# Dynamic Study of Mangrove Wetlands in Shankou, Guangxi Based on LUCC and Landscape Pattern Change

**Authors:** Zheng Fa, Huang Fulin, Chen Zeheng, Ding Weipin, Ding Weipin

**Date:** 2023-07-28T00:00:00+00:00

## Abstract

Objective: Based on field survey data from the Guangxi Shankou National Mangrove Ecological Nature Reserve (hereinafter referred to as the Shankou Mangrove Reserve) in 2022, combined with LUCC and landscape pattern indices, this study selected remote sensing imagery from six periods between 1987 and 2021, utilizing an object-oriented image classification method with a focus on exploring the change process and important influencing factors of mangrove wetlands in Guangxi Shankou. Results: From the perspective of land use: land types in the study area have been continuously converted over the past 35 years, with cultivated land area continuously decreasing, while Spartina alterniflora flats and aquaculture ponds have increased substantially—the former mainly encroaching upon original coastal tidal flats, and the latter primarily converted from forest land and cultivated land; from the landscape perspective: landscape fragmentation has continuously increased, connectivity has gradually decreased, landscape shape has become increasingly complex, and land type succession has become more frequent; Pearson correlation analysis indicates that there is a highly significant or significant correlation between land use changes in coastal tidal flats, Spartina alterniflora flats, and aquaculture ponds and landscape indices. Conclusion: Over the past 35 years, the Shankou Mangrove Reserve has experienced significant land use changes, with invasive species (Spartina alterniflora flats) and anthropogenic disturbances (aquaculture ponds) being the main factors affecting mangrove wetland changes in the region, as well as the primary causes of continuously increasing landscape fragmentation; the study employs multiple methods and multi-angle analysis to reveal the differences in regional influencing factors, providing a theoretical basis for environmental management and conservation efforts of typical mangrove ecosystems.

## Full Text

# Mangrove Wetland Dynamics in Shankou, Guangxi Based on LUCC and Landscape Pattern Change

## Abstract

[**Objective**] Based on field survey data from the Guangxi Shankou National Mangrove Ecological Nature Reserve (hereinafter referred to as the Shankou Mangrove Reserve) collected in 2022, this study integrates Land Use/Cover Change (LUCC) and landscape pattern indices to examine six periods of remote sensing imagery spanning 1987–2021. Using an object-oriented image classification approach, we explore the dynamics of mangrove wetlands in Shankou, Guangxi, and identify key influencing factors. [**Results**] From a land-use perspective, continuous conversion among land classes occurred over the past 35 years, with cultivated land area persistently decreasing while *Spartina alterniflora* flats and aquaculture ponds expanded substantially. *Spartina alterniflora* flats primarily encroached upon former coastal mudflats, while aquaculture ponds were mainly converted from forestland and cultivated land. From a landscape perspective, landscape fragmentation increased continuously, connectivity gradually decreased, landscape shapes became increasingly complex, and land class succession became more frequent. Pearson correlation analysis revealed highly significant or significant correlations between land-use changes in coastal mudflats, *Spartina alterniflora* flats, and aquaculture ponds and various landscape indices. [**Conclusion**] Over the past 35 years, the Shankou Mangrove Reserve has experienced significant land-use changes, with invasive species (*Spartina alterniflora* flats) and anthropogenic disturbances (aquaculture ponds) representing the primary factors affecting mangrove wetland dynamics and driving the continuous increase in landscape fragmentation. This study employs a multi-method, multi-angle analytical framework to reveal regional differences in influencing factors, providing a theoretical basis for environmental management and conservation efforts in typical mangrove ecosystems.

**Keywords:** mangrove wetland; LUCC; landscape pattern; anthropogenic disturbance; species invasion

## 1. Materials and Methods

### 1.1 Study Area and Data Acquisition

The Shankou Mangrove Reserve is located on both sides of the Shatian Peninsula in Hepu County, Guangxi (centered at 21°28′ N, 109°43′ E) and was inscribed on the International List of Important Wetlands in 2002. The reserve experiences a subtropical maritime monsoon climate with an average annual temperature of 23.4°C (ranging from 2°C to 37.4°C) and annual precipitation of 1500–1700 mm, concentrated between April and September. The tidal regime is characterized by irregular diurnal tides with an average tidal range of 2.35 m and a maximum of 6.25 m. The reserve hosts 10 true mangrove species across 9 families and 6 semi-

mangrove species across 5 families, with dominant species including *Rhizophora stylosa*, *Bruguiera gymnorrhiza*, *Aegiceras corniculatum*, and *Avicennia marina*. *Spartina alterniflora* forms monospecific stands or co-occurs with mangroves, primarily distributed in the tidal flats of Dandou Bay and Yingluo Bay.

[Figure 1: see original paper] Geographic location of the study area. This map was produced based on the standard map (review number GS(2019)3333) downloaded from the National Surveying and Mapping Geographic Information Bureau Standard Map Service website, with the red line indicating the study area boundary.

Remote sensing imagery was sourced from the Landsat series at 15m/30m resolution, with one scene per period (Table 1). To distinguish between *Spartina alterniflora* flats and mangrove forests, we selected imagery from autumn and winter months when *Spartina alterniflora*, a perennial herbaceous plant that withers in colder seasons, contrasts with evergreen mangrove shrubs. Additionally, all images were selected at low tide to minimize tidal effects on identification accuracy.

Information table of remote sensing image data

### 1.2 Classification Standards and Evaluation Methods

Based on the Technical Regulations for the Third National Land Survey (final draft) and multiple field investigations, we established a classification system comprising seven categories: cultivated land, mangrove forest, construction land, forestland, coastal mudflat, aquaculture pond, and *Spartina alterniflora* flat (i.e., mudflats colonized by *Spartina alterniflora*).

Image preprocessing was conducted using ENVI 5.3 software, including radiometric calibration, atmospheric correction, and clipping. Classification employed an object-oriented approach using eCognition 9.0 software. Layer weights for image segmentation were adjusted according to their suitability and importance, with values ranging from 0–10, where higher weights indicate greater contribution of that layer's information to segmentation. Following multi-scale segmentation, supervised classification (nearest neighbor) was applied for land class extraction. Compared with unsupervised classification, this approach allows explicit definition of classes and improved accuracy through training set refinement. A 5-6-4 false-color composite (SWIR1-NIR-Red assigned to Red-Green-Blue) effectively distinguished land classes. Accuracy assessment using Sentinel-2 3m resolution imagery and field validation points achieved overall accuracy >90% and Kappa coefficient of 0.85 for 2021. To further improve results, we employed manual visual interpretation using high-resolution historical imagery (Google Earth Pro, Esri ArcGIS) and national land-use classification maps (2000–2020) to correct misclassified objects in ArcMap 10.8, generating final land use/cover distribution maps.

[Figure 2: see original paper] True color example (left) and false color example

(right). Imagery from Geospatial Data Cloud (https://www.gscloud.cn/).

Landscape indices effectively integrate spatial pattern data and convey structural composition and spatial arrangement characteristics. Based on established landscape ecology research, we selected eight metrics: Number of Patches (NP), Patch Density (PD), Landscape Shape Index (LSI), Perimeter-Area Fractal Dimension (PAFRAC), Evenness Index (SHEI), Splitting Index (SPLIT), Shannon's Diversity Index (SHDI), and Contagion Index (CONTAG). These indices were calculated using Fragstats 4.2 software, and Pearson correlation analysis was performed using SPSS to reveal relationships between land class changes and landscape patterns.

## 2. Results

### 2.1 Land Use/Cover Change and Conversion Rates

As shown in Figure 3, the study area comprises wetland, cultivated land, construction land, forestland, and *Spartina alterniflora* flats, with continuous conversion among classes during 1987–2021. Wetland dominated the area, showing an initial increase followed by decrease. Cultivated land area decreased consistently, while *Spartina alterniflora* flats exhibited a leapfrog growth pattern. Forestland and construction land remained relatively stable. The wetland system consisted of mangrove forest, coastal mudflat, and aquaculture ponds, with coastal mudflats occupying the largest area. Aquaculture ponds increased from 6.96% to 21.13% of the total study area between 1987 and 2021, playing a dominant role in wetland area changes.

The land transfer matrix (Table 2) reveals that cultivated land decreased by 1,620.62 ha during 1987–2021, with 708.05 ha converted to aquaculture ponds. The 932.40 ha increase in aquaculture ponds primarily originated from cultivated land and forestland conversions. After 1993, *Spartina alterniflora* flats expanded from 27.37 ha to 470.09 ha, mainly encroaching upon former coastal mudflat areas.

[Figure 3: see original paper] Classification result chart
[Figure 4: see original paper] Dynamic change of area of each landscape type in Shankou Mangrove Reserve
Landscape transfer matrix of the Shankou Mangrove Reserve 1987-2021

### 2.2 Landscape-Level Landscape Pattern Change Characteristics

Figure 5 shows that over the 35-year period, NP and PD increased continuously, reaching maxima in 2021 (394 patches and 4.93 density). The LSI exhibited a decreasing-increasing-decreasing trend, peaking in 2016 (14) and bottoming in 2002 (10), with a 34.75% increase from 1987 to 2021. PAFRAC followed a similar trend to LSI but decreased in 2021. CONTAG showed a persistent decline from a maximum of 53.69 in 1987 to a minimum of 42 in 2021. SHDI

increased gradually, showing the opposite trend to CONTAG. SPLIT experienced a decreasing-increasing-decreasing fluctuation, peaking at 8.55 in 2016 and reaching a minimum of 5.93 in 1992. SHEI showed an increasing trend, with values approaching 1.

[Figure 5: see original paper] Changes in landscape index of the Shankou Mangrove Reserve

### 2.3 Response of Landscape Type Changes to Landscape Pattern Indices

Landscape structure stability in a region is primarily determined by rational land use. Unreasonable land use can lead to biodiversity loss, patch fragmentation, and habitat degradation. Pearson correlation analysis between land-use/cover changes and landscape indices revealed that area changes in coastal mudflats and *Spartina alterniflora* flats were significantly or highly significantly correlated with all landscape indices. Cultivated land and aquaculture ponds showed significant correlations with most indices. Specifically, cultivated land was significantly negatively correlated with CONTAG, SHDI, and SPLIT; aquaculture ponds were significantly positively correlated with SHDI; *Spartina alterniflora* flats were highly significantly negatively correlated with CONTAG and highly significantly positively correlated with SHDI and SPLIT, as well as significantly positively correlated with PD and NP. Coastal mudflats showed the opposite pattern.

Correlation coefficients between landscape pattern indices and landscape type area changes in Shankou mangrove wetland

## 3. Discussion

From a LUCC perspective, the Shankou Mangrove Reserve experienced dramatic land-use changes during 1987–2021. Cultivated land area decreased continuously, mostly converting to forestland and aquaculture ponds—reflecting effective implementation of the Grain-for-Green policy and evolving livelihood strategies among coastal residents. Aquaculture ponds expanded from 6.96% to 21.13% of the study area, dominating wetland area changes. *Spartina alterniflora* flats showed explosive growth, primarily encroaching upon coastal mudflats, attributable to the species' high salt tolerance, flood resistance, and strong dispersal capacity, combined with favorable natural environmental conditions in China. The Shankou Mangrove Reserve has become one of the most extensively invaded regions by *Spartina alterniflora*.

Mangrove forest and coastal mudflat conversions were substantial, with 223.18 ha of coastal mudflats converting to mangrove forest during 1993–2002 due to enhanced conservation awareness and artificial planting. After 2009, *Spartina alterniflora* flats began encroaching upon mangrove forests, with invasion occurring more readily in sparse, low-density stands than in dense, continuous

forests, leading to competitive dynamics and frequent alternation among these three cover types that significantly altered wetland areas.

From a landscape ecology perspective, landscape fragmentation in the Shankou Mangrove Reserve increased continuously from 1987 to 2021, peaking in 2021. LSI and PAFRAC followed similar trends, indicating increased human disturbance that decreased in 2021. The persistent decline in CONTAG reflects gradually decreasing landscape connectivity and increasingly dense, multi-element distribution patterns. Increasing SHDI indicates enhanced landscape richness. SPLIT's fluctuating pattern suggests increasingly complex landscape distributions and more frequent succession among landscape types. The rising SHEI approaching 1 indicates evenly distributed landscape patch types without obvious dominance.

Overall, landscape heterogeneity increased during 1984–2021, with various landscape types becoming more balanced and the dominant position of wetlands gradually declining—consistent with Zhou Haiju et al.'s findings on landscape pattern dynamics in the Beibu Gulf Economic Zone of Guangxi. Pearson correlation analysis demonstrates significant associations between land-use changes and landscape indices for coastal mudflats, *Spartina alterniflora* flats, cultivated land, and aquaculture ponds. Invasive species and anthropogenic disturbances primarily affected the reserve's landscape structure. Specifically, *Spartina alterniflora* expansion and coastal mudflat reduction drove increased local fragmentation and frequent succession, while the reverse changes enhanced landscape connectivity. *Spartina alterniflora* expansion was the main cause of increased landscape richness, with aquaculture pond expansion and coastal mudflat reduction also contributing.

Numerous international studies confirm that ecosystems similar to the Shankou Mangrove Reserve experience land-use/cover and landscape pattern changes due to human activities. Wang et al. documented significant LULC changes from human activities, Lee et al. emphasized intensified human disturbance to landscapes, and Guan et al. linked land-use types to human activity characteristics. Our study further indicates that invasive species disturbance may exceed anthropogenic disturbance in certain contexts due to regional geographic conditions. Future research should explore these factors' impacts on landscape structure and ecosystem function to develop more effective management strategies.

## 4. Conclusions and Considerations

1. During the study period, wetlands dominated the area, showing an initial increase followed by decrease. Cultivated land area decreased consistently, while *Spartina alterniflora* flats exhibited leapfrog growth. Forestland and construction land remained relatively stable.

2. The combined intervention of aquaculture ponds and *Spartina alterniflora* flats dominated wetland area changes, while forestland growth primarily resulted from cultivated land conversion.

3. Area changes in coastal mudflats and *Spartina alterniflora* flats showed significant or highly significant correlations with all landscape indices. Cultivated land and aquaculture ponds were significantly correlated with most landscape indices.

These findings demonstrate that regional landscape structure is influenced by invasive species impacts, with *Spartina alterniflora* exhibiting strong adaptability and invasiveness. Aquaculture pond expansion represents another important factor in land-use/cover changes, potentially leading to biodiversity loss, patch fragmentation, and habitat degradation. Future management should emphasize rational land-use planning and control measures, such as effective *Spartina alterniflora* eradication methods and pond-to-forest/wetland restoration, while balancing livelihood needs and maintaining harmony between humans and nature.

## References

Cameron Clint, Hutley Lindsay B, Friess Daniel A, 2019. Estimating the full greenhouse gas emissions offset potential profile between rehabilitating and established mangroves[J]. Science of the Total Environment, Vol.665(1): 419-431.

Junyao Zhang, 2021. Remote Sensing Based Spatial-Temporal Monitoring of the Changes in Coastline Mangrove Forests in China over the Last 40 Years[J]. Science Remote Sensing, Vol.13(10).

Anh Ngoc Thi Do, Hau Duc Tran, Matthew Ashley, 2022. Anh Tuan Nguyen.Monitoring landscape fragmentation and aboveground biomass estimation in Can Gio Mangrove Biosphere Reserve over the past 20 years[J]. Ecological Informatics, Vol.70: 101743.

J. Pastor-Guzman, J Dash, Jadunandan, 2018. Atkinson, Peter M.Remote sensing of mangrove forest phenology and its environmental drivers[J]. Remote Sensing of Environment, Vol.205: 71-84.

Zhang Yihan, Li Xia, Liu Xiaoping, et al, 2015. Self-modifying CA model using dual ensemble Kalman filter simulating urban land-use changes[J]. International Journal of Geographical Information Science, Vol.29(9): 1612-1631.

Zhang Wei, Chen Zhenghua, Wang Jikun, 2015. Remote sensing monitoring of mangrove forest changes in the coastal zone of Beibu Gulf, Guangxi[J]. Journal of Guangxi University (Natural Science Edition), 40(06): 1570-1576 (in Chinese with English abstract).

Zhang Yun, Liao Bowen, 2022. Analysis of the current status of research on ecological restoration technology of mangrove wetlands in China[J]. China Science Foundation, Vol. 36(3): 412-419 (in Chinese with English abstract).

Han Shumei, 2012. Dynamics of mangrove landscape pattern and its driving force in Dongzhai Harbor, Hainan[D]. Beijing Forestry University (in Chinese with English abstract).

Wu Tingtian, Ding Shan, Chen Zongzhu, 2020. Study on the dynamics of mangrove wetlands in Dongzhai Harbor, Hainan based on LUCC and landscape pattern changes[J]. Forestry Science Research, Vol. 33(5): 154-162 (in Chinese with English abstract).

Wei Jiangling, Wang Zengjun, Pan Lianghao, 2019. Evaluation of heavy metal content and ecological risk of mangrove wetland sediments in Yamaguchi[J]. Journal of Subtropical Resources and Environment, 14(02): 28-33 (in Chinese with English abstract).

Yu Chenxing, Yang Gang, Lu Zhou, 2014. Utilization of different types of coastal wetlands by waterbirds during the migration season - A case study of Shankou Mangrove Nature Reserve in Guangxi[J]. Marine and Lakes and Marshes, 45(03): 513-521 (in Chinese with English abstract).

Wei Jiangling, Sun Renjie, Liu Wenai, 2020. Bird diversity in mangrove wetlands of Shankou, Guangxi[J]. Journal of Subtropical Resources and Environment, 15(01): 1-10 (in Chinese with English abstract).

Wu Jianguo, 2000. Landscape Ecology: Patterns, Processes, Scales and Hierarchies[M]. Beijing: Higher Education Press.

Chen Wenbo, Xiao Duning, Li Xiuzhen, 2002. Research classification, application and construction of landscape index[J]. Journal of Applied Ecology, (1): 121-125 (in Chinese with English abstract).

Li Lifeng, Liu Wenai, Tao Yancheng, 2021. Dispersal dynamics and driving forces of M. intermedia in Shankou Mangrove Reserve, Guangxi[J]. Journal of Ecology, 41(17): 6814-6824 (in Chinese with English abstract).

Shen Hongkun, Zhao Boyi, Chen Mingyang, 2022. Changes in the area of mutualistic ricegrass and mangrove forests in Shankou Mangrove National Nature Reserve, Guangxi, 1995-2019[J]. Journal of Applied Ecology, 33(02): 397-404 (in Chinese with English abstract).

Pan Lianghao, Shi Xiaofang, Tao Yancheng, 2016. Distribution status and dispersal study of mutualistic ricegrass on the coast of Guangxi[J]. Wetland Science, Vol. 14(4): 464-470 (in Chinese with English abstract).

Zhao Yan, Wang Sen, Yang Wenqing, 2022. Progress and Prospect of Research on Control Measures of Miscanthus in China[J]. Journal of Biosafety, Vol. 31(3): 210-216 (in Chinese with English abstract).

Jia Mingming, 2014. Remote sensing analysis of mangrove dynamics in China from 1973 to 2013[D]. Graduate School of Chinese Academy of Sciences (Northeast Institute of Geography and Agroecology).

Wang Tao, Zhang Chao, 2017. Spatial and temporal changes of cropland landscapes in the Aksu River Basin from 1998 to 2014[J]. Journal of Southwest Forestry University, Vol. 37(2): 171-178 (in Chinese with English abstract).

Guan Daoming, 2009. Ecosystem and Management of Miscanthus Saltmarshes in Coastal Wetlands of China[M]. Beijing: Ocean Press.

Li Hui, Zhang Xiaoyuan, Guo Honglei, 2021. Characteristics of spatial and temporal changes of ecosystem service values in the Three Gorges Reservoir area in the last 30 years based on land use[J]. Research on Soil and Water Conservation, 28(2): 309-318 (in Chinese with English abstract).

Zhou Haiju, Liu Xiaoying, Hu Liangda, 2022. Dynamic change analysis of landscape pattern in Beibu Gulf Economic Zone of Guangxi based on the optimal analysis granularity[J]. Journal of Ecology and Rural Environment, Vol. 38(5): 545-555 (in Chinese with English abstract).

A. Azizi, B. Malakmohamadi, H. Jafari, 2016. Land use and land cover spatiotemporal dynamic pattern and predicting changes using integrated CA-Markov model[J]. Global Journal of Environmental Science and Management-GJESM, Vol.2(3): 221-230.

Turner M G, Gardner R H, O'Neill R V, 2001. Landscape Ecology: Theory and Practice[M]. New York: Springer-Verlag.

Jongman R.H.G., Ter Braak C.J.F., Van Tongeren O.F.R, 1987. Data analysis in community and landscape ecology[J]. Data analysis in community and landscape ecology.,: 299.

Burel F, Baudry J, 2003. Landscape Ecology: Concepts, Methods, Applications[M]. Science Publishers.

Wang H, Liu X, Zhao C, et al, 2021. Spatial-temporal landscape pattern analysis of landscape ecological risk assessment based on land use/land cover change in Baishuijiang National nature reserve in Gansu Province, China[J]. Ecological Indicators, 124: 107454.

Lee S W, Hwang S J, Lee S B, et al., 2009. Landscape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics[J]. Landscape and Urban Planning, 92(2): 80-89.

Guan D, Gao W, Watari K, et al, 2008. Land use change of Kitakyushu based on landscape ecology and Markov model[J]. Journal of Geographical Sciences, 18: 365-374.

*Note: Figure translations are in progress. See original paper for figures.*