbo nucifera*	0,125	2,541
5	BM_5	*Ischaemum rugosum*	0,050	4,020
6	BM_6	*Panicum repens*	0,048	3,544
	Total		**1,000**	

4.2.2. Quality of major biomes

The responses regarding the integrity of the biomes are summarized in **Table 2**. The *Melaleuca cajuputy* (BM_1) biome was rated as highly intact by 10 out of 12 experts (83%). Conversely, 9 out of 12 experts (75%) rated the *Eleocharis dulcis* (BM_4) and *Oryza rufipogon* (BM_2) biomes as less intact or not intact. This allowed the authors to determine the quality ratios (**Qi**) of the biomes.

Tab. 2. Integrity levels of biomes in TCNP

Code	Biome name	**Integrity level** (number/ratio of experts)					Q_i (%)
		Very integrity	Integrity	Fairly integrity	Less integrity	Not integrity	
BM_1	*Melaleuca cajuputy*	10/ 83%	0/ 0%	1/ 8%	1/ 8%	0/ 0%	**90,91%**
BM_2	*Oryza rufipogon*	1/ 8%	0/ 0%	2/ 17%	6/ 50%	3/ 25%	**38,18%**
BM_3	*Nelumbo nucifera*	7/ 58%	2/ 17%	0/ 0%	2/ 17%	1/ 8%	**78,18%**
BM_4	*Eleocharis dulcis*	2/ 17%	1/ 8%	0/ 0%	5/ 42%	4/ 33%	**41,82%**
BM_5	*Ischaemum rugosum*	6/ 50%	3/ 25%	1/ 8%	0/ 0%	2/ 17%	**76,36%**
BM_6	*Panicum repens*	8/ *67%*	0/ *0%*	1/ *8%*	1/ *8%*	2/ *17%*	**76,36%**

4.3. Calculation of Biodiversity Points and Value Estimates

Biodiversity points for the biomes were determined using formula (2). The willingness to pay (WTP) for the biodiversity conservation scenario in TCNP was based on the study by Do Thang Nam et al. (Nam & Bennett, 2009). The biodiversity value estimated using formula (3) for the entire TCNP was **4,350.57** million VND/year (**Table 3**). According to the results, the *Melaleuca cajuputy* biome (BM_1) had the highest value, accounting for nearly 81% of the total biodiversity value of the park, followed by the *Nelumbo nucifera* biome (BM_3) and the *Oryza rufipogon* biome (BM_2).

Tab. 3. Estimated biodiversity value results for TCNP

Index	Unit	Biome code					
		BM_4	BM_2	BM_1	BM_3	BM_5	BM_6
Weight (w_i)	(%)	0,42	0,20	0,16	0,13	0,05	0,05
Quality (Q_i)	(%)	0,42	0,38	0,91	0,78	0,76	0,76
Biodiversity point (PoB)	(-)	0,18	0,08	0,14	0,10	0,04	0,04
WTP (*)	(mVND/ha/yr)	9,44	9,44	9,44	9,44	9,44	9,44
Biodiversity unit value	(mVND/ha/yr)	1,66	0,71	1,36	0,92	0,36	0,35

Area (A_i)	(ha)	27,85	405,37	2.574,56	396,52	144,37	250,56
Biodiversity Value (VoB)	(mVND/year)	46,28	287,76	3.512,13	365,71	52,02	86,68
Area ratio	(%)	1,06	6,61	80,73	8,41	1,20	1,99
Total biodiversity value of TCNP		**4.350,57 mVND/year**					

(*) The estimated net social benefits of the NP's biodiversity conservation program range from US$2,54 million to US$3,15 million per year. (Nam & Bennett, 2009).

4.4. Biodiversity Point and Value Maps of Tram Chim National Park

Based on the calculated biodiversity points and values (**Table 3**), the authors assigned values to the spatial distribution units of the biomes (**Figure 3**). These points and values were categorized using the Equal count method in GIS software. The classification levels and color schemes adhered to FAO regulations (FAO, 2014) (**Figures 4 and 5**).

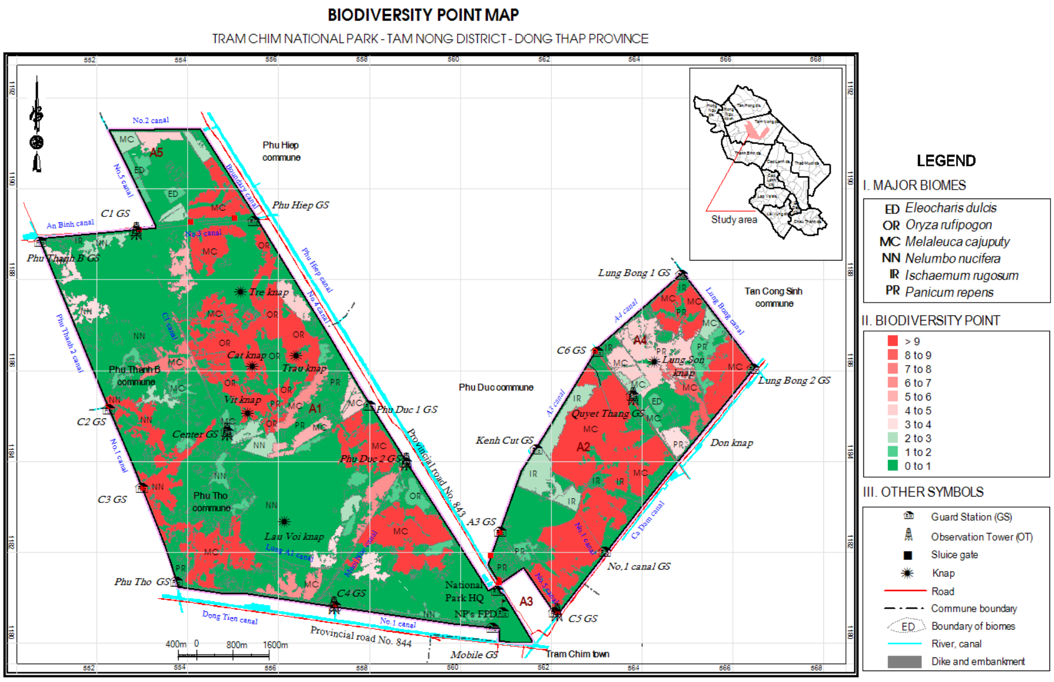

Fig. 4. Biodiversity point map of Tram Chim National Park

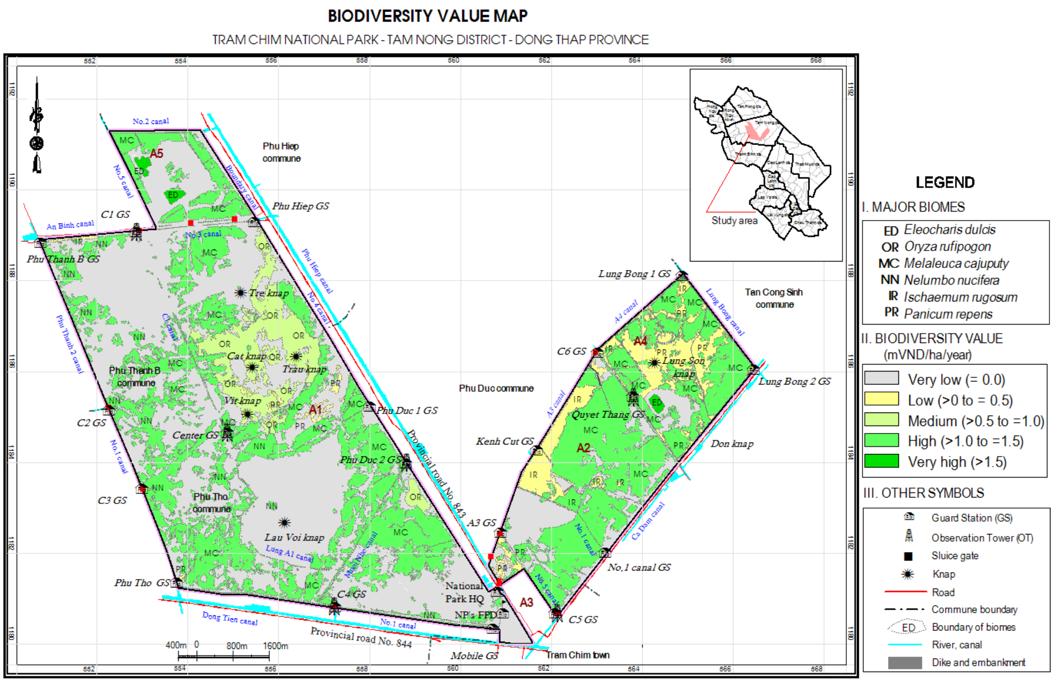

Fig. 5. Biodiversity value map of Tram Chim National Park

5. Discussion

Areas with high biodiversity points (> 9) cover a total area of 1,973 ha, accounting for 27% of the national park (**Figure 4**). This area is primarily distributed in the central regions of zones A1 and A2, the southeast of zone A5, and the northeast of zone A4. High biodiversity points are concentrated in three main biomes: *Melaleuca cajuputy* (BM_1), *Oryza rufipogon* (BM_2), and *Nelumbo nucifera* (BM_3).

Areas with high to very high biodiversity values (> 1.0 million VND/ha/year) cover a total area of 3,000 ha, accounting for 41% of the national park (**Figure 5**). These areas mainly focus on three biomes: *Melaleuca cajuputy* (BM_1), *Nelumbo nucifera* (BM_3), and *Eleocharis dulcis* (BM_4). By zone, high and very high biodiversity values are concentrated in A2 and A4, with distribution in A1 and A5.

6. Conclusion

Biodiversity is one of the most important values of wetland areas. The objective of this study was to apply the Natural Policy Model (MNP) to estimate the biodiversity value for Tram Chim National Park. Input data for the valuation included the communites map established by TCNP in 2022, the results of a survey conducted in July 2024 with 12 experts knowledgeable about TCNP, and the willingness to pay (WTP) for the biodiversity conservation scenario of TCNP published by Nam & Bennett in 2009. Four key results obtained from this study include: (i) the identification of a weight set for the main communities using the AHP-GDM method, where *Eleocharis dulcis* (BM_4), *Oryza rufipogon* (BM_2), *Melaleuca cajuputy* (BM_1), and *Nelumbo nucifera* (BM_3) are the biomes with the highest weights; (ii) the assessment of the integrity (quality) ratio of the biomes, with *Oryza rufipogon* (BM_2) and *Eleocharis dulcis* (BM_4) having the lowest quality, approximately 40%; (iii) the biodiversity scoring results indicate that the *Melaleuca cajuputy* community (BM_1) has the highest point, followed by *Oryza rufipogon* (BM_2) and *Nelumbo nucifera* (BM_3); and finally (iv) the study has produced distribution maps of biodiversity points and values for Tram Chim National Park. The findings of this study will assist managers in decision-making through four key approaches: (i) rapidly identifying ecological losses in the event of an environmental incident (such as a forest fire); (ii) analyzing trade-offs between actions and inactions (e.g., retaining water to prevent fires versus draining and accepting fire risks); (iii) evaluating the cost-effectiveness of conservation or ecological restoration projects; and (iv) developing plans for resource utilization or land-use transformation in specific areas.

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