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Andi Gunawan * and Ignasia Germania M. Rada

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Landscape Model of Waerebo Village: Topographic Adaptation & Indigenous Spatial Patterns (Horizontal - Vertical) Based on Local Culture

Andi Gunawan [1,*] and Ignasia Germania M. Rada [2]

[1] Department of Landscape Architecture, Faculty of Agriculture, IPB University, Bogor, Indonesia

[2] Agrotechnologi Study Program, Faculty of Agriculture & Business, Satya Wacana Christian University, Salatiga, Indonesia

* Correspondence: andi_gunawan@apps.ipb.ac.id

Abstract

Waerebo Village, a UNESCO World Cultural Heritage site in Indonesia, represents a profound harmony between the Manggarai people, nature, and spirituality, yet the technical functional role of its traditional zoning remains under-researched. This study examines the Waerebo landscape model by integrating horizontal and vertical spatial patterns through literature reviews, field observations, interview and GIS-based analyses, including Digital Elevation Models (DEM) and multi-temporal NDVI from 2015 to 2025. Findings indicate that Waerebo's landscape is organized into three concentric zone—core, utilization, and sacred zones—mirroring a tripartite spiritual framework of God, ancestors, and nature spirits. Geospatial data reveals a sophisticated indigenous landscape engineering system where the settlement is strategically positioned on a stable 16° terrace, while sacred forests are maintained on extreme 85° slopes to protect watersheds and mitigate landslides. Multi-temporal NDVI analysis confirms an increase in forest density from 0.47 in 2015 to 0.52 in 2025, validating the effectiveness of customary laws in maintaining ecological integrity despite tourism pressures. The study concludes that Waerebo's cosmic spiral model achieves a vital balance between culture, socio-economic survival and environmental conservation, offering a functional blueprint for resilient cultural heritage management in challenging topographies.

Keywords: cultural landscape; indigenous landscape engineering; landscape character; NDVI analysis; topographic adaptation

1. Introduction

Indigenous communities in Indonesia play a significant role in shaping the cultural landscape through local wisdom passed down from generation to generation, emphasizing harmony between humans and nature [1]. This local wisdom includes spiritual ceremonies, the designation of certain areas for agriculture or protection, and spatial planning based on cultural understanding [2]. One of the local wisdoms that is still preserved to this day is the Waerebo traditional village [3,4].

Situated at an altitude of 1,200 meters above sea level, Waerebo consists of only seven main traditional houses, known as *Mbaru Niang*. These traditional houses are not only architectural icons but also embody profound cultural values and social functions, with each level of the house having a different purpose related to the community's way of life [5,6]. In August 2012, UNESCO designated Waerebo as one of the preserved World Cultural Heritage Sites. Waerebo comes from the word "Wae" which means water, and "Rebo" which means fog or dew in the Manggarai language. This name represents the natural and geographical conditions of Waerebo Village, which is surrounded by springs and shrouded in fog, also known as the "Village above the clouds". The people who inhabit the village are from the Manggarai tribe.

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Waerebo faces physical challenges in the form of steep mountainous topography and intense fog cover, which directly impact the local hydrological system and agricultural activities [7]. The village's spatial arrangement, which integrates natural, man-made, and social elements, reflects local adaptation to the topography and hydrological dynamics of the Todo protected forest area. UNESCO's recognition not only confirms its importance as a representation of architecture and tradition, but also as a symbol of local wisdom practiced by the Manggarai indigenous people. The term "Manggarai" encompasses not only the region, but also all the social, cultural, and moral concepts (known as customs or *adat* in Bahasa) of the people who live there.

The Manggarai indigenous people have a strong spiritual connection to the natural environment and surrounding forests, and see themselves as guardians, not owners, of the land [8,9]. These customs then become a reference in the spatial planning of Waerebo Village. The village's spatial planning and traditional landscape model are formed from spatial patterns that reflect the interaction between the natural environment, culture, and social activities of the community [10]. The interaction of natural factors such as topography and hydrology, as well as cultural traditions and ethnic values, influences settlement patterns and the use of public spaces that reflect the identity of the local community [11].

Besides Waerebo, several indigenous communities in Indonesia also have local wisdom in the form of traditions, guidelines in life that form the uniqueness of their landscape models such as the Gayo indigenous community (Banda Aceh Province) [12],, Minangkabau (West Sumatra Province) [13], Lampung Saibatin (Bandar Lampung Province) [14], Sunda (West Java Province) [15], Dayak Ngaju (Province of Central Borneo) [16], Tana Toraja (Province of South Celebes) [17], Uma Lengge, Bima Mariah (Province of West Nusa Tenggara) [18] dan Sasak Limbungan [19]. By upholding traditions, indigenous communities help maintain the ecological balance of the landscape and ensure that natural resources are used sustainably, not overexploited.

While the cultural significance of Waerebo has been well documented, there is a research gap regarding the quantitative functional role of its vertical and horizontal zoning. Current literature has not yet explored how these traditional zones operate as a form of adaptive landscape engineering and local wisdom to mitigate geological hazards and maintain forest conservation. Furthermore, as environmental pressures from tourism development increase, there is an urgent need to identify and map spatial within the cultural landscape that are crucial for maintaining ecological cycles and disaster resilience [20–23]. The purpose of this study is to analyze the landscape model of Waerebo Village by integrating horizontal and vertical spatial patterns that reflect the harmonious relationships among humans, the natural environment, and the philosophical values of local communities. This research is essential to ensure that cultural landscape development remains aligned with cultural preservation and ecological conservation, thereby safeguarding this Waerebo Cultural Landscape for future generations.

2. Materials and Methods

The research was conducted in Waerebo Village, Satar Lenda Subdistrict, West Satarmese District, Manggarai Regency, East Nusa Tenggara Province, Indonesia (Figure 1). Waerebo Village is geographically located at 8°47'16" South Latitude and 120°24'3" East Longitude. The entire customary area is located in the Todo Protected Forest area. This study focuses on the vertical and horizontal landscape zoning that defines the spatial structure of the village. This research was conducted in several stages as can be seen in Figure 2.

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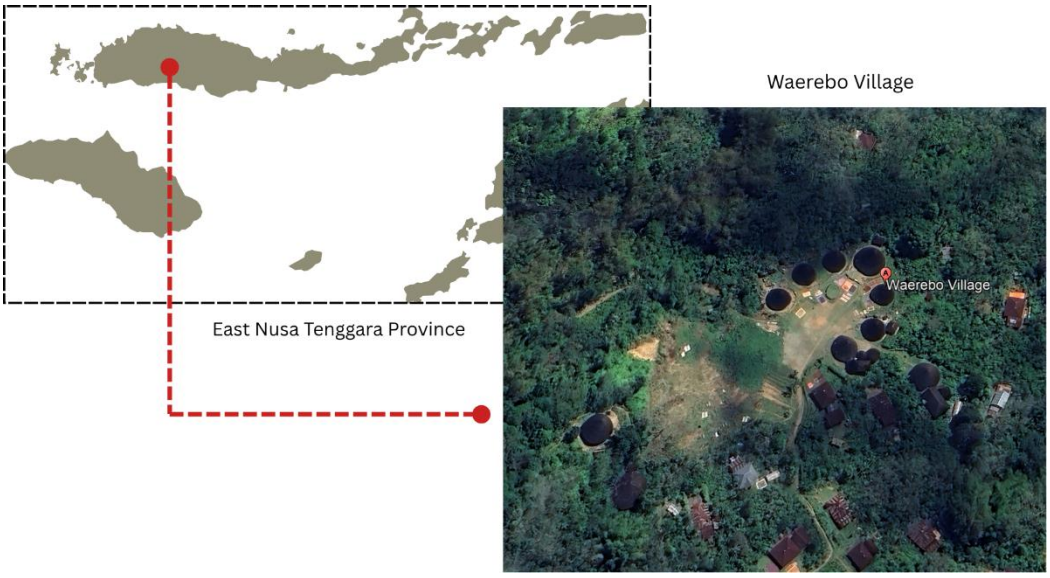

Figure 1. Research Location (source. Google Earth)

The first stage was a literature review, collecting and reviewing various relevant written sources, such as scientific articles, journals, books, and documents related to Waerebo Village. Waerebo Village does not have an officially documented traditional manuscript like those in Bali Province [24] dan Gayo, Aceh Province [12] so that traditional knowledge and cultural values are passed down orally from generation to generation. The results of the literature study were then used as a guideline for identifying the village's landscape features, which were divided into natural, artificial, and socio-cultural features in Table 1.

Observations were conducted as a follow-up step to validate the initial study results and document the landscape features that constitute the Waerebo settlement. This step is carried out in accordance with the Waerebo guest reception tradition, in which each visitor is required first to enter the main traditional house to meet with the traditional elders and participate in the *Tiba Meka*, or reception ritual. Before this ritual, guests are prohibited from wandering around or taking any form of documentation, such as photos, videos, or drones, within the area. After being received according to tradition, in-depth interviews were conducted with the traditional elders and the indigenous community to verify the elements that form the village landscape listed in Table 1 [25]. The presence of the elements in Table 1 was verified to reflect actual conditions in the field.

Figure 2. Research Flow

To validate the relationship between indigenous spatial patterns and the physical environment, this study integrates Geographic Information Systems (GIS) for advanced spatial analysis. Research has demonstrated that GIS-based spatial analysis is highly effective for mapping the intricate

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correlations between traditional spatial arrangements and physical environmental conditions, particularly across residential clusters, cultural landscapes, and natural resource distributions [26,27].This integration allows for a precise examination of how traditional zoning aligns with geomorphological constraints and ecological priorities. A Digital Elevation Model (DEM) with a 30m resolution was employed to conduct contour, slope, and elevation analysis. These parameters are critical for assessing the geomorphological stability of the site and the indigenous adaptations that have shaped the current settlement morphology. Furthermore, the Normalized Difference Vegetation Index (NDVI) was analyzed using Landsat 8 and 9 satellite imagery to quantify vegetation density across the forest and the sacred. The vegetation density was evaluated across three distinct temporal milestones: 2015 (representing the initial state following the site's recognition as a cultural heritage), 2020 and 2025 as reflecting the current landscape condition and its ecological resilience. The NDVI assessment specifically focuses on the protected forest areas to quantify temporal changes and evaluate the effectiveness of customary laws (*adat*) in safeguarding these zones. In this cultural landscape, forest conservation and traditional regulations are inextricably linked to the preservation of ecological sustainability. This quantitative approach serves to verify the ecological function of traditional forests as vital watershed protection areas, effectively bridging the gap between local wisdom and hydrogeological preservation.

The results of these four stages were synthesized to develop a comprehensive landscape model of Waerebo Village. This model is analyzed based on landforms, topographical positions, and their intricate relationship with the community's cultural values by examining both horizontal and vertical spatial configurations. This comparison highlights the harmonious relationship between humans and nature, as well as the adaptive processes that have shaped the resilience of the current cultural landscape. This landscape model serves as a spatial blueprint of indigenous resilience, proving that traditional zoning is not merely a cultural artifact but a functional engineering system that adapts to extreme topographical constraints while maintaining ecological integrity

Table 1. Landscape Character

Landscape Features	Basic landscape elements [a]	Explanation
Natural landscape	(1) Forest, (2) Farm, (3) Hidrology, (4) Plants (5) Land use	The location, form, and function of elements in space and the cultural activities of society
Man-made landscape	(5) Building (Landform), (6) Sirculation	
Social - Culture	(7) Belieft, (8) Kinship, (9) Ceremony	

[a] Modification from [13,18,28,29].

3. Results

3.1. General Condition and Culture History

Waerebo Village is estimated to have been established approximately 1,200 years ago. It is now inhabited by the 20th generation, with each generation lasting approximately 60 years [2]. The main focus of the village is the seven traditional houses called *Mbaru Niang*, where *Mbaru* means house, while *Niang* means tall and round. The seven traditional houses are occupied by direct descendants of ancestors, with each house housing six heads of families. In contrast, *Niang Gendang* (the main house) accommodates eight families. The life of the Waerebo community is maintained according to the customs and culture passed down from generation to generation of the Manggarai Tribe, as reflected in the expression "*Neka hemong kuni agu kalo*," which means Waerebo is the land of birth, heritage, and bloodshed that must not be forgotten. This expression serves as the foundation for indigenous peoples to continue preserving their culture.

According to oral tradition, the ancestor of the Waerebo people, *Empo Maro*, came from Minangkabau, West Sumatra, Indonesia [4]. Empo Maro then settled in Waerebo, following spiritual guidance, to establish a traditional community with seven traditional houses in a flat, mountainous area near a water source. Further studies have shown that, to date, there is no genetic evidence

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showing a direct biological relationship between the Waerebo (Manggarai) and Minangkabau people. However, despite their different forms – the gonjong roof of the Rumah Gadang and the conical roof of the Mbaru Niang – both reflect social values that emphasize community and cooperation [30,31]. The Rumah Gadang houses one clan in a matrilineal system. In contrast, the Mbaru Niang houses the extended family in a patrilineal system, thus demonstrating the different relationships between the two.

Waerebo Village is located within the administrative area of the Lodo Protected Forest, which serves as a space for interaction between humans and nature to fulfill daily needs and to preserve local wisdom through rituals. The community's main occupation is farming, with the main commodities being coffee, cinnamon, candlenut, ginger, and turmeric, using the Lingko space or communal farmland located close to the settlement. The Waerebo community has a way of life in harmony with nature, reflected in the lyrics of the ritual song "*Neka poka puar rantang mora kusam, neka tapar sata rantang mata kaka puar, kudut kembus kid wae teku, mboas kid wae woang*" which means do not burn the forest so that the rain does not disappear, do not burn the fields so that forest animals do not die, so that drinking water continues to flow from its source, and the water of life remains abundant [32].

Previous research [33] describes the spatial pattern of Waerebo Village, which is organized around the *Penti* ritual (annual ceremony), the center of the community's social and spiritual activities. The use of landscape elements and spaces reflects the community's spiritual factors, thereby giving meaning to the area's physical components and their functions within the series of *Penti* traditional rituals. The spatial layout of settlements with traditional houses arranged in a circular pattern is common in several traditional village models in Indonesia, such as Wologai Traditional Village, Ende [34] and Gayo settlements in Aceh [12]. The same pattern is also found in Waerebo Village, where seven traditional houses surround the ritual area or altar. This circular pattern generally reflects social order, the values of togetherness, and the community's spiritual orientation towards landscape space.

3.2. Landscape Elements and Spatial Configuration

The relationship between space, place, and meaning is central to the formation of cultural landscapes [35]. Space is essentially physical and neutral, but through human presence and activity, it transforms into a place with identity, value, and emotional attachment [36]. Philosophically, Waerebo Village is called Beo, consisting of 5 main elements that form the space, namely *Mbaru Niang* (traditional house), *Copang* (altar), *Boa* (cemetery), *Lingko* (communal farmland), and *Wae Teku* (spring) [32]. *Beo* is located on a hilltop plain (*golo*) in the middle of a forest, reached after crossing a river and several springs and community farmland. In addition to the main landscape elements, there are also other elements whose placement has meaning and function, as explained in Table 2.

Table 2. Landscape element layout

	Landscape Feature	Landscape Element		Element zoning	Explanation
Natural Landscape					
a.	Forest	(1)	Utilized forest	Utilization zone	Forests that can be utilized by the community
		(2)	Scared Places	Sacred zone	7 sacred sites that are vital areas and habitats for endemic fauna
b.	Farmland	*(3)*	*Lingko*	Utilization zone	communal farmland area close to residential areas
c.	Hidrology	(4)	Springs	Sacred zone	Located northwest of the settlement
		(5)	Bathing Place	Utilization zone	Sosor divided by gender, Male Sosor and Female Sosor, is located in the southwest

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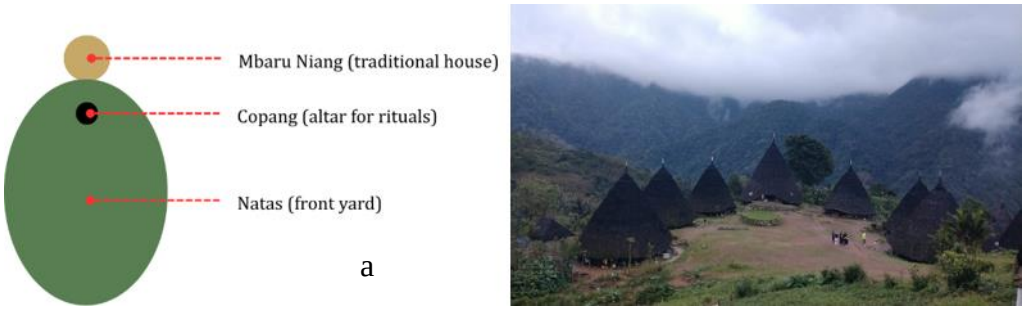
	Landscape Feature	Landscape Element	Element zoning	Explanation
d.	Plants	(6) Forest plants	Utilization zone	Trees used as the main material for traditional houses
Man-made Landscape				
e.	Building	(7) Traditional House	Core zone	Mbaru Niang consists of one main house and six residential houses.
		(8) Altar	Core zone	Place for ritual offerings and located in front of traditional house
		(9) Cemetery	Core zone	Located in the southwest with a higher elevation than the settlement
f.	Landform	(10) Public open space	Core zone	Circular in shape and located in the center of the settlement
g.	Sirculation	(11) Entrace gate	Sacred zone	The single entrance located in the south, serves as the physical and symbolic boundary of the settlement
		(12) Exit gate	Sacred zone	Located northeast within the Todo Protected Forest

The fundamental spatial configuration of Waerebo Village is rooted in the Manggarai philosophy of *go'et*, which defines the landscape as an integrated socio-ecological system (Figure 4). This principle is encapsulated in the phrase: "*gendang one lingko peang, natas bate labar wae bate teku, compang bate takung*" (the translation is: traditional house in the center, communal farmland outside, yard for playing, spring water to draw, and there is an altar for offerings) [37]. It establishes a cohesive bond between the domestic sphere (the communal house), the agricultural periphery (*Lingko*), communal social spaces (*Natas*), vital hydrological resources (*Wae*), and the sacred spiritual axis (*Compang*). Based on this philosophy, the landscape elements in Waerebo Village are divided into 3 zones: the core zone, the utilization zone, and the sacred zone, according to the elements' functions and locations

Zoning is a strategy for maintaining balance between humans and the landscape. Zoning is not only conservation-based, but also maintains local cultural practices as part of the landscape system [38]. The core zone is an area with the highest ecological and cultural value, with authentic landscapes that are limited by human intervention and serve as a conservation centre [39]. The core zone in Waerebo Village consists of traditional houses, altars, cemetery and public open spaces located in the middle of the settlement, with proximity. The altar, or *Copang*, is located in front of the *Mbaru Gendang* (main house) and is the center of settlement orientation, marked by the position of the main pillar of the house (*bongkok*), which faces altar [40] (Figure 3). The typology of altar and *Natas* (public open spaces) follows the shape of *Beo* [41]. *Beo* in Waerebo Village is circular, so the shapes of altar and public open spaces also follow. The graves or *Boa* are located outside the traditional community settlement area, at a higher elevation on the hillside. This is in accordance with the traditional spatial planning of the Manggarai Tribe, which separates residences from burial places [37].



a) b)

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Figure 3. Spatial typology and physical appearance of the settlement: (a) conceptual diagram of Waerebo village space showing the relationship between *Mbaru Niang* (traditional house), *Compang* (altar), and *Natas* (front yard); (b) panoramic view of Waerebo Village illustrating the actual circular arrangement of the seven *Mbaru Niang* houses surrounding the central ritual area.

The utilization zone is an area composed of landscape elements that support human activities while maintaining ecological and cultural values. Vegetation from forests and communal farmland is an important part of the cultural practices of indigenous communities, including the use of materials for traditional houses, traditional rituals, and the fulfillment of daily needs [42]. One type of tree used is the *worok* tree (*Dysoxylum densiflorum Blume*), which serves as the main pillar, or *siri bongkok*, in the structure of the house [6]. Indigenous communities use seven types of trees from four different families as the main materials for the construction of traditional houses, sourced from utilization forests [4].

The circular pattern in the farm has aesthetic value because it resembles a spider's web. The location of Lingko is usually around the village in accordance with the traditional philosophy of "*Gendang One Lingko Pe'ang*," which emphasizes that the existence of the *Gendang* house is always followed by the *Lingko* around it [43]. *Lingko* in the philosophy of the Manggarai Tribe is divided into communal farmland for agroforestry located on hills and lingko for rice cultivation located along riverbanks. Research [44] suggests that the same local wisdom is also found in the Minangkabau community, where agroforestry land is located on hills at a safe distance from settlements to prevent landslides. The topographical conditions in Waerebo Village are on mountains, so communal farmland are planted with agricultural commodities such as corn, coffee, vanilla, oranges, and passion fruit.

The sacred zone is generally located within the Todo Protected Forest, which safeguards vital areas and the village's main water source. The main water source is the river in *Ulu Waerebo* (part of the 7 sacred places) to the northwest of the village. The community uses the spring, or *Wae Teku*, as its main source of water for daily life, resulting in high intensity. The word "*Wae*," meaning water, has symbolized water's role in the lives of the Waerebo community. The presence of guardian spirits at the spring underscores the sacredness of water in community life [45]. The community's bathing place is called *Sosor*, which is then divided according to the concept of gender in local wisdom, namely *Sosor Pria* and *Sosor Wanita*, located in the southwest. Spiritually, these vital areas are also protected by guardian spirits (*Naga*) at seven different locations. The seven sacred areas are *Gala Ponto*, *Ponto Nau*, *Regang*, *Polo*, *Ulu Waerebo*, *Hembel*, and *Golo Mehe*. This area consists of highlands, springs, and rivers located north of the village and within the village boundaries. The Manggarai people believe that ancestral spirits reside in the north, so they refrain from expanding or clearing land in this area.

The entrance, or *Pa'ang*, is located at the front of the village, just before entering the settlement, marked by the sounding of a gong to signal that guests are entering. The exit, called *Mandung*, is located at the back of the village within the Poto Protected Forest. The location and position of these entrances and exits also form a circular pattern, symbolising defence surrounding the village and the communal farmland. There are two doors traditionally believed to be guarded by guardian spirits. The community's daily life is not constrained by specific circulation patterns because there are no restrictions on movement within the traditional village, including access to graves. The Waerebo community naturally forms circulation patterns, such as dirt roads to water sources and communal farmland located in the residential area.

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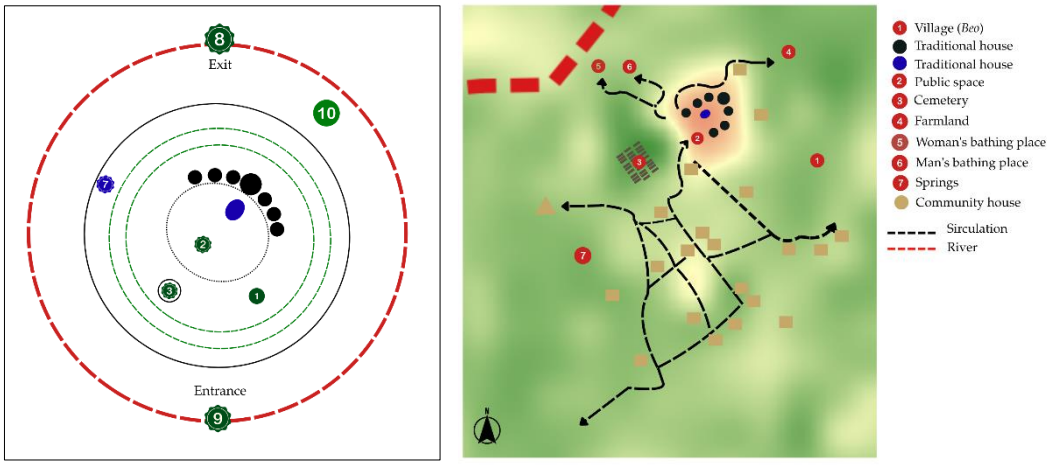

a) b)

Figure 4. Spatial configuration and element layout of Waerebo Village: (a) conceptual diagram representing the circular cultural pattern and local wisdom; (b) actual spatial distribution of landscape elements based on field observation.

3.3. Spatial and Geospatial Analysis

3.3.1. Topographic Adaptation

The spatial analysis of the Waerebo Village landscape reveals a significant correlation between topographical constraints and the placement of traditional zones. As illustrated in Figure 5, the study area lies on a large elevation gradient, ranging from 862 to 1,542 meters above sea level. The highest peaks are located in the mountain ranges on the western and northern sides, which serve as primary catchment areas for rivers and springs. The *Ulu Waerebo* site is located at the highest elevation near the river's headwaters. The placement of one of the sacred sites at this location protects the water source, prevents human intervention, and maintains hydrological sustainability in the downstream area. The river system in Waerebo flows from high elevations on the northern and western sides to lower valleys on the southeastern side. Overall, the area's topography forms a V-shaped valley, with the lowest point along the river's course at the bottom or on the outskirts of the village (Figure 8).

The distribution and cultural arrangement of the seven sacred sites are carefully planned, taking into account their functions. These sites are predominantly located on upper slopes and ridges characterized by extreme topography and high elevations. Many studies have shown that sacred forests are often maintained precisely because they play a crucial role in maintaining local water sources, soil, and climate [46–48]. This sacred value serves as a socio-cultural means of protecting fragile aquatic ecosystems.

Slope analysis identified very rugged terrain with inclinations up to 85° (very steep). The Waerebo settlement, occupied by indigenous people, is strategically located on a local topographic terrace with a relatively moderate slope of around 16° at an altitude of approximately 1,100 meters above sea level, and is surrounded by these steep slopes. This demonstrates the adaptation process undertaken by the first indigenous people to the landscape landform to ensure building stability and safety from landslides [49–51]. The presence of sacred forests on these extreme slopes technically functions to maintain soil stability and protect the settlements below from the threat of land degradation. Consistently, indigenous settlements in steep topographic areas do not adhere to the steepest zones, but instead seek out relatively flat pockets or gentle slopes within the mountainous landscape. This is an adaptation strategy to reduce disaster risks, facilitate agricultural and water access, and maintain ecological and cultural harmony.

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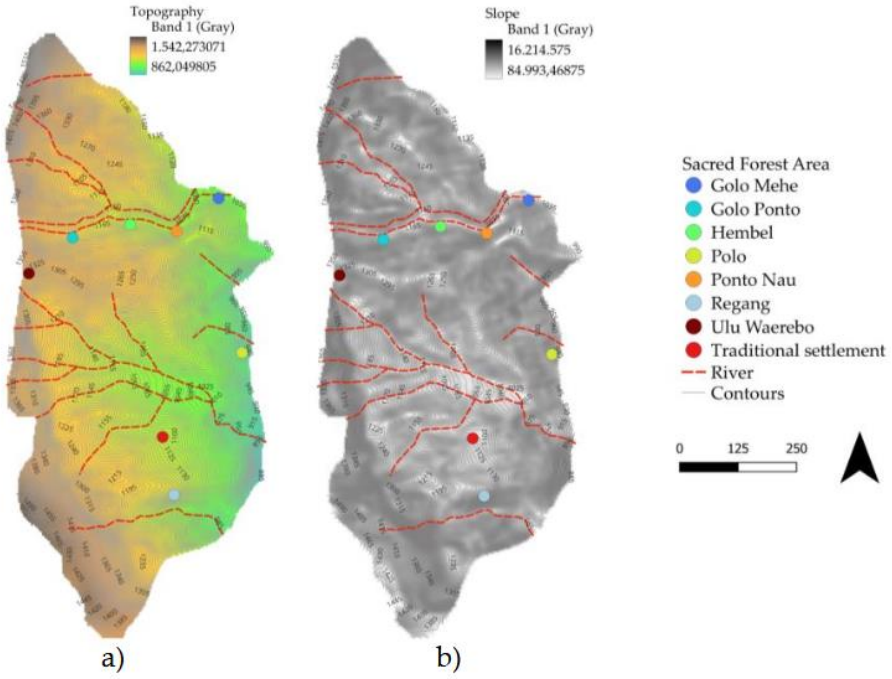

Figure 5. Spatial configuration of Waerebo a) topographic elevation map b) slope gradient map

3.3.2. Forest Protected Area

Multi-temporal analysis using NDVI over ten years showed a significant, though not overwhelming, positive trend in the health of the Waerebo forest ecosystem (Figure 6) [52,53]. The results indicate that, despite increased tourism activity, traditional landscape management systems can maintain—and even enhance—the area's ecological integrity. Vegetation density (Table 3) shows a progressive increase in vegetation density in the Todo Protected Forest. In 2015, NDVI values ranged from 0.13 to 0.47, reflecting the initial conditions after UNESCO designation, when the landscape began to stabilize. By 2020, these values had increased to a range of 0.19 to 0.50, peaking at 0.21 to 0.52 in 2025. This steady increase in baseline values indicates successful natural succession and improved open-space management within the settlement area.

Table 3. Comparison of NDVI index (2015, 2020, 2025)

Year	Min NDVI	Max NDVI	Landscape Condition
2015	0.136	0.475	Post-UNESCO stabilization
2020	0.199	0.502	Established cultural tourism
2025	0.218	0.521	Current resilient ecosystem

Low NDVI values (~0.21) remain spatially concentrated in indigenous settlement areas. This indicates strict adherence to customary laws that prevent the physical expansion of buildings into the surrounding forest, thus preserving the cultural core without degrading the periphery. Moderate NDVI values correlate with communal farmland and agroforestry areas. The increasing density in these zones indicates that the *Lingko* system is maturing, providing better soil protection and higher carbon sequestration than a decade ago.

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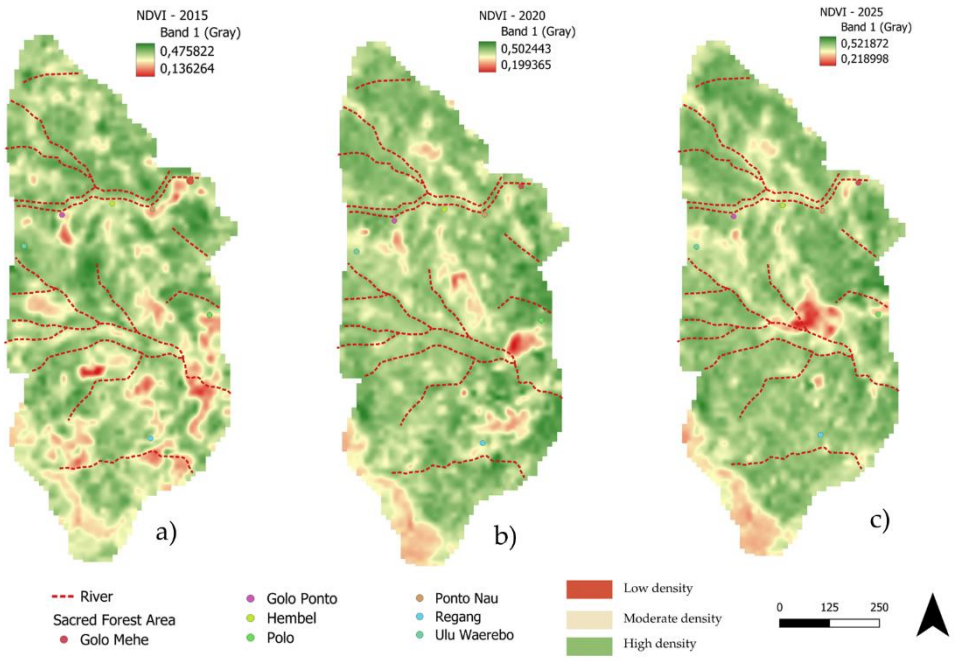

Figure 6. Multi-temporal NDVI (Normalized Difference Vegetation Index) maps of Waerebo Village (a) NDVI 2015: Post-UNESCO stabilization phase; (b) NDVI 2020: Established cultural tourism phase; (c) NDVI 2025: Current resilient ecosystem condition.

As shown in the 2025 map, the highest NDVI values (>0.45) correspond to seven sacred forest sites. This validates the role of local beliefs in forest conservation; these sites act as "biodiversity anchors" that protect the primary forest canopy. These high and stable values validate the effectiveness of the customary rule "*Neka poka puar*" (do not cut down the forest) in maintaining primary forest biomass and preventing deforestation. High-density vegetation (NDVI >0.45) is concentrated in areas with extreme slopes of up to 85°. The root structure of the dense vegetation in this area functions as indigenous engineering to maintain soil stability and prevent landslides in the Manggarai Mountains. The concentration of dense vegetation at the highest elevations (up to 1,542 meters above sea level) on the north and west sides facilitates better groundwater infiltration.

The intersection of the river network along the forest with areas of high-density vegetation (NDVI > 0.45) in the 2025 data indicates a robust hydrological infiltration system. Increased canopy density in the upstream area (Sacred Zone) facilitates better groundwater infiltration. This is crucial for maintaining the flow of springs, the community's primary water source. This "Indigenous Engineering" approach effectively mitigates erosion on the steep slopes of the Manggarai Mountains. Situated on a high topography, dense vegetation cover provides better protection against erosion and landslides on steep topography.

3.4. Landscape Model

Waerebo Village represents a circular spatial model through its traditional circular settlement pattern (Figure 7). This circular pattern consistently appears in various elements of the settlement's landscape, from the village layout, the shape of the altar, the division of traditional house space, the division of communal farmland, to the implementation of ritual traditions carried out in the area. This is also in line with the philosophy of the Manggarai Tribe, which emphasises that life always moves in interconnected cycles, so that the circular pattern is understood as a manifestation of cosmological and social balance. A similar circular pattern can be found in the Wologai Traditional Village in Ende, with the difference being the layout of the traditional house: it is completely circular, whereas in Waerebo Village, the traditional house is located in a semi-circle with a front opening leading to the *Copang* (altar).

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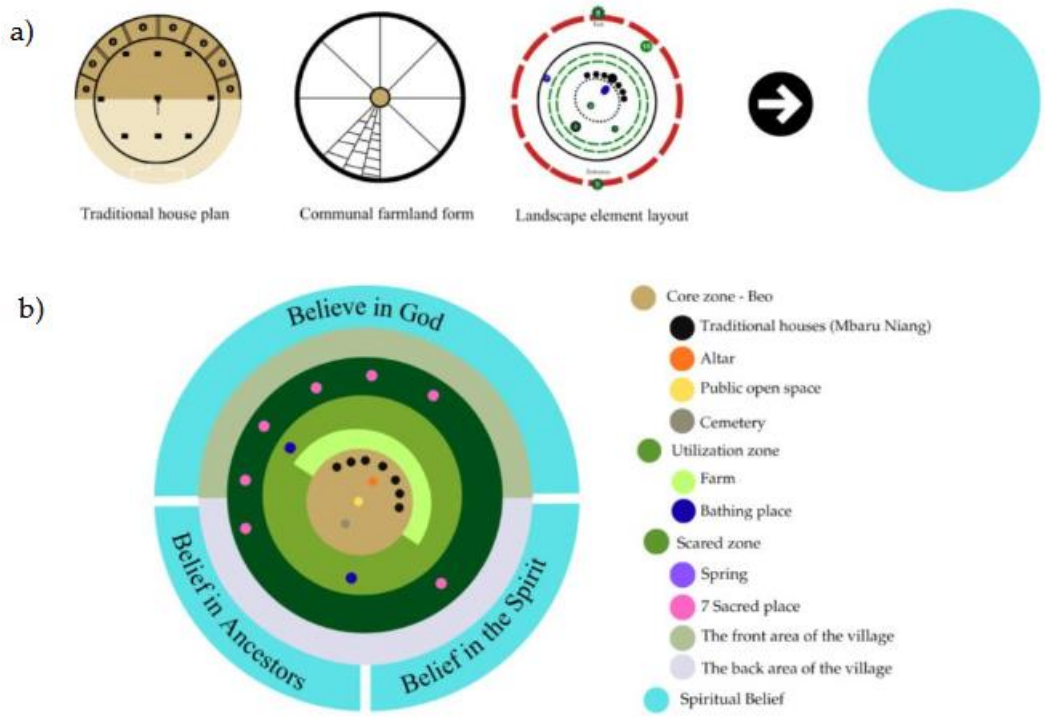

Figure 7. Horizontal landscape model of Waerebo Village a) section illustrates the synthesis of traditional house plans, communal farmland forms (Lingko), and landscape element layouts into a unified circular pattern; b) section represents the integrated concentric zoning model.

The circular layout strengthens social interaction, facilitates supervision, and emphasises the community's collective identity. Public open spaces (*Natas*) are used for traditional ceremonies, deliberations, and joint activities, reflecting the values of togetherness and cooperation. The circular pattern also facilitates resource distribution and communication between residents. The arrangement of settlement elements such as traditional houses (*Mbaru Niang*), *compang* (altar), and *boa* (cemetery) in a circular spatial pattern not only organises the space physically but also reflects the deep connection between the social, spiritual, and ecological aspects of indigenous communities.

Figure 7 explains that Waerebo Village is divided into three zones spatially. Traditional houses are arranged in a circle to the northeast, facing the altar, and in a straight line to the southwest, facing the cemetery. The settlement pattern not only regulates the relationships among the village's internal landscape elements but also considers their connections to the surrounding landscape. This relationship is evident in the presence of communal farmland located close to residential areas to support daily needs, as well as in the Todo Protected Forest, which is maintained as an ecological buffer and a source of environmental balance. The philosophy of life as a circular cycle is reflected in the community's belief system. The traditional beliefs of the Manggarai Tribe are animistic in nature, emphasising respect for God (*Mori*), the highest being, through the intermediaries of *Empo* (ancestors) and *Naga* (nature spirits), which are realised through the performance of traditional rituals. In traditional ceremonies such as *Rowa* (death rituals), the value of belief in *Mori* is very prominent, signifying the vertical relationship between humans and their creator, as well as the belief in life after death [39].

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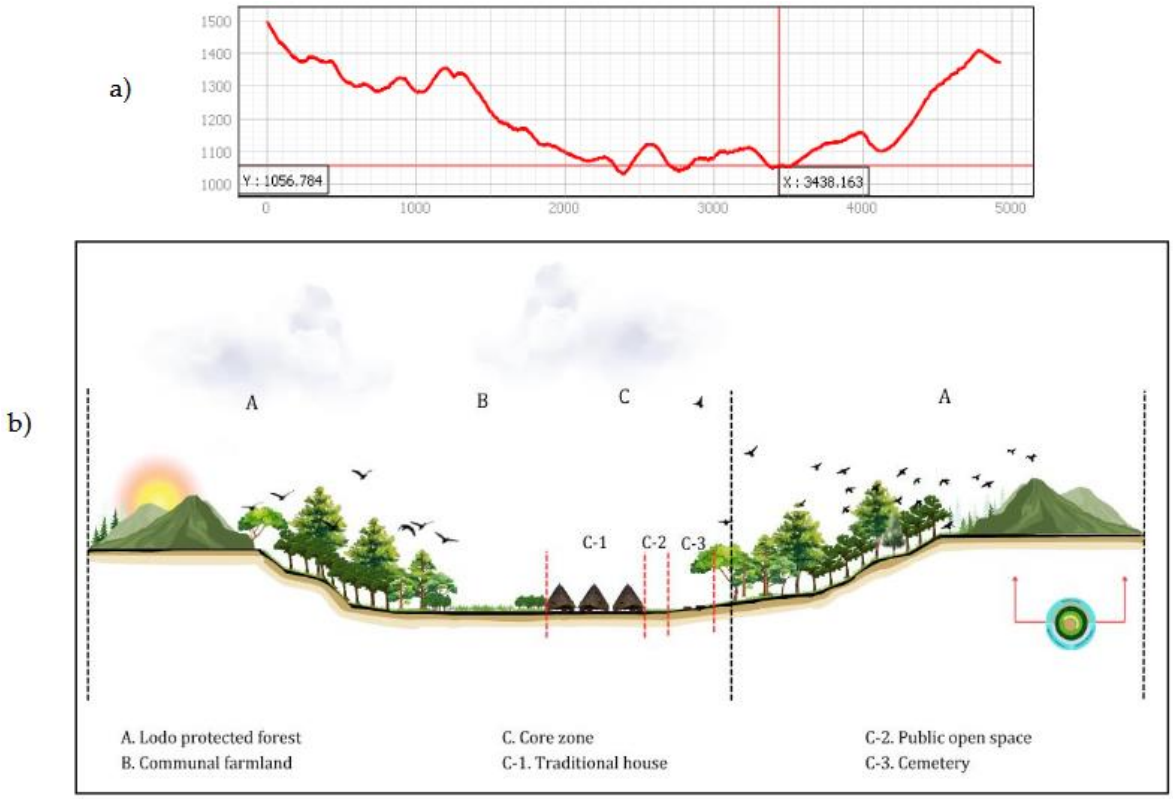

Figure 8. Vertical landscape profile of Waerebo Village: a) elevation transect graph showing the V-shaped valley morphology; b) sectional illustration.

Vertically, it can be seen that the Waerebo Village settlement is located in a valley surrounded by mountains and hills (Figure 8). The cemetery in the southwest are higher than the traditional houses. At the same time, the communal farmland follows the settlement's topographic pattern, which is in a flatter area. The verticality of the Waerebo settlement demonstrates a very specific topographic adaptation, with the village situated on a small plateau within a valley surrounded by mountain ranges and hills. In terms of elevation, the cemetery area on the southwest side is higher than the rows of traditional houses. Conversely, the communal farmland follows a gentler topographic pattern around the settlement, occupying relatively flat areas for efficient land management. This aligns with the explanation for the proximity of communal farms to settlements. This vertical arrangement creates a functional landscape profile: protected forests occupy the highest elevations to protect water sources; cemeteries in higher areas as a symbol of respect; and settlements and agriculture in the more topographically stable central area.

The cross-sectional profile (Figure 8a) clearly demonstrates the 'V-shaped' valley morphology of Waerebo. The topographic transect line shows an extreme gradient, starting from the mountain peak at 1,542 meters above sea level, descending through residential areas at ~1,100 meters above sea level, and reaching the riverbed at 862 meters above sea level. This vertical arrangement demonstrates that the Waerebo indigenous people have not only physically adapted but also developed a traditional landscape engineering system that prioritizes upstream conservation functions to ensure the safety and sustainability of life in the valley below.

3.5. Cultural Activities and Intensity of Space Usage

Indigenous communities in Waerebo actively utilise every available space within the village for daily and ceremonial activities. As demonstrated in Table 4, variations in spatial use intensity are directly influenced by the specific landscape features and the cultural activities occurring within them. This intensity is fundamentally shaped by the inherent ecological, social, and economic functions, as well as the deep-seated cultural values attributed to each landscape element. These

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rituals serve as a means of spiritual communication, strengthening identity, regulating social norms, and preserving culture and the environment [54]. In this context, the high intensity of use recorded in the core zone (traditional houses and altar) during rituals like *Penti.*

The analysis of intensity of space usage (Table 4) reveals that the traditional house (5) and altar (6) serve as the primary convergence points for nearly all cultural activities. These elements function as a cosmic axis, anchoring the village's multidimensional landscape. Horizontally, Waerebo's spatial pattern is centripental. While rituals like *Penti* represent a maximum horizontal expansion—requiring physical effort to reach the forest and springs—the community is spiritually mandated to return to the center. This movement reflects a "cosmic spiral", the vast, exhausting horizontal mobility always concludes in the vertical tranquility of the village core [55]. The spatial analysis reveals that while *Penti* represents the maximum horizontal expansion of landscape usage, ritual activities like *Roco molos poco* demand the highest vertical physical effort, highlighting the tribe's profound interaction with steep topography. Meanwhile, life-cycle rituals such as *Rowa* focus on intensive central-zone usage, reinforcing the sacredness of the village core. The *Penti* ritual is the largest, featuring the most complex cultural activities and involving the entire community. This ceremony is a crucial moment to commemorate the change of the traditional year and to express gratitude for the harvest and prosperity provided by nature. The entire landscape is utilized as part of the *Penti* ritual. The year-long rituals performed in Waerebo Village utilize the traditional house and altar as the most frequently used spaces.

Table 4. Intensity of Space Usage

Cultural activities	Landscape elements								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Reception (*Tiba meka)*					●				●
(2) Birth (*Cear cumpe*)					●	●			
(3) Wedding (*Palak wina*)					●	●		●	
(4) Death (*Rowa*)					●	●	●	●	
(5) Construction of traditional houses (*Roco molos poco*)		●					●	●	
(6) Thanksgiving for agricultural produce (*Penti)*	●	●	●	●	●	●	●	●	●
(7) Rituals to welcome the changing seasons (*Kasawiang*)					●	●		●	
(8) Ritual respect for the guardian spirit of the water source (*Barong wae*)	●		●			●			
(9) Ritual of respect for the forest guardian spirit (*Barong copang*)	●								
(10) Ritual of respect for the spirit guarding the door (*Barong oka*)	●								

Notes: (1) Sacred Forest, (2) Communal farmland, (3) Spring, (4) Bathing place, (5)Traditional house, (6) Altar, (7) Cemetery, (8) Public open space, (9) Gate.

These cultural activities are led by *Tu'a Golo* and *Tu'a Tembong*, with the indigenous community as the primary actors. *Tu'a Golo* comes from the words "*Tu'a*," which means old man, and "*golo*," which means hill. *Tua Teno* occupies the hierarchical system below as the head who handles land issues responsible for the distribution of customary land, *Tua Panga* is the envoy or representative of each nuclear family who is tasked with managing the household affairs of the indigenous community and *Tua Kilo* who plays a role in ritual aspects, especially in maintaining the continuity of traditions and the spiritual dimension of the indigenous community. Indigenous people as actors in cultural activities of the patrilineal kinship system in Waerebo Village are rooted in one ancestor and are called *Wa'u* or *Aseka'e*. *Wa'u* refers to the ancestor, while his descendants are called *Panga*, which

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signifies the lineage's continuity in the community. There are 8 *Panga* in Waerebo Village, and their descendants are called *Kilo*. Panga are representatives of ancestral descendants who have the right to occupy *Mbaru Niang* from the oldest male line.

4. Discussion

4.1. Integrating Horizontal Concentricity and Vertical Hierarchy

The landscape model of Waerebo is a sophisticated integration of horizontal zoning and vertical hierarchy. As illustrated in Figure 7, the horizontal landscape of Waerebo is structured into three concentric rings: the core zone, the utilization zone, and the sacred zone. This spatial arrangement is not merely physical but is deeply embedded within a tripartite spiritual framework: belief in god, ancestors, and spirits. As illustrated in the cross-section (Figure 8), the settlement is strategically positioned on a core zone flanked by productive slopes (communal farmland B) and protected highlands (Lodo protected forest A). This vertical arrangement mirrors the horizontal concentric rings, creating a "bowl-shaped" cosmic logic that functions both ecologically and spiritually.

In this model, the traditional houses and the altar act as the "gravity center" of this model. While daily and ritual activities expand horizontally into the utilization and sacred zones—reaching farms, springs, and sacred sites—there is a mandatory cultural return to the core zone. This spatial behavior confirms that Waerebo operates as an integrated cosmic spiral characterized by two main axes: a horizontal axis representing centripetal movement from the sacred periphery toward the communal center, and a vertical axis symbolizing a hierarchical ascent from the earthly domain toward the spiritual peak. This synthesis reveals three primary findings crucial to the resilience of the Waerebo landscape. First, vertical protection is achieved through the Lodo protected forests at the highest elevations, serving as a "spiritual crown" and an ecological buffer that ensures watershed stability and slope protection. Second, horizontal centripetality dictates that all ritual and daily movements flow inward, establishing the public open space and traditional houses as the topographical anchor for the entire valley. Third, the spiral connection facilitates a transition from lower productive lands to elevated residential areas as both a physical and symbolic ascent.

The cosmic spiral concept ultimately explains how Waerebo survives its challenging topography; by concentrating the most intensive social and spiritual activities at the center while maintaining the highest elevations (sacred forest) for ecological protection, the community achieves a vital balance between socio-economic survival and environmental conservation. This integration demonstrates that the physical elements of the landscape, such as the conical building formation and elevation-based zoning, are not merely aesthetic responses but rather a form of indigenous landscape engineering. The vertical zoning, which places protected forests at the highest peaks, automatically creates a watershed protection and erosion-prevention system that maintains the settlement's stability.

4.2. Natural Hazards Mitigation and Ecological Resilience

The integration of physical landscape elements and elevation zoning in Waerebo is not merely an aesthetic response, but rather a form of indigenous landscape engineering. This model technically functions as an environmental management system through two primary mechanisms: slope stability management and disaster mitigation, and a water resource conservation and management system. The placement of the Lodo protected forest on the highest peaks (up to 1,542 meters above sea level) functions as a natural "bio-engineering" system. The dense vegetation roots in areas with extreme slopes of up to 85° play a crucial role in binding the soil structure, thereby mitigating the risk of landslides that could threaten the settlements below.

To date, there are no historical records of landslides occurring in the Waerebo settlements. The landslides that occurred were on the hiking trails (prolonged rain) located in low-lying areas. These were triggered by heavy rain and extreme weather in the mountainous region, making the hiking trails vulnerable and temporarily closed for tourist safety. The long-term sustainability of Waerebo

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depends heavily on maintaining vegetation density in sacred zones to preserve slope integrity amid increasing rainfall intensity driven by climate change. Furthermore, through hydrological pathways, through sacred sites such as Ulu Waerebo at the headwaters of the river, the community has created an effective watershed protection system. This sacred value technically prevents human intervention in the main watershed area, thus ensuring the continuity of the community's water supply. By placing upstream conservation functions at the highest hierarchical level (the mountaintop), the community achieves a vital balance between socio-economic needs and environmental sustainability. This managed "V-shaped valley" model demonstrates that local knowledge can create an environmental management system that has withstood the challenges of extreme topography for centuries.

5. Conclusions

The conclusion of this study shows that the Waerebo Village landscape model is a sophisticated integration of topographic adaptation and traditional spatial patterns, functioning as a highly resilient indigenous landscape engineering system. Horizontally, the concentric zoning, consisting of a core zone, a utilization zone, and a sacred zone, is closely intertwined with a vertical hierarchy that places the Lodo protected forest as a "spiritual crown" at the highest elevation to maintain the stability of extreme slopes up to 85° and to protect the watershed. Multi-temporal NDVI analysis during the period 2015–2025 proves that the community's strict adherence to the customary law has succeeded in increasing vegetation density (from 0.47 to 0.52), which technically plays a role in mitigating landslide disasters and maintaining the stability of the springs amidst the challenges of climate change and increasing tourism activities. Through the concept of a "cosmic spiral" that centers socio-spiritual activities in the village center while maintaining conservation functions in the upstream area, the Waerebo community has achieved a vital balance between socio-economic sustainability and long-term environmental preservation, which can serve as an important reference for sustainable cultural heritage frameworks in other regions.

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