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Economic currents and land use: Coastal change during the construction of the eco-island carbon neutral demonstration zone in Chongming Island

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ABSTRACT

This study investigates the dynamic relationship between economic currents and land use changes on Chongming Island, China, during the period from 2000 to 2020, coinciding with its transformation into an Ecological Island Carbon Neutral Demonstration (ECND) Zone. Employing remote sensing and Geographic Information Systems (GIS), our research not only identifies significant spatiotemporal changes, such as an 8.72% increase in constructed land and an 11.79% decline in water areas, but also delves into the nuanced shifts in forested and grassland areas. These findings prompt a critical exploration of the intricate balance between economic growth and ecological preservation within the context of urbanization. Our research resonates with interdisciplinary studies and policy objectives, emphasizing the imperative of sustainable urban development that respects the island's ecological equilibrium. Amidst the challenges posed by rapid urbanization, the oscillations in forested and grassland areas underscore the vital importance of strategic land use planning and habitat restoration. This quantitative analysis not only contributes to Chongming Island's evolution as an ECND Zone but also provides a valuable model for estuarine islands worldwide grappling with similar issues. As Chongming Island continues its journey towards ecological sustainability, our study stands as a quantitative guide for informed decision-making in sustainable land management and preservation, shedding light on the intricate interplay between economic currents and land use changes in this unique context.

1. Introduction

Since the beginning of the 21st century, the global phenomenon of climate change has continued to worsen, giving rise to severe environmental challenges, such as rising sea levels, which have garnered widespread attention on a global scale. Excessive emissions of greenhouse gases, notably carbon dioxide, constitute the primary driver of climate change. The concept of "carbon neutrality" has rapidly emerged as a pivotal idea, receiving extensive global support (Chen, 2021). As a major contributor to carbon emissions, China plays a crucial role in global carbon neutrality efforts. On September 22, 2020, China made a significant commitment at the 75th session of the United Nations General Assembly, pledging to peak its carbon emissions by 2030 and strive to achieve carbon neutrality by 2060 (Zhang et al., 2021).

In the pursuit of carbon neutrality, the ecological development of islands has gained attention through regional policies. Due to their isolation from the mainland by water bodies, islands form relatively self-contained natural systems with limited environmental carrying capacity, making their ecosystems highly vulnerable (Chen et al., 2020, 2022; Chuai et al., 2014). Consequently, the array of environmental issues triggered by global climate change poses a greater threat to already fragile island ecosystems. Among the severely affected islands, "estuarine islands" located at the confluence of rivers and oceans play a critical role in the development of river delta urban clusters and coastal economic zones, providing crucial locational resources, natural assets, and ecosystem services (Lin et al., 2020; Shen et al., 2019; Tan and Solangi, 2023). They also tend to have closer connections between urban centers compared to "oceanic islands." Therefore, the urgent sustainable development of estuarine islands distributed in China is not only vital due to the fragility of their ecosystems but also aligns with the sustainable development strategies of coastal regions. Moreover, the sensitivity of island ecosystems makes them focal points of research and

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experimental fields for addressing global issues such as geomorphological and landscape changes, population migration, and urbanization in the context of climate change.

In this context, China has introduced the concept of Ecological Island Carbon Neutrality Demonstration Zones (ECND zones) aimed at showcasing environmentally friendly carbon neutrality practices. This initiative integrates renewable energy, sustainable construction, and carbon offset projects while emphasizing research, education, and community engagement (Halvorssen, 2005; Ishii et al., 2010; Tan and Solangi, 2023). In these designated areas, coastal transformation primarily focuses on implementing anti-erosion measures, mangrove restoration, wetland conservation, and sustainable fisheries practices to protect coastlines. This region effectively illustrates the synergistic relationship between carbon neutrality and the preservation of coastal ecosystems. It represents a comprehensive strategy that integrates cultural and economic factors, including renewable energy, sustainable infrastructure, carbon offset initiatives, and innovative technologies. Among these factors, carbon offset initiatives and sustainable infrastructure are closely related to land use changes on Chongming Island (Kuang et al., 2022; Li et al., 2023; Linna et al., 2014). Their goal is to develop green spaces, eco-friendly buildings, and sustainable transportation systems to reduce environmental impact, create a healthy living environment, and offset carbon emissions through extensive afforestation projects. The implementation of the ECND zone project holds great significance as it demonstrates the practical benefits and advantages of carbon neutrality and sustainable lifestyles. Renowned islands like Chongming Island, with its rich ecological diversity, proximity to urban centers, tourism potential, and suitability for showcasing various carbon–neutral strategies, make it an ideal location for the ECND zone project.

However, existing research on ecological governance similar to the ECND zones remains limited and under-discussed. Prior studies have primarily focused on oceanic islands, with research themes spanning Pacific island nations, tourism management, island case studies, sustainable financing, and energy vulnerability between 2005 and 2019 (Wu, 2020). Oceanic islands have been the primary focus of sustainable island research, with a key emphasis on the conflict between island ecological carrying capacity and resource development, resulting in issues such as land use conflicts, biodiversity loss, and environmental pollution. In contrast, estuarine islands, particularly those near economically developed regions, have received less attention (Grigoraș and Urițescu, 2019; Polykretis et al., 2020; Wang et al., 2021, 2023). Hence, this study selects Chongming Island, an estuarine island located in the economic hub of Shanghai, as the research subject. It focuses on land use changes on Chongming Island from 2000 to 2020, with particular attention to changes in land use since it was initially designated as an ECND zone in 2005.

Land-Use and Land-Cover Change (LUCC) is a significant challenge for sustainable development in economically developed regions. Changes in land use patterns alter terrestrial ecosystems and have a profound impact on the Earth's carbon cycle. This transformation has become a major catalyst for global and regional carbon emissions changes (Li et al., 2022; Nijdam et al., 2012; Yang et al., 2020). China's rapid economic development in recent years has led to significant changes in land use, resulting in a substantial increase in carbon emissions. Given this enormous challenge and practical need, we believe that studying the recent temporal and spatial changes in land use in the region and revealing their underlying drivers are crucial for promoting carbon neutrality and formulating region-specific governance strategies.

In recent years, research on the spatiotemporal dynamics of land use has made significant progress in terms of data sources and methodologies (Bai et al., 2021; Zhang et al., 2023). Techniques such as remote sensing, GIS analysis, and model simulations have provided powerful tools for understanding the spatiotemporal patterns and influencing factors of land use change (Hansen, 2013; Nwakaire et al., 2020; Raihan and Tuspekova, 2022). To assess the extent of tropical forest deforestation, Hansen et al. (2013) used satellite remote sensing data to track annual changes in forest cover in the Amazon rainforest, revealing an increasing rate of deforestation year by year, posing a significant threat to the Amazon rainforest. Forest cover loss not only negatively impacts global ecosystem stability but also releases a substantial amount of carbon, accelerating climate change. Similarly, Smith et al. (2019) employed remote sensing technology to monitor land use changes in the vicinity of a major Chinese city, with a specific focus on the speed and pattern of urban expansion. Their research found that urban expansion had severe effects on surrounding farmland and ecosystems, leading to challenges such as decreased land resources and food security issues in agriculture. Additionally, urban expansion exacerbated traffic congestion and environmental pollution. Zhang et al. (2018) conducted a similar study, integrating data on urban expansion, population growth, land quality, and infrastructure development using GIS technology to assess the impact of urbanization on farmland and the natural environment. The results showed that urbanization led to a reduction in farmland, wetland degradation, and ecosystem loss, providing valuable insights for urban planning and land management. Furthermore, studies using model simulations mostly focus on predicting future land use/cover changes, especially in the context of natural disasters and climate change. For instance, Zhang et al. (2019) employed model simulations to assess the potential impact of flood disasters on land use/cover.

In terms of methodologies, research methods for studying land use change have continuously advanced. In the field of image classification and interpretation, deep learning techniques such as Convolutional Neural Networks (CNN) have made significant progress, improving the accuracy of automated classification (Maroulis & Xu, 2020). Both supervised and unsupervised classification algorithms have benefited from the application of deep learning and advanced clustering techniques (LeCun & Hinton, 2015). Change detection methods have continuously improved, particularly through the integration of multisource remote sensing data to enhance change detection accuracy (Wang & Gong, 2019). Spatial analysis techniques have benefited from the ongoing development of GIS technology and spatial data mining methods (Goodchild & Gahegan, 2021). Model simulation methods have become increasingly complex, considering more factors and driving factors, while the use of open data and tools has improved the accessibility of models (Ruane & Sultan, 2018).

These advancements contribute to a more comprehensive understanding of the complexity of land use change and provide a stronger scientific basis for the formulation of sustainable land management strategies. Interdisciplinary research and data integration will continue to drive the forefront of land use change research (Chen and Mather, 2019; Shi et al., 2016; Smith et al., 2016), aligning with the high complexity and diversity of land use changes observed globally in recent years. Multiple factors, including urbanization, agricultural expansion, and nature conservation, interact, leading to dynamic changes in land use patterns. Simultaneously, the demands of socio-economic development and environmental protection drive the continuous evolution of land use patterns. These changes have profound implications for sustainable development and ecological balance. Thus, a deep understanding of the trends and driving factors of spatiotemporal changes in land use is crucial for the formulation of scientifically sound land management policies. In conclusion, future research should continue to focus on data integration from multiple sources, delve into driving factors, and use this as a basis for formulating sustainable land use management strategies.

Therefore, this study utilizes remote sensing images of Chongming Island from 2000 to 2020, combined with RS and ArcGIS tools, to determine land use data and transition matrices. It examines the spatiotemporal changes in land in the region in recent years, along with their driving forces, and analyzes the ecological environmental effects of changes in land use types. The aim is to provide scientific references for the rational development and utilization of land resources and ecological environmental protection in the research area.

2. Methodology

2.1. Overview of the study area

As an important ECND zone, Chongming Island is situated within Shanghai, positioned at the mouth of the Yangtze River. It is bounded by the East China Sea to the east, connected to the Yangtze River on its western side, and faces the Pudong New Area, Baoshan District, and Taicang City of Jiangsu Province to the south. To the north, it is separated from the cities of Haimen and Qidong in Jiangsu Province by a narrow waterway. This island features predominantly flat terrain without any discernible hills. Based on data from the 2017 National Geographic Monitoring, the land area of Chongming Island encompasses approximately 1,500 km2. Within this expanse, approximately 224 km2 (15 %) is designated for construction purposes, 904 km2 (59 %) is utilized for agricultural activities, 169 km2 (11 %) is covered by forests and grasslands, 237 km2 (15 %) comprises water bodies, and a negligible percentage represents unutilized land, classified as desert or barren terrain. Furthermore, beyond the confines of Chongming Island's land area, the region boasts an additional expanse of nearly 2,500 km2 comprising diverse wetland resources. These resources encompass silty beaches, intertidal saltwater marshes, estuarine waters, deltas, sandbars, sand islands, herbaceous marshes, and forested marshlands. The focal scope of this study pertains to the land area of Chongming Eco-Island, which is depicted in Fig. 1.

2.2. Research methods

2.2.1. Dynamics of land use

The concept of Land Use Dynamics Degree serves as a crucial metric in portraying the extent of transformative changes occurring within a specific geographical area. Moreover, it elucidates the disparities that exist within the pace of alteration across diverse land utilization categories within the same region (Xu et al., 2018). In the context of this study, the focal objectives revolve around the utilization of both the Single Land Use Dynamic Degree and the Integrated Land Use Dynamic Degree. These metrics are instrumental in quantitatively encapsulating the rate at which alterations unfold, be it for a particular land category or encompassing the entirety of land types, over a designated timeframe. The formulation underlying these dynamic degree indices can be expressed as follows:

$$D = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \tag{1}$$

where D is the dynamic degree of a land use type during the analysis period; U_a、U_b respectively represent the area of a land use type at the beginning and end of the analysis period; T is the length of the analysis period.

2.2.2. Land use transfer matrix

The Land Use Transfer Matrix serves as a comprehensive tool for elucidating both the magnitude and direction of shifts in regional land utilization patterns. This methodology finds its origins in the realm of quantitative analyses applied to system states and their transformations within system theory, effectively capturing the evolutionary trajectory of system states over time (Wu et al., 2014). This model is rooted in the formulation of system dynamics, wherein changes are encapsulated by the interplay of various components within a given system. The expression formula that encapsulates this model is as follows:

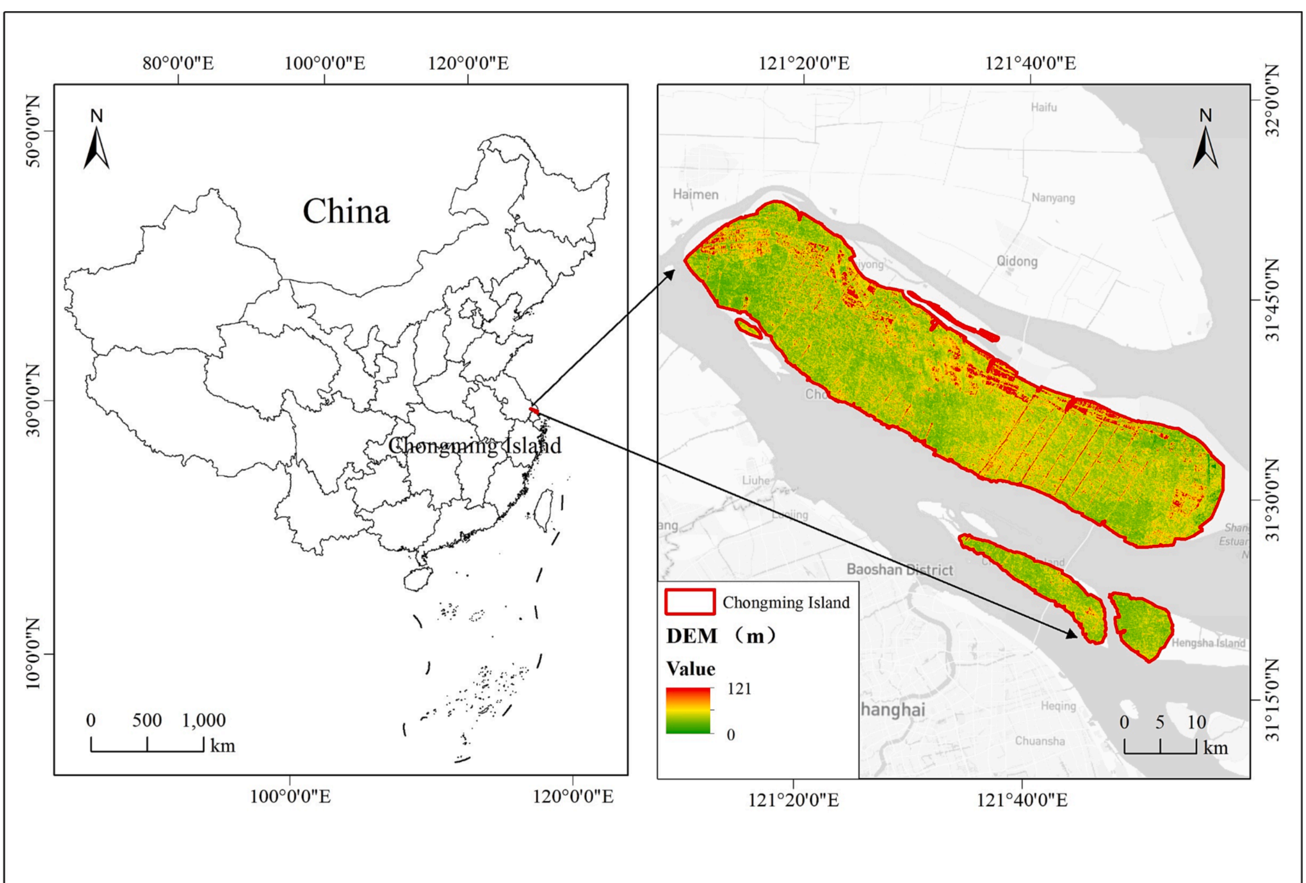


Fig. 1. Chongming Island.

$$\boldsymbol{T}_{ij} = \begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1n} \\ T_{21} & T_{22} & \cdots & T_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ T_{n1} & T_{n2} & \cdots & T_{nn} \end{bmatrix} \tag{2}$$

where $\boldsymbol{T}_{ij}$ is the area of the "i-th" land use type converted into the "j-th" land use type at a certain time, and "n" is the number of land use types. In this study, using GIS software, land use data for consecutive years on Chongming Island during the study period were superimposed, and the spatial analysis module was used to calculate the land use transfer matrix between each adjacent year from 2000 to 2020 in Chongming Island.

2.2.3. Unary linear regression model

Regression analysis is mainly used to explain the correlation between variables and is generally divided into unitary and multiple regression models. The Unary linear regression model is based on statistical principles for unary linear and nonlinear regression curve fitting. In this study, the unitary regression model is mainly selected and the formula is:

$$y = a + bx + \varepsilon \tag{3}$$

Where x、y are the independent and dependent variables, respectively; a、b are regression coefficients; ε is a random variable of the error term. The first step in this model is to use the P value to determine whether there is a unitary regression relationship between x and y, the smaller the P value, the better. And then, the closeness of the linear correlation between the two variables should be determined, in which the correlation coefficient R^2 is an important judgment indicator, taking a value range of [0,1], the closer its value is to 1, the stronger the linear correlation between the two variables.

3. Results

3.1. Land use changes analysis

In the study period spanning from 2000 to 2020, the land use data reveals noteworthy trends that have significant implications for both environmental policy and urban planning (see Table 1 and Fig. 2). Most prominently, Cultivated Land holds a majority share throughout the years, undergoing a slight increase from 74.91 % in 2000 to 76.86 % in 2020, indicating the sustained importance of agriculture in land utilization. Forest Land, although smaller in proportion, remains relatively stable around 2.5 %, experiencing only a minor decrease from 2.57 % in 2000 to 2.35 % in 2020. This stability suggests that deforestation is not a major issue within the observed timeframe. Interestingly, Grassland, despite its minimal share, presents a curious rebound, surging from 0.11 % in 2015 to 0.37 % in 2020, which may warrant further investigation. On the other hand, Water Areas see a dramatic decline from 13.21 % in 2000 to 6.64 % in 2020, almost halving its share, which could signal rising environmental stress and necessitate immediate conservation efforts. Complementing this decline is the consistent expansion of Constructed Land from 9.07 % in 2000 to 13.78 % in 2020, indicative of an ongoing urbanization trend. This data-driven insight into the evolution of land use categories can serve as a foundational pillar for policymakers, offering a nuanced understanding that aids in crafting targeted and effective land management strategies.

As demonstrated in Table 2, the dynamic shifts characterizing Chongming Island's land use during the interval of 2000–2020 are notably discerned through a comparative lens, considering alterations between selected preceding and subsequent years:

Cultivated Land: The area of cultivated land experiences modest fluctuations, yielding little substantial change. Over the two-decade period, the cultivated land area contracts by 14.69 km^2, reflecting a

Table 1
Proportion of Different Land Types in Chongming from 2000 to 2020.

Year	Cultivated land		Forest land		Grassland		Water area		Constructed Land	
	Area	Percentage	Area	Percentage	Area	Percentage	Area	Percentage	Area	Percentage
2000	1017.3915	74.91 %	34.8633	2.57 %	3.4524	0.25 %	179.3547	13.21 %	123.1713	9.07 %
2005	1034.9199	76.20 %	35.316	2.60 %	3.3372	0.25 %	146.25	10.77 %	138.4101	10.19 %
2010	1010.3481	74.39 %	34.5114	2.54 %	3.3084	0.24 %	144.7128	10.65 %	165.3525	12.17 %
2015	1012.6773	74.56 %	34.3656	2.53 %	1.5453	0.11 %	140.2686	10.33 %	169.281	12.46 %
2020	1033.0803	76.86 %	31.6458	2.35 %	4.9599	0.37 %	89.2134	6.64 %	185.2146	13.78 %

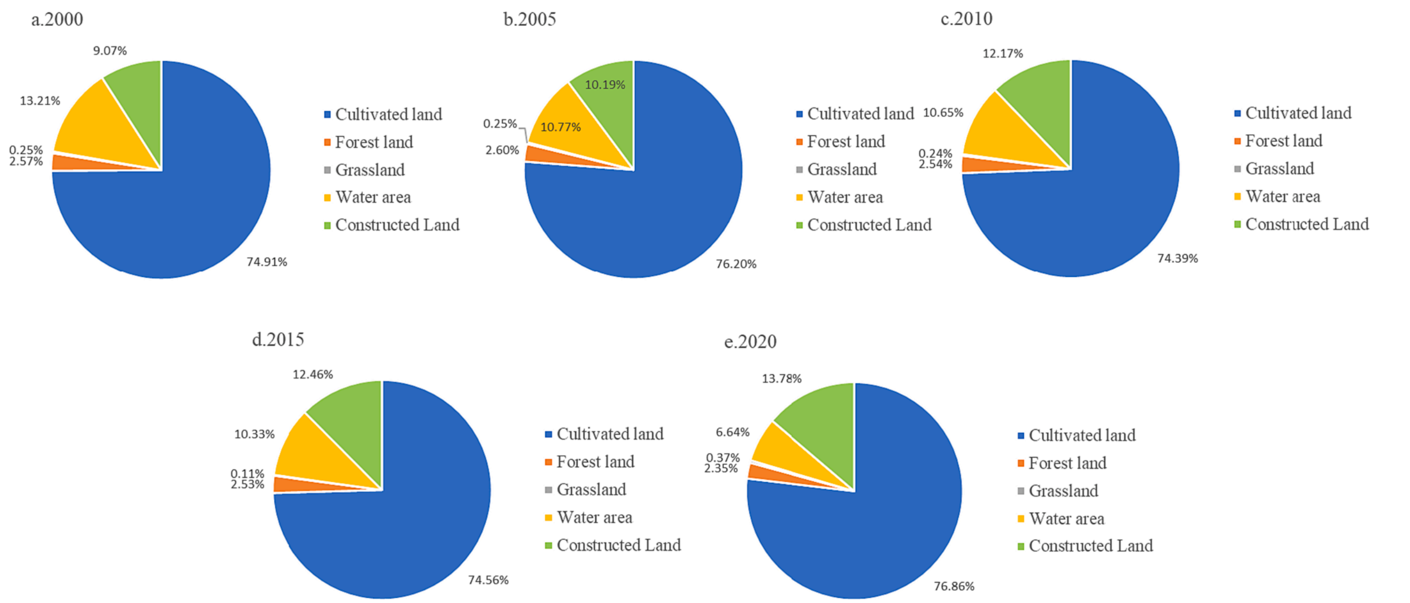


Fig. 2. The proportion of different land types in 2000–2020.

Table 2
Changes of Different Land Types in Chongming from 2000 to 2020.

	Year Range									
	Cultivated land		Forest land		Grassland		Water area		Constructed land	
	Area	Dynamic Degree	Area	Dynamic Degree	Area	Dynamic Degree	Area	Dynamic Degree	Area	Dynamic Degree
2000–2005	−17.5284	−0.34 %	−0.4527	−0.26 %	0.1152	0.67 %	33.1047	3.69 %	−15.2388	−2.47 %
2005–2010	24.5718	0.47 %	0.8046	0.46 %	0.0288	0.17 %	1.5372	0.21 %	−26.9424	−3.89 %
2010–2015	−2.3292	−0.05 %	0.1458	0.08 %	1.7631	10.66 %	4.4442	0.61 %	−3.9285	−0.48 %
2015–2020	−20.403	−0.40 %	2.7198	1.58 %	−3.4146	−44.19 %	1.0552	7.28 %	−15.9336	−1.88 %

decrease rate of 0.32 %. Notably, this evaluation involves a comparative analysis between two specific years, such as subtracting the area in 2000 from 2020.

Constructed Land: A significant surge in constructed land area underscores the degree of transformation with pronounced dynamism. Throughout these twenty years, the region witnesses a remarkable increase of 62.04 km^2 in constructed land area, signifying a growth rate of 8.72 %. Correspondingly, the proportion of constructed land within the total area expands from 15.76 % in 2000 to 23.70 % in 2020. This substantial shift corroborates the escalating prominence of constructed land as a pivotal land use category within the study area.

Forested Land: The trajectory of forested land unfolds as a succession of increments followed by decreases, culminating in an overall reduction of 3.22 km^2, translating to a decrease rate of approximately 1.86 %. This pattern underscores the practice of deforestation to facilitate the expansion of cultivated and constructed land during the urbanization process.

Water Bodies: The aggregate area of water bodies experiences a noteworthy contraction, accompanied by dynamic fluctuations that depict an inclination towards more pronounced alterations. Over two decades, the cumulative decrease amounts to 90.14 km^2, signifying a decrease rate of 11.79 %. This decline is most notable among all land types, primarily attributable to the oscillation of water levels stemming from global warming and shifts in rainfall patterns.

Grassland Area: The grassland area undergoes a sequence of decrease followed by augmentation. Over the past fifteen years, the grassland area records a net increase of 1.51 %. This development points towards an amplified awareness of the pivotal role played by grasslands in maintaining environmental quality during later periods. This is highlighted by the initiation of an upswing in the area designated for artificial greenery.

In essence, the assessment of land use alterations takes into account the disparities between two selected years, unveiling the intricate landscape dynamics of Chongming Island over the designated period.

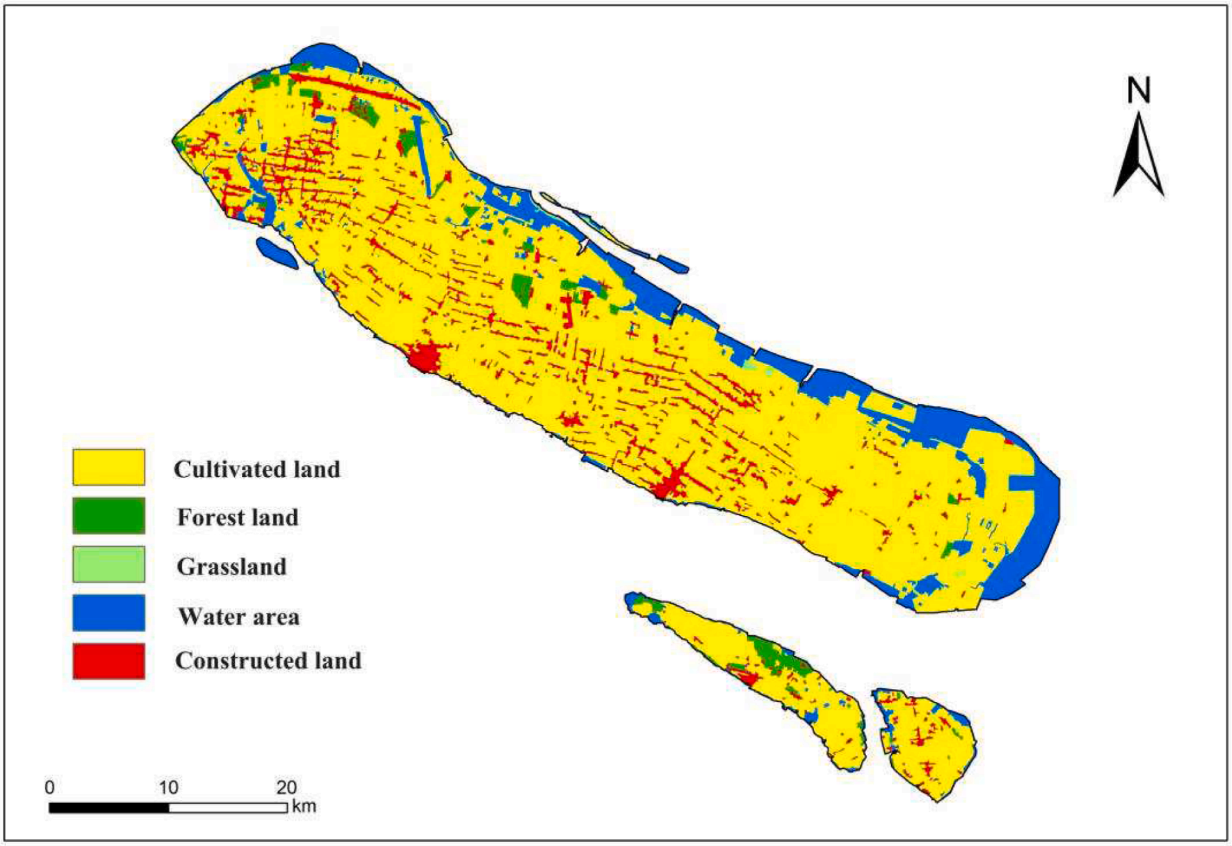
Fig. 3 represents the spatial distribution of land on Chongming Island spanning the years 2000 to 2020, thereby elucidating the salient characteristics underpinning its land use dynamics:

Cultivated Land: Encompassing all areas except expansive water bodies, cultivated land exhibits a consistent trend of diminishing proportions annually. This pervasive trend is perceptible in the spatial distribution map, highlighting the incremental reduction of cultivated land over the years.

Constructed land: Notably clustered in the urban epicenter, constructed land's spatial allocation undergoes a noticeable evolution as time progresses. Its distribution expands from the city center towards the surrounding regions, yet largely remains clustered. A conspicuous feature is the significant aggregation of constructed land within the city center, denoting the distinct clustering phenomenon.

Water Areas: Primarily situated in the eastern, northern, and southern sections, water areas have significantly diminished across the two-decade span due to the compounded effects of global warming and decreasing precipitation. Notably, the eastern waters have undergone a transformative shift, evolving into a transition zone that has culminated in the establishment of the Dongtan Wetland Park.

Forest Land and Grassland: Concentrated in the northeast and southwest sectors of the urban expanse, both forest land and



(a) 2000

Fig. 3. Spatial Distribution of Different Land Types in Chongming from 2000 to 2020.

grassland maintain relatively stable spatial distribution patterns. Despite the passage of twenty years, these land use categories exhibit minimal alterations in terms of their spatial distribution.

In summary, Chongming Island's predominant land use types in 2000 encompassed cultivated land, water areas, and constructed land. However, over the ensuing two decades, the landscape has undergone transformation. Noteworthy developments include the decline in the proportion of cultivated land, a significant increase in constructed land, a reduction in forest land proportions, and substantial changes in water areas. Additionally, with the exception of cultivated land distributed throughout the island, other land types manifest varying degrees of concentration across specific regions.

3.2. Land use transfer matrix characteristics

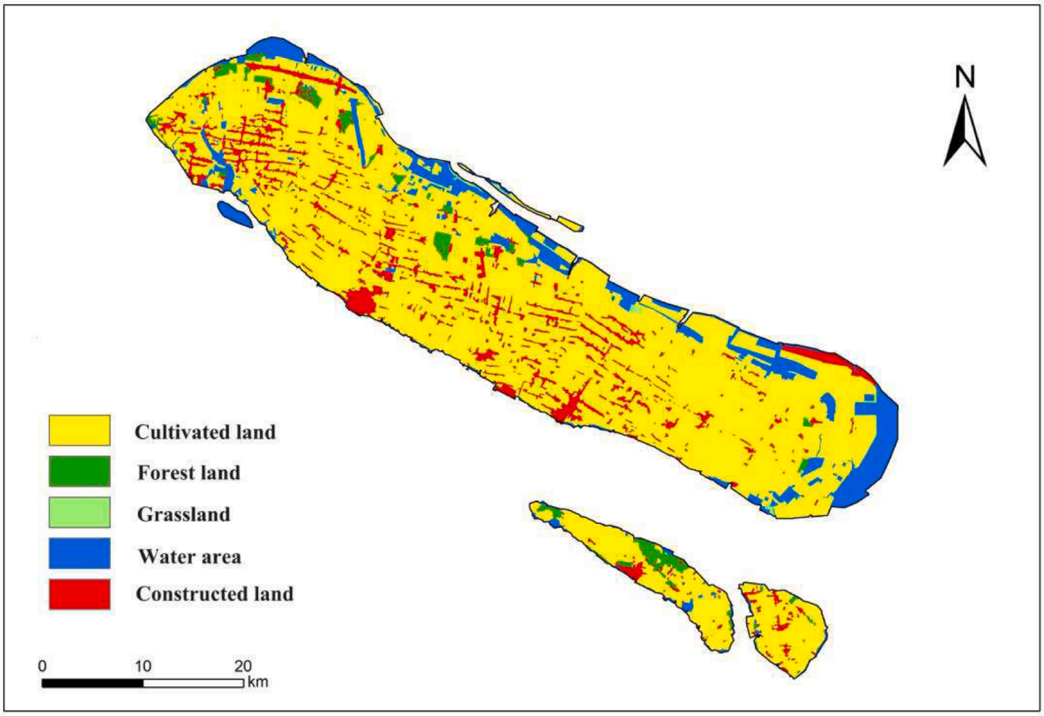
By amalgamating the insights from Table 3 and Table 4, the evolving landscape of Chongming Island's land use unveils the following salient characteristics:

Constructed land: The expansion of constructed land remains a rapid and pronounced trend, significantly driven by the conversion of cultivated land. Over the span of two decades, the constructed land area surges from an initial 123.17 km^2 to 185.21 km^2, reflecting an average annual increment of 4.14 km^2. This is mirrored in the proportional increase from 15.76 % to 23.70 %, with an average annual growth rate of 0.52 %. Notably, approximately 88.27 km^2 of cultivated land transitions into constructed land, emphasizing the pivotal role of cultivated land in the augmentation of constructed land area. This robust shift underscores the ongoing process of urbanization within the district.

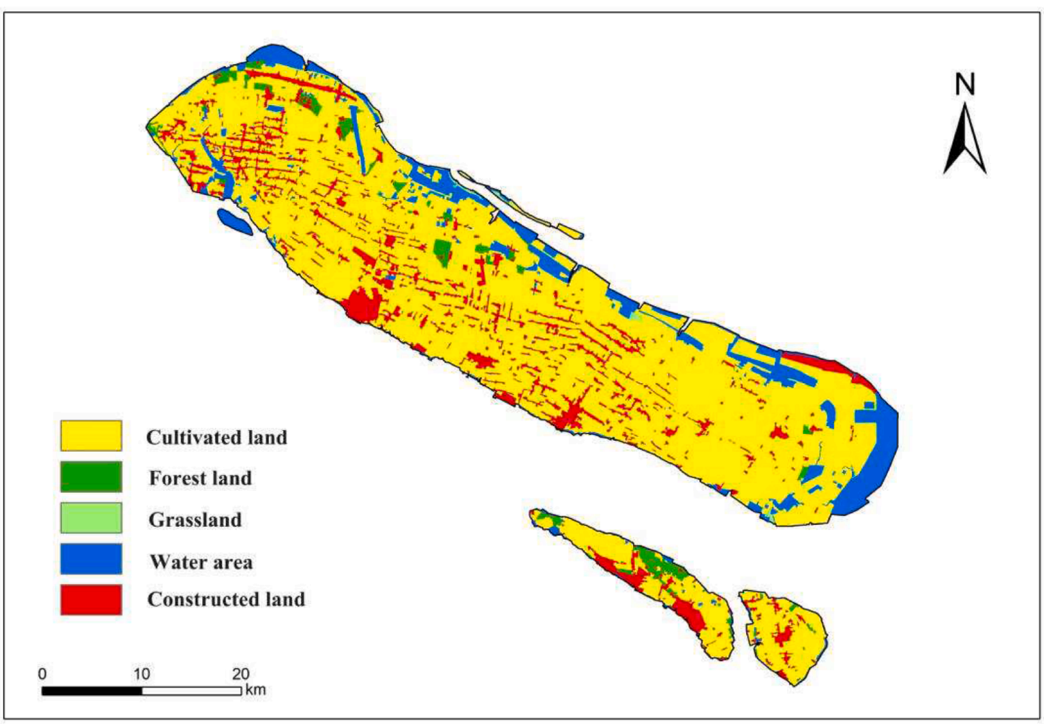
Non-Constructed land Types: Within this category, discernible structural adjustments become evident. These adjustments manifest in the more moderate alterations observed in the area encompassing cropland, forest land, and grassland. Forest land and grassland exhibit notable resilience, refraining from undergoing extensive shifts to other land types on a large scale.

Water Areas: The decline in the overall area of water bodies emerges as a significant phenomenon. However, upon scrutinizing Table 4, it is evident that the shift from water areas to other land types remains relatively limited. Consequently, the transformation in water area dimensions is intrinsically linked to factors like global warming and fluctuations in water surface levels, primarily attributed to shifts in rainfall patterns.

In summation, the synthesis of data from Table 3 and Table 4 offers an insightful perspective into the evolving landscape of Chongming Island's land use. Notably, constructed land's expansion is propelled by the conversion of cultivated land, non-constructed land types demonstrate measured structural adjustments, and water area dynamics are largely influenced by global warming and precipitation-induced alterations in water surface levels.



(b) 2005

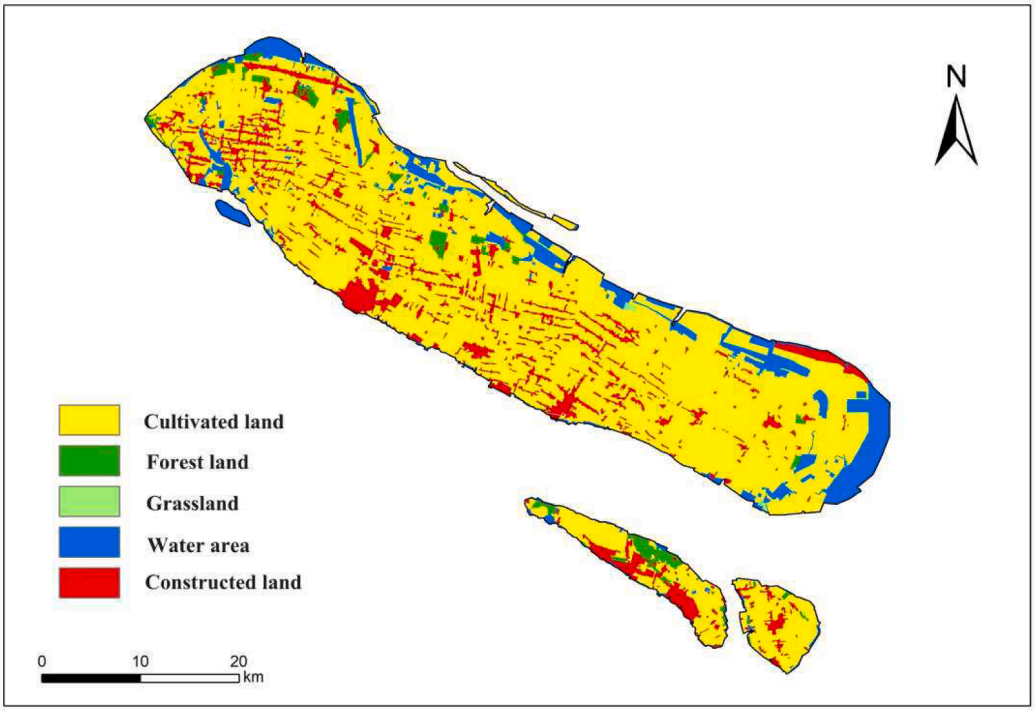


(c) 2010

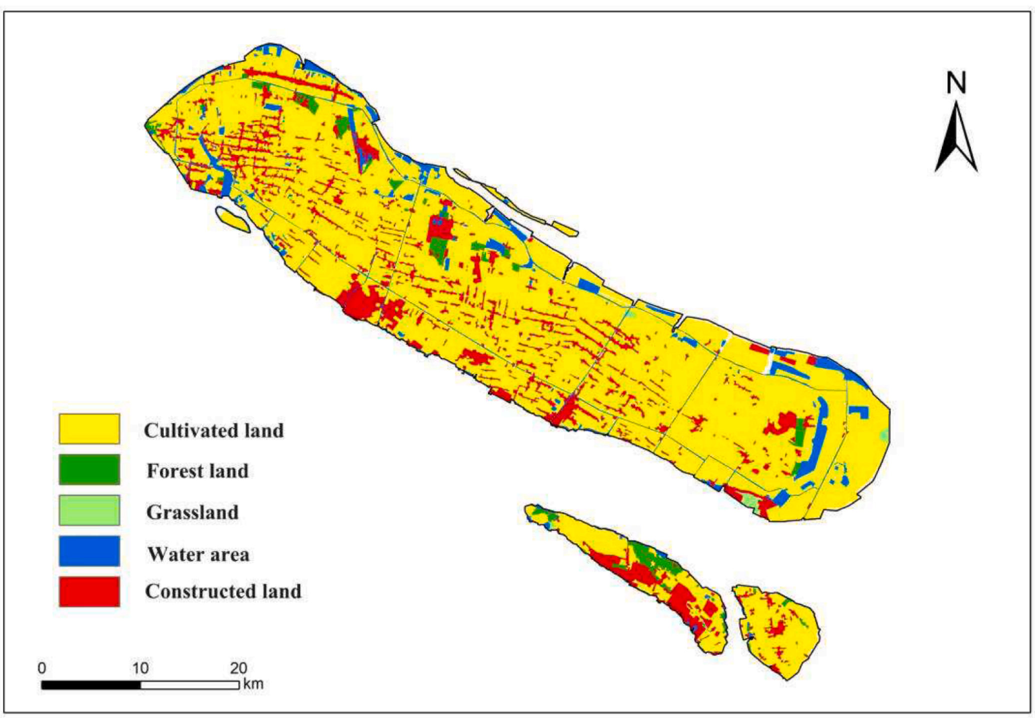
Fig. 3. (*continued*).

4. Discussion

In terms of policy context and objectives, over the past two decades, Chongming Island has implemented proactive policy measures to facilitate its development as an Ecological Island Construction Demonstration (ECND) Zone. The "Chongming Three-Island Master Plan



(d) 2015



(e) 2020

Fig. 3. (*continued*).

(Chongming County Regional Master Plan) 2005–2020," released in 2005, outlined the objective of developing Chongming Island into a modern integrated ecological island. Subsequently, the "Chongming World-Class Ecological Island Development 13th Five-Year Plan" in 2016 further emphasized the significance of advancing ecological construction during the 13th Five-Year Plan period. These policy documents

Table 3
2000–2020 Chongming Island Land Use Transfer Matrix/km^2.

Land types					2000	2020
Cultivated land	Forest land	Grassland	Water area	Constructed land	Total	Total
919.6353	2.8899	1.2762	29.1267	64.2996	1017.3915	1033.0803
2.3058	0	0.7245	0.3537	0.0549	3.4524	4.9599
95.4684	0.4473	2.9592	56.7639	9.7767	179.3547	89.2134
11.4021	0.2259	0	1.9827	109.5606	123.1713	185.2146

Table 4
Land use transfer matrix/km^2 at different stages of Chongming Island.

Time Period		Cultivated land	Forest land	Grassland	Water area	Constructed land
2000–2005	Cultivated land	999.2151	0.4311	0.009	4.1238	13.6125
	Forest land	0.2826	34.3413	0	0.0378	0.2016
	Grassland	0.6363	0	2.6748	0.1413	0
	Water area	28.089	0.4086	0.6444	141.8607	8.352
	Constructed land	6.6969	0.135	0.009	0.0864	116.244
	Total in 2005	1034.9199	35.316	3.3372	146.25	138.4101
2005–2010	Cultivated land	1004.5575	0.3465	0.0144	1.2969	28.7046
	Forest land	0.3015	33.9804	0	0.0531	0.981
	Grassland	0.0171	0	3.2733	0.0369	0.0099
	Water area	0.9936	0.0639	0.0207	143.2089	1.9629
	Constructed land	4.4784	0.1206	0	0.117	133.6941
	Total in 2010	1010.3481	34.5114	3.3084	144.7128	165.3525
2010–2015	Cultivated land	1003.4316	0.1341	0.0171	0.6246	6.1407
	Forest land	0.1566	34.1496	0	0.0279	0.1773
	Grassland	1.6587	0	1.5201	0.1296	0
	Water area	5.0967	0.0396	0.0054	139.4001	0.171
	Constructed land	2.3337	0.0423	0.0027	0.0864	162.792
	Total in 2015	1012.6773	34.3656	1.5453	140.2686	169.281
2015–2020	Cultivated land	940.0743	2.7819	1.287	28.2033	39.8169
	Forest land	4.3551	28.3635	0	1.0152	0.6282
	Grassland	0.0819	0	0.7677	0.1017	0.5823
	Water area	66.4974	0.1161	2.8566	52.7193	4.6863
	Constructed land	22.0716	0.3843	0.0486	7.1685	139.4109
	Total in 2020	1033.0803	31.6458	4.9599	89.208	185.1246

have played a pivotal role in guiding the island's land use changes and ecological development. The analysis of Chongming Island's land use changes over the past two decades offers a compelling perspective on its journey as an Ecological Island Carbon Neutral Demonstration (ECND) Zone, particularly concerning land use governance. While the island's strides towards ecological sustainability are evident, a more comprehensive evaluation demands a closer scrutiny of the intricate interplay between economic, housing, and population factors, combined with insights from prior research.

The conspicuous decline in water areas, attributed partly to global warming and shifting rainfall patterns, underscores the island's adaptability to environmental shifts. However, this adaptive response necessitates a more holistic strategy. As Chongming Island endeavors to fulfill its ECND objectives, proactive measures are imperative to address the underlying causes of water area reduction. This need for anticipation and proactive intervention aligns with the findings of Zhou et al. (2020) and Zhang et al. (2020), who stress the importance of incorporating multi-source remote sensing data for enhanced change detection accuracy and predictive landscape analysis.

The substantial expansion of constructed land, primarily concentrated within urban cores, reflects the island's reaction to economic growth and population dynamics. While urbanization is a worldwide trend, its implications for land use management within the ECND framework warrant careful consideration. The critical concern lies not only in accommodating urbanization but also in cultivating sustainable urban development that acknowledges the ecological limits of the island. To achieve this, the insights from research by Gang (2020) can be harnessed, emphasizing the necessity of interdisciplinary studies and data fusion to address complex land use dynamics.

Amid the complexities posed by economic growth, housing demands, and burgeoning population, the surge in constructed land area on Chongming Island demands a comprehensive analysis. While the alignment of construction expansion with economic prosperity and the need for housing is evident, a fundamental question arises: Does the rapid pace of construction harmonize with the island's delicate ecological balance? Answering this query requires a meticulous examination of housing policies within the broader context of environmental preservation. To draw insights from analogous ecological contexts, we can turn to the research of Lau (2020) and Asha (2021), whose work underscores the necessity of a judicious and balanced approach to development, particularly on estuarine islands akin to Chongming. Their findings underscore the imperative equilibrium to strike between swift urbanization and the safeguarding of the island's unique ecological fabric. By heeding their insights, Chongming Island can chart a course that converges progress with the protection of its natural heritage.

The ebb and flow of forested land, intertwined with dynamic shifts in grassland area, lay bare the intricate challenges of harmonizing urbanization with ecological preservation. The intricate interplay between urban needs and the imperative of conserving natural habitats compels the formulation of robust mitigation strategies. This ecological riddle resonates with the discoveries of Matos et al. (2019), who underscore the far-reaching impacts of urban expansion not just on immediate landscapes, but also on adjoining farmlands and intricate ecosystems. The heart of this predicament underscores the pressing need for an amplified focus on habitat restoration initiatives and the scrupulous orchestration of land use planning.

Within the evolving tapestry of Chongming Island's metamorphosis, it becomes distinctly clear that the expansion of constructed land, the fluctuations in forested expanses, and the shifting grasslands are all interconnected threads in the grand narrative of harmonizing human advancement with ecological stewardship. As Chongming Island embarks on its trajectory towards a thriving and harmonious ecological future, it must embrace the synergy of research insights, visionary policies, and community participation to ensure that every stride taken resonates harmoniously with the island's ecological rhythm.

5. Conclusion

In conclusion, the analysis results provide valuable insights into Chongming Island's trajectory as an ECND Zone, yet a critical examination unveils disparities between aspirations and implementation. To excel as an ECND Zone, Chongming Island must harmonize economic, housing, and population factors with robust ecological principles. This entails integrating a diverse range of research findings and implementing multidisciplinary strategies to comprehensively address the challenges of land use governance. By leveraging insights from these studies, Chongming Island can fortify its role as a paradigm for sustainable development and ecological harmony.

While this study utilized RS and GIS technology to delineate changes in land types and their proportions on Chongming Island from 2000 to 2020, along with the interconversion matrix of land types across different periods, it's essential to acknowledge some limitations. The analysis primarily relied on data reports and literature reviews, with limited on-site survey and data actual measurement. Future research endeavors should focus on enhancing data collection through more extensive fieldwork and measurement techniques to ensure the accuracy and reliability of the findings.

The study highlights several key findings:

In 2020, cultivated land dominates the land use types on Chongming Island, followed by constructed land, with the latter gaining prominence as a pivotal urban land use category.

Over the 2000–2020 period, significant changes in land use are evident, with water areas consistently diminishing and constructed land expanding.

Transitions between land types vary across different stages, with cultivated land primarily transforming into constructed land, indicating the latter's main source of expansion.

The human impact on land use, driven by socio-economic development, urbanization, and policies, outweighs natural factors in shaping Chongming Island's land use dynamics.

As Chongming Island progresses, it's imperative to establish a sustainable land use strategy that balances economic growth with ecological preservation. This requires careful planning and adaptation to local conditions, ensuring the preservation of vital ecosystems while fostering continued development. Moreover, addressing the implications of land use changes on ecological systems, such as Dongtan Wetland Park, is essential for long-term sustainability.

In summary, this study underscores the complex interplay between natural processes and socio-economic forces in shaping Chongming Island's land use dynamics. While socio-economic factors have played a significant role in driving changes, the island must navigate a fine line between development and conservation to achieve its ecological and sustainable goals.

While this study provides valuable insights into Chongming Island's land use changes, it is limited by the reliance on existing data and literature reviews with minimal on-site surveys. Future research will build upon this foundation and (Bai et al., 2021; Chuai et al., 2022; Xia and Cai, 2023; Zhang et al., 2023) for more extensive fieldwork to enhance accuracy. Additionally, the intricate interplay between natural and socio-economic factors calls for further exploration. In summary, this study contributes insights into land use dynamics but requires more comprehensive research addressing data limitations and complex relationships.

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CRediT authorship contribution statement

Hongbo Xu: Conceptualization, Validation. **Chengsi Wang:** Validation, Investigation. **Xiaoyin Hu:** Resources, Investigation, Funding acquisition, Supervision. **Yue Wu:** Conceptualization, Methodology, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Asha, J., 2021. Coastal Conundrums in India-A Critical Approach through Judicial Decisions and Environmental Principles. Indian JL & Legal Rsch. 2, 1.
Bai, Y., Chou, L., Zhang, W., 2021. Industrial innovation characteristics and spatial differentiation of smart grid technology in China based on patent mining. J. Energy Storage 43, 103289. Chicago.
Bai, Y., Dai, J., Huang, W., Tan, T., Zhang, Y., 2021. Water conservation policy and agricultural economic growth: Evidence of grain to green project in China. Urban Clim. 40, 100994.
Chen, J.M., 2021. Carbon neutrality: Toward a sustainable future. Innovation 2 (3).
Chen, Y., Li, S., Cheng, L., 2020. Evaluation of cultivated land use efficiency with environmental constraints in the Dongting lake eco-economic zone of Hunan Province, China. Land 9 (11), 440.
Chen, R.M.L., Mather, P.M., 2019. Advances in land use change research: Linking remote sensing, GIS, and models. CRC Press.
Chen, L., Msigwa, G., Yang, M., Osman, A.I., Fawzy, S., Rooney, D.W., Yap, P.S., 2022. Strategies to achieve a carbon neutral society: a review. Environ. Chem. Lett. 20 (4), 2277–2310.
Chuai, X., Huang, X., Wang, W., Wu, C., Zhao, R., 2014. Spatial simulation of land use based on terrestrial ecosystem carbon storage in coastal Jiangsu, China. Sci. Rep. 4 (1), 5667.
Chuai, X., Xia, M., Ye, X., Zeng, Q., Lu, J., Zhang, F., Zhou, Y., 2022. Carbon neutrality check in spatial and the response to land use analysis in China. Environ. Impact Assess. Rev. 97, 106893.
Gang, H., 2020. A critical-holistic approach to the place-specific geographies of inhabited river islands on the rural-urban fringe of inland china. Shima 14 (2).
Goodchild, M.F., Gahegan, M., 2021. Spatial data mining and knowledge discovery: Recent progress and future challenges. Prog. Hum. Geogr. 45 (5), 771–796.
Grigoraş, G., Urițescu, B., 2019. Land use/land cover changes dynamics and their effects on surface urban heat island in Bucharest, Romania. Int. J. Appl. Earth Obs. Geoinf. 80, 115–126.
Halvorssen, A.M., 2005. The Kyoto Protocol and Developing Countries-The Clean Development Mechanism. Colo. J. Int'l Envtl. l. & Pol'y 16, 353.
Hansen, M.C., et al., 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (6160), 850–853.
Ishii, S., Tabushi, S., Aramaki, T., Hanaki, K., 2010. Impact of future urban form on the potential to reduce greenhouse gas emissions from residential, commercial and public buildings in Utsunomiya, Japan. Energy Policy 38 (9), 4888–4896.
Kuang, W., Zhang, S., Du, G., Yan, C., Wu, S., Li, R., Liu, J., 2022. Monitoring periodically national land use changes and analyzing their spatiotemporal patterns in China during 2015–2020. J. Geog. Sci. 32 (9), 1705–1723.
Lau, S. H. Y. (2020). *Chinese coastal megaproject development: A multi-method case study of the shifting ecologies of the Greater Bay Area* (Doctoral dissertation).
LeCun, Y., Hinton, G., 2015. Deep learning. Nature 521 (7553), 436–444.

Li, L., Li, J., Peng, L., Wang, X., Sun, S., 2023. Optimal pathway to urban carbon neutrality based on scenario simulation: A case study of Shanghai, China. J. Clean. Prod. 137901.
Li, Y., Shen, Y., Wang, S., 2022. Spatial and temporal characteristics and effects of terrestrial carbon emissions in Anhui Province based on land use change. J. Soil Water Conserv. 36 (1), 182–188.
Lin, H.C., Chou, L.C., Zhang, W.H., 2020. Cross-Strait climate change and agricultural product loss. Environ. Sci. Pollut. Res. 27, 12908–12921.
Linna, W.u., Shengtian, Y., Xiaoyan, L., Ya, L., Zhou, X.u., Haigen, Z., 2014. Response of land use change to human activity in Beiluo River Basin since 1976. Acta Geograph. Sin. 69 (1), 54–63.
Maroulis, A., Xu, D., 2020. Deep learning advances in remote sensing image processing: A review. ISPRS J. Photogramm. Remote Sens. 168, 154–170.
Matos, C., Petrovan, S.O., Wheeler, P.M., Ward, A.I., 2019. Landscape connectivity and spatial prioritization in an urbanising world: A network analysis approach for a threatened amphibian. Biol. Conserv. 237, 238–247.
Nijdam, D., Rood, T., Westhoek, H., 2012. The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. Food Policy 37 (6), 760–770.
Nwakaire, C.M., Onn, C.C., Yap, S.P., Yuen, C.W., Onodagu, P.D., 2020. Urban Heat Island Studies with emphasis on urban pavements: A review. Sustain. Cities Soc. 63, 102476.
Polykretis, C., Grillakis, M.G., Alexakis, D.D., 2020. Exploring the impact of various spectral indices on land cover change detection using change vector analysis: A case study of Crete Island, Greece. Remote Sens. 12 (2), 319.
Raihan, A., Tuspekova, A., 2022. Dynamic impacts of economic growth, energy use, urbanization, tourism, agricultural value-added, and forested area on carbon dioxide emissions in Brazil. J. Environ. Stud. Sci. 12 (4), 794–814.
Ruane, A.C., Sultan, B., 2018. Climate change impacts on irrigation water requirements: Effects of mitigation, adaptation, and uncertainty in estimating future demands. Agric. For. Meteorol. 253–254, 230–238.
Shen, D., Xia, M., Zhang, Q., Elahi, E., Zhou, Y., Zhang, H., 2019. The impact of public appeals on the performance of environmental governance in China: A perspective of provincial panel data. J. Clean. Prod. 231, 290–296.
Shi, K., Chen, Y., Yu, B., Xu, T., Yang, C., Li, L., Wu, J., 2016. Detecting spatiotemporal dynamics of global electric power consumption using DMSP-OLS nighttime stable light data. Appl. Energy 184, 450–463.
Smith, J., et al., 2019. Urban Expansion and Its Effects on Land Use and Land Cover Changes in Northeast China. Remote Sens. (Basel) 11 (9), 1017.
Smith, P., House, J.I., Bustamante, M., Sobocká, J., Harper, R., Pan, G., Pugh, T.A., 2016. Global change pressures on soils from land use and management. Glob. Chang. Biol. 22 (3), 1008–1028.
Tan, J., & Solangi, Y. A. (2023). Assessing impact investing for green infrastructure development in low-carbon transition and sustainable development in China. Environment, Development and Sustainability, 1-24.
Wang, Z., Gong, J., 2019. Change detection from remotely sensed images: From pixel-based to object-based approaches. ISPRS J. Photogramm. Remote Sens. 150, 116–133.
Xu Y F, Chen C, & Chen H S. (2018). Dynamic change of land use in Yunnan-Guizhou Plateau from 2001 to 2013. Soil and Water Conservation in China, 11.
Wang, C., Su, C., Li, Z., Hu, X., 2023. Waterfront ecotourism quality evaluation under the water ecological challenge in West Strait, China. Front. Environ. Sci. 11, 1134905.
Wang, Y., Wei, H., Wang, Y., Peng, C., Dai, J., 2021. Chinese industrial water pollution and the prevention trends: An assessment based on environmental complaint reporting system (ECRS). Alex. Eng. J. 60 (6), 5803–5812.
Xia, M., Cai, H.H., 2023. The driving factors of corporate carbon emissions: An application of the LASSO model with survey data. Environ. Sci. Pollut. Res. 30 (19), 56484–56512.
Yang, H., Huang, J., Liu, D., 2020. Linking climate change and socioeconomic development to urban land use simulation: Analysis of their concurrent effects on carbon storage. Appl. Geogr. 115, 102135.
Zhang, L., et al., 2018. Assessing the Impact of Rapid Urbanization on Land Use Changes in a Changing Megaregion in Southern China. Sustainability 10 (8), 2746.
Zhang, Y., et al., 2019. Simulating the Impacts of Flooding Hazards on Land-Use Planning: A Case Study of Xiamen, China. J. Hydrol. 573, 250–261.
Zhang, Y., Chao, Q., Chen, Y., Zhang, J., Wang, M., Zhang, Y., Yu, X., 2021. China's carbon neutrality: Leading global climate governance and green transformation. Chin. J. Urban Environ. Stud. 9 (03), 2150019.
Zhang, X., Xiao, X., Wang, X., Xu, X., Chen, B., Wang, J., Li, B., 2020. Quantifying expansion and removal of Spartina alterniflora on Chongming island, China, using time series Landsat images during 1995–2018. Remote Sens. Environ. 247, 111916.
Zhang, W.H., Yuan, Q., Cai, H., 2023. Unravelling urban governance challenges: Objective assessment and expert insights on livability in Longgang District, Shenzhen. Ecol. Indic. 155, 110989.
Zhou, T., Geng, Y., Chen, J., Liu, M., Haase, D., Lausch, A., 2020. Mapping soil organic carbon content using multi-source remote sensing variables in the Heihe River Basin in China. Ecol. Ind. 114, 106288.