Research Paper

Typhoon-Resilient Spatial Patterns in the Chaoshan Region of Guangdong, China

Leveraging Time-honored Indigenous Knowledge for Future-oriented Heritage Conservation and Resilience Planning

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Abstract

Enhancing urban-rural resilience against natural disasters has gained increasing global attention, particularly in coastal regions prone to typhoons. While current research on spatial resilience focuses on individual elements, systemic spatial connections remain understudied. This study develops a methodology to extract typhoon-resilient spatial patterns from coastal regions, focusing on the Chaoshan area of Guangdong, China. Through spatial feature extraction, pattern mining, and validation against typhoon events, complemented by indigenous knowledge interpretation, the study identifies two significant spatial patterns: a multi-layered windbreak system and a "fish farm - salt field - rice field" agricultural zoning arrangement. These patterns demonstrate sophisticated integration of traditional ecological knowledge with spatial planning principles, effectively mitigating typhoon impacts while maintaining productive land use. The findings contribute to resilience planning theory by emphasizing the critical role of systemic spatial interrelationships and provide practical insights for incorporating indigenous knowledge into contemporary planning practices. The study methodology provides a framework for analyzing resilient spatial patterns in other disaster-prone areas of the world.

Keywords

Typhoon resilience, Spatial patterns, Indigenous knowledge, Coastal settlements, Heritage conservation, Resilience planning

1. Introduction

1.1. Research Background

Globally, enhancing the resilience of both urban and rural areas to natural hazards has been in the spotlight of many countries over recent years, including those in the typhoon region. According to the latest data, storms-including typhoons-are one of the major types of natural disasters all over the world (UNDRR and CRED, 2020) (Figure 1). These extreme events are a serious threat to urban spatial development and heritage conservation, particularly in coastal areas where historical settlements have evolved over many centuries of adaptation to environmental challenges.

Current research into spatial resilience, although having made some significant progress, remains focused mainly on individual elements rather than systemic spatial connections (Sharifi and Yamagata, 2016). It is particularly problematic because sometimes effectiveness in resilience strategies cannot be derived independently but through its inter-relationship with other constituent spatial elements (Meerow et al., 2016). Local-scale levels of resilience equally often lack approaches that are context-adaptive and never consider resourceful indigenous stocks of knowledge based on generations or centuries of experiencing environmental adaptation (Hadlos et al., 2022).

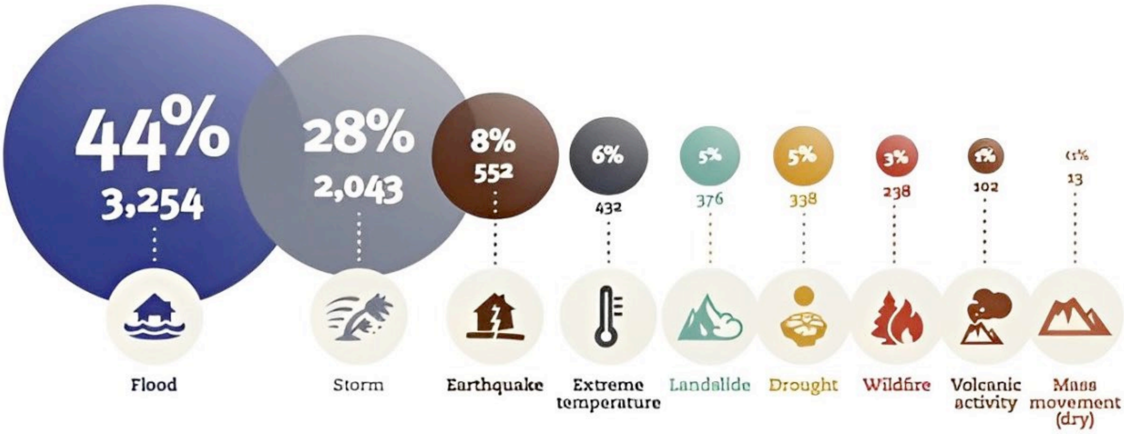

Figure 1. Percentage of occurrences of disasters by disaster type (2000-2019). Source: Centre for Research on the Epidemiology of Disasters (CRED) & United Nations Office for Disaster Risk Reduction (UNDRR).

There would always have been an interesting case study herein using ecological indigenous spatial wisdom to investigate this typhoon that has hit time and again, Chaoshan, Guangdong, China. For long, this frequent typhoon site transformed into a greatly productive agricultural spot and a great place for productive settlement, fully based on development in disaster-resilient settled experiences migrated accumulation in certain ways (Wang and Liu, 2021). These spatial patterns that have emerged in this region represent the sophisticated manifestations of indigenous knowledge and local urban planning philosophy, yet remain understudied in the context of modern resilience planning.

1.2. Research Objectives and Questions

This research develops a methodology to extract and analyze typhoon-resilient spatial patterns from coastal regions, focusing on the Chaoshan area of Guangdong, China. It points to two main questions: (1) What characteristic spatial patterns can explain the resilience of typhoons in the coastal settlements of Chaoshan? (2) How can the understanding of such patterns be interpreted through indigenous local knowledge so that their efficacy may be validated with regard to informing their future use in heritage conservation and locally adapted resilience planning?

The research will fill the knowledge gap between traditional wisdom and current planning practices through the identification and analysis of site-specific spatial patterns that have traditionally been effective against typhoon impacts. This research can contribute to deepening both theoretical understanding of the concept of spatial resilience and practical approaches in coastal urban planning by interpreting indigenous knowledge on the basis of spatial analysis techniques.

2. Literature Review and Theoretical Framework

2.1. Urban Resilience and Natural Disasters

There has been considerable evolution in the arguments on urban resilience in the last few decades, especially with regard to natural disaster threats. Resilience in urban systems is how cities maintain or rapidly return desired functions in light of disturbance, adapt to changed conditions, and can rapidly transform systems that currently limit or are expected to limit future adaptive capacity (Meerow and Newell, 2019). In the context of natural disasters such as typhoons, resilience involves physical infrastructure adaptability and socio-ecological system robustness. Researchers have also established the need for considering multiple dimensions of resilience jointly (Amirzadeh et al., 2022).

Traditional approaches concerned themselves basically with physical infrastructure, while on the contrary, there is presently a call to have a framework that is comprehensive in the social, ecological, and spatial dimensions of resilience (Sharifi, 2019). This is the recognition that, actually, effective disaster resilience requires analysis of the configuration of the interplay between the built environment and natural systems in all their complexities.

2.2. Spatial Patterns and Urban Morphology

Spatial patterns are defined by Alexander (1977) as relatively permanent associative integrations of urban spatial elements that emerge through a process of long-term human adaptation to environmental conditions. In disaster studies, these usually embody knowledge that has accumulated about effective spatial arrangements for mitigation (Kropf, 2018). The latest research was able to emphasize how specific spatial configurations can promote the enhancement of regions' resistance to and recovery from natural disasters.

There is an increasing application of advanced methodologies such as remote sensing and machine learning techniques in the analysis of spatial patterns with the aim to identify and validate effective spatial arrangements (Li et al., 2023). but little is known about how those patterns contribute to typhoon resilience, in particular in traditionally adapted coastal settlements.

2.3. Indigenous Knowledge in Disaster Risk Reduction

Among these underutilized resources in contemporary planning practices is indigenous knowledge on the reduction of disaster risks. That type of knowledge, usually developed over several generations through adaptation to the environment, can particularly be rich in the subtleties regarding local ecological processes and thus appropriate strategies related to risk reduction (Hadlos et al., 2022). Thus, on typhoon-prone coasts, indigenous knowledge has led to adaptive settlement and agriculture.

Indigenous knowledge (IDK) received increased interest in modern approaches to planning. In this respect, many studies have identified that traditional practices among the local community hold the key to sustainable and effective solutions against disaster risks (Hiwasaki et al., 2014). But how such tacit knowledge is to be translated into formal planning frameworks without losing its contextual relevance remains a challenge.

3. Methodology

3.1. Study Area

The Chaoshan region of Guangdong Province was selected as the site for this study due to the area's high annual frequency of exposure to typhoons and rich heritage in indigenous adaptation strategies. This is approximately 10,610 km² with a population of about 13.65 million people in 2020, encompassing several historically important coastal settlements. In this research, the area of interest was mainly the 500-meter buffer zone from the coastline because it is here that the typhoon impacts are strongest and the traditional adaptation patterns most clearly visible.

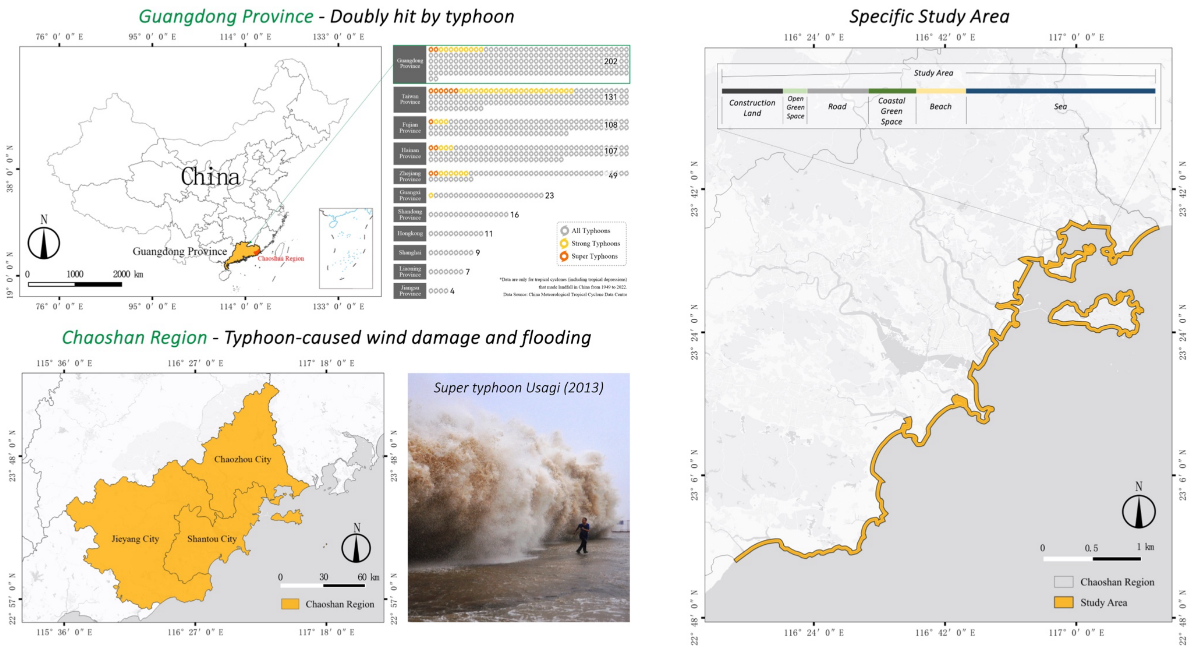

Figure 2. Study area. Source: Drawn by the author.

The region on average receives five typhoons annually with great impacts like strong winds, storm surges, and flooding. This represents an ideal case study for the investigation of typhoon-resistant spatial patterns because sophisticated spatial adaptation strategies have been developed by local communities through centuries of settlement.

3.2. Data Collection and Processing

Many types of sources have been used in this research to ensure comprehensiveness. The main spatial data used in this study are high-resolution satellite imagery and land use/land cover data from the SinoLC-1 dataset (Li et al., 2023). Temporal data included satellite imagery before and after Super Typhoon Usagi in September 2013 and enabled the assessment of the resilience of spatial patterns. On the other hand, indigenous knowledge was captured through local chronicles, historic documents, and semi-structured interviews with community elders.

3.3. Study Design

In this study, a four-step analytical framework was applied to identify and validate the typhoon-resilient spatial pattern (Figure 3). In stage one, the Object-based Image Analysis (OBIA) and remote semantic segmentation technique were used to extract the spatial features. Following Li et al. (2023), ten categories of spatial elements, such as road networks, tree cover, cropland, buildings, water bodies, and wetlands, were considered for classification. For each of the extracted features, spatial dimensions, geographic locations, and relationships with neighborhood elements were analyzed.

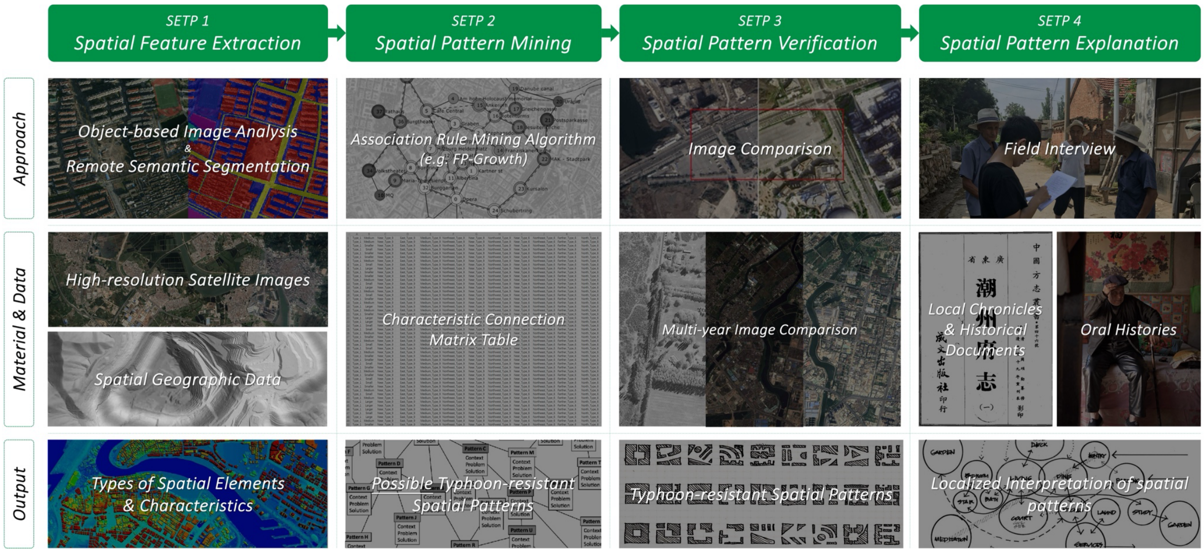

Figure 3. Four-stage analytical framework to identify and validate typhoon-resilient spatial patterns. Source: Drawn by the author.

In the mining pattern stage, FP-Growth was applied as an algorithm to mine important spatial patterns from the real extracted features (Li et al., 2021). Further, we constructed characteristic connection matrices of spatial elements and calculated the support and lift values to determine meaningful spatial associations. The algorithm was set with a minimum support threshold value of 0.02 to ensure that very meaningful patterns would be found while eliminating spurious associations (Han et al., 2019).

Verification of the pattern was done as the third step in our analysis, taking as a case study Super Typhoon Usagi (2013). Pattern resilience was considered against three scenarios of sustaining structural integrity, recovery time, and continuity of functionality based on the assessment framework (Lei et al., 2015).

Interpretation of the pattern through indigenous knowledge analysis forms the last stage of analysis. We thus undertook a critical scrutiny of the local annals and historical accounts to supplement the semi-structured interviews executed on a random sample of twenty elderly residents. This methodological approach may also take into consideration calls by recent studies to include local knowledge in disaster resilience research, as the study of Hadlos et al. states (Hadlos et al., 2022).

4. Results

4.1. Spatial Pattern Mining and Verification

The major types of spatial elements extracted in the Chaoshan region include roads (Type 1), tree cover (Type 2), grassland (Type 4), cropland (Type 5), buildings (Type 6), barren and sparse vegetation (Type 7), water (Type 9), and wetland (Type 10). We constructed characteristic connection matrix tables to record the spatial relationships among elements such as relative distances, orientations, and areas.

The FP-Growth algorithm analysis revealed several significant spatial associations, with varying degrees of support and lift values. The spatial rules network visualization further revealed complex interconnections among these elements (Figure 4). For example, key associations include: (1) Road-Building-Cropland relationship (support=0.0215, lift=46.5668), indicating a strong systematic arrangement of transportation infrastructure with settlements and agricultural areas. (2) Tree cover with buildings and cropland (support=0.0391, lift=25.5629), suggesting consistent integration of vegetation barriers with built environments. (3) Tree cover with buildings, cropland, and barren/sparse vegetation (support=0.0260, lift=38.4789), showing complex multi-element spatial arrangements.

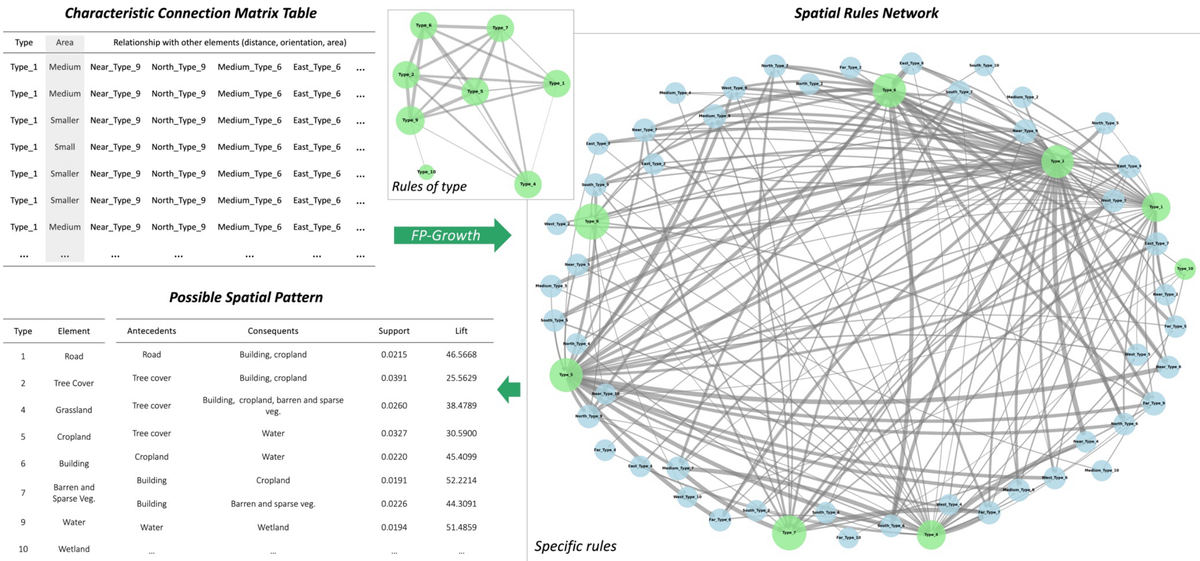

Figure 4. Results of spatial pattern mining by FP-Growth algorithm and its visualization. Source: Drawn by the author.

Using Super Typhoon Usagi (2013) as a temporal observation point, we identified three distinct situations through comparison of pre-typhoon and post-typhoon satellite imagery (Figure 5). The first situation showed patterns maintaining stability with minimal damage during the typhoon. The second revealed patterns that, although damaged, demonstrated rapid recovery to their original state, indicating high resilience. A third situation, where patterns transformed into new spatial forms, was observed but not included in our resilient pattern analysis due to uncertainty about their long-term stability.

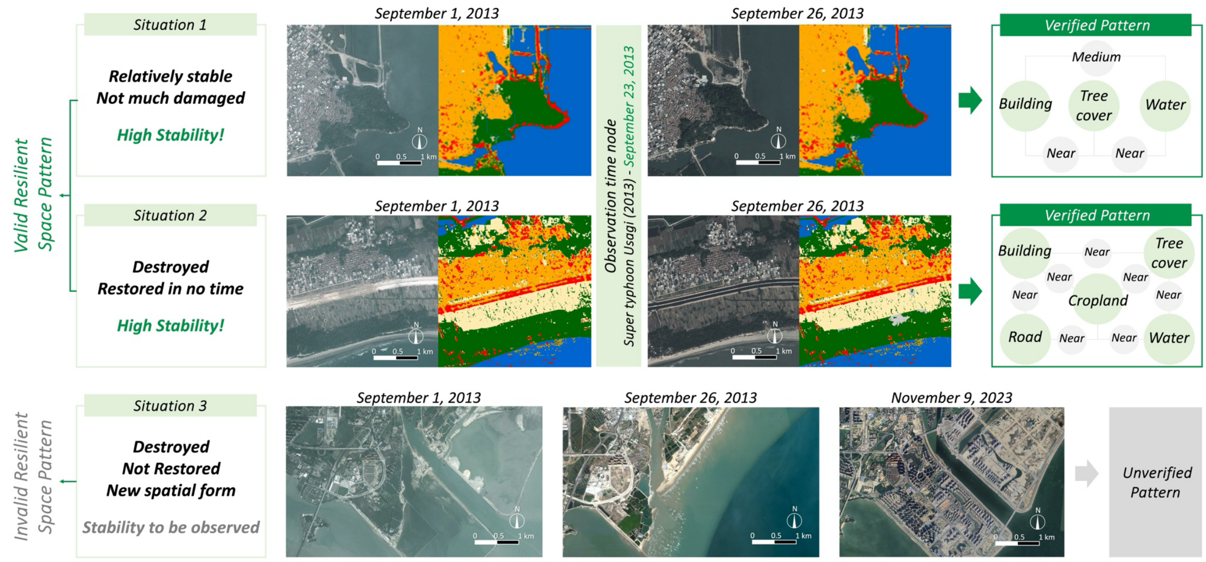

Figure 5. Identified three distinct situations through comparison of pre-typhoon and post-typhoon satellite imagery. Source: Drawn by the author.

4.2. Identified Typhoon-Resilient Spatial Patterns and Their Explanation by IDK

Two typical spatial patterns were identified through algorithmic rule mining and verification using historical satellite images.

The first typhoon-resilient pattern is a multi-layered windbreak forest system designed specifically to mitigate typhoon-induced sea spray and wind damage (Figure 6). This system manifests as a series of strategically positioned forest barriers that protect coastal settlements and agricultural lands. Along the coastline, windbreak forests are systematically integrated with seawalls, with vegetation root systems reinforcing coastal defense structures. Field observations and historical records indicate that over 75% of Chaoshan villages maintain settlement windbreaks, which evolved from the early immigrants' practice of surrounding thatched cottages with bamboo groves. These settlement windbreaks, now recognized as Feng Shui forests, serve both protective and cultural functions within the community structure (Chen et al., 2018). The agricultural areas are protected by a unique combination of street trees and fruit trees positioned along field boundaries, creating an economically efficient dual-purpose system that provides both wind protection and agricultural products.

The second significant and effective pattern is a distinctive coastal-to-inland spatial sequence that demonstrates sophisticated adaptation to both tidal dynamics and typhoon-induced flooding (Figure 7). This pattern consists of a systematic arrangement of fish farms, salt fields, and rice fields, progressing inland from the coast. The fish farming zone effectively utilizes the intertidal area, serving as an initial buffer against storm surges while maintaining productive aquaculture activities. The intermediate salt field zone represents a transitional space where communities have developed sophisticated soil management techniques to address salinity issues, including strategic freshwater pumping and salt-tolerant crop cultivation. The innermost rice field zone exhibits careful adaptation to seasonal typhoon patterns, with cultivation cycles aligned with the traditional lunar calendar to minimize crop exposure during peak typhoon seasons.

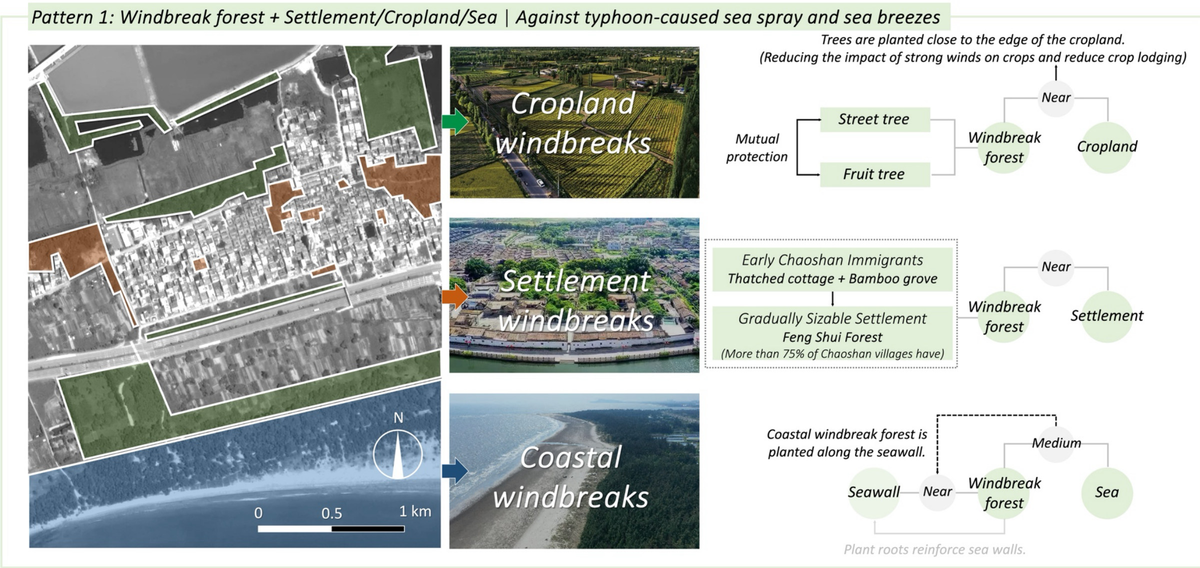

Figure 6. Typhoon-resilient pattern 1: Multi-layered windbreak forest system designed specifically to mitigate typhoon-induced sea spray and wind damage. Source: Drawn by the author.

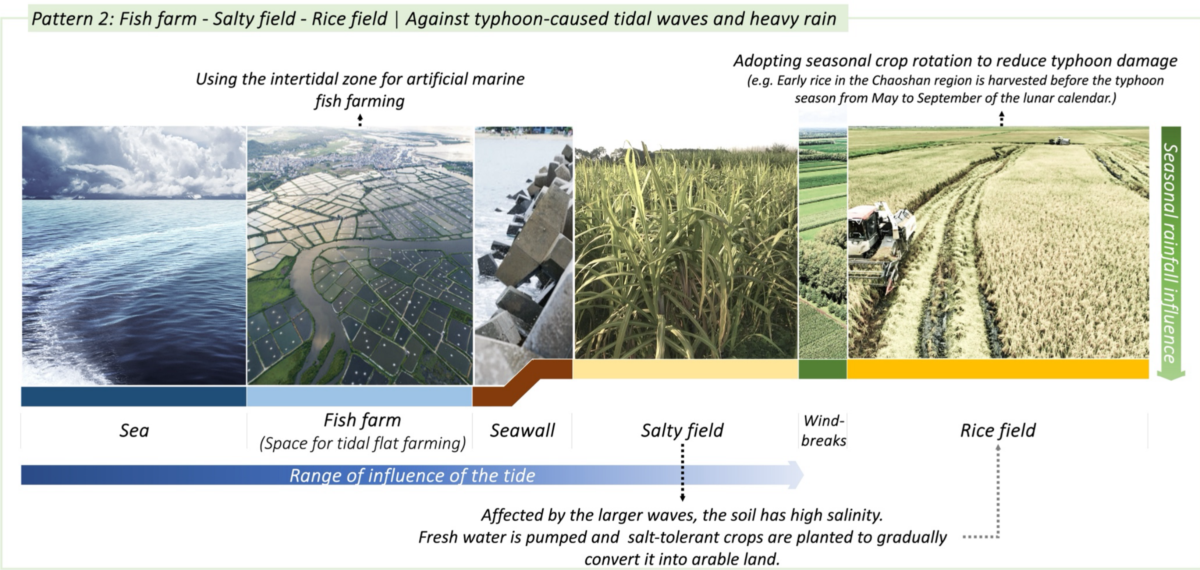

Figure 7. Typhoon-resilient pattern 2: Distinctive coastal-to-inland spatial sequence that demonstrates sophisticated adaptation to both tidal dynamics and typhoon-induced flooding. Source: Drawn by the author.

The efficacy of such spatial patterns is supported by several lines of evidence. For example, satellite images before and after Typhoon Usagi (2013) demonstrated that such spatial arrangements were resistant to extreme climate events, particularly in the traditional pattern areas. Semi-structured interviews with elderly residents provided the rich historical context for the development and evolution of such patterns, while local chronicles documented their long-term effectiveness in mitigating typhoon impacts. Of particular significance is how such spatial arrangements were integrated within traditional governance structures and community practices that ensured their preservation across generations.

5. Discussion

5.1. Integration of Indigenous Knowledge and Modern Planning

These typhoon-resilient spatial patterns revealed in this study have shown the real possibility of deeply integrating indigenous knowledge with contemporary planning practices. This multilayered windbreak system and the general agricultural zoning pattern demonstrate in-depth knowledge about environmental dynamics, which is instructive for modern-day resilience strategies. The findings accord with the recent scholarly emphasis on the primacy of indigenous knowledge in climate adaptation, as espoused by Hiwasaki et al. (2014), with specific spatial implementation strategies.

In integrating traditional knowledge with modern planning, the needed attention is accorded by the physical and spatial arrangement and their socio-economic mechanisms. The very persistence of Feng Shui forests through embeddings in local governance structures allows a foresight into how the old practices, in fact, keep finding their relevance through institutions. This observation lends credence to Jigyasu's argument (2016) that successful strategies of resilience need to consider both technical and social dimensions of traditional practices and that modern approaches to planning should similarly be embracing this duality.

5.2. Implications for Heritage Conservation

The spatial patterns in this research are representative of the complex integration between functional adaptation and cultural heritage values. These embody what Taylor and Lennon (2021) describe as living heritage, wherein traditional practices serve vital contemporary functions within a continuous cultural significance. The multifunctionality of these spatial arrangements resists conventional approaches to heritage conservation that artificially separate physical and intangible heritage elements.

Our findings thus suggest a radical reorientation in conserving heritage within coastal contexts is called for, shifting from one that treats their spatial patterns of artefactness as static aspects of history to approaches that place such artefactness within long-term dynamics while retaining essential protection functions into the present. And this role played by community governance in their perpetuation thus extends to how effectively conservational concerns can operate well beyond concerns of physical protection through and within social systems within which those patterns continually adapt and change.

5.3. Applications for Resilience Planning

These found patterns bring key messages for current resilience planning in coastal areas, as the systematic arrangement of protective elements shows how a set of risk-reduction strategies can be combined into coherent spatial frameworks that fit emergent trends in resilience thinking centered on systemic approaches rather than isolated interventions (Meerow and Newell, 2019). The graduated transition from sea to inland uses provides important lessons in the management of coastal vulnerabilities while maintaining productive land use, while the integration of settlement and agricultural systems illustrates how different land uses can mutually reinforce disaster resilience.

It is particularly relevant to consider traditional windbreak systems because of their multiple functions in a contemporary green infrastructure design. These systems show how protective functions can be combined with productive land uses and cultural significance and thereby offer a model for modern green infrastructure that goes beyond simple hazard mitigation toward incorporating broader social and economic benefits.

5.4. Research Limitations and Future Development

These findings must be interpreted in the light of several methodological limitations. While the FP-Growth algorithm identified the spatial pattern effectively, applications to complex spatial relationships may render this incapable of capturing all nuanced variations in spatial arrangements. While the paper appropriately limits itself to a 500-meter coastal buffer zone in its focus on immediate typhoon impacts, it misses broader spatial relationships extending further inland. Further, reliance on Super Typhoon Usagi (2013) as a principal verification case, while no doubt instructive, provides only a limited temporal window into the more complex history of typhoon impacts.

These limitations point toward several promising directions for future research. Comparative studies examining similar coastal regions facing typhoon risks could reveal variations in resilient spatial patterns and their cultural embedding, potentially identifying both universal principles and context-specific adaptations. The challenge of climate change suggests a need for research into how traditional spatial patterns might be adapted to address intensifying impacts, particularly in relation to sea-level rise and increasing typhoon intensity. Additionally, investigation of effective policy mechanisms for incorporating indigenous spatial knowledge into formal planning frameworks while respecting traditional governance systems would provide valuable guidance for practical implementation.

6. Conclusion

This study advances our understanding of typhoon-resilient spatial patterns in coastal settlements through systematic analysis of the Chaoshan region of Guangdong, China. Through the integration of spatial analysis techniques and indigenous knowledge interpretation, we have identified and validated specific spatial patterns that demonstrate effective adaptation to typhoon impacts while preserving cultural heritage values.

The research reveals how indigenous knowledge, accumulated through generations of environmental adaptation, has shaped sophisticated spatial arrangements that address multiple aspects of typhoon risk. The identified multi-layered windbreak system, combining coastal, settlement, and agricultural protective elements, demonstrates the integration of ecological understanding with practical risk reduction strategies. Likewise, the agricultural zoning pattern that graduates from fish farms through salt fields to rice fields bespeaks deep understanding of coastal dynamics and seasonal typhoon patterns.

Hence, these findings develop a significantly enriched contribution to theory in resilience planning, which draws heavily, for the very first time ever in documented history, onto systemic, spatially interrelational means that take a prominent role over individuals. What makes this finding particular is the expression wherein the efficacy to generate effective typhoon resilience rises not from discrete features alone or in concert through judicious placing to combine in expanded social-ecological systems and is what fundamentally reforms conventional ways where approaches toward achieving resilience have stressed isolated interventions instead of an integral-spatiated approach.

This is valuable learning that can be used in planning practice to devise context-specific resilience strategies. The spatial patterns extracted provide tangible examples of how traditional wisdom can be used to develop an informant approach to contemporary planning while ensuring continuity of the culture concerned. This developed methodology of spatial pattern mining combined with indigenous knowledge validation provides a framework that can be extended and used to investigate resilient spatial patterns in other disaster-prone regions globally.

The study's findings support the need for better conservation of indigenous knowledge systems in an attempt to learn from them in handling environmental problems relevant in the contemporary era. These need to be scaled up in response to increased vulnerabilities of climate change and extreme weather events along the coastlines across the globe. The identification and understanding of such traditional strategies of resilience is valuable in its adaptation processes.What should follow in future research is how these patterns are adaptable within a changing climate regime and their applicability across cultural and geographical divides.

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