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Integrating Indigenous Socio-Cultural Values into GIS–AHP-Based Customary Forest Zoning

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ABSTRACT

Customary forests play an important role in maintaining ecological functions, cultural values, and local livelihoods. However, most forest zoning studies based on Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) primarily emphasize biophysical parameters and rarely integrate indigenous socio-cultural values as spatial decision-making criteria. This limitation is particularly relevant in customary forest areas, where traditional norms and sacred sites strongly influence land-use practices and resource management. Therefore, this study aimed to analyze the biophysical and socio-cultural factors influencing forest management and to develop a management zoning system for the Suaka Katuwua To Lindu Customary Forest using an integrated GIS–AHP approach. The study employed nine parameters, namely slope, elevation, land cover, distance from rivers, soil type, rainfall, distance from roads, distance from settlements, and sacred areas. Biophysical data were obtained from DEMNAS, Landsat 8 imagery, RBI BIG maps, CHIRPS rainfall data, and soil maps, while socio-cultural data were collected through interviews and participatory mapping conducted with the To Lindu Indigenous Community. All parameters were reclassified into five scoring classes and weighted using AHP based on assessments from three experts. The weighted parameters were subsequently integrated through spatial overlay analysis to generate a zoning index. The results showed that slope had the highest weight (22%), followed by sacred areas (21%), distance from settlements (11%), distance from roads (10%), land cover (9%), distance from rivers and elevation (8% each), soil type (6%), and rainfall (5%). These findings indicate that indigenous socio-cultural values have a level of importance comparable to that of biophysical factors in determining forest management priorities. Based on the zoning index, the 6,473-ha customary forest was classified into four management zones: Core/Protected Zone (1,352.40 ha; 20.89%), Buffer Zone (2,628.25 ha; 40.60%), Limited Utilization Zone (640.91 ha; 9.90%), and Intensive Utilization Zone (1,851.44 ha; 28.60%). The novelty of this study lies in the integration of sacred areas as socio-cultural spatial criteria within a GIS–AHP framework for customary forest zoning. The resulting zoning map provides a practical decision-support tool for indigenous institutions, local governments, and other stakeholders in promoting sustainable customary forest management and spatial planning.

Keywords: Customary Forest, Management Zoning, Geographic Information System, Analytical Hierarchy Process.

1. INTRODUCTION

Forests provide essential ecological services, including biodiversity conservation, water regulation, carbon sequestration, and climate stabilization. In customary forest landscapes, these ecological functions are closely connected with the cultural values, traditional knowledge, and livelihood systems of indigenous communities. Since the recognition of indigenous peoples' rights through Constitutional Court Decision No. 35/PUU-X/2012, customary forests in Indonesia have

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gained increasing importance as community-managed conservation areas. Nevertheless, many customary forests continue to face challenges related to land-use pressures, resource utilization, and the absence of spatial management frameworks capable of balancing ecological protection with socio-cultural interests. As a result, the development of zoning systems that accommodate both environmental and indigenous dimensions has become an important requirement for sustainable customary forest management.

Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) have been extensively utilized in spatial planning, land suitability assessment, conservation prioritization, and natural resource management. GIS enables the integration and analysis of spatial information derived from multiple environmental variables, while AHP facilitates the systematic determination of parameter importance through pairwise comparisons and consistency evaluation. The combination of GIS and AHP has proven effective in supporting multi-criteria decision-making because it allows diverse datasets to be synthesized within a transparent analytical framework. Previous studies have successfully applied this approach to environmental zoning and conservation planning using parameters such as slope, elevation, land cover, hydrological characteristics, accessibility, and soil conditions.

Despite the growing application of GIS–AHP methods, most existing studies remain largely focused on biophysical variables, with limited consideration of indigenous socio-cultural factors as explicit spatial decision criteria. In many customary forest areas, however, traditional institutions, sacred sites, customary regulations, and cultural practices strongly influence patterns of land use and resource management. Consequently, zoning models that rely solely on ecological and physical parameters may not adequately represent the management realities of indigenous territories. The integration of socio-cultural values into spatial decision-making remains relatively underexplored, particularly in the context of customary forests in Indonesia, creating a need for approaches that can simultaneously accommodate ecological and cultural priorities within a single zoning framework.

The Suaka Katuwua To Lindu Customary Forest in Sigi Regency, Central Sulawesi, represents a socio-ecological landscape where forest management is shaped by both environmental conditions and indigenous cultural values. The presence of sacred areas, customary norms, and traditional governance systems continues to influence the protection and utilization of forest resources by the To Lindu Indigenous Community. However, information regarding the relative contribution of biophysical and socio-cultural factors in determining management priorities within this customary forest remains limited. Therefore, this study aims to analyze the biophysical and

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socio-cultural factors influencing customary forest management, determine the priority weight of each zoning parameter using the Analytical Hierarchy Process (AHP), and develop a management zoning model through the integration of GIS and AHP. The novelty of this study lies in the explicit incorporation of sacred areas as socio-cultural spatial criteria within a GIS–AHP framework for customary forest zoning. By integrating ecological and indigenous cultural considerations into a single spatial decision-support model, this research contributes to the development of more inclusive and context-sensitive approaches for sustainable customary forest management and spatial planning.

2. RESEARCH METHOD

Study Area and Data Collection

This study was conducted in the Suaka Katuwua To Lindu Customary Forest, located in Sigi Regency, Central Sulawesi, Indonesia. The research employed a spatial multi-criteria analysis approach integrating Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) to develop a customary forest management zoning model. Nine parameters were used, including slope, elevation, land cover, distance from rivers, soil type, rainfall, distance from roads, distance from settlements, and sacred areas. Biophysical data were obtained from DEMNAS, Landsat 8 imagery, CHIRPS rainfall data, RBI maps, and soil maps, while socio-cultural data were collected through interviews and participatory mapping involving the To Lindu Indigenous Community.

Spatial data processing and analysis were conducted using ArcGIS 10.8. All spatial datasets were projected to the WGS 84 / UTM Zone 51S coordinate reference system (EPSG:32751) to ensure spatial consistency throughout the analysis. Elevation and slope parameters were derived from the Indonesian National Digital Elevation Model (DEMNAS) with a spatial resolution of approximately 8.25 m. Land cover information was obtained from Landsat 8 imagery with a spatial resolution of 30 m, while rainfall data were derived from CHIRPS datasets. Prior to analysis, all spatial layers were standardized and converted into a common spatial framework to facilitate overlay analysis and multi-criteria evaluation.

Spatial Analysis and Parameter Weighting

Parameter weighting was performed using the Analytical Hierarchy Process (AHP) following the procedure proposed by Saaty (1980). Pairwise comparisons among the nine zoning parameters were conducted using the Saaty scale ranging from 1 (equal importance) to 9 (extreme importance). Three experts were purposively selected based on their authority, experience, and

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involvement in customary forest governance and territorial management. The selected experts represented key stakeholder groups directly associated with the study area, namely the Chairperson of the Lindu Customary Council as the representative of indigenous institutions, the Head of Anca Village as the representative of local governance, and the Head of the Central Sulawesi Office of the Indigenous Territory Registration Agency (BRWA) as the representative of indigenous territory management and mapping practitioners.

The inclusion of these experts ensured that ecological, socio-cultural, and institutional perspectives were adequately represented in the parameter weighting process.Individual pairwise comparison matrices were aggregated using the geometric mean method to generate a collective judgment matrix. Priority weights were subsequently calculated using the eigenvector approach, and the consistency of expert judgments was evaluated through the Consistency Ratio (CR). A CR value below 0.10 was considered acceptable, indicating a satisfactory level of consistency in the decision-making process.

Table 1. Experts Involved in the AHP Assessment

Expert	Institution	Role in the Study	Expertise
Expert 1	Lindu Customary Council	Indigenous Institution Representative	Customary governance and sacred area management
Expert 2	Anca Village Government	Local Government Representative	Community land-use management and village development
Expert 3	BRWA Central Sulawesi	Indigenous Territory Mapping Organization	Indigenous territory mapping and customary forest management

GIS-Based Zoning Analysis

The weighted parameters were integrated using a Weighted Linear Combination (WLC) approach within a GIS environment. The zoning index was calculated by multiplying the score of each parameter by its corresponding weight and summing the results for each spatial unit. The resulting zoning index was subsequently classified into four management zones: Core/Protected Zone, Buffer Zone, Limited Utilization Zone, and Intensive Utilization Zone. These zones were designed to accommodate ecological protection, cultural value preservation, and sustainable resource utilization within the customary forest landscape.

3. RESULTS AND DISCUSSION

Expert Assessment and Parameter Weighting Using AHP

The results indicate that slope (22%) was the most influential parameter, followed closely by sacred areas (21%), distance from settlements (11%), and distance from roads (10%). The dominance of slope reflects the importance of topographic conditions in determining conservation

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priorities due to their influence on erosion susceptibility, land stability, and accessibility. Similar findings have been reported in spatial planning and conservation studies where slope was identified as a primary determinant of land suitability and ecological protection.

However, the relatively high weight assigned to sacred areas represents a distinctive characteristic of the present study. Unlike many GIS–AHP applications that predominantly emphasize biophysical criteria, the findings demonstrate that indigenous socio-cultural values can exert a level of influence comparable to that of environmental factors in determining management priorities. This result supports recent studies highlighting the contribution of indigenous knowledge systems and customary institutions to biodiversity conservation and sustainable landscape management. The findings further suggest that spatial planning approaches in customary forest areas should not rely exclusively on ecological variables but also incorporate cultural values that shape resource governance and conservation practices.

Table 2. Priority Weights of Zoning Parameters Derived from AHP

Parameter	Weight (%)	Rank	Management Implication
Slope	22	1	Determines conservation priority by reducing erosion risk, maintaining slope stability, and protecting sensitive ecological areas.
Sacred Areas	21	2	Preserves indigenous cultural values, spiritual sites, and customary conservation practices.
Distance from Settlements	11	3	Minimizes human disturbance and supports the protection of ecologically sensitive areas.
Distance from Roads	10	4	Reduces accessibility-related pressures such as land conversion, extraction, and habitat disturbance.
Land Cover	9	5	Reflects ecosystem condition and vegetation integrity, supporting biodiversity conservation.
Distance from Rivers	8	6	Protects water resources and maintains hydrological functions within the watershed.
Elevation	8	7	Influences ecosystem characteristics, habitat distribution, and conservation suitability.
Soil Type	6	8	Supports land capability assessment and helps minimize land degradation risks.
Rainfall	5	9	Contributes to ecological processes and vegetation growth but shows relatively low spatial variation within the study area.

The results indicate that slope (22%) was the most influential parameter, followed by sacred areas (21%), distance from settlements (11%), and distance from roads (10%). The high weight assigned to slope highlights the importance of topographic conditions in determining conservation priorities due to their relationship with erosion risk, land stability, and accessibility. Meanwhile, the substantial contribution of sacred areas suggests that cultural values and customary

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protection systems play a role nearly equal to that of biophysical factors in determining spatial management priorities. This finding differs from many previous GIS–AHP studies, which generally emphasize biophysical variables while giving limited attention to socio-cultural dimensions in spatial decision-making (Cammerino et al., 2023; Nguyen et al., 2024).

Characteristics of Biophysical and Socio-Cultural Factors

The spatial analysis revealed that the Suaka Katuwua To Lindu Customary Forest is characterized by diverse biophysical conditions that strongly support conservation functions. Steep to very steep slopes dominate a large proportion of the study area, while elevations are primarily distributed between 1,000 and 1,300 m above sea level. The landscape is largely covered by primary and secondary forests, with smaller portions occupied by agroforestry and community-managed land. In addition, much of the area is located in close proximity to river networks that contribute to the hydrological stability of the Lake Lindu watershed. These characteristics indicate that the customary forest performs important ecological functions, including soil protection, water regulation, habitat provision, and biodiversity conservation. Similar findings have been reported in mountainous forest ecosystems where topography, forest cover, and hydrological connectivity are considered major determinants of ecological integrity and conservation effectiveness (Cammerino et al., 2023; Nguyen et al., 2024).

The socio-cultural characteristics of the study area are equally important in shaping management priorities. Participatory mapping conducted with the To Lindu Indigenous Community identified sacred areas distributed throughout the customary territory with varying levels of cultural significance. Areas classified as High Sacred and Core Sacred represented a substantial proportion of the mapped customary landscape, demonstrating the continued influence of customary institutions and traditional beliefs in regulating resource use. The persistence of sacred areas as community-recognized conservation spaces supports previous studies showing that indigenous governance systems and customary norms contribute significantly to biodiversity conservation and sustainable landscape management (Halder et al., 2022; Hamzari et al., 2025). Similar observations have also been reported in indigenous territories where sacred sites function as informal conservation areas that complement formal environmental protection mechanisms (Nguyen et al., 2024).

The combination of these biophysical and socio-cultural characteristics highlights the socio-ecological nature of the Suaka Katuwua To Lindu Customary Forest. Ecological conditions provide the environmental foundation for conservation, while customary institutions and cultural values contribute to resource governance and landscape protection. These findings suggest that

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effective customary forest management requires the integration of both dimensions, as reliance solely on ecological criteria may overlook cultural factors that influence land-use decisions and conservation practices. This result reinforces the growing recognition that conservation planning in indigenous territories should incorporate local knowledge systems and socio-cultural values alongside conventional biophysical criteria (Cammerino et al., 2023; Hamzari et al., 2025).

Management Zoning of the Customary Forest

The integration of the nine parameters through a weighted overlay analysis produced four management zones representing different levels of conservation and utilization priority.

Gambar 1. Map of Zonation Suaka Katuwua To Lindu Customary Forest

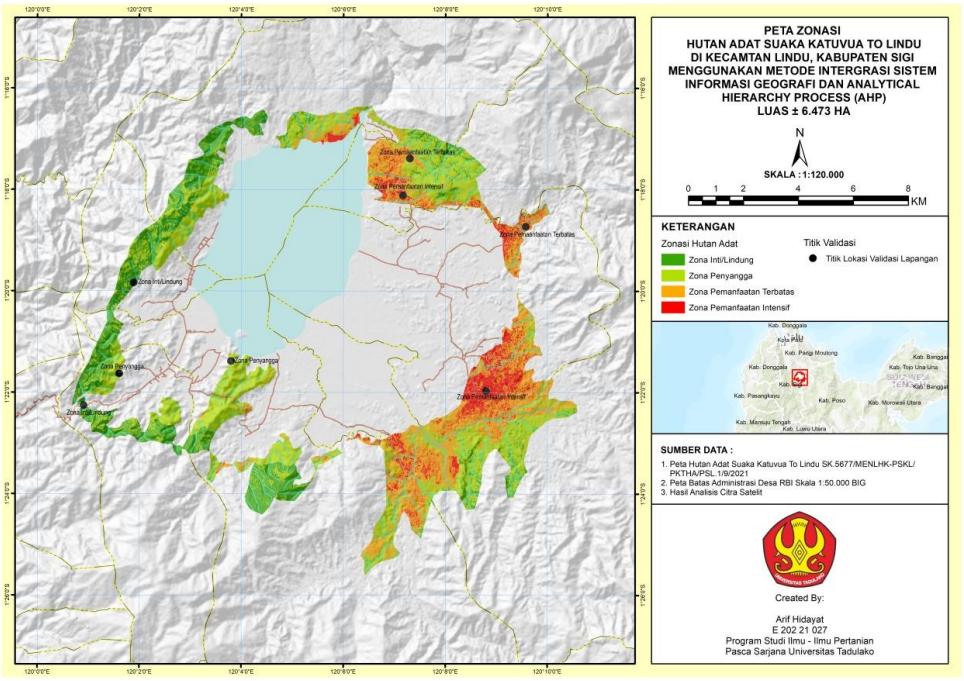

Figure 1: Zoning map of the Suaka Katuwua To Lindu customary forest

Table 3. Area and Proportion of Management Zones in the Suaka Katuwua To Lindu Customary Forest

Management Zone	Area (ha)	Percentage (%)	Primary Function
Core/Protected Zone	1,352.40	20.89	Biodiversity and sacred area protection
Buffer Zone	2,628.25	40.60	Ecological buffering and restoration
Limited Utilization Zone	640.91	9.90	Controlled resource utilization
Intensive Utilization Zone	1,851.44	28.60	Community livelihoods and agroforestry

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The integration of nine biophysical and socio-cultural parameters through weighted overlay analysis generated four management zones representing different levels of conservation and utilization priority within the Suaka Katuwua To Lindu Customary Forest. The zoning results indicate that the Buffer Zone occupies the largest proportion of the study area, covering 2,628.25 ha (40.60%), followed by the Intensive Utilization Zone covering 1,851.44 ha (28.60%). The Core/Protected Zone covers 1,352.40 ha (20.89%), while the Limited Utilization Zone accounts for 640.91 ha (9.90%) of the total customary forest area. The dominance of the Buffer Zone suggests that a substantial portion of the customary forest functions as a transitional landscape that supports both ecological protection and sustainable community use.

The spatial distribution of the zones reflects the combined influence of topographic conditions, ecological characteristics, accessibility, and indigenous socio-cultural values. Areas classified as Core/Protected Zones are generally associated with steep slopes, relatively intact forest cover, limited accessibility, and the presence of highly protected sacred areas. These characteristics indicate that the zone plays a critical role in maintaining ecological integrity, protecting biodiversity, safeguarding watershed functions, and preserving culturally important sites. Similar conservation-oriented zoning patterns have been reported in GIS–AHP-based spatial planning studies where environmentally sensitive areas were prioritized for protection due to their ecological vulnerability and conservation significance (Cammerino et al., 2023; Nguyen et al., 2024).

The Buffer Zone serves as an intermediary area between conservation and utilization functions. This zone is characterized by moderate environmental sensitivity and relatively lower concentrations of sacred sites compared to the Core Zone, making it suitable for ecological restoration, habitat connectivity, and controlled resource use. The extensive coverage of the Buffer Zone indicates that management strategies in the customary forest should emphasize sustainable practices that maintain ecosystem functions while accommodating community needs. Similar findings have been reported in community-based conservation landscapes where buffer areas play a key role in reducing pressure on strictly protected zones and enhancing long-term conservation effectiveness.

In contrast, the Intensive Utilization Zone is predominantly located near settlements and transportation networks where agricultural and agroforestry activities are already established. The concentration of human activities within this zone demonstrates that the zoning framework effectively recognizes existing land-use patterns while minimizing potential conflicts between conservation and livelihood objectives. Meanwhile, the Limited Utilization Zone provides

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additional opportunities for sustainable resource use under specific management restrictions. The resulting zoning framework demonstrates that integrating biophysical and socio-cultural criteria through GIS and AHP can produce a spatial management model that balances ecological conservation, indigenous cultural values, and local economic activities. This finding supports the growing recognition that effective management of customary forests requires spatial planning approaches capable of accommodating both environmental and socio-cultural dimensions within a single decision-making framework.

Implications for Customary Forest Management

The findings of this study provide important insights into the development of customary forest management strategies that integrate ecological and socio-cultural considerations. The high weighting assigned to sacred areas demonstrates that indigenous cultural values contribute significantly to spatial decision-making and should be recognized as an essential component of conservation planning. This finding expands the application of GIS–AHP approaches beyond conventional biophysical assessments by demonstrating that socio-cultural factors can be incorporated as measurable spatial criteria within a multi-criteria decision-making framework. Similar studies have emphasized that indigenous knowledge systems and customary institutions play a crucial role in maintaining ecosystem integrity and supporting long-term conservation outcomes (Halder et al., 2022; Hamzari et al., 2025). Consequently, the present study contributes to the growing body of evidence supporting the integration of indigenous perspectives into sustainable landscape management.

From a management perspective, the resulting zoning framework provides a practical basis for allocating conservation, restoration, and utilization activities according to the ecological and cultural characteristics of different parts of the customary forest. The Core/Protected Zone can serve as a priority area for biodiversity conservation, watershed protection, and safeguarding sacred sites, while the Buffer Zone can support ecological restoration and community-based conservation initiatives. The Limited Utilization Zone and Intensive Utilization Zone offer opportunities for sustainable livelihood activities, including agroforestry and non-timber forest product utilization, under management arrangements that minimize environmental degradation and respect customary regulations. Similar approaches have been recommended in spatial planning studies where zoning systems are used to balance conservation objectives with local development needs (Cammerino et al., 2023; Nguyen et al., 2024).

The study also has important policy implications for customary forest governance in Indonesia. The zoning map developed through the GIS–AHP approach can function as a decision-

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support tool for indigenous institutions, local governments, and other stakeholders in formulating management plans, conservation programs, and spatial development policies. By explicitly incorporating sacred areas into the zoning process, the framework supports the recognition of indigenous rights and cultural values within formal planning mechanisms. This finding aligns with the growing international recognition that conservation policies in indigenous territories should integrate ecological objectives with cultural values and traditional governance systems (Nguyen et al., 2024; Hamzari et al., 2025). Therefore, the approach developed in this study may serve as a replicable model for other customary forest areas seeking to balance biodiversity conservation, cultural preservation, and sustainable resource utilization within a single spatial management framework.

4. CONCLUSIONS

This study demonstrates that both biophysical and socio-cultural factors play significant roles in determining the management zoning of the Suaka Katuwua To Lindu Customary Forest. Among the nine parameters evaluated, slope (22%) and sacred areas (21%) were identified as the most influential factors, indicating that ecological conditions and indigenous cultural values have nearly equal importance in shaping spatial management priorities. The findings highlight that customary conservation practices embedded within sacred areas contribute substantially to landscape protection and should be considered alongside conventional environmental criteria in customary forest planning.

From a methodological perspective, the integration of Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP) proved effective in supporting multi-criteria spatial decision-making for customary forest management. The study demonstrates that socio-cultural variables, particularly sacred areas, can be incorporated as measurable spatial criteria within a GIS–AHP framework. This approach expands the application of conventional GIS–AHP models, which have traditionally focused on biophysical variables, by providing a more comprehensive framework that accommodates both ecological and indigenous cultural dimensions.

The resulting zoning model classified the 6,473-ha customary forest into four management zones, namely the Core/Protected Zone, Buffer Zone, Limited Utilization Zone, and Intensive Utilization Zone. These zones provide a spatial basis for balancing conservation objectives, cultural preservation, and sustainable resource utilization. Therefore, the zoning framework developed in this study can serve as a decision-support tool for indigenous institutions, local governments, and other stakeholders in formulating customary forest management plans and

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spatial policies. Furthermore, the approach may be adapted and applied in other customary forest areas seeking to integrate biodiversity conservation with indigenous socio-cultural values within sustainable landscape management strategies.

Recommendations

The zoning framework developed in this study can be utilized by indigenous institutions, local governments, and relevant stakeholders as a reference for preparing management plans and conservation strategies within the Suaka Katuwua To Lindu Customary Forest. Particular attention should be given to the protection of the Core/Protected Zone and sacred areas, considering their important ecological and cultural functions. Furthermore, sustainable livelihood programs, including agroforestry development and non-timber forest product utilization, should be prioritized within the Limited Utilization Zone and Intensive Utilization Zone to ensure that community welfare objectives remain compatible with long-term conservation goals.

Future studies are encouraged to incorporate additional socio-economic, institutional, and ecosystem service variables to improve the comprehensiveness of customary forest zoning models. The inclusion of broader stakeholder participation and field-based validation approaches may also enhance the applicability and adaptability of the GIS–AHP framework in other customary forest landscapes and indigenous territories.

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