

TRANSFORMATION AND FRAGMENTATION
OF WETLANDS IN MEKONG DELTA FLOODPLAINS:
A CASE STUDY IN DONG THAP PROVINCE, VIETNAM

Ho Nguyen^{1,2✉}, Tran The Dinh^{3,4}, Phu Phan-Van⁵,
Hau Nguyen-Quoc⁶

Received on November 8, 2024

Presented by I. Zagorchev, Member of BAS, on January 28, 2025

Abstract

Wetlands in the Vietnam Mekong Delta (VMD) have experienced significant reduction and fragmentation since the economic reforms of 1986. This study analyzes land use/land cover (LULC) changes impacting wetland cover between 1990 and 2022 using Landsat imagery within the VMD floodplain, with a particular focus on Dong Thap Province. Landscape metrics were employed to quantify wetland loss and fragmentation. Results indicate that by 2022, approximately 80% of wetlands had been converted to other LULC types, predominantly for rice cultivation. Analysis of landscape metrics, including the number of patches, patch area, core area, and edge characteristics, reveals increased fragmentation, with smaller and more isolated patches replacing larger, contiguous wetlands over the past three decades. Key drivers of this fragmentation include population growth, land reclamation, agricultural expansion, and shifts in farming systems. Given the escalating impacts of climate change, these findings provide essential insights for land use planning and the development of wetland conservation strategies in the Dong Thap Province, the VMD.

Key words: remote sensing, GIS, land management, wetland loss, land use/land cover change, landscape fragmentation

Introduction. Wetlands are considered among the most productive ecosystems worldwide, providing a wide array of ecosystem services (ES) such as flood

This research is supported by the project B2022.SPD.05.
<https://doi.org/10.7546/CRABS.2025.02.06>

control, shoreline stabilization, groundwater recharge, nutrient maintenance, water filtration, biodiversity conservation, climate regulation, and food supply [1]. Despite these benefits, wetlands are one of the most intensively converted land cover types on a global scale [2].

The largest area of wetlands in Vietnam is found in the Mekong Delta (VMD), and these wetlands are classified into two types: inland and coastal. Before the economic reforms (Doi Moi) in 1986, seasonally flooded grasslands and *Melaleuca* forests dominated the inland wetlands of the floodplains in the VMD [3,4]. Dong Thap Province is one of the key regions with extensive seasonal wetlands and *Melaleuca* forests [5]. However, due to the need to expand and intensify agricultural production, especially rice cultivation and aquaculture, alongside economic reform policies, migration, and the development of new economic zones, the natural wetland areas in the VMD and in Dong Thap have significantly decreased [3,4,6]. Additionally, population growth and urban expansion have led to an increase in built-up areas in the region [4]. Together with the expansion of agricultural land, these factors have been key drivers of wetland loss in Dong Thap [4,7].

Beyond the loss of area, wetlands in this region have experienced significant fragmentation due to land use and land cover (LULC) conversions, as well as changes in the local environment [8]. Fragmentation reduces the ecological functions of wetlands, thereby weakening the diverse ES they provide [1]. Therefore, monitoring changes in wetlands and their fragmentation is crucial to support decision-making aimed at sustainable wetland use and conservation.

Due to the inaccessibility of many wetland areas, field surveys often require substantial time and financial resources. Thus, remote sensing techniques that use multi-temporal satellite imagery (with extensive geographic coverage) offer an optimal method for comprehensively investigating wetland changes. To supplement and update data on wetlands in the VMD, this study focuses on analysing wetland loss in Dong Thap Province from 1990 to 2022 using Landsat imagery. Based on this analysis, the study uses various landscape metrics to assess wetland fragmentation across three levels: area patterns, edge patterns, and landscape patterns. The results of this study will provide a foundational database and scientific basis to support the conservation of the remaining wetland landscapes in Dong Thap Province and the VMD as a whole.

Methodology. Study area. Dong Thap is a province in the Mekong Delta region, with a total area of 338 384 hectares. Its northern and north-western borders are adjacent to Cambodia (Fig. 1). The Tien River – one of the two main branches of the Mekong River, flows through Dong Thap for 132 kilometres, dividing the province into two major regions. The northern area of the Tien River is part of the Plain of Reeds, characterized by flat terrain. The southern area, situated between the Tien and Hau Rivers (Bassac River), has a basin-like topography and is frequently flooded during the annual flood season. Dong Thap's climate

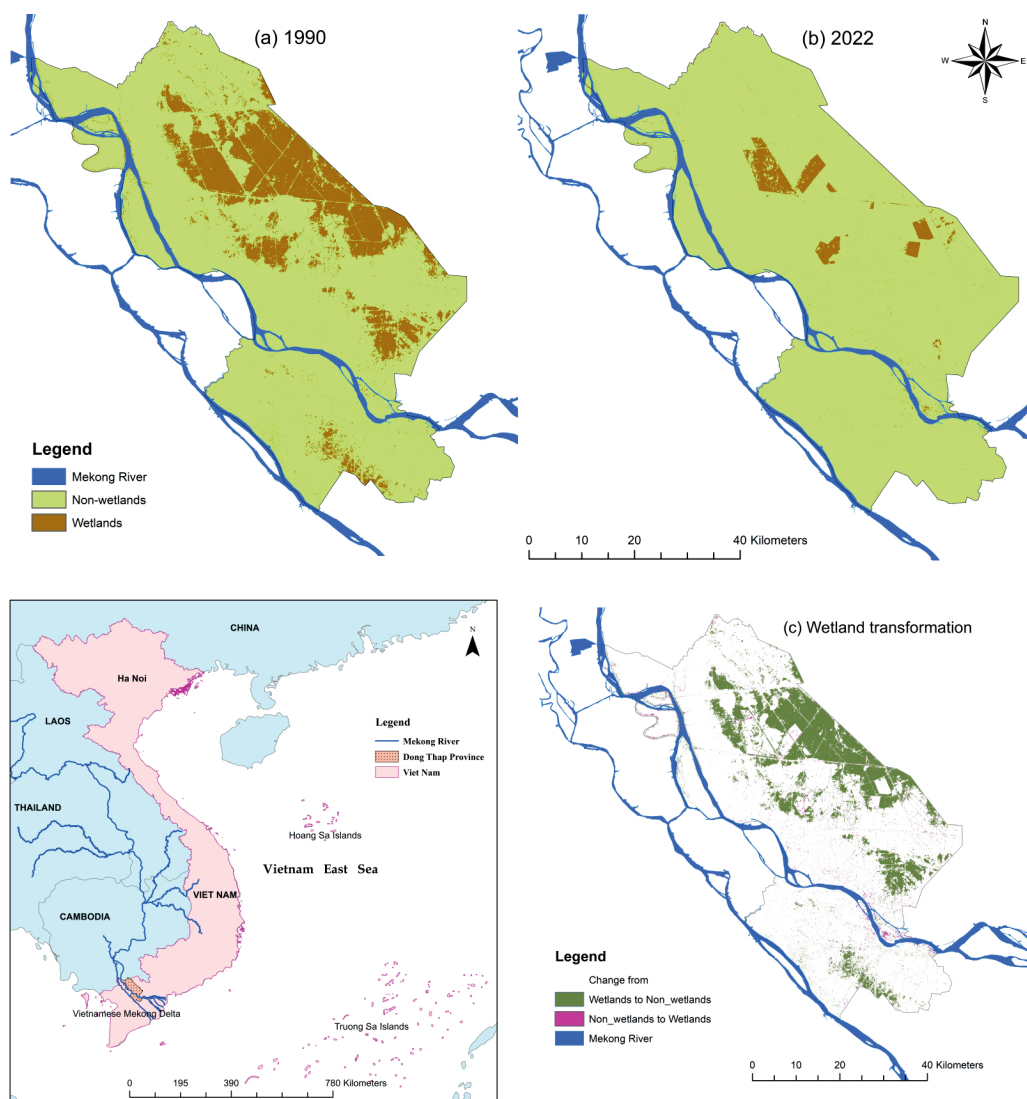


Fig. 1. Map of the location of the study area – Dong Thap Province (bottom-left corner), and (a) Wetland 1990, (b) Wetland 2022, and (c) Wetland loss in the period 1990–2022

is tropical monsoon with two distinct seasons: the dry season (from December to April) and the rainy season (from May to November). The average annual temperature is 27°C , with high humidity (above 80%) and abundant sunshine, especially during the dry season. Annual rainfall averages around 1500 mm. The province's soils are mainly classified into four types: Acrisol, Cambisol, Fluvisol, and Gleysol [9]. The rich water resources from the Tien and Hau Rivers, combined with favourable climatic and soil conditions, support intensive agricultural development (particularly rice cultivation, flowers, ornamental plants, and fruit trees) as well as aquaculture in the region.

T a b l e 1

Specification of Landsat images used in this study

Landsat	Image name	Path/ Row	Acquisition date (y/m/d)	Source
5 TM	LT05_L1TP_125053_19900103	125/053	1990/01/03	USGS
	LC08_L1TP_125053_20190308_20190324_01_T1	125/053	2019/03/08	
8 OLI	LC08_L1TP_125053_20200223_20200822_02_T1	125/053	2020/02/23	USGS
	LC08_L1TP_125053_20220228_20220309_02_T1	125/053	2022/02/28	

Land use/land cover (LULC) data and wetland data for the study area. The wetland data in this study was obtained through three main steps. First, LULC data for 1990 and 2019 were derived from the findings of NGUYEN et al. [4] and updated for 2022 based on the administrative boundaries of Dong Thap Province. Details on the LULC maps are available in Nguyen et al. [4], where LULC data for the entire VMD was classified using Landsat 5 TM (1990) and Landsat 8 OLI (2019, 2020–2022–updated) images (see Table 1), with overall accuracy (OA) of 90% and 95%, respectively [4]. Next, to align with the study’s objectives, the Dong Thap LULC was extracted from the broader LULC dataset and reclassified into five types: (1) agricultural land, (2) wetlands, (3) orchards and perennial crops, (4) built-up land, and (5) open water. Finally, from the updated LULC maps, a simplified classification was created that included only two categories: wetlands and non-wetlands (including agricultural land, orchards and perennial crops, built-up land, and open water). This classification enabled tracking changes and fragmentation of wetland areas from 1990 to 2022.

Landscape ecology metrics analysis. Landscape ecology metrics were employed at the landscape and class level to quantify and characterize the fragmentation of wetlands in the study area from 1990 to 2022. These metrics were calculated based on MCGARIGAL et al. [10], and MCGARIGAL and MARKS [11], with detailed metric descriptions provided in Table 2. The calculations were conducted using the Vector-based Landscape Analysis Tools Extension (V-LATE 2.0) in ArcGIS® (version 10.8) [12].

Results and discussion. Wetland changes from 1990 to 2022. A visual examination reveals that nearly one-fifth of the study area was covered by wetlands in 1990 (Fig. 1a). However, the wetland area experienced a significant decline from 1990 to 2022 (Fig. 1b). The spatial distribution of wetland areas that have been lost/converted in the study area is clearly shown in Fig. 1c. The data indicates a substantial loss of wetland areas over the 32-year period from 1990 to 2022, with an 81.59% reduction, translating to a loss of 54 533 hectares. In contrast, rapid expansion in non-wetland areas (agricultural land, orchards and perennial crops, and built-up areas) was observed in the study area. Overall, non-wetland areas increased by the same amount (54 533 hectares) during this period, reflecting a 20.07% increase (Fig. 2).

T a b l e 2

Description of Landscape ecology metrics used for evaluating wetland fragments in Dong Thap Province (Sources: McGarigal et al. [10], McGarigal and Marks [11])

Metric	Description
NP (Number of Patches)	Total number of wetland patches.
CA (Class Area)	Wetland class area, representing the sum of areas (m ²) for all wetland patches of the respective type.
MPS (Mean Patch Size)	Average size of each wetland patch type.
MSI (Mean Shape Index)	Mean Shape Index, calculated as the total length of the edge (or perimeter) of a class divided by the minimum possible length of class edge (or perimeter) for a maximally aggregated class. MSI > 1, and MSI = 1 when patches are circular (polygons) or square (grids).
MPAR (Mean Perimeter-Area Ratio)	Average ratio of perimeter to area, indicating the “edge” density for a landscape or class.
MFRACT (Mean value of Fractal Dimension)	Mean fractal dimension, reflecting patch shape complexity. The fractal dimension approaches 1 for simple shapes and 2 for more complex shapes. A value greater than 1 for a two-dimensional landscape indicates increasing complexity.
ED (Edge Density)	Edge density (m/ha), defined as the total edge length divided by total area within a class, enabling comparison across differently sized landscapes.
TE (Total Edge)	Sum of edge lengths (m) for all edge segments involving the corresponding patch type.
MPE (Mean Patch Edge)	The average edge length of patches.

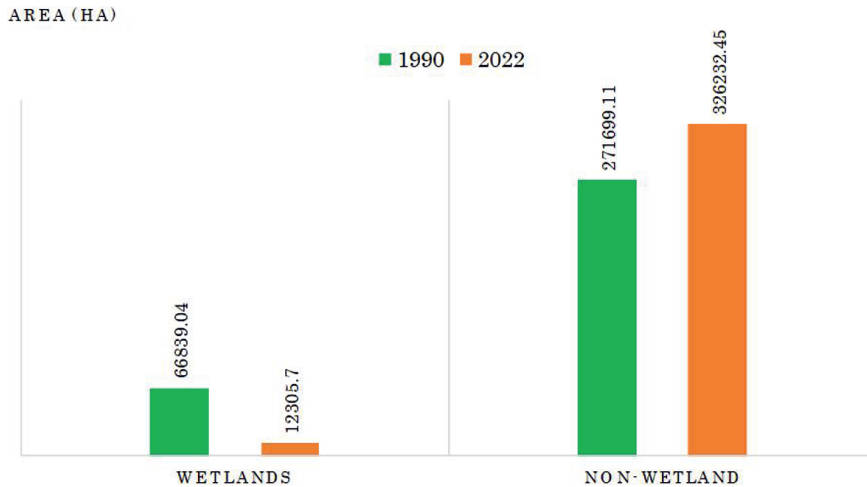


Fig. 2. Wetlands vs. Non-wetlands in 1990 and 2022

The results of this study align with trends observed in other studies on wetland reduction in the VMD [4,13] and Plain of Reeds [5,7]. Previous studies have identified the conversion of seasonally flooded grasslands, forested wetlands, and

T a b l e 3

Landscape ecology metrics for wetland fragments in Dong Thap Province for 1990 and 2022

Wetlands	<i>Area patterns</i>	NP		CA (ha)		MPS (ha)	
		1990	2022	1990	2022	1990	2022
		13 818	9964	66 622.36	12 217.47	4.82	1.22
	<i>Edge patterns</i>	ED (m/ha)		TE (m)		MPE	
		1990	2022	1990	2022	1990	2022
		87.56	184.57	5 833 280.4	2 255 033.93	422.15	226.32
	<i>Landscape patterns</i>	MSI		MPAR		MFRACT	
		1990	2022	1990	2022	1990	2022
		1.275	1.222	0.115	0.121	1.402	1.406

other wetland areas into agricultural land and aquaculture as major threats to the inland wetland ecosystem of the VMD [5, 6, 13, 14].

Landscape metrics for wetland fragments over thirty years. Area patterns. The reduction in the number of wetland patches (NP), total area of wetlands (CA), and average size of wetland patches (MPS) suggests an overall decline in the complexity and fragmentation of wetland areas in Dong Thap Province (Table 3). Over the 30-year period from 1990 to 2022, the NP decreased by approximately 27.89%. The decrease in the number of wetland-patches indicates that smaller patches might have merged, or some patches were completely lost due to LULC changes, mainly agricultural expansion in the study area [5]. Furthermore, a dramatic decrease of approximately 81.66% in the CA was observed in the study area. The substantial reduction in the CA points to a significant loss of wetland ecosystems in Dong Thap Province. Such a reduction in CA could have severe implications for biodiversity, water regulation, and local livelihoods that depend on wetlands [15, 16]. Similarly, the MPS decreased by 74.5%. Alarming decreased values of MPS reflect an increasing fragmentation of wetlands, with larger patches being broken down into smaller, more isolated fragments. This fragmentation can lead to habitat degradation and reduced ecological connectivity, which are critical for the survival of many wetland-dependent species [8, 15, 16].

Edge patterns. Edge patterns in landscape metrics are essential for understanding the ecological dynamics of fragmented habitats [17, 18]. In wetlands and forest, edges can influence factors such as biodiversity, hydrology, and habitat quality [19]. In Dong Thap Province, ED increased by approximately 110%, from 87.56 m/ha (1990) to 184.57 m/ha (2022) over the 32-year period (Table 3). The significant increase in ED indicates that the wetland patches have become more fragmented, with more edges per unit area. Such an increase often results when larger patches are broken down into smaller, more numerous patches, increasing the amount of edge relative to the area. This result reflects decades of agricultural expansion policies, particularly land reclamation efforts in the Plain of Reeds area [3]. During these reclamation campaigns, numerous canals were constructed

to reduce the acidity of acid sulphate soils in wetlands, enabling an expansion of rice cultivation [3]. As a result, many wetland areas were converted into rice fields [5] leaving the remaining wetlands reduced in area and more fragmented.

In the meanwhile, the TE has decreased substantially over the period, dropping to less than half its original value – from 5 833 280.4 m (1990) to 2 255 033.93 m (2022). This reduction suggests that many of the edges in the wetland landscape have disappeared, likely due to the merging or complete loss of smaller wetland fragments. This trend aligns with the increase in ED, as it points to an overall decline in patch abundance but an increase in perimeter density per patch unit. Similarly, the period from 1990 to 2022 witnessed a decline of more than 46% in MPE (from 422.15 m in 1990 to 226.32 m in 2022), indicating that the remaining patches tend to be smaller and simpler in shape. This could reflect a simplification of the wetland landscape, where larger, more irregular patches have been lost or have become more regular in shape.

Landscape patterns. In this study, the MSI, MPAR, and MFRAC_T metrics were used to assess the complexity of wetland patches in the landscape over a 32-year period. Table 3 shows a decrease of approximately 4.16% of MSI. This change suggests that the wetland patches have become more compact and regular in shape over time. This could indicate a loss of the irregular, natural edges typically found in less disturbed landscapes [15], mostly due to LULC changes in the area [4, 7]. In the opposite direction, we recorded an increase 5.2% in the MPAR index from 0.115 (1990) to 0.121 (2022). The increase in the MPAR indicates that the wetland patches have become more elongated or fragmented. The last metric, MFRAC_T, only recorded a slight increase of approximately 0.3% for the period 1990–2022. This insignificant increase suggests a marginal rise in the complexity of the shapes of wetland patches in recent years.

Conclusion. This study highlights significant wetland loss and fragmentation in Dong Thap Province in the Vietnamese Mekong Delta floodplain from 1990 to 2022. Wetland area decreased by 81.59%, largely converted to agricultural and built-up land, reflecting pressures from land reclamation, agricultural and urban expansion. Landscape metrics reveal increased fragmentation, with smaller, more isolated patches replacing larger wetlands, reducing habitat quality and ecological connectivity. These findings underscore the urgent need for sustainable land use and conservation efforts to protect remaining wetlands, which are crucial for biodiversity and ecosystem resilience in Dong Thap Province and the VMD, particularly under the pressures of climate change. This analysis provides a foundation for informed decision-making to protect the inland wetland ecosystems in the study area.

Acknowledgments. The authors are grateful to the U.S. Geological Survey (USGS, <https://earthexplorer.usgs.gov/>) for providing the Landsat data. We acknowledge support from the open access publication fund of the University of Münster.

REFERENCES

- [1] MITSCH W. J., B. BERNAL, M. E. HERNANDEZ (2015) Ecosystem services of wetlands, *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.*, **11**(1), 1–4, <https://doi.org/10.1080/21513732.2015.1006250>.
- [2] DAVIDSON N. C. (2014) How much wetland has the world lost? Long-term and recent trends in global wetland area, *J. Mar. Freshw. Res.*, **65**(10), 934, <https://doi.org/10.1071/MF14173>.
- [3] NGUYEN H., P. DARGUSCH, P. T. MOSS, D. B. TRAN (2016) A review of the drivers of 200 years of wetland degradation in the Mekong Delta of Vietnam, *Reg. Environ. Change*, **16**(8), 2303–2315, <https://doi.org/10.1007/s10113-016-0941-3>.
- [4] NGUYEN H., T. H. TRUNG, D. C. PHAN et al. (2022) Transformation of rural landscapes in the Vietnamese Mekong Delta from 1990 to 2019: a spatio-temporal analysis, *Geocarto Int.*, **37**(26), 13881–13903, <https://doi.org/10.1080/10106049.2022.2086623>.
- [5] NGUYEN H., P. PHAN VAN, P. NGUYEN THI et al. (2020) Wetland monitoring in the Plain of Reeds using Landsat images, *HNUE J. Sci.*, **65**(3), 194–204, <https://doi.org/10.18173/2354-1059.2020-0022>.
- [6] TORELL M., A. M. SALAMANCA (2003) Wetlands management in Vietnam’s Mekong Delta: an overview of the pressures and responses. In: *Wetlands Management in Vietnam: Issues and Perspectives*, WorldFish Center, Penang, Malaysia, 1–16, <https://hdl.handle.net/20.500.12348/2204>.
- [7] BINH N. A., H. S. NHUT, N. N. AN et al. (2021) Thirty-year dynamics of LULC at the Dong Thap Muoi area, Southern Vietnam, using Google Earth Engine, *IJGI Int. J. Geo-Information*, **10**(4), 226, <https://doi.org/10.3390/ijgi10040226>.
- [8] DUONG V. N., R. J. SAFFORD, E. MALBY (2001) Environmental change, ecosystem degradation and the value of wetland rehabilitation in the Mekong Delta. In: *Living with Environmental Change* (ed. W. N. Adger), Routledge, London, 122–136, <https://doi.org/10.4324/9780203995570>.
- [9] PHUONG N. T., H. NGUYEN (2024) Soil Degradation due to Long-term Citrus Cultivation in the Upper Vietnamese Mekong Delta, *C. R. Acad. Bulg. Sci.*, **77**(5), 780–790, <https://doi.org/10.7546/CRABS.2024.05.17>.
- [10] MCGARIGAL K., S. A. CUSHMAN, E. ENE (2023) FRAGSTATS v4: spatial pattern analysis program for categorical maps, Computer software program produced by the authors, <https://www.fragstats.org>.
- [11] MCGARIGAL K., B. J. MARKS (1995) FRAGSTATS: spatial pattern analysis program for quantifying landscape structure, PNW-GTR-351, <https://doi.org/10.2737/PNW-GTR-351>.
- [12] LANG S., D. TIEDE (2003) vLATE Extension für ArcGIS – vektorbasiertes Tool zur quantitativen Landschaftsstrukturanalyse (Version 2.0), ESRI.
- [13] FUNKENBERG T., T. T. BINH, F. MODER, S. DECH (2014) The Ha Tien Plain – wetland monitoring using remote-sensing techniques, *Int. J. Remote Sens.*, **35**(8), 2893–2909, <https://doi.org/10.1080/01431161.2014.890306>.
- [14] BUCKTON S. T., C. NGUYEN, Q. Q. HA, D. T. NGUYEN (1999) Conservation of key wetland sites in the Mekong Delta (BirdLife International Vietnam Programme Conservation Report 12), BirdLife International Vietnam Programme.

- [15] COSENTINO B. J., R. L. SCHOOLEY (2016) Dispersal and wetland fragmentation. In: *The Wetland Book* (eds C.M. Finlayson et al.), Springer Netherlands, Dordrecht, 1–7, https://doi.org/10.1007/978-94-007-6172-8_56-4.
- [16] NGUYEN D. T., T. T. PHAM, T. K. H. TANG (2024) Biodiversity status of the Mekong Delta, Vietnam, Center for International Forestry Research (CIFOR), Bogor, Indonesia, <https://doi.org/10.17528/cifor-icraf/009134>.
- [17] UUEMAA E., M. ANTROP, J. ROOSAARE et al. (2009) Landscape metrics and indices: an overview of their use in landscape research, *Living Reviews in Landscape Research*, **3**, 1–28, <https://doi.org/10.12942/lrlr-2009-1>.
- [18] WANG X., F. G. BLANCHET, N. KOPER (2014) Measuring habitat fragmentation: an evaluation of landscape pattern metrics, *Methods Ecol. Evol.*, **5**(7), 634–646, <https://doi.org/10.1111/2041-210X.12198>.
- [19] HARPER K. A., S. E. MACDONALD, M. S. MAYERHOFER et al. (2015) Edge influence on vegetation at natural and anthropogenic edges of boreal forests in Canada and Fennoscandia, *J. Ecol.*, **103**(3), 550–562, <https://doi.org/10.1111/1365-2745.12398>.

¹*Department of Land Management, Dong Thap University,
87000 Cao Lanh City, Dong Thap, Vietnam
e-mail: nguyenho@dtthu.edu.vn (<https://orcid.org/0000-0002-2991-0011>)*

²*Institute of Landscape Ecology, University of Münster,
48149 Münster, Germany
e-mail: ho.nguyen@uni-muenster.de*

³*Department of Geography, Faculty of Education, An Giang University,
An Giang, Vietnam
e-mail: tt dinh@agu.edu.vn (<https://orcid.org/0000-0003-2266-4943>)*

⁴*Vietnam National University, Ho Chi Minh City, Vietnam*

⁵*Faculty of Geography, Ho Chi Minh City University of Education,
70000 Ho Chi Minh City, Vietnam
e-mail: phupv@hcmue.edu.vn (<https://orcid.org/0009-0006-3623-2067>)*

⁶*Institute of Science and International Cooperation, Mien Tay Construction University,
89000 Vinh Long City, Vinh Long, Vietnam
e-mail: nguyenquochau@mtu.edu.vn (<https://orcid.org/0009-0002-1719-2881>)*