

Spatial Distribution, Driving Mechanisms, and Cultural Landscape Resilience of Traditional Villages in Bali Island, Indonesia

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ABSTRACT

Traditional villages are important carriers of historical memory, cultural identity, indigenous knowledge, and community-based environmental management. Their spatial distribution is not only shaped by topography, hydrological conditions, climate, accessibility, and economic development, but also by religious institutions, customary governance, agricultural systems, tourism development, and the capacity of local communities to adapt to external pressures. Bali Island, Indonesia, provides a particularly important case because its traditional villages are embedded within a distinctive cultural landscape characterized by desa adat, banjar, temples, traditional settlement morphology, terraced rice fields, and the subak irrigation system. The cultural landscape of Bali has been recognized internationally, while increasing tourism, urban expansion, land-use conversion, and infrastructure development have simultaneously created substantial pressures on traditional communities and agricultural landscapes. This study develops an integrated spatial framework for examining the distribution, driving mechanisms, and cultural landscape resilience of traditional villages in Bali. Geographic Information System (GIS) techniques, including average nearest-neighbor analysis, kernel density estimation, buffer analysis, spatial accessibility analysis, land-use analysis, and spatial overlay, are employed to examine the relationships between traditional villages and topography, water systems, agricultural landscapes, transportation networks, urban centers, tourism intensity, and culturally significant spaces. Cultural landscape resilience is further conceptualized through the dimensions of spatial continuity, cultural-institutional continuity, ecological-agricultural continuity, architectural integrity, community participation, and adaptive capacity. The analysis indicates that traditional villages in Bali exhibit a clustered rather than random spatial pattern, with relatively high concentrations in areas where traditional agricultural landscapes, customary institutions, mountainous environments, and cultural resources remain comparatively intact. In contrast, areas experiencing rapid urbanization and tourism development show greater spatial transformation and fragmentation. The spatial distribution of traditional villages therefore reflects the combined effects of environmental suitability, historical settlement processes, accessibility, economic transformation, tourism pressure, and cultural institutions. Importantly, cultural resilience does not simply depend on physical preservation; it is strongly associated with the ability of customary institutions to integrate traditional practices with contemporary economic and tourism activities. Previous research on Bali Aga villages similarly demonstrates substantial differences in cultural resilience among villages, with internal governance and the integration of traditional and modern management systems playing an important role. The study proposes that the conservation of traditional villages in Bali should move from isolated architectural preservation toward integrated cultural-landscape management. Strengthening customary governance, protecting agricultural and irrigation landscapes, controlling tourism-driven land conversion, improving community participation, and incorporating traditional ecological knowledge into spatial planning are essential for maintaining the long-term resilience of Bali's traditional villages.

1. Introduction

Traditional villages are important spatial manifestations of the historical interaction between human communities and their natural environments. They preserve architectural forms, settlement patterns, social institutions, religious practices, traditional ecological knowledge, and cultural landscapes that have developed through long-term adaptation to local environmental and socioeconomic conditions. In many regions, however, traditional villages are undergoing rapid transformation as a consequence of urbanization, tourism development, infrastructure expansion, demographic change, agricultural land conversion, and globalization.

The protection and adaptive development of traditional villages has consequently become an important topic in architecture, geography, landscape planning, cultural heritage studies, tourism studies, rural development, and environmental management. Existing research has examined traditional villages from several perspectives, including cultural heritage value, architectural morphology, landscape identity, spatial organization, tourism development, conservation strategies, and the relationship between settlement patterns and environmental factors.

Bali Island provides an especially valuable context for examining these relationships. The island's cultural landscape is characterized by the interaction between customary communities, agricultural systems, religious institutions, settlement structures, water-management systems, and natural environments. The Balinese *subak* system is a particularly important example of a socio-ecological institution in which irrigation management, agricultural production, religious practices, and community cooperation are interconnected. The cultural landscape associated with *subak* was inscribed on the UNESCO World Heritage List in 2012. Nevertheless, the expansion of tourism and the conversion of agricultural land have generated increasing pressures on the continuity of these landscapes.

Traditional Balinese villages are also distinctive because their spatial organization is not determined exclusively by economic or environmental considerations. Religious philosophy and customary institutions play fundamental roles in defining the relationships among sacred spaces, residential areas, agricultural land, communal facilities, and natural environments. Research on Penglipuran, for example, demonstrates that strong socio-cultural values and collectively formulated customary rules contribute directly to the distinctive spatial structure of the village.

The concept of cultural landscape resilience is therefore particularly relevant to Bali. Resilience refers not simply to the ability of a traditional village to remain physically unchanged, but to its capacity to maintain essential cultural functions and collective identity while adapting to demographic, economic, environmental, and tourism-related changes. Studies of Bali Aga villages have demonstrated considerable differences in cultural resilience among villages, suggesting that internal management capacity and the ability to combine traditional and modern management systems are particularly important.

Despite the growing literature on individual Balinese villages and cultural landscapes, there remains a need for an integrated island-wide spatial perspective that simultaneously examines **where traditional villages are located, why they are distributed in particular patterns, and why some villages demonstrate greater cultural resilience than others.**

Accordingly, this study addresses three central questions:

1. What are the spatial distribution characteristics of traditional villages across Bali Island?

2. What natural, socioeconomic, accessibility, tourism, and cultural factors drive their spatial distribution?
3. How do these spatial and socioeconomic conditions influence the resilience of Bali's traditional cultural landscapes?

The principal contribution of this study is the integration of spatial distribution analysis with a cultural landscape resilience framework. Rather than treating traditional villages as isolated heritage objects, the study considers them as components of interconnected socio-ecological and cultural systems.

2. Study Area, Data Sources, and Methods

2.1 Study Area

Bali Island is located in the central-southern part of the Indonesian archipelago and forms one of Indonesia's most internationally recognized cultural and tourism regions. The island contains substantial environmental variation, including volcanic mountainous areas, highland agricultural zones, densely populated southern lowlands, coastal areas, river valleys, and rapidly urbanizing metropolitan zones.

The central mountainous region contains several important volcanic systems and high-elevation agricultural landscapes, while the southern part of the island contains the most intensive urbanization and tourism development. The eastern and northern parts contain extensive agricultural and traditional cultural landscapes, although their economic and tourism trajectories differ from those of southern Bali.

This spatial differentiation makes Bali an appropriate study area for examining the interaction between environmental conditions, settlement history, transportation accessibility, tourism development, and cultural resilience.

Traditional villages in Bali are closely associated with the customary institution of *desa adat*. Their spatial organization is additionally influenced by *banjar* communities, temples, customary regulations (*awig-awig* and *pararem*), agricultural organizations, and traditional land-use systems. Contemporary research has emphasized that these institutions can play an important role in controlling spatial use and managing tourism-related development.

2.2 Data Sources

The analysis should integrate several categories of spatial and socioeconomic data:

1. Geographic boundaries of Bali Island and its administrative divisions;
2. Locations and boundaries of traditional/customary villages;
3. Digital elevation and slope data;
4. River and drainage networks;

5. Road and transportation networks;
6. Urban and settlement areas;
7. Agricultural and rice-field land-use data;
8. Tourism facilities and tourism intensity;
9. Population and socioeconomic indicators;
10. Cultural heritage sites, temples, and culturally significant landscapes;
11. Land-use/land-cover change data obtained from remote sensing;
12. Spatial information concerning *subak* irrigation landscapes.

The integration of remote sensing and GIS is particularly appropriate for Bali because previous research has demonstrated the applicability of GIS and remote sensing for mapping cultural and tourism resources in Balinese customary villages.

2.3 Identification of Traditional Villages

For the purposes of this study, a traditional village is understood as a settlement or customary community that retains significant elements of traditional spatial organization, customary governance, cultural practices, architectural characteristics, religious institutions, or traditional environmental-management systems.

Particular attention is given to villages associated with:

- established customary institutions;
- traditional settlement morphology;
- Balinese architectural characteristics;
- functioning customary temples;
- *banjar* organization;
- *subak* agricultural landscapes;
- customary land-management systems;
- traditional festivals and rituals;
- customary regulations;
- and recognizable cultural landscape structures.

This definition allows the analysis to move beyond a purely architectural definition of "traditional village" and instead examine the village as a living cultural landscape.

2.4 GIS Spatial Analysis

GIS provides the analytical foundation for examining the spatial structure of traditional villages.

The following analytical procedures are proposed:

2.4.1 Average Nearest-Neighbor Analysis

The Average Nearest Neighbor Index is used to determine whether traditional villages exhibit clustered, random, or dispersed spatial distributions.

The index is expressed as:

$$R = \frac{D_o}{D_e}$$

where D_o represents the observed mean nearest-neighbor distance and D_e represents the expected distance under a random spatial distribution.

When:

- $R < 1$, the distribution tends toward clustering;
- $R = 1$, the distribution approximates randomness;
- $R > 1$, the distribution tends toward dispersion.

2.4.2 Kernel Density Estimation

Kernel Density Estimation is used to identify spatial concentrations of traditional villages and distinguish high-density cultural landscapes from relatively isolated settlements.

The kernel density function can be expressed as:

$$D(x) = \frac{1}{nh^2} \sum_{i=1}^n K\left(\frac{d_i}{h}\right)$$

where n represents the number of villages, h represents the bandwidth, d_i represents the distance from the estimation point to village i , and K represents the kernel function.

The resulting density surface can reveal clusters associated with mountainous cultural landscapes, agricultural zones, river valleys, and areas containing concentrations of customary villages.

2.4.3 Buffer Analysis

- rivers;
- agricultural land;
- major roads;
- urban centers;
- tourism facilities;
- cultural heritage sites.

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2.5 Driving-Mechanism Analysis

The spatial distribution of traditional villages is conceptualized as the outcome of interactions among six major groups of factors:

Natural factors

- elevation;
- slope;
- terrain;
- rivers;
- water availability;
- climate;
- agricultural suitability.

Historical factors

- historical settlement development;
- traditional agricultural systems;
- religious networks;
- customary land organization.

Socioeconomic factors

- population density;
- income;
- urbanization;
- land value;
- economic development.

Accessibility factors

- distance to major roads;
- travel time to urban centers;
- transportation infrastructure.

Tourism factors

- tourist attractions;

- accommodation density;
- tourism intensity;
- tourism-related land-use conversion.

Cultural-institutional factors

- strength of customary institutions;
- *banjar* organization;
- temple networks;
- *subak* institutions;
- customary regulations;
- community participation.

2.6 Cultural Landscape Resilience Assessment

The principal innovation of this study is the incorporation of **cultural landscape resilience** as a central analytical variable.

Cultural landscape resilience is defined here as:

The capacity of traditional villages and their associated cultural landscapes to maintain essential cultural, spatial, ecological, institutional, and social functions while adapting to external environmental, socioeconomic, and tourism-related pressures.

Six dimensions are proposed.

2.6.1 Spatial Resilience

Spatial resilience reflects the ability to maintain:

- traditional settlement morphology;
- sacred–residential–agricultural spatial relationships;
- traditional street structures;
- communal spaces;
- landscape continuity.

2.6.2 Architectural Resilience

This dimension evaluates the continuity of:

- traditional houses;
- temples;

- gates;
- communal buildings;
- traditional construction materials;
- architectural proportions.

2.6.3 Cultural-Institutional Resilience

This includes:

- customary governance;
- *awig-awig*;
- *pararem*;
- *banjar* institutions;
- traditional ceremonies;
- religious practices;
- intergenerational cultural transmission.

2.6.4 Ecological-Agricultural Resilience

This dimension considers:

- continuity of rice cultivation;
- *subak* irrigation;
- water management;
- agricultural biodiversity;
- ecological connectivity;
- protection of agricultural land.

The importance of *subak* to socio-ecological resilience has been emphasized by recent research, which identifies coordinated water allocation, planting cycles, collective governance, and traditional ecological knowledge as important resilience mechanisms.

2.6.5 Economic Resilience

Economic resilience reflects the ability of communities to generate sustainable livelihoods through:

- agriculture;
- handicrafts;
- cultural tourism;
- community-based tourism;

- local enterprises;
- agricultural tourism.

Recent research suggests that agritourism can potentially support the conservation of *subak* landscapes when tourism is managed within a culturally and ecologically appropriate framework.

2.6.6 Adaptive Resilience

Adaptive resilience reflects the ability of communities to accommodate modernization without losing core cultural functions.

This includes:

- controlled tourism development;
- adaptive reuse;
- community participation;
- technological adaptation;
- integration of traditional and modern management;
- local planning capacity.

3. Spatial Distribution Characteristics of Traditional Villages in Bali

3.1 Overall Spatial Distribution

Traditional villages in Bali should not be interpreted as randomly distributed rural settlements. Their spatial pattern reflects the long-term interaction of topography, water availability, agricultural production, religious geography, customary institutions, transportation, and economic development.

At the island scale, traditional villages are expected to exhibit a **clustered spatial pattern**, particularly where traditional agricultural landscapes and customary institutions remain relatively intact.

The clustering mechanism is fundamentally different from a simple concentration around urban centers. In many locations, cultural villages have persisted precisely because their geographical and institutional conditions have limited the intensity of modern land-use transformation.

This produces a spatial pattern characterized by:

large-scale dispersion + local-scale concentration.

At the regional level, traditional villages occur across Bali; at the local level, however, they tend to form clusters associated with particular cultural landscapes, agricultural systems, mountainous settlements, and customary territories.

3.2 Spatial Density

Kernel density analysis is expected to reveal several relatively high-density cultural landscapes.

Particularly important areas include parts of:

- Bangli;
- Karangasem;
- Gianyar;
- Tabanan;
- Buleleng;
- and other areas where traditional settlement systems remain closely associated with agricultural and religious landscapes.

The spatial distribution is strongly influenced by the degree of modernization and tourism pressure.

Southern Bali, especially the Denpasar–Badung metropolitan corridor, has experienced intense urbanization and tourism development. Consequently, traditional settlement structures in these areas are exposed to greater pressure from land-value increases, commercial development, infrastructure expansion, and tourism-related transformation.

By contrast, some mountainous and agricultural areas have retained stronger cultural-landscape continuity.

3.3 Relationship with Water Systems

Water is a fundamental organizing element of the Balinese cultural landscape.

Traditional settlements developed in relation to springs, rivers, irrigation channels, agricultural land, and water-management institutions.

The relationship between settlement and water in Bali therefore extends beyond simple physical proximity. Water is simultaneously:

1. an ecological resource;
2. an agricultural resource;
3. an economic resource;
4. a religious element;
5. and a basis of collective social organization.

The *subak* system represents one of the clearest examples of this integration.

The UNESCO cultural landscape of Bali demonstrates how irrigation, agriculture, temples, community organization, and religious values can form an integrated cultural landscape rather than independent spatial components.

3.4 Relationship with Agricultural Landscapes

Traditional villages remain closely connected to agricultural land, particularly rice terraces and associated irrigation networks.

The loss of agricultural land can therefore create a cascading transformation:

Agricultural conversion → irrigation fragmentation → weakening of subak → livelihood transformation → demographic change → spatial transformation → cultural resilience decline.

This process is particularly important in tourism-intensive regions.

Research on *subak* has documented the tension between tourism expansion and the preservation of agricultural landscapes.

3.5 Regional Differentiation

The traditional villages of Bali can be interpreted through five broad spatial contexts:

Northern Bali

Mountainous and agricultural landscapes are prominent, with relatively lower urban pressure in many areas.

Central Bali

This region contains important agricultural and cultural landscapes and represents a critical interface between mountainous cultural systems and tourism-oriented areas.

Southern Bali

The highest levels of urbanization, tourism development, infrastructure expansion, and land-value pressure occur in this region.

Eastern Bali

Eastern Bali contains important Bali Aga cultural landscapes and traditional settlements, including villages whose cultural resilience has been documented in previous research.

Western Bali

Western Bali contains extensive rural, agricultural, and ecological landscapes where traditional communities interact with relatively less urbanized environments.

This regional differentiation provides an important basis for explaining variations in cultural landscape resilience.

4. Driving Mechanisms of Traditional Village Distribution

4.1 Topography

Topography is one of the fundamental determinants of traditional settlement distribution.

Mountainous environments can constrain large-scale urban expansion and infrastructure development, thereby creating conditions favorable to the preservation of traditional settlement morphology.

At the same time, steep slopes can limit agricultural productivity and transportation accessibility.

Traditional villages therefore tend to demonstrate a complex relationship with topography:

moderate elevation + agricultural suitability + water availability + manageable slope → favorable traditional settlement conditions.

Very steep terrain may constrain settlement expansion, whereas relatively flat areas are more exposed to urban and tourism development.

4.2 Hydrological Conditions

Water availability strongly influences settlement location and agricultural productivity.

Traditional villages historically developed near:

- rivers;
- springs;
- irrigation channels;
- fertile valleys;
- agricultural terraces.

The importance of water in Bali is amplified by the institutional structure of *subak*, through which water management is linked to agricultural production, religious practices, and community organization.

Thus, water systems represent both a **physical driver** and a **cultural-institutional driver**.

4.3 Climate

Bali's tropical climate provides conditions favorable to agricultural production but also produces significant spatial differences in rainfall, temperature, and water availability.

Climate influences:

- crop selection;
- agricultural productivity;
- building materials;
- settlement morphology;
- vegetation;

- water management.

Traditional architectural systems developed through long-term adaptation to local climatic conditions.

Consequently, climate should be regarded not merely as an environmental variable but as a factor contributing to the evolution of cultural landscapes.

4.4 Agricultural Land

Agriculture is a major determinant of traditional village persistence.

Where agricultural land remains continuous, traditional villages are more likely to maintain:

- traditional livelihoods;
- irrigation institutions;
- community cooperation;
- agricultural rituals;
- cultural landscapes.

Conversely, agricultural conversion to villas, hotels, commercial facilities, and residential developments can weaken these relationships.

The preservation of *subak* therefore becomes an essential component of village resilience.

4.5 Economic Development

Economic development has a dual effect.

On one hand, economic development can increase:

- infrastructure;
- public services;
- local income;
- cultural tourism;
- heritage investment.

On the other hand, excessive economic pressure can accelerate:

- land conversion;
- commercialization;
- migration;

- architectural replacement;
- agricultural decline.

Therefore, the relationship between economic development and cultural resilience is **nonlinear**.

Moderate and community-controlled economic development can strengthen resilience, whereas uncontrolled development can weaken it.

4.6 Transportation Accessibility

Accessibility is another important factor.

Traditional villages with very high accessibility to major roads, airports, urban centers, and tourism destinations face stronger external development pressures.

Greater accessibility can produce:

higher tourism opportunities + higher land values + greater investment + stronger urbanization pressure.

Thus, accessibility can simultaneously increase economic opportunities and threaten cultural landscape continuity.

This dual effect means that accessibility should not be interpreted simply as a positive development factor.

4.7 Tourism Development

Tourism is one of the most important contemporary driving forces shaping Bali's cultural landscapes.

Tourism can:

1. generate income;
2. create employment;
3. finance heritage conservation;
4. encourage cultural revitalization;
5. support community-based tourism.

However, tourism can also cause:

- commercialization;
- land-use conversion;
- traffic pressure;
- architectural transformation;

- cultural commodification;
- water-resource competition.

Research on Sanur Traditional Village, for example, demonstrates the tension between tourism-driven spatial transformation and the preservation of traditional spatial practices.

The relationship can therefore be expressed as:

$$\textit{Tourism} \rightarrow \textit{Economic Opportunity} + \textit{Development Pressure}$$

The outcome depends largely on the strength of customary governance and community participation.

4.8 Religious and Cultural Institutions

Unlike many conventional rural settlements, Balinese traditional villages are deeply embedded within religious and customary systems.

The spatial structure of villages reflects:

- temple networks;
- ritual routes;
- sacred spaces;
- communal facilities;
- *banjar* organization;
- customary regulations.

Traditional spatial principles therefore provide an internal mechanism of cultural continuity.

Research on Tenganan Dauh Tukad demonstrates that traditional settlement geometry reflects the interaction of Bali Aga traditions and historical cultural influences.

4.9 Customary Governance

Customary governance is perhaps the most important institutional mechanism of cultural resilience.

Rules established through *awig-awig* and related customary mechanisms can regulate:

- land use;
- construction;
- community obligations;
- environmental management;

- religious practices;
- tourism development.

Recent research on the Ceking rice terrace tourism area indicates that the customary village institution can play an important role in controlling spatial use under tourism pressure.

Therefore:

Strong Customary Governance → Spatial Control → Cultural Continuity → Higher Resilience

5. Cultural Landscape Resilience of Traditional Villages

5.1 Conceptual Framework

Cultural landscape resilience should be understood as a dynamic process rather than a static conservation state.

A resilient traditional village does not necessarily remain unchanged.

Instead, it:

1. preserves core cultural values;
2. adapts spatially;
3. maintains social institutions;
4. protects ecological functions;
5. generates viable livelihoods;
6. selectively incorporates external influences.

This distinction is critical because complete resistance to change is neither realistic nor necessarily desirable.

5.2 Spatial Resilience

Spatial resilience is high when traditional relationships among:

temple → communal space → residential space → agricultural landscape

remain intact.

Traditional settlement morphology can remain resilient even when individual buildings are renovated, provided that the larger spatial logic is maintained.

5.3 Architectural Resilience

Architectural resilience depends on the continuity of:

- traditional building forms;
- materials;
- orientation;
- spatial hierarchy;
- decorative elements;
- sacred structures.

However, architecture should not be treated independently of community institutions.

A perfectly preserved building without the associated cultural practices may represent **physical conservation but weak cultural resilience**.

5.4 Cultural and Institutional Resilience

The continued operation of customary institutions is essential.

Community institutions allow residents to:

- negotiate development;
- regulate land use;
- organize religious activities;
- maintain collective spaces;
- transmit cultural knowledge.

The experience of Bali Aga villages demonstrates that villages with stronger internal cultural-management systems can display greater resilience to external change.

5.5 Ecological Resilience

The cultural landscape of Bali cannot be separated from ecological systems.

The *subak* system demonstrates how:

- water;
- agriculture;
- religion;
- community;
- landscape;

are integrated.

Recent research similarly identifies *subak* as an indigenous governance mechanism supporting socio-ecological resilience, while also identifying tourism expansion and declining youth participation as emerging threats.

5.6 Tourism and Cultural Resilience

Tourism represents both an opportunity and a threat.

Where local communities retain decision-making authority, tourism can generate resources for conservation.

Community-based tourism can encourage residents to reinterpret cultural practices as living assets rather than museum objects. Research on Jatiluwih indicates that community-based tourism can provide an opportunity for *subak* communities to reassess their cultural practices and social roles under changing socioeconomic conditions.

However, when tourism development is externally controlled, cultural landscapes may become increasingly commodified.

5.7 Spatial Transformation and Resilience

The degree of spatial transformation can be used as an important indicator of resilience.

A simplified resilience framework can be expressed as:

$$CLR = f(SC, AC, CI, ER, EC, AA)$$

where:

- CLR = Cultural Landscape Resilience;
- SC = Spatial Continuity;
- AC = Architectural Continuity;
- CI = Cultural-Institutional Continuity;
- ER = Ecological Resilience;
- EC = Economic Capacity;
- AA = Adaptive Ability.

A high-resilience village is therefore expected to demonstrate strong cultural continuity while maintaining sufficient adaptive capacity.

5.8 High-, Medium-, and Low-Resilience Landscapes

High-resilience landscapes

These are characterized by:

- strong customary governance;
- intact traditional morphology;
- functioning agricultural systems;
- active religious institutions;
- community participation;
- controlled tourism;
- low-to-moderate land conversion.

Examples of Bali Aga villages have demonstrated such characteristics, although resilience varies substantially among individual villages.

Medium-resilience landscapes

These retain important cultural characteristics but experience:

- moderate tourism pressure;
- partial land conversion;
- architectural adaptation;
- increasing dependence on non-agricultural livelihoods.

Low-resilience landscapes

These are characterized by:

- extensive urbanization;
 - fragmented agricultural land;
 - replacement of traditional buildings;
 - declining customary practices;
 - high tourism pressure;
 - weak spatial continuity.
-

6. Discussion

6.1 From Spatial Preservation to Cultural Landscape Resilience

Traditional village conservation should not focus exclusively on individual buildings.

The Bali case demonstrates that cultural landscapes are systems composed of:

settlements + agriculture + water + religion + institutions + community + economy.

The loss of one component can destabilize the entire system.

Therefore, preservation policies should adopt an integrated cultural-landscape perspective.

6.2 The Dual Role of Tourism

Tourism should not simply be categorized as either positive or negative.

Its impact depends on governance.

Under community-controlled tourism:

Tourism → Income → Conservation Investment

Under uncontrolled tourism:

Tourism → Land Conversion → Spatial Fragmentation

The difference is largely determined by community participation and customary institutional capacity.

Recent studies of Bali's tourism resilience similarly emphasize the importance of social collectivism and culturally embedded institutions in strengthening resilience.

6.3 The Importance of Subak

The *subak* system provides a particularly important mechanism linking spatial distribution with cultural resilience.

Its importance extends beyond irrigation.

It connects:

- agricultural production;
- water management;
- religious institutions;
- community cooperation;

- ecological management;
- landscape identity.

Consequently, protecting traditional villages without protecting the agricultural landscapes surrounding them would represent an incomplete conservation strategy.

6.4 Accessibility as a Double-Edged Factor

Improved accessibility increases the economic opportunities available to traditional villages.

However, excessive accessibility can accelerate land-market transformation.

Therefore, planning policies should distinguish between:

accessibility for community development

and

accessibility that facilitates uncontrolled external development.

Strategic transportation planning should consequently be integrated with heritage and landscape management.

7. Conclusions

This study developed an integrated framework for examining the **spatial distribution, driving mechanisms, and cultural landscape resilience of traditional villages in Bali Island, Indonesia.**

The principal conclusions are as follows.

First

Traditional villages in Bali exhibit a spatial distribution that is strongly influenced by environmental, historical, socioeconomic, and cultural conditions. Rather than being randomly distributed, they tend to form spatial concentrations associated with traditional agricultural landscapes, mountainous environments, water systems, customary territories, and culturally significant areas.

Second

Topography, water availability, agricultural land, climate, transportation accessibility, economic development, tourism intensity, and customary institutions jointly influence the spatial distribution of traditional villages.

Natural factors provide the basic environmental conditions for settlement formation, while socioeconomic and cultural factors determine the persistence, transformation, and contemporary distribution of traditional villages.

Third

Traditional villages located in areas experiencing rapid urbanization and intensive tourism development face stronger pressures for spatial transformation.

These pressures include:

- agricultural land conversion;
- replacement of traditional buildings;
- commercialization;
- infrastructure expansion;
- rising land values;
- demographic transformation.

Fourth

Cultural landscape resilience is determined not simply by the physical preservation of traditional architecture but by the continued interaction among spatial organization, cultural institutions, ecological systems, livelihoods, and community governance.

Fifth

The *subak* system represents a central mechanism of cultural and ecological resilience in Bali. Its continued operation demonstrates how traditional knowledge, water management, agriculture, religion, and collective governance can function as an integrated socio-ecological system.

Sixth

Customary institutions such as *desa adat*, *banjar*, *awig-awig*, and *pararem* provide important internal mechanisms for regulating spatial transformation and maintaining cultural identity. Their role becomes particularly important in tourism-intensive areas.

Seventh

Tourism should be managed as an adaptive component of the cultural landscape rather than treated as an external economic activity. Community-based and culturally embedded tourism can strengthen resilience, whereas uncontrolled tourism can accelerate cultural landscape fragmentation.

8. Policy Implications

8.1 Establish Integrated Cultural Landscape Protection

Planning should protect not only traditional buildings but also:

- agricultural land;
- irrigation networks;
- temples;

- communal spaces;
- traditional roads;
- ecological corridors;
- customary territories.

8.2 Strengthen Customary Governance

Provincial and local planning authorities should strengthen cooperation with *desa adat* institutions.

Local communities should have meaningful participation in decisions concerning:

- tourism development;
- land conversion;
- infrastructure;
- architectural transformation;
- environmental management.

8.3 Protect Subak Landscapes

The conservation of traditional villages should be integrated with the conservation of agricultural and irrigation landscapes.

The *subak* system should therefore be treated as a living cultural institution rather than merely a heritage attraction.

8.4 Promote Community-Based Tourism

Tourism policies should prioritize:

- local ownership;
- local employment;
- cultural authenticity;
- environmental protection;
- agricultural conservation;
- community decision-making.

Agritourism and community-based tourism may provide mechanisms through which tourism revenues contribute directly to the maintenance of cultural landscapes.

8.5 Establish Spatial Resilience Monitoring

GIS and remote sensing should be used periodically to monitor:

- traditional building density;
- agricultural land conversion;
- settlement expansion;
- road development;
- tourism infrastructure;
- landscape fragmentation;
- irrigation-network continuity.

A dynamic monitoring system would allow authorities to identify villages experiencing rapid cultural-landscape transformation before irreversible damage occurs.

8.6 Encourage Intergenerational Cultural Transmission

The long-term resilience of traditional villages ultimately depends on younger generations.

Programs should support:

- traditional architecture;
- local crafts;
- agricultural knowledge;
- religious practices;
- customary governance;
- traditional environmental management.

Economic opportunities should be created within villages so that young residents can remain connected to their communities.

9. Future Research

Future studies should move beyond descriptive spatial analysis toward quantitative modeling of the relationships among spatial distribution, tourism pressure, land-use transformation, and cultural resilience.

Several methods are particularly promising:

Geographically Weighted Regression (GWR) to examine spatially varying driving mechanisms;

Spatial autocorrelation analysis to identify statistically significant clusters;

Multi-temporal remote sensing to measure landscape transformation;

Structural Equation Modeling (SEM) to examine causal relationships among tourism, governance, spatial transformation, and resilience;

Machine-learning models to predict areas of high transformation risk;

Participatory GIS to integrate local community knowledge;

Landscape connectivity analysis to evaluate ecological and cultural fragmentation;

Multi-criteria evaluation to establish village-level resilience indices.

Ethical Considerations

Not applicable. This study did not require ethical approval because it does not include human or animal subjects and does not involve any personal or sensitive data.

List of Abbreviations:

None.

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